The SHIFT study: exploring the role of a baby-led feeding approach on infant growth - implications for childhood obesity.

Sara Wyn Jones

Swansea University, 2019

Submitted to Swansea University in fulfilment of the requirements for the Degree of Doctor of Philosophy

Summary

Recently, a baby-led weaning method of complementary feeding, where infants are allowed to self-feed whole foods has grown in popularity. Proponents of the method posit that it may reduce risk of overweight because the self-feeding aspect (and the lower level of maternal control that this affords) is likely to allow infants to better regulate their appetite, and this has been supported by exploratory research (Brown & Lee, 2011b; Brown & Lee, 2012). However, the impact of the method on infant growth has been largely untested, with studies focussing on the potential effects of baby-led weaning on later overweight (Townsend & Pitchford, 2012; Brown & Lee, 2015). Furthermore, studies focus on the self-feeding aspect of the baby-led weaning method, and do not consider the impact of, and the interaction with other feeding behaviours. The SHIFT (Studying Healthy Infant Feeding and growth Trajectories) study explored associations between aspects of infant feeding; milk-feeding, the age of introduction to complementary foods, the transition from milk onto foods, the method of introduction to food (self-feeding or spoon-fed), diet and texture offered, and growth outcomes of infants aged 6-12 months. This research did not find a conclusive association between the baby-led weaning method (i.e. self-feeding) and infant growth. However, behaviours which could be considered to be more broadly 'baby-led' in approach; breastfeeding, later age of introduction to complementary foods and a gradual transition from milk onto a diet consisting of mainly whole foods, appeared to foster healthier weight gain trajectories. These findings support the WHO (2003b) recommendation for 'responsive' infant feeding. Why mothers choose a more baby-led or parent-led approach is complex; concerns around infant weight, intake and behaviour are commonly cited as driving parent-led behaviour (Redsell et al., 2010; Clayton et al., 2013; Brown & Harries, 2015), and were also reported by mothers in this study. The SHIFT study provides the impetus for effective support for parents in infant feeding, so that they feel confident adopting a baby-led, responsive approach.

Declarations and Statements

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed .... (candidate)

Date ....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed .... (candidate)

Date ....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed .... (candidate)

Date ....

Table of Contents

CHAPTER 1: INTRODUCTION **17**

CHAPTER 2: LITERATURE REVIEW **20**

2.1. LITERATURE SEARCH 20
2.3. THE PROBLEM OF OVERWEIGHT AND OBESITY 21
2.3.1. The impact of overweight and obesity 22
2.4. WHAT INCREASES THE RISK OF CHILDHOOD OBESITY? 23
2.4.1. Genetic and biological influences 24
2.4.2. Family, social and environmental influences 25
2.4.3. Gene-environment interactions 28
2.5. THE IMPORTANCE OF EARLY INTERVENTION 30
2.5.1. Tracing obesity back to infancy 31
2.5.2. Rapid weight gain in infancy 32
2.6. PRE-NATAL AND INFANCY RISK FACTORS 33
2.6.1. Birthweight 33
2.6.2. Maternal age 36
2.6.3. Socioeconomic status 37
2.6.4. Mode of birth 37
2.6.5. Antibiotic use 38
2.7. THE IMPORTANCE OF INFANT FEEDING 38
2.8. MILK FEEDING 39
2.8.1. The content of breast milk and infant formula 41
2.8.2. The microbiome 44
2.8.3. Behavioural differences between breastfeeding and bottle feeding 45
2.8.4. Milk feeding: Confounding factors 49
2.9. THE COMPLEMENTARY FEEDING STAGE 51
2.9.1. Timing of introduction of complementary foods 51
2.9.2. Timing of complementary feeding and risk or overweight/obesity 53
2.9.3. Timing of introduction to complementary foods: confounding factors 54
2.10. EXPLORING COMPLEMENTARY FEEDING METHODS AND OBESITY RISK 56
2.10.1. Beliefs about the benefits of baby-led weaning 58
2.10.2. Baby-led weaning and overweight and risk of overweight and obesity 59
2.10.3. How might baby-led weaning affect infant growth and/or later risk of overweight? 61
2.10.4. Baby-led weaning and the timing of introduction to complementary foods 62
2.10.5. Baby-led weaning, eating behaviour and appetite 62

2.10.6. Baby-led weaning, diet and food preferences *65*
2.11. THE ROLE OF RESPONSIVE FEEDING 69
2.11.1. Drivers towards non-responsive maternal feeding behaviours *74*
2.11.2. Maternal concern about infant weight or intake *76*
2.11.3. Infant temperament, beliefs around baby behaviour and sleep *78*
2.11.4. Maternal personality and beliefs *79*
2.11.5. Separating responsive feeding from feeding method *82*
2.12. THE TRUST MODEL FOR CHILD FEEDING 84
2.13. SUMMARY AND RATIONALE FOR THIS RESEARCH 87
2.13.1. Research questions *91*

CHAPTER 3: SHIFT STUDY DESIGN AND METHODOLOGY 93

3.1. STUDY DESIGN 93
3.2. PARTICIPANTS 94
3.4. TOOLS 95
3.4.1. The questionnaire *97*
3.5. PROCEDURE 103
3.5.1. Recruitment *103*
3.5.2. The process of a session *104*
3.6. RELIABILITY AND VALIDITY 107
3.6. ETHICS 109
3.7. DATA ANALYSIS 111
3.7.1. Anthropometric Measures *111*
3.7.2. Analysis of the 24-hour diet diaries *114*
3.7.3. Analysis of free text answers *115*
3.7.4. Statistical tests *116*
3.7.5 *Power calculations of required sample size*........ *117*

CHAPTER 4: MATERNAL AND INFANT DEMOGRAPHIC CHARACTERISTICS AND ASSOCIATIONS WITH INFANCY GROWTH. 119

4.1. RATIONALE 119
4.2. BACKGROUND 120
4.3. PARTICIPANTS 122
4.4. MEASURES 122
4.5. DATA ANALYSIS 122
4.6. RESULTS 123
4.7. DISCUSSION 129

CHAPTER 5: EXPLORING MILK FEEDING AND INFANCY GROWTH DURING COMPLEMENTARY FEEDING. 134

5.1. RATIONALE 134
5.2. BACKGROUND 135
5.3. PARTICIPANTS 137
5.4. MEASURES 137
5.5. DATA ANALYSIS 138
5.6. RESULTS 139
5.7. DISCUSSION 153

CHAPTER 6: EXPLORING TIMING OF INTRODUCTION TO COMPLEMENTARY FOODS AND INFANCY GROWTH.......................... 158

6.1. RATIONALE 158
6.2. BACKGROUND 158
6.3. PARTICIPANTS 161
6.4. MEASURES 161
6.5. DATA ANALYSIS 162
6.6. RESULTS 162
6.7. DISCUSSION 175

CHAPTER 7: EXPLORING COMPLEMENTARY FEEDING METHODS AND INFANCY GROWTH 182

7.1. RATIONALE 182
7.2. BACKGROUND 183
7.3. PARTICIPANTS 185
7.4. MEASURES 185
7.5. DATA ANALYSIS 186
7.6. RESULTS 187
7.7. DISCUSSION 199

CHAPTER 8: EXPLORING THE TRANSITION TO COMPLEMENTARY FEEDING AND INFANCY GROWTH 203

8.1. RATIONALE 204
8.2. BACKGROUND 204
8.3. PARTICIPANTS 209
8.4. MEASURES 209
8.5. DATA ANALYSIS 210
8.6. RESULTS 210
8.7. DISCUSSION 222

CHAPTER 9: EXPLORING THE CONTENT AND TEXTURE OF DIET OFFERED AND INFANCY GROWTH... 228

9.1. RATIONALE 228
9.2. BACKGROUND 229
9.3. PARTICIPANTS.. 231
9.4. MEASURES 231
9.5. DATA ANALYSIS 233
9.6. RESULTS 233
9.3. DISCUSSION.. 247

CHAPTER 10: EXPLORING MATERNAL REPORTED REASONS FOR THE CHOSEN APPROACH TO COMPLEMENTARY FEEDING............ 250

10.1. RATIONALE 251
10.2. BACKGROUND 251
10.3. PARTICIPANTS... 253
10.4. MEASURES 253
10.5. DATA ANALYSIS... 253
10.6. RESULTS 256
10.7. DISCUSSION... 262

CHAPTER 11: WHAT ARE THE KEY FACTORS INFLUENCING INFANT GROWTH? EXPLORATION OF THE DATA USING REGRESSION ANALYSIS. 266

11.1. RATIONALE 266
11.2. BACKGROUND 268
11.3. PARTICIPANTS... 271
11.4. MEASURES. 271
11.5. DATA ANALYSIS... 272
11.6. RESULTS 273
11.7. DISCUSSION... 284

CHAPTER 12: GENERAL DISCUSSION, LIMITATIONS OF THE RESEARCH, CONCLUSIONS AND RECOMMENDATIONS.................... 290

12.1. KEY FINDINGS... 290
12.2. THE CENTRAL ROLE OF RESPONSIVE FEEDING... 292
12.3. GROWTH TRAJECTORIES OVER TIME 297
12.4. PRACTICAL IMPLICATIONS OF SHIFT... 299
12.5. SHOULD WE BE RECOMMENDING THE BLW METHOD? 304
12.6. SUPPORTING PARENTS WITH RESPONSIVE FEEDING.. 310

12.7. LIMITATIONS OF THE SHIFT STUDY 312
12.8. FUTURE RESEARCH 316
12.9. CONCLUSIONS 317

REFERENCES 320

APPENDIX 1 – QUESTIONNAIRE 367

APPENDIX 2- POSTER 376

APPENDIX 3 – INFORMATION PACK AND CONSENT FORM 377

Acknowledgements

I would like to thank Swansea University for giving me the opportunity to undertake this study with a full studentship, and for all the support from the College of Human and Health Sciences post-graduate research team. I have been a student on and off at Swansea University since 2005 and have had nothing but friendly and supportive experiences.

I wish to also like to express my heartfelt gratitude to my supervisors Professor Amy Brown and Professor Michelle Lee for being so approachable, knowledgeable and wise. Especially Amy, thank you for your patient willingness to look at yet another email or draft, and for keeping me afloat with your sense of humour, internet memes and extracts from the Piled Higher and Deeper comic. Your passion for this field of research and its practical applications for parents have kept my own fire burning four years on. I don't think I'll ever grow tired of talking about milk or baby-food!

I, of course, would like to thank the parents, babies and baby-group leaders who took part in my research. When data collection was complete I must admit, I missed the opportunities to chat with you all over a slice of cake.

Finally, 'thank you' to all my family, friends and all-round favourite humans. Your moral support and provision of infinite cups of tea when I was working late were invaluable. You all always believed in me and filled up my cup up (with tea) when it was running low. I swear, I will not utter the 'three letter word'… for a while. Non-human furry friends, 'thanks' for the unconditional love and cuddles. Jumping in the sea every now and again also kept me sane. I'd recommend it.

Post-Viva addition: I'd also like to thank my examiners Claire Farrow and Menna Price for an enjoyable and engaging discussion and for their helpful insights and advice.

Tables and Figures

Table 1: Initial contact and recruitment procedure 106

Table 2: Food types and descriptors 114

Table 3: Descriptive statistics. Maternal education. 123

Table 4: WIMD ranking and codes given 124

Table 5: Baby group locations. WIMD ranking. 125

Table 6: Infant demographics. Sex, birth weight and mean age, by age sub-group. 126

Table 7: Infant demographics. Longitudinal cohort. Sex, birth weight and mean age. 126

Table 8: Descriptive statistics. Milk feeding at birth and status at the time of measurement. 139

Table 9: Milk type at birth and growth outcomes by age group. 141

Table 10: Milk type at the time of measurement and growth outcomes by age group. 143

Table 11: Milk feeding at birth, 6 months and 12 months. Longitudinal participants. .144

Table 12: Descriptive statistics. Milk feeding time one to time two. Longitudinal data. 146

Table 13: Breastfeeding duration of partial or exclusive breastfeeding and growth outcomes. 152

Table 14: Descriptive statistics. Timing groups. 163

Table 15: Cross tabulation. Milk feeding type at the time of measurement and timing of complementary feeding. 165

Table 16: Timing of introduction to complementary foods groups and growth outcomes. 167

Table 17: Longitudinal differences in WAZ and timing of complementary feeding. ...170

Table 18: Longitudinal difference in LAZ and timing of complementary feeding. 172

Table 19: Longitudinal differences in BMIZ and timing of complementary feeding. ..173

Table 20: Descriptive statistics. Method groups by self-feeding. 187

Table 21: Method groups (at time of introduction to complementary foods) and growth outcomes. 189

Table 22: Method groups (at the time of measurement) and growth outcomes...........191

Table 23: Self feeding at introduction to complementary feeding and at 12 months. Longitudinal participants. 193

Table 24: Longitudinal differences in WAZ and method group at introduction to complementary feeding. 194

Table 25: Longitudinal differences in LAZ and method group at introduction to complementary feeding. 196

Table 26: Longitudinal differences in BMIZ and method group at introduction to complementary feeding. 197

Table 27: Feeding method and number of milk feeds/ occasions food offered. 211

Table 28: Cross-tabulation complementary feeding method group and parental estimation of proportion of infant diet coming from either milk or food. 212

Table 29: Cross-tabulation complementary feeding method group and parental estimation of proportion of infant diet coming from either milk or food at age 6-8 months. 213

Table 30: Longitudinal differences in WAZ and the proportion of milk to food at 6 months 218

Table 31: Longitudinal differences in LAZ and the proportion of milk to food at 6 months 220

Table 32: Longitudinal differences in BMIZ and the proportion of milk to food at 6 months 221

Table 33: Descriptive statistic. Texture groups 233

Table 34: Cross-tabulation. Feeding method group by texture group. 234

Table 35: Food types offered according to feeding method group................................235

Table 36: Food types (frequency of exposure) and age of infant at time of questionnaire. Spearman's rho correlations. 236

Table 37: Texture groups at introduction to complementary feeding and growth outcomes. 238

Table 38: Texture groups at time of measurement and growth outcomes. 240

Table 39: Food type (frequency of exposure) and growth outcomes, Spearman's rho correlations. 241

Table 40: Longitudinal differences in WAZ and texture group at introduction to complementary feeding. 243

Table 41: Longitudinal differences in LAZ and texture group at introduction to complementary feeding. 245

Table 42: Longitudinal differences in BMIZ and texture group at introduction to complementary feeding. 246

Table 43: Broad themes and sub-themes 254

Table 44: Sub-themes. Frequencies. 258

Table 45: Unstandardised and standardised regression coefficients for variables associated with WAZ. Whole sample........273

Table 46: Unstandardised and standardised regression coefficients for variables associated with WAZ. Age group 6-8 months........274

Table 47: Unstandardised and standardised regression coefficients for variables associated with WAZ. Age group 9-12 months. 275

Table 48: Unstandardised and standardised regression coefficients for variables associated with LAZ. Whole sample 276

Table 49: Unstandardised and standardised regression coefficients for variables associated with LAZ. 6-8 months........276

Table 50: Unstandardised and standardised regression coefficients for variables associated with LAZ. 9-12 months........277

Table 51: Unstandardised and standardised regression coefficients for variables associated with BMIZ. Whole sample. 277

Table 52: Unstandardised and standardised regression coefficients for variables associated with BMIZ. 9-12 months. 278

Table 53: Unstandardised and standardised regression coefficients for variables associated with WAZV. Whole sample. 279

Table 54: Unstandardised and standardised regression coefficients for variables associated with WAZV. 6-8 months 279

Table 55: Unstandardised and standardised regression coefficients for variables associated with WAZV. Age group 9-12 months 280

Table 56: Summary of regression findings. 281

Table 57: Unstandardised and standardised regression coefficients for variables associated with WAZV. Longitudinal analyses of infants aged 6-12 months. 283

Figure 1: Extract from questionnaire. Self Feeding 100

Figure 2: Extract from questionnaire. Texture 100

Figure 3: Z-scores as they relate to centiles 113

Figure 4: WAZ. Longitudinal analysis. 148

Figure 5: LAZ. Longitudinal analysis. 149

Figure 6: BMIZ. Longitudinal analysis. 150

Figure 7: Longitudinal trajectories of WAZ and timing of complementary feeding. ...171

Figure 8: Longitudinal trajectories of LAZ and timing of complementary feeding 173

Figure 9: Longitudinal trajectories of BMIZ and timing of complementary feeding. ..174

Figure 10: Longitudinal trajectories of WAZ and feeding method group at introduction to complementary feeding. 195

Figure 11: Longitudinal trajectories of LAZ and feeding method group at introduction to complementary feeding. 196

Figure 12: Longitudinal trajectories of BMIZ and feeding method group at introduction to complementary feeding. 197

Figure 13: Extract from questionnaire. Proportion of milk to complementary foods. 209

Figure 14: Longitudinal trajectories of WAZ and proportion of milk to food group at 6 months 219

Figure 15: Longitudinal trajectories of LAZ and proportion of milk to food group at 6 months 220

Figure 16: Longitudinal trajectories of BMIZ and proportion of milk to food group at 6 months 222

Figure 17: Longitudinal trajectories of WAZ and texture group at introduction to complementary feeding. 244

Figure 18: Longitudinal trajectories of LAZ and texture group at introduction to complementary feeding. 245

Figure 19: Longitudinal trajectories of BMIZ and texture group at introduction to complementary feeding. 246

Figure 20: Example of coding of a free-text answer. 255

Figure 21: The socio-ecological model 301

Figure 22: Strategies for responsive feeding extracted from Black & Hurley (2017). ..311

Abbreviations

ALSPAC Avon Longitudinal Study of Parents and Children study

BLISS Baby-Led Indroduction to SolidS

BLW Baby-led Weaning

BMI Body Mass Index

BMIZ Body Mass Index z-score

CFQ Child Feeding Questionnaire

CHILD Canadian Healthy Infant Longitudinal Data study

DARLING Davis Area Research on Lactation and Growth study

DH Department of Health

DONALD Dortmund Nutritional and Anthropometric Longitudinally Designed

EAH Eating in the Absence of Hunger

EFSA European Food Safety Agency

EU European Union

FIBFECS Feedings Infants: Behaviour and Facial Expression Coding System

FITS Feeding Infants and Toddlers Study

GEMINI UK twin study

IDEFICS Identification and prevention of Dietary and lifestyle-Induced health Effects in Children and infantS

IGF Insulin-like Growth Factor

LAZ Length-for-age z-score

LBW Low-birth weight

LGA Large for gestational age

NHS National Health Service

NOURISH Australian infant feeding study

OECD Organisation for Economic Co-operation and Development

RCFCS Responsiveness to Child Feeding Cues Scale

SACN Scientific Advisory Committee for Nutrition

SCF Standard Complementary Feeding

SES Socio-economic status

SGA Small for gestational age

SHIFT Studying Healthy Infant Feeding and growth Trajectories study

WAZ Weight-for-age z-score

WAZV Weight-for-age z-score velocity

WHO World Health Organisation

CHAPTER 1: Introduction

Overweight and obesity is an urgent public health issue and is high on the agenda of the World Health Organization (WHO) and governments worldwide. The prevalence and gravity of the problem is exemplified in the way that obesity has been termed an 'epidemic' by the World Health Organization (WHO, 2003a) and more locally the Welsh Government has identified obesity is a leading cause of preventable death in Wales (Welsh Government, 2019). Overweight and obesity prevalence in children has been recently estimated to be at 47.1% globally (WHO, 2016a). Meanwhile, in Wales, the overall level of childhood overweight and obesity stands at 34%, the highest in the UK (Welsh Government, 2015a). These figures are particularly concerning as there is important evidence showing that childhood obesity is likely to extend into adulthood (Simmonds, Llewellyn, Owen & Woolacott, 2015).

The trajectory to obesity is now thought to begin as early as infancy. Rapid growth that occurs in the first year of life is strongly linked to risk of overweight and obesity in later childhood (Weng, Redsell, Swift, Yang & Glazebrook, 2012; Wang et al., 2016). While genetic influences (Rode et al., 2007; Wardle, Llewellyn, Sanderson & Plomin, 2009), prenatal factors (Ross & Desai, 2014) and birthweight (Chiavaroli, Derraik, Hofman & Cutfield, 2016) are linked to infant growth, how and what infants are fed is also thought to be critical in terms of affecting growth in infancy and, importantly, to the development of appetite regulation and food preferences (Wardle, 2007; Hughes & Frazier-Wood, 2016; Ventura, 2017a). Evidence has been building surrounding the efficacy of the baby-led weaning (BLW) complementary feeding method as a way of reducing the risk of rapid infant growth and therefore later childhood overweight and obesity (Brown, Jones & Rowan, 2017).

This aim of this study, which has been named SHIFT (Studying Healthy Infant Feeding and growth Trajectories) was to explore the role of baby-led feeding on infant growth and its possible implications for childhood obesity.

Research questions:

1. Does the method of introducing complementary foods influence infant growth?

2. What elements of the method of complementary feeding affect infant growth? Is self-feeding important? Diet content? Texture of food? Timing of introduction to complementary feeding?

3. How does milk feeding affect this? Given milk feeding is still a predominant part of the diet, does milk feeding predict or continue to affect growth in the latter half of infancy? And does a baby-led weaning method have a different impact upon growth in breast and formula fed infants?

4. What drives mothers to adopt a particular complementary feeding method? Do these driving factors appear to be influenced by infant weight or size, and do they influence infant growth?

Chapter 2 therefore presents a narrative review of the literature surrounding childhood obesity broadly and then will more closely examine the influence of infant feeding practices. **Chapter 3** details the methodology of the study. Subsequent chapters report the results; each one includes a short introduction followed by analysis and discussion of the findings. **Chapter 4** provides an overview of the basic demographic and descriptive information for the study sample, as these relate to all the subsequent chapters. It also explores maternal age, socio-economic status and birthweight as key variables which may affect infant growth. **Chapter 5** explores associations between milk feeding type and infant growth. **Chapter 6** examines associations between the timing of complementary feeding and infant growth. **Chapter 7** investigates any associations between complementary feeding method and infant growth, specifically comparing baby-led weaning to standard complementary feeding. **Chapter 8** explores the transition to complementary feeding from milk to solid food and any relationships to infant growth.

Chapter 9 outlines the findings of the infant diet analysis and any associations with infant growth. **Chapter 10** details the findings pertaining to mother's stated reasons for choosing a feeding method. **Chapter 11** will bring together the findings and assess the importance of any key factors using a regression analysis. The thesis will conclude with **Chapter 12 –** a general discussion.

CHAPTER 2: Literature review

This chapter presents a narrative review of the literature pertaining to the suggested aetiology of childhood overweight and obesity. The impact of complementary feeding methods, in particular baby-led weaning, is a focus.

2.1. Literature search

Literature searches were conducted primarily using PubMed, beginning with the search terms including (but not exclusively); "obesity", "childhood/children", "infants", "infant feeding", "weight", "length", "growth', "growth velocity", "breastfeeding", "rapid weight gain" "bottle feeding", "formula feeding", "complementary feeding", "parental feeding style", "baby-led" and "weaning". Search terms became more specific to explore particular aspects of the literature such as "caesarean section", "microbiome' and so on. Boolean operators and truncation were used to ensure studies with similar concepts were returned. The search was also narrowed, where appropriate to examine publications related to developed countries (UK, European countries, US, Canada, Australia and New Zealand) in the main. Review articles were starting points and from there bibliographies were used to identify primary studies. Citation chaining was also used to search backwards and forwards through the literature to find key papers.

2.2. Literature themes

This review will begin by exploring the prevalence and impact of overweight and obesity in adults and children. It will then explore the aetiology of childhood obesity, taking into consideration biological and socio-cultural factors. The focus will then be tightened onto infancy factors which set the course towards childhood obesity. Again, biological and socio-cultural factors will be considered, before moving on to an in-depth analysis of the literature surrounding key aspects of infant feeding. Specifically, these are; milk feeding, the timing of complementary feeding (introduction of non-milk foods), and complementary feeding methods. Evidence has been building surrounding the efficacy of a method termed baby-led weaning (BLW) to complementary feeding, as a way of reducing the risk of childhood overweight and obesity. Therefore, a critical analysis of the research surrounding baby-led weaning will be presented. The influence of a responsive versus non responsive feeding style and a proposed model of infant feeding are also considered, with particular attention given to the driving factors which lead parents to adopt a feeding style.

2.3. The problem of overweight and obesity

Recent figures from the World Health Organization state that in 2016 1.9 billion adults were overweight and of those 650 million were classed as obese (WHO, 2017a). This means that proportionally 39% of the world's population in 2016 were overweight or obese (WHO, 2017a). The problem has accelerated over the past 40 years; rates of obesity and overweight have tripled since 1975 (WHO, 2017a) indicating that this dramatic rise is due to social and environmental factors rather than being an evolutionary occurrence. In the UK specifically, in 2015 26.9% of adults were defined as obese (OECD, 2017) and in Wales, results of the Welsh Health Survey in 2014 show that 24% of adults in Wales were classified as obese with an overall 59% of adults in Wales being either overweight or obese (Welsh Government, 2015b). According to projections in the Foresight report, if current trends continue, by 2050 nearly 60% of the British population could be obese (Butland et al., 2007).

In particular, overweight and obesity in young children is increasing globally, with 41 million children under the age of 5 being classed as overweight or obese in 2016 (WHO, 2017c). In Wales, data from the 2017-18 Childhood Measurement Programme revealed that 14.3% of children aged 4-5 years were overweight, and 12% were obese, and these figures are the highest in the UK (Public Health Wales, 2018). Recent evidence suggests that weight gain at this young age can set a trajectory towards obesity for life. A large systematic review and meta-analysis of over 200,000 participants found that obese children were five times more likely to become obese in adulthood (Simmonds et al., 2015) confirming that addressing childhood obesity is an issue of great importance for public health.

2.3.1. The impact of overweight and obesity

Overweight and obesity may affect a person's ability to take part in every-day activities and confers an increased risk of morbidity and mortality from cardiovascular diseases such as heart attacks and strokes, type 2 diabetes, some cancers and poor mental health (Myers & Rosen, 1999; Public Health England, 2014; WHO, 2017a). According to the most recently available figures from the WHO (2017b) cardiovascular diseases were the leading cause of death in the world in 2012. Perhaps the most well documented and common health complication associated with obesity is type 2 diabetes; obese adults have a seven times greater risk of developing type 2 diabetes than those with a healthy weight (Public Health England, 2014). Diabetes comes with a range of health implications, including cardiovascular disease, blindness, amputation, kidney disease and lower life expectancy (Public Health England, 2014). A recent global review found that almost 6% of cancer cases are attributable to the combined effects of diabetes and obesity (Pearson-Stuttard et al., 2018). The psychological impact of obesity is also well documented as associations have been reported between obesity and depression and anxiety disorders (Scott et al., 2008). Obese and overweight people may also experience loss of self-esteem and may be subject to stigmatization (Myers & Rosen, 1999; Puhl & Heuer, 2010).

In addition to the health impact on the individual, obesity also results in a significant economic burden to society (Withrow & Alter, 2011). Obesity accounts for increased use of health services (Welsh Assembly Government, 2010; Withrow & Alter, 2011), and there are indirect negative socio-economic effects on the economy due to increased sickness and absence from work (Butland et al., 2007). A report from the UK Foresight programme in 2007 provided an estimate of costs of obesity (including these indirect costs) in the United Kingdom to be approximately £49.9 billion by 2050 (Butland et al., 2007).

As in adults, there are numerous health implications of obesity for children. Many diseases, (most of which were previously only evident in adults), are now increasingly being seen in children due to overweight and obesity, including; cardiovascular disease, dyslipidaemia, impaired glucose homeostasis, metabolic syndrome, pulmonary co-morbidities, gastrointestinal co-morbidities, orthopaedic complications, psychosocial and neurocognitive issues, effects on puberty, hyperandrogenism and polycystic ovary syndrome (Yanovski, 2015). Type 2 diabetes in children is also on the increase (Royal College of Paediatrics and Child Health, 2016). Children affected by obesity suffer higher mortality rates and shorter lifespans than children of a healthy weight (Yanovski, 2015). Furthermore, obese children may experience negative effects on their psychological and emotional wellbeing, and they are more likely to be affected by bullying (Russell-Mayhew, McVey, Bardick and Ireland, 2012; vanGeel, Vedder & Tanilon, 2014).

2.4. What increases the risk of childhood obesity?

In basic terms, overweight and obesity occur when the body's energy intake exceeds energy expenditure. Intake of high energy density foods (such as processed foods, red meats and sweet and fatty snacks) is positively associated with adiposity, higher weight and increased BMI in children (Zhou & Zhang, 2014; Emmett & Jones, 2015; Rouhani, Haghighatdoost, Surkan, & Azadbakht 2016). Appetite regulation is thought to play a major role in the development of obesity, and studies with adults and children have found inhibited appetite regulation among obese subjects (Wardle, 2007). Overweight and obese children are more likely to eat in response to food cues (Jansen et al., 2003), eat in the absence of hunger (Lansigan, Emond & Gilbert-Diamond, 2015), and eat in response to emotional or reward cues (Webber, Hill, Saxton, Jaarsveld & Wardle, 2009; Hill, Saxton, Webber, Blundell & Wardle, 2009; Blissett, Haycraft, & Farrow, 2010) demonstrating higher responsiveness to 'external' cues and lower responsiveness to 'internal' hunger and satiety signals.

Furthermore, evidence suggests that children, even those as young as pre-school age, now do not undertake enough physical activity to expend energy (Reilly et al., 2004; Hinckley, Salmon, Okely, Crawford & Hesketh, 2012; Colley et al., 2013, Royal Society for Public Health, 2015). Lack of physical activity and sedentary behaviour, such as screen watching requires very little caloric effort (Duch, Fisher, Ensari & Harrington, 2013; Wakefield, 2015) and has long been identified as a risk factor for overweight in older children (Dietz & Gortmaker, 1985) and pre-school children (Lumeng, Rahnama, Appugliese, Kaciroti & Bradley, 2006).

There are multiple internal and external determinants which are thought to influence diet, appetite and other obesogenic behaviours (Wardle, 2007; Skelton, Irby, Grzywacz & Miller, 2011). Childhood obesity has therefore been termed a 'profoundly complex problem' (Skelton et al., 2011) and there has been extensive research exploring the aetiology of this issue from a variety of perspectives. It is an example of a 'biopsychosocial' issue, with multiple factors influencing overall risk, including genetic and biological effects and social and environmental factors and the interaction between these often interrelated aspects.

2.4.1. Genetic and biological influences

The neuroendocrine system exerts a significant influence on weight control, through the influence of hormones which affect hunger and appetite (Skelton et al., 2011). Some syndromes and conditions which affect hormones, such as Prader-Willi syndrome and auto-immune thyroid disease (typically Hashimoto's) are known to cause overweight in children. While the incidence of these conditions is relatively rare with about 1:22,000 -1: 52,000 children having Prader-Willi syndrome (Prader-Willi Syndrom Association UK, 2018) and 1:3500 children having thyroid disease (British Thyroid Foundation, 2019), they demonstrate the effect of hormones on the development of overweight, leading researchers to pay attention to broader impact of the neuroendocrine system and the possible genetic influences on its functioning in the wider population.

Genetics are thought to play an important part in the development and action of hormonal responses which work within the body and brain to affect appetite and influence energy consumption, in particular leptin which inhibits hunger, and ghrelin which stimulates appetite (Klok, Jakobsdottir & Drent, 2007; Skelton et al., 2011; van der Klaauw & Farooqi, 2015). The genetics of obesity is a complex field of study with over 100 known genetic loci implicated in increased BMI in adults (Chesi & Grant, 2015). One gene in particular, the FTO gene, is now well known to influence obesity risk following an influential study by Frayling et al (2007) of over 38, 000 participants, which first identified this particular gene's effects. Work by psychologist Jane Wardle and colleagues built on this and identified links between the FTO gene and childhood obesity and overeating behaviour in children (Wardle et al., 2008a; Wardle et al., 2009).

Twin studies have assessed the influence of genetics by examining the within-pair differences between monozygotic (genetically identical) twins and between dizygotic (non-identical/fraternal) twins. If a phenomenon has a genetic cause one would expect less variation between monozygotic twins (who share nearly 100% of their genes), when compared with dizygotic twins (who only share around 50% of their genes). Twin studies are useful because they can also eliminate many of the environmental family influences, as most twins will have the same upbringing. For example, Wardle, Carnell, Haworth & Plomin (2008b) examined the BMI and waist circumference of 5092 twin pairs aged 8-11 years and found that genetic factors may contribute to around 40% of inter-individual variation in BMI (Wardle et al., 2008b).

However, at a population level, it is thought that the effects of known genetic loci only amount to less than a 2% variation in BMI, meaning that genetics can not fully explain the obesity epidemic (Loos, 2009; Felix et al., 2015). However this field of study is growing all the time, and more recent thinking is that there may be a cumulative genetic risk, with those with multiple genetic loci being at greater risk (Wang et al., 2019). Despite the discovery of new genetic loci and the potential for a cumulative effect, it has been argued that the considerable incline in obesity rates in the last 40 years can not be explained by genetics alone. Wardle's Behavioural Susceptibility Theory posits that while genes undoubtedly provide a component of the answer, weight gain is likely to arise from a combination of genetic susceptibility and social and environmental factors (Llewellyn & Fildes, 2017). One could say that "genetic background loads the gun, but the environment pulls the trigger" (Bray, 2004 p.115).

2.4.2. Family, social and environmental influences

Obesity risk is not solely driven by genetics but also by experiences around the child that affect what and how much they eat. In particular, eating behaviour and appetite in children is thought to be strongly influenced by parental feeding practices (Shloim, Edelson, Martin & Hetherington, 2015). Feeding practices which are not 'responsive' (i.e. not reciprocal to the child's signs of hunger or satiety) may undermine children's ability to respond to these internal appetite cues (Black & Aboud, 2011; Hurley, Cross & Hughes, 2011). Non-responsive feeding practices include those which control intake such as restriction, monitoring and pressure to eat, and evidence suggests that all of these may hinder children's development of an adaptive and healthy relationship to food (Rodgers et al., 2013a).

Perhaps counter- intuitively food restriction is generally associated with higher child BMI possibly due to children preferring 'forbidden' foods, usually highly palatable and energy dense snack foods (Faith & Kerns, 2005; Shloim et al., 2015). Food restriction has also been shown to be associated with eating in the absence of hunger and emotional eating, thus increasing the risk of overweight (Fisher & Birch, 1999; Farrow, Haycraft & Blissett; 2015). On the other hand, while monitoring and pressuring food intake are broadly linked to lower child weight (Shloim et al., 2015), there may be consequences which are not immediately apparent. For example, pressure to eat has been linked to increased food fussiness (Powell, Farrow & Meyer, 2011), which in turn may lead to lower intake of healthy foods such as fruit and vegetables (Perry et al., 2015). Higher incidence of food fussiness has also been found in obese and overweight children, compared with normal weight children aged 2-6 years (Finistrella et al., 2012).

Parenting strategies which use food to respond to the child's behaviour, for example as a reward or to alleviate distress may also be problematic (Black & Aboud, 2011; Hill et al., 2009). Using food as an emotional regulating tool has been linked to emotional overeating and obesity in young children (Wardle, Sanderson, Guthrie, Rapoport & Plomin, 2002; Blissett et al., 2010).

The relationship between child eating behaviour and weight status does not, however, have a clear causal pathway as it has been suggested that parental feeding practices may be a reaction to child weight, rather than the cause (Farrow & Blissett, 2008). For example, parents of overweight children may respond with restriction and parents who are concerned about child underweight or fussiness may be more likely to pressure intake (Webber, Hill, Cooke, Carnell & Wardle, 2010; Gregory, Paxton & Brozovic, 2010; Holley, Haycraft & Farrow, 2018).

As well as parental feeding practices, what and how parents eat may also be influential on their children's habits and preferences. A recent report of the Health Survey for England showed that children of mothers who are overweight or obese are more likely to be overweight or obese (NHS Digital, 2018). It is thought that this may occur, in part, through children's modelling of parental eating behaviour (Scaglioni, Salvioni & Galimberti, 2008; Palfreyman, Haycraft & Meyer, 2015). For example, one study found significant associations between low parental fruit and vegetables consumption and child consumption of these foods (Wyse, Campbell, Nathan & Wolfenden, 2011). Parental preference for poor-quality energy dense foods is likely to mean that these are the types of foods readily available in the household (Wyse et al., 2011). This may be exacerbated by the relative affordability of these foods, especially in low-income families (Mwatsama & Stewart, 2005). The culture and eating behaviours within a family are therefore likely to be affected family and wider socio-economic circumstances.

Socio-economic status (SES) is a key determinant of overweight and obesity, as according to the most recent report by NHS England 13% of reception-aged children living in the most deprived areas are obese compared with 5% of those living in the least deprived areas (NHS Digital, 2017). A UK cohort study found that children of mothers with a higher level of education (a proxy for socio-economic status) were less likely to be overweight or obese at age 4-6 years (Lakshman et al., 2013).

Families from more disadvantaged socio-economic backgrounds have less money to spend on food than those on higher incomes (Office for National Statistics, 2015) and there is often poor availability of good quality, healthy foods in shops in socially deprived areas; this phenomenon is termed 'food poverty' (Mwatsama & Stewart, 2005; Cummins et al. 2010). Evidence suggest that some low-income families may also experience poor levels of 'food literacy', which relates to understanding of nutrition, food labelling, budgeting and food preparation skills (Cluss et al., 2013; Vidgen & Gallegos, 2014; Adams

& White, 2015; Lovelace & Rabiee-Khan, 2015; Lam & Adams, 2017; McGowan et al., 2017). Studies have also measured dietary quality rather than energy density, and found that children with a lower dietary quality (assessed by their consumption of fruits, vegetables and fish) had a 14% increase in fat mass by the age of 6 when compared with children who had a higher quality diet (Okubo et al., 2015).

Moreover, there is a wider pattern of influences that together can increase risk of overweight, often referred to as the 'obesogenic environment'. The obesogenic environment is considered to be the 'sum of influences that the surroundings, opportunities or conditions of life have on promoting obesity in individuals or populations' (Swinburn, Egger and Raza 1999, p.564). Obesogenic environmental factors may be separated into two key aspects, which are the 'built' or the 'food' environment (Lake & Townshend, 2006; Birch & Anzman, 2010). The built environment refers to urban design, transport options and local amenities and how conducive these aspects are to obesity. (Lake & Townshend, 2006). For example, there is often limited children's outdoor play space in urban areas (Davy, 2016).

The food environment refers to the availability of good quality food as well as the wider social impact of food industry marketing (Lake & Townshend, 2006). The Foresight report highlighted food marketing techniques, the mass production of cheap non-perishable foods and the increase in sugar in manufactured food and drinks as significant contributors to the rise in obesity in the UK (Butland et al., 2007). Concerns around the food market were also echoed by participants in a UK public survey, which called for reassurance over the proportion of the food chain which can be influenced by profit to the detriment of public health (Food Standards Agency, 2016).

2.4.3. Gene-environment interactions

The myriad of effects discussed above around genes and the environment do not occur in isolation of each other, and there are often complex interactions at play in the development of overweight and obesity. In this way, genetic propensity to obesity may be made manifest by exposure to an obesogenic environment (Huang & Hu, 2015; Reddon, Gueant & Meyre, 2016). For example, dietary and energy intake may be dependent on genes. In a study of adult women, those with the Glu27 polymorphism, consumed more carbohydrates and had a higher risk of obesity than those without the Glu27 allele (Martinez et al., 2003). Twin studies in adults have shown that weight loss in response to diet and exercise programmes varies significantly at the individual level (between pairs of twins, but not within twins) which suggests a heritable component of overweight, despite behaviour (Bouchard et al., 1994; Hainer et al., 2000). Behavioural interventions may be important to offset a pre-existent genetic risk, or even prevent the manifestation of obesity, especially in people at high risk (Huang & Hu, 2015).

However, in relation to children, what and how they eat is highly dependent on their parents. Indeed, a systematic review of twin and adoption studies concluded that both genes and shared environment affect BMI variation in childhood, however only up until adolescence, after which point shared environmental factors appeared to be less important. The authors suggested that this may be because of increasing independence of the child and a decreased influence of parents (Silventoinen, Rokholm, Kaprio & Sorensen, 2010). The findings of this review therefore point to the importance of modifiable parenting behaviours as key environmental influences on children's obesity risk, especially where genetic predisposition exists.

For example, recent data from the ALSPAC study in the UK, found that exclusive breastfeeding for at least 5 months substantially reduced BMI growth trajectories up to age 16 years among children carrying the FTO adverse variant, which is implicated in obesity (Wu, Lye & Brollais, 2017). Children with a propensity for obesity may also be exposed to parental feeding styles which may reflect attempts to prevent a child becoming obese, but which may exacerbate risk, as in the case of food restriction. Faith et al. (2004) explored differences in the effects of maternal –child feeding style among children who had a propensity for obesity (defined as those whose parents were overweight) compared with those who did not, and found that restriction predicted higher BMI among 'high-risk' children.

Wardle (2007) has pointed out that the responsibility of attenuating obesity risk does not lie only in modifying behaviour, because at an individual level, many have difficulty with behaviour change especially if they are born with, or have developed, maladaptive appetite regulation systems. Furthermore, she stated that society and the wider environment also must change in order to create a marked difference in overall incidence of obesity. Research and interventions into reducing obesity should therefore take account of genetic, behavioural, social and environmental factors. Likewise, Perez-Escamilla & Kac (2012) discuss a social-economical life-course model which posits that individual behavioural choices related to overweight and obesity are embedded within interconnected micro- and macro- systems, with strong intergenerational links. It has therefore been suggested that a systems approach to preventing obesity in early life may be the answer to breaking the cycle of obesity transmission from parent to child (Perez- Escamilla & Kac, 2013; Nader et al., 2012).

2.5. The importance of early intervention

To return to the physiological principles of weight gain; simply, consuming more energy than is expended results in increased body mass or weight gain (Hill, Wyatt & Peters, 2012). Energy expenditure occurs via three methods; the resting metabolism (basal metabolic rate - the amount of energy required to fuel the body at rest), the thermic effect of food (the energy required to metabolise food consumed) and physical activity (Hill et al., 2012). However, the body's basal metabolic rate can alter in relation to challenges it faces (Hill, 2006). During episodes of food restriction (dieting) there may be a concurrent reduction in basal energy expenditure; effectively this is the body's way of trying to 'hold on' to body fat, and this is thought to be especially true if there has been a long period of sustained obesity. Eating too much however produces less compensatory change in energy expenditure, making weight gain easier. The body is, in this sense, more protective over weight loss than weight gain (Hill, 2006).

It is therefore crucial to focus on prevention of weight gain in early childhood, rather than on weight loss interventions in older childhood or adolescence which may be too late. A Cochrane review found that interventions focused on tackling obesity in later childhood and adolescence had limited effectiveness, because the development of obesity often begins at a young age (Brown et al., 2019). A large longitudinal study of over 7700 children, which showed that the risk of being overweight or obese at age 5-14 was four times higher amongst children who were already overweight by age five (Cunningham, Kramer & Venkat Narayan, 2014).

However, it may not be enough to simply prevent weight gain in young children. It is also vital to address formative early life experiences which contribute to the development and programming of eating behaviour and appetite traits which may be instrumental in determining the chances of becoming overweight or obese in later life (Wardle, 2007; Harshaw, 2008; Llewellyn et al., 2011; Hughes & Frazier-Wood, 2016)

2.5.1. Tracing obesity back to infancy

Over the last couple of decades, increasing attention has turned to the importance of considering the very earliest influences on child obesity, particularly within the first 1000 days of life (Pietrobelli, Agosti & the MeNu Group, 2017). Increasing evidence shows that although later experiences are important, the trajectory to obesity can be traced back to infancy (Snethen, Hewitt & Goretzke, 2007; Stettler, 2007; Robinson, 2017). For example, a recent large study in the north of England of over 16,000 children found that proportions of children above the 85^{th} and 95^{th} percentiles at birth, 8 months and 40 months were consistently higher than the reference data (the UK-90 population), indicating that the presence of overweight could be seen as early as infancy (Perry & Thurston, 2016).

Increased weight in infancy is thought to be strongly linked to overweight in later life. Druet et al. (2011) performed a large meta analysis of data from 10 studies comprising over 47, 000 participants and concluded that every +1 increase in weight SD (standard deviation) scores under the age of 1 year conferred a two-fold higher risk of obesity in childhood and a 23% higher risk of obesity in adulthood. A later study of over 3000 children by van der Willik and colleagues (2015) also found that being overweight in infancy increased the odds of childhood overweight 4-fold.

The identification of the course to obesity and overweight originating in infancy has led to a widespread recognition by researchers that there is an "urgent need for preventative strategies in early life, before excess weight is gained" (Robinson, 2017, p1). The WHO, in their recent Report of the Commission on Ending Childhood Obesity, has therefore adopted a life –course approach, incorporating interventions to address risk factors in the infancy period (WHO, 2017c).

2.5.2. Rapid weight gain in infancy

How quickly infants gain weight in the first year of life is thought to influence later risk of childhood overweight and obesity (Stettler, Kumanyika, Katz, Zemel & Stallings, 2003; Baird et al., 2005; Monteiro & Victora, 2005; Ong & Loos, 2006; Dennison, Edmunds, Stratton & Pruzek, 2006; Dubois & Girard, 2006; Druet et al., 2011; Penny, Jiminez & Martin, 2016).

Weight gain may be considered 'rapid' if there is an increase in weight-for-age z-score of greater than 0.67 (which equates to the crossing of one centile band on a standard percentile chart) from birth to age 1 (Azad et al., 2018) or from birth to any age point in infancy (Sacco et al., 2013). However, definitions of rapid weight gain vary, with some studies classing infants as gaining weight rapidly if they were in the highest tertile or quintile for monthly weight gain.

Weng et al., (2012) conducted a large systematic review and meta-analysis of thirty studies and found significant associations between rapid weight gain in the first year of life and later childhood overweight. A key Canadian study, of over 2000 children found that being in the highest quintiles of weight gain between birth and 5 months conferred double the odds of being overweight at age 4 and a half (Dubois & Girard, 2006). A more recent study by Wang et al. (2016) of over 2000 children found that rapid weight gain in infancy resulted in weight 'tracking' (following the same upward trajectory) up to age 2 years. Furthermore, this study found significant associations between weight gain in the first 4 months of life and overweight and obesity at age 2-7 years. The risk of overweight or obesity increased by 50% for each increase of one standard deviation in weight gain in the first four months. Extremely rapid weight gain (classed as an increase in weight-for age-z-score of >1.28) resulted in an increased risk of childhood overweight and obesity of 60% (Wang et al., 2016).

2.6. Pre-natal and infancy risk factors

Factors which contribute to obesity risk are evident before conception, during pregnancy, and in infancy. Factors such as maternal age, maternal pre-pregnancy and gestational weight gain, mode of birth, infant birthweight, antibiotic use and infant feeding all may play a role (Robinson, 2017). Many of these factors are interrelated, and having a combination of factors may compound the risk. Data from the Southampton Women's Survey examined the relationship between five early life risk factors for obesity (maternal pre-pregnancy obesity, excess gestational weight gain, smoking during pregnancy, low maternal vitamin D status and short duration of breastfeeding) and found that by age 4-5 years children with 4 or 5 risk factors had around 4 times the risk of being obese compared to children who had none (Robinson et al., 2015). Some of these factors will be briefly discussed before focusing on infant feeding

2.6.1. Birthweight

Several studies identify birthweight is a key predictor of infant growth (Rogers, 2003; Monteiro & Victora, 2005; Baird et al., 2005; Stettler, 2007; Yu et al., 2011; Ross & Desai, 2014; Wang et al., 2016; Chiavaroli et al., 2016). It seems logical that babies that are larger at birth, will continue to grow along that percentile line, being larger throughout infancy, and some evidence suggests this is the case. For example, a US study of around 40,000 people found that birthweight was concordant with body weight up to 47 months, with smaller new-born infants remaining smaller and larger infants remaining larger generally through infancy and early childhood, despite relative weight increases in smaller infants ('catch up' growth) and relative weight reduction in large infants (known as 'catch down' growth) (Hediger et al., 1998).

Macrosomic babies (>4000g) or babies who are born large for gestational age (LGA) (>90th percentile for weight) are more likely to be overweight or obese later in childhood and adulthood (Rogers, 2003; Monteiro & Victora, 2005; Baird et al., 2005; Chiavaroli et al., 2016). A systematic review and meta-analysis reviewed seven studies which found that high birthweight conferred an increased risk of obesity in older childhood and adulthood (Weng et al., 2012). However, this relationship is complex; while higher birthweight is linked to higher BMI in childhood, this may be more likely to be lean mass rather than fat mass (Ong, 2006). Moreover, not all studies have found associations between high birthweight and later overweight. For example, data from ALSPAC study revealed no association between birthweight or birth length and central adiposity in 9-10 year olds (Rogers et al., 2006).

Low-birthweight (LBW) (<2500g) or small for gestational age (SGA) may also be a risk for overweight. Definitions of SGA vary but is generally considered to be less than the 10th percentile for weight, or more than 2 standard deviations below the population mean (Zeve, Regelmann, Holzman & Rapaport, 2016). It has been hypothesised that babies who are severely under-nourished in-utero and born SGA or with a LBW may be at a higher risk of obesity in later life. This is known as the 'thrifty phenotype', a term coined by Hales and Barker, who suggested that infants that had been undernourished in utero and in early life may be genetically 'programmed' to function in frugal nutritional conditions, however, once nutritional availability improves in later life, these altered metabolic functions become maladaptive and result in poor insulin/glucose function, which in turn may increase risk of obesity (Prentice, 2005; Hales & Barker, 2013).

Babies who have a LBW, are SGA or are born pre-term may also be subject to a requirement to 'catch up' their weight postnatally. For example, catch-up growth was seen in over 86% of SGA infants in one Swedish cohort study of over 3000 infants (Karlberg & Albertsson-Wikland, 1995). Therefore, a large proportion of these infants are likely to gain weight more rapidly than normal birthweight babies placing them at risk for overweight and obesity later on (Ong, Ahmed, Preece & Dunger, 2000; Stettler, 2007; Ross & Desai, 2014; Wang et al., 2016) (see section 2.5.2.).

Another large cohort study of over 19,000 participants did not find any association between birthweight and overweight status in childhood, but instead found that rapid growth in infancy was a significant predictor (Stettler et al., 2002). This suggests that rather than birthweight itself subsequent rapid growth in infancy may be the important factor. Nonetheless birthweight is likely to be a key variable influencing infant growth, both in terms of weight in infancy relative to birthweight (i.e. large babies staying large and small babies staying small) and in terms of risk for rapid weight gain (more likely in babies who are smaller at birth who then undergo catch-up growth).

Genetics appear to play a role in birthweight. Genes which affect insulin and insulin –like growth factors and receptors have effects on fetal growth (Ong & Dunger, 2004). A large cohort twin study, of 868 monozygotic and 1141 dizygotic twins found that heritability of birthweight was around 25-40% (Clausson, Lichtenstein & Cnattingius, 2000). However, preconception and intrauterine factors may also affect babies' birth weight. For example, high birthweight is more likely in overweight or obese mothers, mothers who gain weight during pregnancy and mothers with gestational diabetes (Rode et al., 2007; Williams, Mackenzie & Gahagan, 2014; Santangeli, Sattar & Huda, 2015). A Danish study of 2248 singleton neonates demonstrated a strong correlation between maternal weight gain during pregnancy and giving birth to an LGA baby. This association was more apparent in previously normal weight women who had gained weight during pregnancy than it was in women who were already overweight or obese pre-pregnancy (Rode et al., 2007). This suggests that it is what happens within the maternal body environment whilst pregnant that is crucial to the offspring's outcomes.

A suggested reason for this is that overweight and obese pregnant women are at a greater risk of gestational diabetes which, if present, may expose the fetus to an abnormal hyperglycaemic intra-uterine environment, which is known to stimulate growth and result in increased birthweight (Santangeli et al., 2015). Research in the field of epigenetics also proposes that fetal gene expression may be affected by excessive nutrition in the in-utero environment (Lillycrop & Burdge; 2011; Chiavaroli et al., 2016). The impact of gestational weight gain can persist into childhood; a large US study of 1044 mother/baby pairs found a relationship between maternal gestational weight gain and overweight in their children at age 3 years, after adjustments for maternal BMI and breastfeeding duration (Oken, Taveras, Kleinman, Rich-Edwards & Gillman, 2007).

Low birthweight has been linked to maternal smoking, alcohol use and stress (Magee, Hattis & Kivel, 2004; Witt et al., 2016), The exact mechanism by which these factors affect birthweight is unclear, but emergent research suggests that exposure to certain levels of hormones or to some toxins may change the epigenetic expression of genes which determine fetal growth (Tyrell et al., 2012; Engel et al., 2014).

2.6.2. Maternal age

Maternal age is associated with infant growth, and this thought to occur because of differing fetal growth and birthweight outcomes for infants of particularly young or older mothers, and because of differences in feeding according to maternal age. Younger mothers (especially adolescent mothers) for example are more likely to have infants with a low birthweight (Restrepo-Mendez et al., 2015), and are also less likely to breastfeed (Oakley, Renfrew, Kurinczuk & Quigley, 2013; McAndrew et al., 2012) which is thought to be protective against obesity (which will be discussed in section 2.8.). Older mothers (>35years) on the other hand, while being more likely to breastfeed (McAndrew et al., 2012) they are also more likely to have a low birthweight baby, due to the increased likelihood of undiagnosed diseases or reduced cardiovascular reserve which can impact placenta function (Restrepo-Mendez et al., 2015). As previously discussed (see section 2.6.1.) infants born at a low-birth weight may be more likely to experience 'catch up growth' (Hediger et al., 1998; Singhal, 2017), which is known to increase risk of overweight in childhood (Ong et al., 2000).

The impact of maternal age may be compounded by the effect of socio-economic status as younger mothers are more likely to come from more deprived backgrounds and older mothers are more likely to have a higher level of education, often having pursued a career before having a baby (Pilgrim et al., 2010).

2.6.3. Socioeconomic status

Socio-economic status (SES) is also well known to affect birthweight, infant growth and later child weight status. For example, mothers from lower SES backgrounds are more likely to have a low birth-weight baby. Large population studies from the UK, Canada and Italy found that lower maternal education was associated with increased odds of a low birthweight baby (Spencer, Bambang, Logan & Gill, 1999; Joseph, Liston, Dodds, Dahlgren & Allen, 2007; Chevalier & O'Sullivan, 2007; Cantarutti, Franchi, Compagnoni, Merlino & Corrao, 2017). Mechanisms which are thought to explain this are differences in gestational length, smoking during pregnancy, accessibility to ante-natal care, maternal nutrition and maternal stress (Chevalier & O'Sullivan, 2007).

Lower SES has also been associated with rapid early infancy growth; the Gemini Study found that lower SES was associated with higher infant weight at three months, and greater incidence of rapid growth (Wijlaars, Johnson, van Jaarsveld & Wardle, 2011). This phenomenon may be due increased incidence of low birth weight among lower SES groups resulting in catch-up growth, or may occur because of different infant feeding methods; mothers from lower socio-economic groups are less likely to breastfeed, for example (Oakley et al., 2013; McAndrew et al., 2012).

2.6.4. Mode of birth

Mode of birth is also thought to have an impact on childhood obesity. Several studies have shown an association between caesarean section birth and overweight and obesity in childhood (Huh et al., 2012; Mueller et al., 2015; Li, Zhou & Liu, 2013; Pluymen et al., 2016; Kuhle, Tong & Woolcott, 2015; Yuan et al., 2016). One possible mechanism for this association is that the mode of delivery affects the neonatal gut microbiome. It is thought that the lack of infant exposure to vaginal secretions and increased likelihood of antibiotic use inhibits the normal development of the infant's gut microbiome (Ajslev, Andersen, Gamborg, Sorensen, & Jess 2011; Huh et al., 2012; Paolella & Vajro, 2016). In addition, labour activates a cascade of hormonal responses in the neonate which may modify the genes that affect obesity (Huh et al., 2012).

However, the relationship between mode of birth and childhood obesity is not clear and there are a number of potentially interrelated factors. For example, infants born to overweight mothers are more likely to be overweight (Williams et al., 2014), however, women who are overweight are also more likely to require a caesarean section, (Scott-Pillai, Spence, Cardwell, Hunter & Holmes, 2013). Furthermore, infants born by caesarean section are less likely to be breastfed (Prior et al., 2012).

2.6.5. Antibiotic use

Several recent studies have concluded that there is a link between antibiotic use in infancy and childhood obesity (Trasande et al., 2013; Mueller et al., 2015; Saari, Virta, Sankilampi, Dunkel & Saxen, 2015; Azad, Bridgman, Becker & Kozyrskyj, 2014; Bailey et al., 2014; Scott et al., 2016; Gerber et al., 2016). One recent study also found that this risk increases with repeated exposures (Schwartz et al., 2016). It is thought that antibiotics may adversely affect the diversity of the infant's gut microbiome, which in turn may increase risk of obesity, although this field of study is relatively new (Koleva, Bridgman and Kozyrskyj, 2015; Yassour et al., 2016; Miller, Wu & Oremus, 2018).

Conversely, a recent large study of over 260,000 participants found that infection in infancy (but not antibiotic use) was associated with increased childhood obesity risk. However, the authors did not rule out the potential impact that antibiotics might have on the microbiome (Li, Chen, Ferber & Odouli, 2017).

2.7. The importance of infant feeding

In light of the pregnancy and maternal factors already discussed, and while these need to be addressed, what and how a baby is fed in infancy is thought to be crucial for breaking the 'maternal-child life course obesity cycle' (Nader et al., 2012). There are two key stages to infant feeding, the milk feeding stage where infants are fed breast milk or infant formula as their only source of nutrition, recommended until 6 months (WHO, 2002) and then the complementary feeding stage, from around 6 -12 months (WHO, 2001) where infants are introduced to non-milk foods alongside continuing milk feeds. Both stages are considered to be important not only for influencing weight gain during infancy, but also for the development of eating behaviours which may continue into later life (Nader et al., 2012).

The mechanisms by which infant feeding affects weight and later obesity risk are however, complex. While components of milk type (breastmilk or formula), and the content of the complementary feeding diet play a role, it has increasingly been recognized that maternal-child feeding style is likely to have an impact both on energy consumption during infancy and on the development of eating behaviour, which may in turn affect early appetite regulation (Bartok & Ventura, 2009).

The following sections will explore first the milk feeding stage, then the complementary feeding stage. How each stage may affect weight gain in infancy and subsequent childhood overweight and obesity will be examined, considering both the content of the diet and the influence of maternal feeding style on the development of appetite and food preferences. The next section will consider milk feeding, before going on to look at the complementary feeding stage.

2.8. Milk feeding

While not all studies have found significant associations (Hediger, Overpeck, Kuczmarski & Ruan, 2001; Li, Parsons & Power, 2003), several systematic reviews and meta-analyses have demonstrated that broadly breastfeeding appears to be a protective factor against overweight and obesity in childhood. (Dewey, Heinig, Nommsen, Peerson & Lonnerdal, 1992; Armstrong & Reilly, 2002; Weng et al., 2012; Yan, Liu, Zhu, Huang & Wang, 2014; Horta, Loret de Mola & Victora, 2015; WHO, 2016b; Rito et al., 2019). Key criticisms of research finding associations between breastfeeding and overweight are that the differences are small and that studies may be affected by potential effect of confounders such as maternal socio-economic status, or maternal weight status, and this will be discussed further later on (section 2.8.4.) (Owen et al., 2005). Despite these concerns, evidence continues to build, linking breastfeeding with reduced risk of obesity. Earlier this year, a WHO study of 22 countries and over 30,000 children concluded that breastfeeding can reduce the chances of a child becoming obese by up to 25% (Rito et al., 2019).

One proposed reason for this effect is that formula fed infants gain more weight in infancy, acquire greater fat mass and gain weight more rapidly. Dewey et al.'s (1992) seminal research, the DARLING study showed that by 12 months of age breastfed infants weighed on average 0.65kg less than the formula fed infants, despite length measurements being similar between the groups, suggesting a leaner body composition of the breastfed infants. A later systematic review and meta-analysis found that when compared with breastfed infants, formula feeding is associated with higher fat mass acquisition during infancy (Gale et al., 2012). Furthermore, de Beer and colleagues (2015) found that this body composition effect extends into childhood. The NOURISH trial in Australia of over 600 infants found that formula feeding was associated with rapid weight gain in infancy (Mihrshahi, Battistutta, Magerey & Daniels, 2011). A more recent systematic review of the evidence supported this association (Appleton et al., 2018a).

However, milk feeding is not a simple dichotomous behaviour of either feeding exclusively from the breast or formula feeding from birth. Variations occur in duration and exclusivity of breastfeeding. It appears that the longer the duration of breastfeeding and exclusive breastfeeding the greater the benefits (Oddy et al., 2014; de Beer et al. 2015; WHO, 2016b). A large US study of over 177,00 infants found that longer duration of breastfeeding was associated with reduced risk of overweight at age 4 (Grummer-Strawn & Mei, 2004). Two meta-analyses supported this dose-responsive effect (Harder, Bergmann, Kallischnigg & Plagemann, 2005; Yan et al., 2014) An Australian study explored longitudinal data of 2800 participants and found that shorter duration of breastfeeding (<4 months) increased the odds of infants experiencing rapid growth in infancy (Oddy et al., 2014) and that duration of breastfeeding of less than <6 months was associated with increased BMI and likelihood of obesity throughout childhood up to age 20 (Oddy et al., 2014).

However, duration and exclusivity of breastfeeding are not always adequately explored in research with many studies focusing on exclusive breastfeeding versus formula feeding, or simply comparing 'ever breastfed', with 'never breastfed' and do not consider degrees of exclusive or partial breastfeeding (Yan et al., 2014). Studies which have explored this have found that partial or combination feeding (any degree of formula feeding alongside breastfeeding) is associated with decreased overall breastfeeding duration (Holmes, Auinger & Howard, 2011), and earlier introduction to complementary foods (Azad et al., 2018).

In terms of growth, the Canadian CHILD study of over 2500 infants found that at 12 months, combination fed infants' BMI was closer to that of formula fed babies, compared with those who had been exclusively breastfed to 6 months, who had the lowest BMI. However, partial breastfeeding alongside complementary foods (rather than formula) was not significantly associated with increased BMI in this study, indicating the effect seen was due to the formula milk (Azad et al., 2018). Looking at long term obesity risk, in a study of 884 children, van Rossem et al. (2011) found that by age 3, children who had been exclusively breastfed, or partially breastfed for 6 months had a lower BMI at age 3 compared with children who had been partially breastfed for less than 6 months or children who had never been breastfed. The authors calculated that every month of breastfeeding duration (whether exclusive or not) was associated with a 14% reduced odds of being obese at age 3 (Van Rossem et al., 2011). Duration and degree of partial breastfeeding therefore appears to be important.

These differences between breast and formula fed infants are thought to occur due to the differing contents of breastmilk and infant formula and because of behavioral differences between breastfeeding and bottle feeding (Mihrshahi et al., 2011).

2.8.1. The content of breast milk and infant formula

Breastmilk and formula milk contain different components which are thought to explain some of the differences in growth patterns. The main differences are in terms of nutrient content, in particular, protein as well as differing hormonal and bacterial profiles.

Protein

Luque, Closa-Monasterolo, Escribano and Ferre (2016) discuss the 'early protein hypothesis' to explain the phenomenon of rapid weight gain in formula fed babies. The protein content in breastmilk is lower than in formula, with the average protein content of breastmilk being around 0.9- 1.2g per 100ml (Ballard & Morrow, 2013) and the most recent EU regulations stipulating that formula can contain between 1.2 – 2.0g per 100ml (Crawley & Westland, 2019). Formula contains higher levels of protein because it is derived from cow's milk, which is ideal for promoting growth of cows, but not as important for humans where the focus is on brain development (Hambreus, 1977; Legarraga, 2006). Dairy protein has been seen to have a stimulating effect on growth in humans, through increasing insulin-releasing amino acids, insulin and insulin-like growth factor 1 (IGF-1) which encourage growth and adipogenic (fat forming) activity (Ziegler, 2006; Luque et al., 2016; Grenov & Michelsen, 2018).

Exacerbating growth in infants presents a risk of weight gain that is excessive and rapid, which poses an increased risk of later overweight (as discussed in section 2.5.2.). The DARLING study was one of the earliest to explore the effect of high protein intake in infancy (Heinig, Nommsen, Peerson, Lonnerdal & Dewey, 1993). In this important study the authors found that total protein intake (from either milk and complementary foods) was 66-70 % higher in formula fed babies than in breast fed babies age 3-6 months, which the authors concluded was attributable to the formula milk. However, the potential for differing protein intake from complementary foods between the groups was not reported.

More recent research has also compared high protein formula with lower protein formula or breastfeeding, with one large multi-centre European study of over 1000 infants finding that those fed higher protein formula (compared to formula with a lower protein content) had greater weight at 24 months, however no difference was seen between the low protein formula group and the breastfed group (Koletzko et al., 2009a). These findings were replicated in a smaller Mexican study last year (Oropeza-Ceja et al., 2018). These early protein effects may extend into later childhood; Weber et al (2014) found that by age 6 years, children who received the high protein formula had a significantly higher BMI and a 2.43 increased risk of becoming obese than in the low protein formula or breastfed groups, however, again, no significant difference was seen between low protein and breastfed groups (Weber et al., 2014). This finding has been further echoed in a large recent European study of over 1000 formula fed infants (Totzauer et al., 2018).

The most recent opinion from the European Food Safety Authority (EFSA) in 2014 (p.16) was that "whether protein plays a role in the observed increased growth rate and higher BMI in childhood is still matter of debate and requires more research". EFSA went on, however, in 2017 to recommend lowering the protein content of follow on formulae (only) from 1.8g to 1.6g per 100ml (EFSA, 2017). EFSA also pointed out that the constantly changing amount and composition of protein found in breastmilk can not be replicated by infant formula (EFSA, 2014). Protein in breastmilk is highest during the first 1-2 months and then decreases in line with the infant's requirements, therefore, Ziegler (2006) suggested that the static higher levels of protein available in formula milks are likely to become in excess of infants' requirements after the first 1-2 months. Recently, many formula companies have reduced the amount of protein in their milk, with most in the UK in 2019 being at the lower end of the recommended min-max range (1.2g-2.0g) (Crawley & Westland, 2019). However, some popular UK brands such as Aldi's Mamia first stage milk contains a high protein content relative to other brands, currently 1.6g per 100ml. Follow-on formula and hungry baby preparations also contain higher levels of protein (Crawley & Westland, 2019).

Hormones

Certain appetite regulating hormones, glucose, inflammatory markers and other bioactive compounds that are present in breastmilk have been shown to influence body composition and fat mass acquisition (Fields & Demerath, 2012; Alderete et al. 2015, Chan et al., 2017). For example, higher concentrations of leptin the 'satiety hormone', which is found in breastmilk have been associated with lower infant weight for length at 12 months (Bartok & Ventura, 2009; Chan et al., 2017). Other studies have found the reverse, finding higher leptin levels in formula fed infants aged 3 months, compared with breastfed infants (Breij et al., 2017). However, this study found that formula fed infants also had higher levels of ghrelin 'the hunger hormone' which the authors posited could impair leptin signalling. Breij et al. (2017) also found significant associations between ghrelin and fat mass percentage at 3 months but only amongst formula fed infants, whereas leptin correlated with fat mass percentage in both breastfed and formula fed infants, indicating that the relationship between appetite regulation hormones in infancy is not straightforward and may differ based on feeding type.

Adiponectin is another hormone found in breast milk which modulates glucose and fat metabolism. Higher levels of adiponectin are associated with lower adiposity and increased insulin sensitivity, lower infant weight and lower BMI (Woo et al. 2009; Savino, Liguori, Fissore & Oggero, 2009; Ballard & Morrow, 2013), although this association has not been supported by all studies (Chan et al. 2017). Additionally, IGF-1 (as mentioned above) is associated with rapid growth and is found in lower levels in breastfed babies (Savino et al., 2009). Research is needed on further understanding the interactions between these hormones and feeding type.

2.8.2. The microbiome

Differing compositions of the gut microbiome has also been considered to play an important part in the development of obesity (Reinhardt, Reigstad and Backhed, 2009; Korpela, Salonen, Virta, Kekkonen & de Vos, 2016; Korpela et al., 2017; Emmanouil & Raoult, 2018). Small exploratory studies have observed that over weight and obese children had differing faecal microbiota, compared to normal weight children, in particular obese children showed lower levels of Bifidobacterium (Kalliomaki, Collado, Salminen & Isolauri, 2008; Luoto et al., 2011; Korpela et al., 2017). The connection between antibiotic use and childhood overweight and obesity (see section 2.6.5.), adds to the case that a healthy and diverse microbiome may help to maintain a healthy weight (Miller et al., 2018).

Studies have therefore explored the potential that breastfeeding may have on the early development of the microbiome in infancy. Breastfed infants have been found to have higher levels of Bifidobacterium (Lewis & Mills, 2017; Moosavi et al., 2019). Bacterial diversity (which is thought to be beneficial for gut health and risk of obesity) is also improved by breastfeeding; one small study of 33 infants found that bacterial diversity in the first 30 days of life was greater among infants who were predominantly breastfed by their mother, when compared to those receiving donor milk or infant formula (Cong et al., 2017).

This was supported by a larger study of 107 infants and found that prolonged breastfeeding was associated with increased bacterial diversity by around age 40 days (Pannaraj et al., 2017). This study also found that breastfed infants received around 28% of their gut bacteria from their mothers' breast milk and areolar skin (Pannaraj et al., 2017) demonstrating a route of transmission of microbes from mother to infant, which would not be available to non-directly breastfed infants. The exact mechanism by which the microbiome influences obesity is not yet clear, however animal studies point towards the effect that the gut microbiome may have on appetite regulation (Fetissov, 2017). More research in humans is needed.

2.8.3. Behavioural differences between breastfeeding and bottle feeding

Whilst milk type clearly has an influence, some studies also point to the behavioural differences between breast and bottle–fed babies. A large study of over 1800 infants found significant associations between bottle feeding and increased infant weight, regardless of milk type (expressed breast milk or formula) (Li, Magadia, Fein & Grummer-Strawn, 2012). The Canadian CHILD cohort study of over 2500 infants also found that feeding expressed breast milk from a bottle was associated with higher BMI at 12 months and greater infancy weight gain velocities compared with infants fed directly from the breast (Azad et al., 2018).

This may be because bottle fed infants consume greater volumes of milk. Small studies have found that bottle-fed infants drank more milk at 6 and 14 weeks of age (Kohler, Meeuwise & Mortensen, 1984) and even within the first 2 days of life (Dollberg, Lahav & Mimouni, 2011). In the latter study, breastfed infants were weighed before and one hour after initiation of feeding, and results were corrected for normal infant weight loss. Bottle fed infants' milk intake was measured. On day 1 post-partum, formula fed infants (18.5ml/kg/day) consumed around double that of breastfed infants (9.6ml/kg/day). On day 2 formula fed infants intake increased to 42.2ml/kg/day compared to only 13ml/kg/day in breastfed infants (Dollberg et al., 2011). However, this was a small study of only 43 subjects. More recently, a large study of 1093 infants explored infant growth according to milk volume intakes and the findings demonstrated an association of high volumes of formula intake at 3 months, with increased weight at 6 months and 12 months (Huang et al., 2018).

The potential for greater milk intake in bottle fed infants is perhaps due to the relative ease of drinking from a bottle compared with the breast; bottle feeding is assisted by gravity and requires babies to use fewer sucks per minute when compared with breastfeeding, allowing the bottle-fed baby to easily drink more (Moral et al., 2010). Conversely, in breastfeeding, the infant is required to open their mouth wide, latch correctly and effectively use their tongue to remove the milk, and in this way breastfeeding is more effortful (Daley & Hartmann, 1995). However, as well as these mechanical differences, there are often important differences in the maternal feeding style between breastfeeding and bottle feeding mothers.

The differences in maternal control over milk feeding has been explored by a number of studies (Taveras et al., 2004; Li, Fein & Grummer-Strawn, 2010; Brown, Raynor & Lee, 2011a; Brown & Lee, 2013a). Bottle feeding is particularly associated with a controlling feeding style (Brown et al., 2011a). In a study of 384 mothers of infants aged 0-6 months, using an adapted version of the Child Feeding Questionnaire (CFQ) (an established tool), Brown and Lee (2013a) found that formula feeding mothers were significantly more likely than breastfeeding mothers to report 'feeding to a routine', 'encouraging feeding' or 'limiting feeding', behaviours which indicate a maternal led schedule, rather than being responsive to infant cues. This may be due to the fact that the when baby is bottle-fed, the care-giver is able to visualize the amount of milk consumed and thus may be tempted to manipulate or encourage intake (Li et al., 2012; Brown et al., 2011a; Brown & Lee, 2013a). Conversely, breastfeeding mothers are unable to know how much milk their babies are getting, meaning that control or monitoring of intake is not possible. Furthermore, breastfeeding works on a biomechanical 'supply and demand' system, so any attempts to schedule or delay feeds can damage milk supply. Effective breastfeeding therefore necessitates low maternal control and high responsiveness to infant feeding cues (Daley & Hartmann, 1995; Brown et al., 2011a).

It has also been suggested that breastfed infants are more demonstrative of feeding cues towards their parent, indicating that the communication dynamic between mother and infant is reciprocal, and perhaps learned over time. Researchers in one unique study took video recordings of breastfeeding and formula feeding infants examining differential behaviour (Shloim, Vereijken, Blundell & Hetherington, 2017). In this study, breastfed infants showed higher levels of engagement cues (indicative of hunger) and disengagement cues (indicative of satiety) than formula fed infants, indicating that they were better able to show their parent that they were hungry or had had enough. An earlier study of bottle-fed infants found that they too showed behavioural signals of satiety, however, the less responsive the mother's feeding style, the less consistently the infant showed signs of satiety, indicating that communication from the infant may be dampened by the maternal response (or lack thereof) (Ventura, Inamdar & Mennella, 2015). Furthermore, in this study, infants whose mothers were less responsive, consumed more milk and spat up milk more often (a possible sign of overfeeding).

Breastfed babies may therefore have more opportunity to learn to self-regulate their own appetite, becoming more satiety responsive (the ability to recognize fullness). Appetite regulation, is considered to be strongly influenced by infants' feeding experiences (Wardle, 2007; Harshaw, 2008; Llewellyn et al., 2011; Hughes & Frazier-Wood, 2016). How parents react to infant behaviour may affect how infants learn to understand appetite signals. For example, up to around three months of age, infants respond emotionally to a number of uncomfortable emotional states (such as hunger, temperature states or sleep states) and express this discomfort by crying (DiSantis, Hodges, Johnson & Fisher, 2011a). It is the care-giver's response to crying with feeding which develops the association between a particular feeling of discomfort and hunger; this is known as 'social biofeedback' (Harshaw, 2008, p548). However, after about three months of age infants begin to demonstrate self-regulated behaviour, such as turning their head away from a bottle if not hungry. It is essential therefore that caregivers are attuned to the infants' progression from emotional reactivity to self-regulation, by being responsive to these subtle cues (Disantis et al., 2011a). Missing or ignoring these signs may lead to consistent over-feeding which may mean that a baby learns to override their innate appetite cues, potentially reducing satiety responsiveness.

The effects of decreased satiety responsiveness may be long lasting. Data from the GEMINI study, a large UK cohort twin study, found that infants as young as 3 months old who had decreased satiety-responsiveness continued to show decreased satiety-responsiveness at 9 and 15 months (van Jaarsveld, Llewellyn, Johnson & Wardle, 2011). Lower satiety responsiveness was also associated with increased weight in the GEMINI study. The link between breastfeeding and satiety responsiveness has been shown to extend into childhood with one study showing that mothers of babies who had been breastfed for at least 6 weeks, self-reported that their child was more satiety responsive at 18-24 months compared with those who had breastfed for a shorter duration (Brown & Lee, 2012). This satiety responsiveness effect may be attributed to the mode of milk delivery, rather than the milk type; in a study which explored this satiety responsiveness was increased when infants were directly breastfed rather than fed expressed milk from a bottle, again indicating the influence of maternal control over the feeding (DiSantis et al., 2011b). In another study, babies who were bottle-fed (breast or formula milk) in early infancy were more likely to finish the contents of a bottle or cup in late infancy, further suggesting a link between bottle feeding and reduced capacity to self-regulate appetite (Li et al., 2010).

This effect appears to continue into older childhood, with bottle fed babies who were encouraged to finish the contents of a bottle, being more likely to finish a plate of food at age 6 (Li, Scanlon, May, Rose & Birch, 2014). Another cohort study of 576 adolescents, asked participants to rate satiety responsiveness and measured food intake after an ad-libitum meal (where participants were allowed to eat as much as they wanted) to assess eating in the absence of hunger (EAH). The study found increased satiety responsiveness in adolescents and lower food consumption in the EAH test among participants who had been breastfed for more than 6 months in infancy (Reyes et al., 2014). However, this study failed to account for all covariates, especially given the time that had elapsed between feeding type in infancy and the test.

The research in this area has so far been exploratory and is not conclusive. For example, one study of 428 toddlers failed to find a significant association between any degree of breastfeeding and satiety responsiveness (as rated by the parent using the CFQ) at age 2 (Hathcock et al., 2014). Despite this, the evidence suggests that poor satiety responsiveness in young children and adolescents has been shown to increase the likelihood of eating when not hungry, or eating large portions (Reyes et al., 2013; Carnell & Wardle, 2007) leading to excessive energy intake and subsequent weight gain, overweight and obesity (Carnell & Wardle, 2008). In the West, where high energy foods are readily available and portion sizes are often large (French, Story & Jeffrey, 2001) the development of sensitive appetite regulation may be particularly important (French, Epstein, Jeffrey, Blundell & Wardle, 2013).

2.8.4. Milk feeding: Confounding factors

Some authors have asserted that the relationship between breastfeeding and reduced risk of overweight is more likely attributable to the type of mothers that breastfeed rather than the breastfeeding itself (Owen et al., 2005). For example, according to a large survey of 151 primary care trusts in England, women from more advantaged socio-economic backgrounds, and those with a higher level of education are more likely to initiate and continue breastfeeding, whereas women living in areas of high deprivation are more likely to formula feed (Oakley et al., 2013).

The reasons for the disparities between socio-economic status and breastfeeding are complex and deep rooted. Since breastfeeding in low income communities is not common, there is often lack of experiential expertise about the practicalities of breastfeeding within or around the family, misconceptions about how breastfeeding works, and significant stigma around feeding, especially in public (McFadden & Toole, 2006; MacGregor & Hughes, 2010; Henderson, McMillan, Green & Renfrew, 2011; Trickey et al., 2019). Older maternal age is also associated with increased likelihood of breastfeeding (Oakley et al., 2013), however, this may also be related to socio-economic status, with younger mothers more often coming from low income communities (Boden, Fergusson & Horwood, 2008). Infant birthweight and growth may also be affected by maternal socio-economic status (SES) (see section 2.6.1.)

Women who have had a caesarean section are also less likely to breastfeed, often due to delays in skin-to skin contact initiation, post-operative pain and/or the effects of analgesia (Brown & Jordan, 2013; Hobbs, Mannion, McDonald, Brockway & Tough, 2016). The effect of not being breastfed on the risk of overweight may also be confounded by the evidence that suggests that caesarean section is in itself associated with increased risk of overweight in the child in later life, possibly due to the adverse effect on the development of health gut flora and the use of antibiotics (see section 2.6.5.).

Furthermore, mothers who are overweight or obese are less likely to breastfeed (Amir & Donath, 2007; Wojcicki, 2011; Babendure et al., 2015). Explanations for this, include the mechanical difficulties of having larger breasts, increased likelihood of co-existing medical conditions, increased potential for birth interventions and maternal body image dissatisfaction (Amir & Donath, 2007). Mothers who are worried about body image are less likely to breastfeed due to embarrassment or the perceived effect that breastfeeding may have on their breast shape (Brown, Rance & Warren, 2015). Overweight and obese mothers may also experience delayed onset of milk production due to impaired hormone function, leading to reduced milk supply and early cessation of breastfeeding (Babendure et al., 2015).

The nature of the relationship between socio-economic status, education, maternal age, pre-natal factors, mode of birth/delivery and infant feeding and obesity risk is complex and unclear, indeed, it is likely to be multifactorial in nature. Notwithstanding these important considerations, most studies which account for these covariates continue to find independent associations between breastfeeding and obesity. For example, a meta-analysis of 113 studies, continued to find a significant relationship between breastfeeding and risk of obesity, independent of socio-economic status, mode of birth, and parental anthropometry (Horta et al., 2015).

2.9. The complementary feeding stage

As discussed so far, much of the evidence surrounding infant feeding has focussed on the milk feeding stage, but far less has explored the impact of complementary feeding upon weight and eating behaviour. This stage is, however, also very important for shaping children's relationship with food because it is the infant's first experience of eating anything other than milk.

After 6 months of age the nutritional and energy requirements of babies can no longer be met by milk alone; other food should therefore supplement ongoing milk feeds to meet these needs (WHO, 2001). Complementary feeding is the term used for the process of introducing complementary foods (non-milk food) into a baby's diet alongside a gradual reduction of milk feeds. However, milk should remain a major component of an infant's diet until 12 months, making up around 70% of the daily energy of infants aged 6-8 months and slowly reducing to around 45% of the daily energy intake of infants aged 9-12 months (Michaelsen, Weaver, Branca & Robertson, 2000).

2.9.1. Timing of introduction of complementary foods

UK guidelines (UNICEF UK, 2015; Department of Health, 2018) advocate introducing complementary foods at around 6 months; this recommendation follows the WHO (2002) guidelines for the optimal duration of exclusive breastfeeding to 6 months. The basis of the guideline is therefore strongly linked to the encouragement of exclusive breastfeeding to 6 months, with the rationale that babies that are breastfed until 6 months will benefit, in particular in terms of reduced incidence of infections (Kramer & Kakuma, 2002). The key evidence which underpinned the recommendation came from Kramer & Kakuma's (2002) systematic review of 22 studies (11 from developing countries and 11 from developed countries) which found reduced incidence of gastrointestinal infections if exclusive breastfeeding was continued for 6 months and, crucially, concluded that there was no deficit in terms of growth from prolonged breastfeeding for infants from either developing or developed countries.

Additional benefits of longer duration of breastfeeding were considered to be prolonged lactational amenorrhea, reducing the risk of pregnancies occurring in close succession, and maternal postpartum weight loss which was thought to be beneficial, especially for women from developed countries where gestational weight gain and postpartum weight retention are high.

Kramer & Kakuma's original review found no benefits from the introduction of complementary foods before 6 months. The authors have since updated their review in 2012, with newer literature, and have not changed their recommendation for exclusive breastfeeding for 6 months (Kramer & Kakuma, 2012). A more recent Cochrane review has also found no evidence of any benefit from introducing food before 6 months in breastfed infants (Smith & Becker, 2016). Furthermore, the evidence on the overwhelming protective benefits of breastfeeding are continuing to build, showing that that even in developed countries risk of morbidity for both infants and mothers is reduced by longer duration of exclusive breastfeeding (Victora et al., 2016; Bartick et al., 2017)

However, there is significant scientific divergence on this topic, with a number of European bodies advising that it is safe for babies to start complementary foods between 4 and 6 months of age, due to concerns about the quality of evidence in the WHO reviews pertaining to developed countries. In particular, it has also been highlighted that the Kramer and Kakuma recommendations to wait until 6 months to introduce food relate specifically to the benefits of prolonged breastfeeding and do not therefore give any insights into the age at which predominantly formula fed infants could start complementary foods (Agostini et al., 2008; EFSA, 2009; Alvisi et al., 2015). This year, a draft report from EFSA (2019) which is undergoing a consultation phase, have updated their opinion since their last position statement in 2009, concluding that 'most infants do not need complementary foods for nutritional reasons before 6 months, except some exclusively breastfed infants at risk of iron depletion' (such as pre-term infants, or where the mother has low iron status or there was early umbilical cord clamping) who might benefit from complementary food as an iron source (EFSA, 2019, p1). Overall, therefore EFSA continues to recommend an age range of between 3-4 months and 6 months as appropriate to start complementary feeding.

From a UK point of view, the Scientific Advisory Commission for Nutrition (SACN, 2018) has recently expressed their position, continuing to support delaying complementary feeding until 6 months, citing the benefits of prolonged breastfeeding and that there is insufficient evidence of any of benefit from introducing complementary foods before this age.

2.9.2. Timing of complementary feeding and risk or overweight/obesity

A number of studies and reviews have explored the association between the timing of complementary feeding and risk of rapid growth in infancy and childhood overweight and obesity, however the evidence base is very mixed. Some evidence points towards very early introduction (<4 months of age) being associated with increased childhood obesity risk. In a 2011 systematic, review, of twenty-one studies examined, five found that introducing complementary foods before 3-4 months was associated with higher BMI in childhood. However, thirteen studies have found no association. Three studies which found significant associations, discovered that the differences disappeared after adjustment for confounding variables. The evidence is even more limited supporting the link between childhood obesity and introduction of complementary foods between 4 and 6 months (EFSA, 2009; Moorcroft, Marshall & McCormick, 2011; Huh, Rifas-Shiman, Taveras, Oken & Gillman, 2011, Pearce, Taylor & Langley-Evans, 2013; Barrera, Perrine, Li & Scanlon, 2016; Brown, 2017a).

Due to the nature of this area of research (with most studies being small, observational, and with varying definitions) and the potential impact of confounders it is currently not clear whether there is a link between early introduction to complementary foods and later overweight. In terms of infancy weight gain (rather than later childhood overweight), only a couple of studies have explored this; one has found a relationship between very early complementary feeding (<4 months) and rapid weight gain up to 7 months (Sloan, Gildea, Stewart, Sneddon & Iwaniek, 2007) and another found that complementary feeding before 5 months was associated with increased BMI at 12 months (Azad et al., 2018).

It is possible that infants who are introduced to complementary foods earlier consume more in terms of energy and protein than those who receive only milk for a longer period (Heinig et al., 1993; Ong et al., 2006; Noble & Emmett, 2006; Garcia, Raza, Parrett & Wright, 2013). One of the most common first foods is fortified infant cereal particularly amongst early introducers; over half of infants in the FITS study in the US who started complementary feeding between 4 and 5.9 months ate iron fortified infant cereal (Roess et al., 2018). Fortified infant cereals are also prevalent in the UK (Maslin & Venter, 2017; McAndrew et al., 2012). Infant cereals may be high in protein, as they often contain high amounts of cow's milk powder for example Cow and Gate baby porridge product sold in the UK is 33% cows' milk powder (Cow & Gate, 2018) and Heinz products contains up to 40% cows' milk powder (Heinz, 2019). Porridge is also often made up with cows' milk or infant formula, thereby further increasing the protein intake. Aside from infant cereals, other common first foods are mashed fruit or vegetables, which may be high in sugar (especially if in commercially processed pouches or jars) (Walker & Goran, 2015; Westland & Crawley, 2018). Furthermore, because infants who are started on complementary foods earlier are eating food for a longer time, the progression onto high calorie foods and snacks may occur earlier (Robinson et al., 2007; Garcia et al., 2013; Thompson & Bentley, 2013).

2.9.3. Timing of introduction to complementary foods: confounding factors

The connection between early introduction to complementary foods and risk of overweight and obesity may also be affected by confounding factors. For example, as with formula feeding, early introduction to complementary feeding is associated with younger maternal age, lower educational attainment and socio-economic status (Tarrant, Younger, Sheridan-Pereira, White & Kearney, 2010). Overweight mothers may also be more likely to start complementary feeding early, with the European IDEFICS study finding significant associations between maternal overweight and introduction of complementary feeding before 4 months (Papoustou et al., 2018).

Formula fed infants are also likely to start complementary foods earlier than breastfed infants (Fewtrell, Lucas & Morgan, 2003; Scheiss et al., 2010; Clayton, Li, Perrine & Scanlon, 2013). One explanation for this (besides maternal demographic similarities between mothers who formula feed and mothers who introduce complementary foods earlier), is that reasons for introducing formula to a previously breastfed infant and introducing complementary foods are often similar. Both formula feeding mothers and mothers who introduce complementary foods early, cite perceptions that their baby is hungry or that breastmilk is insufficient for their baby's needs (Arden, 2010; Odom, Li, Scanlon, Perrine & Grummer-Strawn, 2013; Clayton et al., 2013), and that infants who are fed formula or complementary food will sleep longer at night (Hoddinott, Craig, Britten & McInnes, 2011; Clayton et al., 2013). Mothers who are concerned about their babies' intake may be more likely to introduce foods earlier (Arden, 2010; Brown & Rowan, 2016) and subsequently exercise a more pressuring attitude towards feeding, which has been associated with greater intake in infancy in one study (Thompson, Adair & Bentley, 2013).

Due to the complexity and interrelatedness of the relationships between maternal characteristics with regards to milk feeding and age of complementary feeding, it has been suggested that maternal and social factors should be considered as potential effect modifiers rather than confounders (Sirkka et al., 2018). For example, Sirkka et al. (2018) in a study Dutch cohort study, found significant associations between early introduction to complementary foods (<5 months) with higher child BMI at age 5-6 years, but only amongst children of Dutch ethnicity, born to mothers of 'medium' level of education, and a normal pre-pregnancy BMI and who lived in a high-risk neighbourhood (defined in terms of prevalence of childhood obesity).

While there is some evidence surrounding the timing of introduction of solid foods and obesity risk, Moorcroft et al (2011) have made the point that the increase in childhood obesity has occurred during the past 15 years despite the general trend towards later introduction of complementary foods, suggesting that other factors may be more influential, such as maternal BMI, socioeconomic status and milk feeding. Furthermore, since the evidence is weak for the association between timing of introduction (except before 4 months) and obesity risk, authors have suggested that it may be more important to consider research, which explores the effect of maternal-infant feeding style, and the quality of the infants' diet (Grote, Theurich and Koletzko, 2012)

2.10. Exploring complementary feeding methods and obesity risk

Until recently, complementary feeding methods have received relatively little attention from the scientific community. However, it is increasingly being recognised that the complementary feeding stage may represent an important window in the development of lifelong eating patterns, with the potential to modify any risk for obesity posed by early life events and milk-feeding (Daniels et al., 2015a). Complementary feeding practices which promote self-regulation of appetite and the development of healthy food preferences are therefore being considered by researchers (Daniels et al., 2015a). In particular, the baby-led weaning (BLW) method has been subject to increasing interest (Brown et al., 2017).

BLW is a process of introducing complementary foods by 'allowing a baby to take and eat food by himself or herself as opposed to being spoon-fed' (Oxford English Dictionary, 2018). Currently, the World Health Organization recommends starting with spoon-fed pureed foods, then gradually increasing the texture until, by the age of 12 months, infants are eating a normal family diet (WHO, 2003b). In this process, finger foods (graspable pieces of whole foods) should be offered alongside the pureed foods, from around 8 months (WHO, 2003b). The UK guidelines recommends the same process, but encourages finger foods slightly earlier, from 6 months, alongside mashed foods (Department of Health, 2018). This process of initially spoon-feeding, while gradually introducing texture and/or finger foods, will be referred herein as 'standard complementary feeding' (SCF). BLW differs from SCF in that the emphasis of BLW is on infant self-feeding from the very start of the complementary feeding process. In order for self-feeding to be possible in BLW foods are most often presented in their whole form as finger foods, as opposed to pureed or mashed foods. A key tenet of BLW is also eating together with the family (Rapley & Murkett, 2008).

BLW has gained popularity in the UK and other developed countries around the world. It is unclear exactly the proportion of mothers who are adopting BLW, however interest in the method is evident from its almost 2 million hits on Google and its social media following with over 122,000 members on one parent-led Facebook group on the subject (Jones, 2016). Furthermore, the popularity of the method may be assessed by the commercial success of the BLW books on internet bookseller sites, in particular those by Rapley & Murkett (2008), who first coined the term.

Although BLW may be seen as a different method to SCF, broadly, Sachs (2010) points out that BLW does not differ greatly from the current UK Department of Health (2018) complementary feeding recommendations, which encourage finger foods from the start of complementary feeding. The only difference (when BLW is followed strictly) is that mashed foods are completely avoided. Work from cultural anthropologists and food historians has found that until the early 20th century (around the time of the second World War) baby-led feeding was probably quite normal, however, the combined effect of the increasing medical influence over childbearing and infant feeding, and industrialization of the food industry has led to the manufacture and mass popularization of commercial baby- foods, resulting in a common conception that babies need special 'baby-food', rather than eating a family diet (Palmer, 2011; Bentley, 2014; Jones, 2016).

Thus many parents opt for the SCF method of initiating complementary feeding with only purees/mashed food first. According to the Infant Feeding Survey, in the UK in 2010, 94% of mothers reported that their infants' first foods were mashed or pureed (McAndrew et al., 2012). However, 75% of mothers in the Infant Feeding Survey introduced food before 5 months (despite 6 months having been the recommended age for around 7 years at the time of the survey). Early commencement of complementary feeding may explain the high use of pureed/mashed food, as it is not until around 6 months of age that infants usually develop the motor skills to self-feed whole foods (Wright, Cameron, Tsiaka & Parkinson, 2011).

Signs of developmental readiness to eat complementary foods include, sitting up with the head unsupported, reaching out to grab food, moving it to the mouth and chewing, which usually occurs at around 6 months of age (Brown, 2017a). One paper explored babies' ability to reach out and grab food and found that 68% of babies aged 4-6 months had reached out and grabbed food, and this ability increased to 85% at 6-7 months and 96% at 7-8 months (Wright et al., 2011). This suggests that while some babies over 4 months may have the motor skills to self-feed, it is more likely after the age of 6 months. Furthermore, Naylor and Morrow (2001) concluded that, while some babies may be ready earlier, generally 6 months is a safe age to assume that an infant's gastrointestinal and immune systems have matured sufficiently for complementary food.

Rapley (2015a) has therefore argued that because the recommended age to introduce food is 6 months, and that most infants can self-feed at this age, the pureed food stage is no longer necessary. It is feasible, according to Rapley (2015a), that babies can learn to eat whole foods at their own pace, whilst simultaneously receiving most of their energy and nutrition requirements from milk (whether breast or formula). Babies will in this way 'lead' the complementary feeding process and gradually reduce their milk intake as their food consumption increases with age.

2.10.1. Beliefs about the benefits of baby-led weaning

Rapley & Murkett (2008) propose a number of benefits of BLW including an increased enjoyment of a wide range of foods tastes and textures, a reduction in 'fussy' eating, better appetite control, and the development of motor and social skills. These assertions have been echoed in qualitative studies with parents who follow the method (Brown & Lee, 2012; Cameron, Heath & Taylor, 2012b; Arden & Abbott, 2015; D'andrea, Jenkins, Mathews & Roebothan, 2016). Brown et al. (2017) also suggest that BLW offers an alternative to an industry-led commercial baby food culture as it encourages home-made and whole foods. The popularity of the method and its potential benefits as reported by parents has meant that research interest in BLW has grown in the last 10 years. Research on the impact that BLW may have on the timing of solid food introduction, eating behaviour, the development of appetite, food preferences, infant weight gain, and later obesity is gaining momentum (Brown et al., 2017; Lakshman, Clifton & Ong, 2017).

2.10.2. Baby-led weaning and overweight and risk of overweight and obesity

There have only been four published studies examining weight or BMI in relation to BLW. The first study, by Townsend and Pitchford (2012) examined the weight and height of 155 children aged 20-78 months. Some (only the spoon-fed group) were weighed and measured in a laboratory setting but it is not clear how the measurements for the other children were were obtained (perhaps parental self-report). Parents were asked to recall the complementary feeding method they had used in infancy. BMI, BMI-z-scores and percentile ranks were calculated. They found that the spoon-fed children were significantly more likely to be obese (defined as a BMI z-score of >2) (n=8) when compared with those in the BLW group (n=1). They also found a higher incidence of underweight (defined as a BMI z-score of <-2) in the BLW group but this was only a small number (n=3) compared with (n=0). The majority of children in both groups however, were of a healthy weight (81% BLW, 84% SCF). This study was perhaps limited by parent-reported weights/measures and breastfeeding was not controlled for. It also relied on retrospective recall of complementary feeding method, which may have been 6 years prior to the research.

The second study, Brown and Lee's (2015) longitudinal study asked parents of 298 babies aged 6-12 months (Phase 1) to report feeding method, and then collected parent-reported weight measurements of the children aged 18-24 months (Phase 2). This study echoed the findings from Townsend and Pitchford's (2012) work; they found that children in the SCF group were significantly more likely to be overweight for their age (defined as >85th percentile) than those in the BLW group (overweight: 8.1%, BLW; 19.2% SCF), controlling for birth weight, breastfeeding duration, age at introduction to complementary foods and reported maternal controlling feeding behaviour. They also found a slightly higher incidence of underweight (defined as <5th percentile) in the BLW group (5.4%) compared with the SCF group (2.5%). However, the majority of babies in each group were of a normal weight for age. Brown and Lee's (2015) protocol reduced the effect of recall error for feeding method, due to contemporaneous reporting. However, parental reporting of weight was considered to be a weakness. Crucially, height or BMI was not reported in the published paper. This presents a difficulty in interpreting the results in relation to healthy/unhealthy weight; if children in the SCF were also taller, the heavier weight would not necessarily indicate obesity but proportionate growth.

Most recently, the BLISS study published findings of their anthropometric measurements (Taylor et al., 2017). The BLISS study (Baby-Led Introduction to Solids Study) was a large trial of a BLW method by researchers in New Zealand. The researchers assigned babies to a trial group (BLISS group) where mothers were instructed to follow a specified BLW method with additional support and education, or to a usual care group, where participants followed their own choice of complementary feeding method. The BLISS intervention entailed the promotion of high energy and iron rich foods at every mealtime. Researchers measured the weight and height of 206 children at 12 months and 166 of these were followed up again at 24 months. In terms of growth, the BLISS findings did not reflect those of the earlier studies, with no significant difference for any weight or BMI z-score between the baby-led group and the control group. Furthermore, they found no significant difference for energy intakes between the groups (calculated from the weighed food records). No children showed evidence of growth faltering (Taylor et al., 2017). This was a robust study because the randomised sampling reduced any problems that might be attributed to self-selection. It also benefited from reliable measurements of weights and heights by trained researchers. However, it measured the BLISS baby-led feeding intervention, which is a modified form of BLW (mothers were advised to give their infants one high energy food, and one iron-containing food at each mealtime), and may not represent the BLW method as it is most commonly practiced. Additionally, some cross-over between the arms of the study occurred, as would be expected with any behavioural based trial. At age seven months 47% of BLISS group infants were being 'fed by adult and child' compared to 52% in the control group (Taylor et al., 2017).

Finally, Dogan et al. (2018) also examined the BLISS intervention (though these researchers were not associated with the original BLISS study) in a Turkish population. The researchers randomized 280 infants to either the BLISS method or a usual care group and found the BLISS method was significantly associated with lower weight at 12 months, and a decreased rate of weight gain from 6-12 months. However, it was not clear in this study which covariates were controlled for (if any), limiting its overall interpretation. Also the study outcomes were raw weight measurements (rather than standardized z-scores) which may have affected the comparability of infants in the different groups.

2.10.3. How might baby-led weaning affect infant growth and/or later risk of overweight?

While it appears that BLW might have some beneficial impact on growth and later risk of overweight (though the research base is currently very small), it is not clear which elements of the BLW method might be important to this. It may be because BLW necessitates a later introduction to solids (Brown & Lee, 2011a) (which, as discussed in section 2.9.2., may be protective against overweight), or it could be due to the self-feeding component of the method which may enable better appetite regulation? (Brown & Lee, 2015) It is also possible that the differences in content and texture of the diet consumed are having an impact on growth and food preferences (Rowan, Lee & Brown, 2019).

Feeding style may also be important, in particular whether there is higher or lower maternal control. Research in milk feeding and in older children demonstrates that parental control over child feeding appears to be highly influential on the development of eating behaviour (Li et al., 2014; Farrow et al., 2015). It is logical, therefore, that maternal feeding style is likely to also be important during complementary feeding. Furthermore, little consideration in the literature is given for the factors which drive mothers towards a particular feeding style. Maternal concerns over weight, food intake, or issues around baby temperament or sleep may initiate a controlling maternal feeding style which prioritizes infant weight gain or food intake over preserving infants' appetite regulation (Brown et al., 2017).

Finally, it could also be argued that any differences are simply attributable to the types of mothers that adopt baby led weaning; for example, mothers who adopt BLW are typically more affluent, older and had breastfed their baby (Brown & Lee, 2011a) and differ in personality traits, demonstrating less anxiety around feeding and generally (Brown, 2016b).

2.10.4. Baby-led weaning and the timing of introduction to complementary foods

It has been suggested that BLW necessitates later introduction to complementary foods as it depends upon babies' developmental readiness to self-feed, as opposed to spoon feeding which may be started at a much younger age. According to the Infant Feeding Survey (McAndrew et al., 2012), 30% of UK mothers surveyed had started complementary feeding before the age of 4 months, and whilst this figure was significantly lower than in the previous survey from 2005 where 51% of babies at 4 months were already on complementary foods, it is still a high number of babies eating complementary foods far younger than is recommended. Conversely, studies from around the same time as the latest Infant Feeding Survey showed that mothers following a BLW method introduced complementary foods to their infants at a later age, closer to six months (Arden, 2010; Brown & Lee, 2011a; Moore, Milligan & Goff, 2014). However, these were small studies and the reason for delaying introduction of complementary foods (whether due to BLW or some other reason) was unknown.

Meanwhile, in the BLISS study, 65% of mothers assigned to the BLISS group delayed introducing complementary foods to 6 months, compared with only 18% in the usual care group (Erickson, 2015). This further suggests that BLW may lead to later introduction to complementary foods, however, participants in the BLISS group were also given instructions and received frequent visits from study assistants, which may have encouraged them to follow the guidelines more strictly than they would have if they had chosen BLW naturally.

2.10.5. Baby-led weaning, eating behaviour and appetite

It has been proposed that BLW encourages appetite self-regulation, in that infants who are fed in this way are better able to learn to recognise and respond to their internal hunger and satiety cues. A central principle of BLW is allowing the infant to self-feed. In this way BLW may encourage a feeding style which is low in maternal control as has been found in two studies by Brown and Lee (2011b; 2015). The first study of over 700 mothers examined maternal control over child feeding using the CFQ at age 6-12 months. Mothers following a BLW method reported lower levels of restriction, pressure to eat, monitoring and concern over child weight, compared with those following a SCF method (Brown & Lee, 2011b). This finding was reaffirmed in later study of almost 300 parents (Brown & Lee, 2015). It is unclear, however, whether BLW fostered this behaviour in the parent, or whether the parent chose the method as it was congruent with their natural tendency to refrain from control. This may also account for the high correlation between BLW and breastfeeding seen in many studies (Brown & Lee, 2011a; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017) as BLW mirrors the responsive nature of breastfeeding. Mothers who breastfeed report learning to respond to baby hunger cues, being relaxed about intake and trusting the process (Crossley, 2009; Kronborg, Harder & Hall, 2015); this 'trusting' has also been echoed in a qualitative study with mothers who adopted BLW (Arden & Abbott, 2015).

It has been hypothesized that infant self-feeding may also allow for better development of satiety responsiveness; one study found that infants who had been BLW were rated as more satiety-responsive by their parents as toddlers (Brown & Lee, 2015). It is proposed that by self-feeding, the infant will stop eating when he/she is full. Conversely, spoon-feeding is innately 'parent led'; the parent must prepare the food, place the determined amount on the spoon and approach the baby's mouth with the spoon. This situation may lead to a parent continuing to feed the infant past satiety, leading the infant to learn to override their own fullness signals, and to potentially develop a habit of overeating. Overfeeding may also be especially easy to do in spoon-feeding due to misconceptions of appropriate portion-size. In particular, portion sizes of commercial infant food jars often exceed recommendations for the marketed age of the product (Crawley & Westland, 2017).

Furthermore, BLW is thought to encourage a slower pace of consumption due to the eating of whole foods which require handling and prolonged chewing, as opposed to purees which can be slurped off a spoon and swallowed easily (Rapley, Forste, Cameron, Brown & Wright, 2015). Purees and viscous textured foods have been associated with increased speed of swallowing, whereas more textured complementary foods take longer to chew and swallow (Gisel, 1991). Prolonged oral processing time may decrease overall energy intake; small studies of adults have shown that participants who took longest to chew had lower intake of food during a meal and lower intake of snacks after a meal, suggesting improved satiety recognition (Smit, Kemsley, Tapp & Henry, 2011; Higgs & Jones, 2013). Faster eating has also been associated with higher energy intake and higher BMI in children (Fogel et al., 2017) and adults (Shah et al., 2014; Robinson et al., 2014). The speed of eating may also be traced back to milk feeding experiences. Studies have shown that 'vigorous' sucking in bottle feeding and faster speed of milk consumption predicts overweight in early childhood (Agras, Kraemer, Berkowitz & Hammer, 1990; Stunkard, Berkowitz, Schoeller, Maislin & Stallings, 2004). No studies so far have specifically explored speed of eating in relation to BLW.

Carnell and Wardle (2007) measured child eating behaviour with the Child Eating Behaviour Questionnaire (CEBQ) and found significant associations between low levels of satiety responsiveness and overweight in 4-5 year olds. They also found higher levels of 'food responsiveness' (the desire to eat, the opposite of satiety responsiveness) in children who were overweight. Brown and Lee (2015) applied a modified version of the CEBQ in relation to BLW and SCF. They found higher levels of satiety responsiveness and lower levels of food responsiveness in pre-school children who had followed BLW during infancy. Other studies which have explored appetite regulation in BLW, however, found the opposite result; the BLISS study asked parents to complete the CEBQ at 12-24 months and found that BLISS infants were reported to be less satiety-responsive than the control group (Taylor et al., 2017). Furthermore, in the BLISS study no statistically significant difference in energy consumption (which would be suggestive of overeating) was found between the groups (Taylor et al., 2017). A more recent study, using the CEBQ, found no significant difference in satiety responsiveness in toddlers between BLW or SCF groups (Komninou, Halford & Harold, 2019). However, all studies were limited by the data being collected through parental self-reporting and by small sample sizes. Experimental research in this area, such as those measuring 'eating in the absence of hunger' (EAH) or those which measure children's ability to compensate for energy intake of a test meal after a pre-load (COMPX studies) may be beneficial to understand the existence and effect of appetite regulation in relation to BLW.

2.10.6. Baby-led weaning, diet and food preferences

Diet in infancy is clearly important for growth because certain foods which are more energy dense (such as those high in sugar) and certain nutrients (such as protein) may promote faster growth (Koletzko et al., 2009b; Pearce & Langley-Evans, 2013; Haschke et al., 2016). In addition, diet offered in infancy may affect later food fussiness and preferences for healthy or unhealthy foods which can in turn affect weight (Finistrella et al., 2012; Perry et al., 2015). Some research has explored the differences in diet consumed in BLW compared with SCF.

Infant cereal

A number of studies have found that first foods differ, with the SCF groups significantly more likely to offer infant cereal as a first food (Brown & Lee, 2011a; Komninou et al., 2019). Brown and Lee (2011a) found that around 60% of spoon-fed infants were given baby rice as a first food, compared with 10% of infants in the BLW group. Morison et al (2016) collected 1 to 3- day Weighed Diet Records (WDRs) from 51 age and sex-matched infants at 6-8 months, and also found that BLW infants were much less likely to be offered infant cereals when compared to SCF. The BLISS study also collected 3-day WDRs to explore the diets of 147 infants aged 7 months (Erickson, 2015). This study found higher consumption of infant cereals at age 7 months in the BLISS BLW group, which was unusual since infant cereals need to be spoon-fed (with the exception of porridge bars which are sometimes given in BLW). This incongruent finding was likely due to the fact that adherence to BLW among the BLISS group was low, with 47% of BLISS infants reported as being 'fed by adult and child' (Taylor et al., 2017).

As previously mentioned (section 2.9.2.) differences in levels of consumption of infant cereals are of interest because they often contain high amounts of cow's milk powder for example (Cow & Gate, 2018; Heinz, 2019) and porridge is also often made up with cows' milk or infant formula, thereby further increasing the protein intake. High consumption of cow's milk protein has been associated with accelerated growth (Ziegler, 2006; Thorisdottir, Gunnarsdottir, Palsson, Halldorsson, & Thorsdottir 2014; Luque et al., 2016; Grenov & Michelsen, 2018).

Protein

Adequate levels of dietary protein are required to support growth, however, how much protein infants need is not clear and recommendations vary among international sources (Michaelsen, Larnkjaer & Molgaard, 2012). Estimates suggest that protein requirements of infants are actually quite low, at only around 5-7% of the total energy percentage at 6 months (compared with around 10-30% for adolescents and adults) (Michaelsen et al., 2012). Excessive protein intake in infancy can speed up growth to rates which are considered 'rapid' and therefore increase the risk of later overweight and obesity (Koletzko et al., 2009b; Haschke et al., 2016). This may be more likely in formula fed infants who are already receiving higher levels of protein from milk (Luque, et al., 2016; Haschke et al., 2016). Conversely, it may be important that breastfed infants receive their protein from complementary foods in the latter half of infancy as breastmilk is lower in protein than formula (Dupont, 2003). Types of protein consumed might also be important, for example, the DONALD study in Germany found that consumption of dairy protein (but not meat or vegetable protein) in infancy was linked to later overwieght (Gunther, Remer, Kroke & Buyken, 2007).

In the BLISS study, compared to the control, babies in the BLISS group were more likely to consume meat, cow's milk or dairy products (items high in protein). While the BLISS study found no difference between the groups for energy intake at 7 months (Erickson, 2015) in terms of the proportion of energy attributed to macronutrients, BLISS infants consumed more protein than the usual care group at 7 months (after controlling for breast or formula feeding) (Erickson, 2015). A further analysis of BLISS study data by Morison et al. (2018), explored 3-day WDRs of 206 infants, at 7, 12 and 24 months. This study also found that BLISS promoted greater food variety, in particular, a greater variety of 'meat and other protein sources' at 7 months. Infants aged 12 months were also reported to have a greater preference (as indicated by the parent) for 'savoury-non-meat high-protein' foods, but that this preference did not continue to age 24 months. Rowan et al., (2019) study which looked at 24hour diet diaries, also found a statistically significant increase in exposure to protein amongst BLW infants. While it is not clear from these studies if protein intake was excessive amongst BLW infants, since BLW is strongly associated with breastfeeding, it may be reassuring that BLW might encourage protein intake, which may be low in 6-12 month old breastfed infants (Dupont, 2003).

Sweet foods

Children are born innately preferring sweet foods, and this was thought to be beneficial from an evolutionary perspective as sweet foods indicate high energy density, which is required for growth and survival (Schwartz & Puhl, 2003). In Western obesogenic societies, however, processed sweet foods are cheap and easily available (Mwatsama & Stewart, 2005) and developing a preference for sweet foods in childhood could pose a risk for being overweight (Schwartz & Puhl, 2003; Zhou & Zhang, 2014; Emmett & Jones, 2015; Rouhani et al., 2016). Two studies found no significant differences between BLW and SCF for exposure to sweet foods (Rowan et al., 2019) or foods with sugar added (Morison et al., 2016). In contrast the BLISS study found a different result finding higher consumption of sweet foods amongst BLISS group compared to the usual care group (Erickson, 2015). However, as previously mentioned there was low adherence to BLW in this study.

It is important to note, that in one qualitative study health professionals expressed concerns that there is a higher risk of consumption of sweet foods such as confectionary or biscuits in BLW, as these items are easier to offer as finger foods (Cameron, Heath & Taylor, 2012b). However, perhaps equally concerning is the use of commercial infant foods (common in SCF) as these are typically high in sugar (McAndrew et al., 2012; Walker & Goran, 2015; Maslin & Venter, 2017; Crawley & Westland, 2017).

Commercial infant foods and snacks

Commercial infant foods have elicited concern, in particular in relation to the large portion sizes, high sugar content, and nutritional value (as micronutrients are depleted by high-heat treatment undertaken in the manufacturing process) (Walker & Goran, 2015; Westland & Crawley, 2018; Sparks & Crawley 2018). One study compared commercial baby foods with home-made samples found that the commercial foods in jars contained more vegetable variety per meal, than many homemade baby-food recipes (Carstairs, Craig, Marias, Bora & Kiezebrink, 2016). However, despite the increased number of vegetables available in processed baby food, Garcia, McLean and Wright (2016) have noted that they often contain added fruit and fruit juice by manufacturers, which mask more bitter-tasting vegetables. This is thought to potentially lead to a preference for sweet foods and therefore may not actually be conducive to liking of vegetables in later childhood. There is also concern that processed baby foods do not allow babies to experience the unique flavours of single foods as the flavour of the vegetable is often combined with other foods in mixed purees (Garcia et al., 2016; Chambers et al., 2016)

Studies have explored the prevalence of commercial food in baby-led weaning. Morison et al (2016) found no significant difference in exposure to commercially prepared baby-foods between BLW and SCF groups. Other studies have found a difference. In Erickson's (2015) exploration of the BLISS study data infants in the usual care group consumed significantly more commercial infant foods that infants in the BLISS BLW group. Rowan et al (2019) also found that SCF infants were more likely to consume 'infant meals', compared with BLW infants. However, these were defined in this study as being composite meals with a variety of ingredients and were not necessarily processed or shop-bought.

Effects on future dietary preferences

Food fussiness is a commonly reported problem in children causing considerable concern for many parents (Taylor, Wernimont, Northstone & Emmett, 2015). While food fussiness can be associated with underweight and poor growth due to limited intake (Taylor et al., 2015), food fussiness has also been shown to increase the risk of overweight or obesity in children as young as 2, due to rejection of healthier foods in preference for sweet or highly palatable, energy dense foods (Finistrella et al., 2015; Hayes et al., 2017). BLW is proposed to reduce food fussiness (Rapley & Murkett, 2008) and this has been perceived to be true by mothers who used the method (Brown & Lee, 2015; Taylor et al., 2017).

Reducing food fussiness and improving acceptance of foods may be achieved through early flavour learning, and dietary diversity, particularly in relation to vegetables (Mennella & Trabulsi, 2012; Lange et al., 2013; Harris & Coulthard, 2016; Chambers et al., 2016). Flavour-learning is arguably easier in BLW due to the consumption of whole foods. Thus single flavours can thus be tasted individually as opposed to being blended together in composite (Rapley & Murkett, 2008; Cameron, Heath & Taylor, 2012a; Brown & Lee, 2013b; Arden & Abbott, 2015; D'Andrea et al., 2016). Infants who are fed using a BLW method have been found to have greater dietary diversity across all food groups at age 7 months, and greater fruit and vegetable variety at 24 months (Morison et al., 2018).

BLW is also thought to encourage the sensory exploration of food. Handling and playing with fruit and vegetables has been demonstrated to improve their acceptance in a number of studies with toddlers (Dazeley & Houston-Price, 2015; Coulthard & Sealey, 2017). So far, research is scant on the effect of BLW on later liking of fruit and vegetables; only Townsend and Pitchford (2012) have explored this and found no significant association between later preference for fruit and vegetables and BLW. Townsend and Pitchford (2012) also found however, greater preference for sweet foods in toddlers who had been spoon-fed in infancy compared with BLW. It is not known whether infants in this particular study were exposed to sweet foods in infancy which prompted this preference. This was also a small study which relied on parental self-reporting of food preferences.

Rowan and Harris (2012) propose that the BLW principle of eating alongside the family may help to undo the idea that there is a difference between 'baby food' and 'adult food', further reducing the likelihood of food fussiness. Their research explored this and found that babies who were following BLW ate at the same time as the parent approximately 3 times a day and 57% of foods consumed were similar to the meal eaten by the parent. Research from Cameron, Taylor and Heath (2013), and Morison and colleagues (2016) also found that BLW was associated with eating broadly the same foods as the family, at the same time as the family. Modelling of parental eating behaviour has also been linked to reduced food fussiness in children (Palfreyman, Haycraft & Meyer, 2015). However, modelling may have a detrimental effect if the parent's diet is unhealthy (Robinson et al., 2007).

2.11. The role of responsive feeding

So far, this chapter has outlined the content and behavioural differences in infant feeding both in terms of milk feeding and complementary feeding, and has touched upon how maternal control over feeding may influence appetite and satiety responsiveness. The overarching term used to reflect feeding styles which are low in care-giver control and high in sensitivity to children's appetite cues is 'responsive feeding'. The WHO recommends responsive feeding, describing it as feeding 'in response to early hunger cues' and 'without verbal or physical coercion' (2001, p13). Responsive feeding in childhood is linked to healthier, more gradual weight gain trajectories and lower risk of overweight in childhood (Hurley et al., 2011; Shloim et al., 2015). Conversely, characteristics of a non-responsive feeding style include controlling, restricting or pressuring food intake (Hurley et al., 2011). In a recent systematic review, the authors concluded that controlling feeding practices in childhood were associated with higher child BMI at ages 4-12 years (Shloim et al., 2015).

Research into the impact of responsive feeding has been focused mainly on milk feeding, and feeding of older children, with few studies examining the impact of responsive feeding in complementary feeding. However, this stage is likely to be crucial, because it is the first time infants are exposed to non-milk foods, and thus represents the beginning of their relationship with food. It is also a time when mothers are able to have the greatest opportunity for control over what and how much children eat, compared to when they are older (Spyreli et al., 2019).

Maternal restriction of food may be particularly prevalent, as infants are usually unable to access food without it being given to them. In the short term, restriction may help to prevent excess child weight, with Farrow and Blissett's (2008) study finding associations between maternal use of restriction at age 1 and lower child weight at age 2. Similarly, Gubbels et al. (2009) found that maternal restriction was successful in reducing consumption of restricted foods at age 2. However, efforts to restrict certain foods are likely to backfire when children are older and more able to choose or access previously restricted foods themselves, ultimately leading to increased risk of overweight and maladaptive behaviours such as emotional eating (Fisher & Birch, 1999; Faith & Kerns, 2005; Farrow et al., 2015)

Perhaps a more immediately influential controlling feeding behaviour may be that of maternal use of pressure to eat. Infants who are pressured to eat may be at risk of over-consumption and dysregulation of appetite. It is not clear how common pressure to eat is in complementary feeding as there are very few studies which have explored this. While broadly pressure to eat in older children and toddlers has been associated with lower child weight (Farrow & Blissett, 2008; Shloim et al., 2015), this has been attributed to reverse causality with mothers of underweight children perhaps more likely to pressurise eating (Farrow & Blissett, 2008; Webber et al., 2010; Gregory et al., 2010; Taylor et al., 2015; Holley et al., 2018). It is also important to recognise that pressure to eat may present differently and have a different impact for infants compared with older children. For example, older children are commonly pressured to eat specific foods that they had previously refused or expressed that they do not like (typically fruit and vegetables) (Finistrella et al., 2012). In infancy, the motivation to pressure intake is likely to be driven by other factors, for example, concern about growth, infant temperament, or perceptions that food will help with sleep (these aspects will be explored further in sections 2.11.2 & 2.11.3.). If these are the reasons for pressuring eating, then the foods that are encouraged are perhaps less likely to be fruit and vegetables and instead might comprise palatable foods that the parent considers 'filling' such as infant cereals or rusks.

It is also possible that pressure to eat may be more of problem for encouraging excessive weight gain in infancy than in older children, for a number of reasons. First, there is a common desire to have a 'big baby' as this is viewed as 'healthy'; this theme has emerged in qualitative work with US and UK mothers over time (Baughcum, Burklow, Deeks, Powers & Whitaker, 1998; Redsell et al., 2010). Research with mothers exemplifies this phenomenon; for example, in a recent UK qualitative study, mothers of infants aged under 12 months were interviewed about the issue of infant overweight. The study found lack of awareness of the future risk posed by excessive weight gain in infancy and respondents thought that underweight or poor growth was more worrying (Bentley, Swift, Cook & Redsell, 2017). An earlier survey of 239 US mothers of infants aged 2 weeks to 6 months found that mothers were more likely to agree with statements pertaining to a pressuring feeding style than a restrictive feeding style, again indicating a tendency towards encouraging weight gain (Gross et al., 2011). However, a preference for a 'bigger' baby appears to diminish as children grow older, when it may be easier to recognise overweight and because negative connotations associated with overweight may arise. Parents who begin to become worried about their child's overweight status may start to restrict access to certain foods (May et al., 2007; Gregory et al., 2010; Farrow, Blissett & Haycraft, 2011). However, there is also evidence that misconceptions of child weight status persist as they get older, with one review finding a number of studies showing parental lack of recognition of overweight into childhood (Rietmeijer-Mentick, Paulis, Middelkoop, Bindels & van der Wouden, 2012).

Second, pressuring intake may also be easier to do infancy than in older childhood, because of the different stages of child development. It is not until toddlerhood (around ages 1-3 years) that children usually start to indicate a reluctance to try new foods or are more likely to demonstrate food refusal, with conflict between parents and children around food being reportedly common in this age group (Lumeng, Miller, Appugliese, Rosenblum & Kaciroti, 2018). While infants can and do demonstrate food refusal, for example, by crying, or trying to climb out of a high-chair, mothers have reported coaxing or distracting infants, slipping food into their mouths while playing (Chatoor & Ganiban, 2003; Spyreli et al., 2019). This is likely to become more difficult as children get older and more assertive.

Third, mothers of infants may be less able to recognize their children's food cues or have misconceptions of infants' dietary requirements. Studies have found that maternal recognition of infant appetite cues are highly variable (Shloim et al., 2017) as well as perceptions of appropriate portion sizes (McCrickerd & Forde, 2016a). Mothers may be concerned about intake, perceiving it to be low, perhaps being unaware of how much energy infants actually require from complementary foods (as little as 200kcal per day at 6-8 months) (WHO, 2003b). Furthermore, the extent to which infant behaviours indicate problematic 'food refusal' or whether they are simply normal indications of satiety may be a subtle but important distinction that is more easily missed in infancy.

Despite the greater potential for maternal control over feeding throughout infancy relatively few studies have explored the impact of maternal control over child feeding upon the growth of infants, especially during the complementary feeding period. One study of 217 infants aged 3-12 months found an association between pressure to eat and greater infant energy intake, but not greater weight (pressure to eat was actually associated with lower weight in this study, though again the relationship with weight was considered to be possibly bi-directional) (Thompson et al., 2013). In another smaller study of sixty-nine infants, researchers observed maternal-child mealtime interactions at 6 months, coding for controlling feeding behaviour using the Feeding Interaction Scale (FIS) (Farrow & Blissett, 2006). Infants were weighed and measured at 6 and 12 months. The authors found that where maternal control was low, infants appeared to moderate their own intake. In this group, infants with rapid early weight gain up to 6 months slowed down in the second half of infancy, and infants with slower early weight gain accelerated in growth in later infancy. Conversely, in the group whose mothers demonstrated higher levels of control over feeding at 6 months, the infants continued to either accelerate if they had been on an upward growth trajectory or continued to show slower weight gain if they were slow to grow between 0-6-months of age (Farrow & Blissett, 2006). Farrow and Blissett (2006) therefore suggested that given greater autonomy, infants will naturally modify their weight gain in late infancy. A similar study using mealtime observations (*N*=96) found that reduced maternal sensitivity to feeding cues at 6 months resulted in greater infant weight gain between 6 and 12 months (Worobey, Lopez & Hoffman, 2010). A more recent large study of over 1200 videotaped mealtime interactions with children slightly older than 1 year found that pressure to eat was linked with increased weight-for-length and BMI at 15 months (and this was also seen in the same sample later at 24 and 36 months). In this study, researchers found that children whose mothers prompted them to eat in an assertive or intrusive manner (akin to pressure to eat), had increased weight-for-length z-scores and BMI-z-scores (Lumeng et al., 2012).

These studies benefit from being based on observations, which are likely to be more accurate than using a parental-reported feeding assessment tool. Indeed, discrepancies have been observed between parental reports of feeding behaviours and actual observations. For example, one study found that Child Feeding Questionnaire answers and observations in relation to pressure to eat were discordant (Lewis & Worobey, 2011). Another found that amongst two-thirds of respondents there was a lack of correspondence between what parents reported in a semi-structured interview and what was seen in videotaped observations (Sacco et al., 2007). Again, Farrow and colleagues (2011) found poor correspondence between maternal perceptions of their use of controlling feeding practices and researcher observations. More research is required on maternal control (and in particular pressure to eat) over intake and weight within the complementary feeding period. Further refinement of tools used to measure mother-infant feeding interactions might also be beneficial.

Aside from the potential impact that pressuring infants to eat could have on intake or growth, it is possible that pressuring may increase the likelihood of future fussy or picky eating. Pressuring feeding has been associated with fussy eating in several studies (Ventura & Birch, 2008; Gregory et al., 2010). The development of fussiness is problematic for children's future relationship with food, and this has been explored in older children. It is thought that fussiness (secondary to having been pressured to eat) may increase the risk of overweight because children who are pressured may develop an aversion to some foods (which may often be healthier foods) in preference for sweet or highly palatable, energy dense foods (Finistrella et al., 2012; Perry et al., 2015; Samuel, Musa-Veloso, Ho, Venditti & Shahkhalili-Dulloo, 2018). The evidence linking food fussiness with weight status is mixed. While some studies have linked fussiness to lower child weight (Galloway, Fiorito, Lee & Birch, 2005; Ekstein, Laniado & Glick, 2010), others have reported the opposite result. For example, Finistrella et al (2012) found a higher incidence of food fussiness among obese and overweight children aged 2-6 years. Fussiness also appears to be relatively stable, with one longitudunal study of 120 children aged 2-11 years finding that up to 40% of children identified as fussy would continue to be so for longer than 2 years (Mascola, Bryson & Agras, 2010). However, it should be recognised that this research linking pressure to eat and fussiness relates to older children and not infants. Research in this area is therefore required.

2.11.1. Drivers towards non-responsive maternal feeding behaviours

While we know that maternal-infant feeding practices are likely to shape growth and eating behaviour, there is very little research exploring maternal drivers towards their feeding choices. These reasons are important to explore because they may point towards a general tendency towards a more or less responsive feeding style. Feeding choices such as milk feeding type (breast or formula) and complementary feeding method (baby-led weaning or standard complementary feeding) have been associated with more or less responsive feeding styles. For example, breastfeeding (compared to formula feeding) has been associated with a feeding style low in maternal control and high in responsiveness

(Brown et al., 2011a). Similarly, BLW is thought to foster reduced controlling feeding practices and greater maternal responsiveness (Brown & Lee, 2011b). However, it is not clear whether it is the method which determines the feeding style, or whether mothers are attracted to a particular feeding method because it reflects their desire for control (or not) (Brown et al., 2017).

For example, it is virtually impossible to pressure, control or restrict intake in breastfeeding or BLW because of the supply and demand nature of effective breastfeeding (Daley & Hartmann, 1995; Brown et al., 2011a) and the central 'baby-led' ethos of BLW (Rapley & Murkett, 2008). Correlations between prevalence of breastfeeding and BLW have been found in the literature (Brown & Lee, 2010; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017). Thus, it may be that mothers who choose to breastfeed are given the opportunity to learn over time, through the process of feeding, to recognise and respond to infant hunger and satiety cues and to trust that their infant is able to regulate their own appetite, thus allowing them to feel comfortable to adopt BLW. Conversely, formula feeding may serve to create an attitude of monitoring as the mother is able to see how much their infant is consuming, leading to a preference for spoon-feeding where monitoring of intake can continue. It is possible, therefore, that the milk feeding method is influencing the mother's behaviour and choice of complementary feeding method.

However, another perspective is that mothers may be drawn to introduce complementary foods earlier and/or adopt a particular complementary feeding method because of other underlying reasons. Themes emerging in the literature include, concern over infant size or perceived requirements/intake (Arden, 2010; Brown & Rowan, 2016), infant temperament or sleep (see sections 2.11.2; 2.11.3) and maternal characteristics such as anxiety (Meedya, Fahy, & Kable, 2010; Brown & Arnott, 2014; Rollins, et al., 2016) all of which may influence the way in which mothers feed their infants. Furthermore, mothers cite reasons such as convenience around the household routine or pressure from other family members as drivers to start complementary feeding (Anderson et al., 2001; Walsh, Kearney & Dennis, 2015; Spence, Hesketh, Crawford & Campbell, 2016). On the other hand, mothers who choose to adopt a BLW method report waiting for developmental readiness before starting complementary feeding (Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015) and are less anxious about infant weight and intake (Brown & Lee, 2011a, Brown & Lee, 2011b). These factors warrant exploration because understanding them is at the root of what influences these crucial early maternal-child interactions which may have far reaching implications.

2.11.2. Maternal concern about infant weight or intake

Parental concerns about infant size has been shown to predict controlling parental feeding practices and later overweight risk (Redsell et al., 2010). Studies have found that parents of smaller infants, or those who were worried about their child being underweight in the future are more likely to pressure feeding and monitor intake and conversely, parents of larger infants, or those who were worried about their child being overweight in the future may tend towards restriction (Gross et al., 2011; Fildes, van Jaarsveld, Llewellyn, Wardle & Fisher, 2015). However, other studies have considered that bigger babies may be perceived to be hungrier and therefore requiring of more food meaning that mothers of bigger babies may also encourage intake (Anderson et al., 2001; Wright et al., 2004; Carroll, Gallagher, Clarke, Millar & Begley, 2015; Brown & Rowan, 2016). Moreover, misconceptions of adequate infant growth and the food requirements of infants are strongly influenced by social and cultural norms, such as the perception that a 'big baby' is healthier (Baughcum et al., 1998; Redsell et al., 2010). Perhaps babies who are a healthy weight according to growth standards may still be perceived to be small by their parent, who desires a 'big baby'.

Mothers who are concerned about their baby's intake or growth may therefore be more attracted to formula feeding, as they can monitor how much is 'going in' and encourage intake. Formula feeding mothers are more likely to show controlling feeding behaviours, for example, a UK study of over 500 mothers found that mothers who formula feed were more likely to schedule feeds and encourage intake in the first 6 months of infancy compared to breastfeeding mothers (Brown, Raynor & Lee, 2001b). This may be due to the ease at which milk can be measured and visualized in a bottle (Li et al., 2012; Brown et al., 2011a; Brown & Lee, 2013a).

For mothers who initially try to breastfeed, frequent feeding (while biologically normal) may also present a concern for some mothers who are worried about intake, leading them to move onto formula feeding in order to monitor intake. In the early-days post- partum, perceptions of insufficient milk supply are common amongst mothers who cease breastfeeding or who supplement breastfeeding with formula (Dewey, Nommsen-Rivers, Heinig & Cohen, 2003; Meedya et al., 2010; Peacock –Chambers et al., 2017). In later weeks, slow infant growth and perceptions of hunger (because of behavioural or temperamental cues, see next section) may prompt parents to believe that breastmilk is not satisfying their baby leading to the introduction of formula (Redsell et al., 2010; Odom et al., 2013).

However, actual rates of milk insufficiency are thought to be as low as 5% (Meedya et al., 2010) so in reality perceptions of milk insufficiency are likely to stem from a misconception of normal infant growth and behaviour (Dewey et al., 2002). Being worried about milk sufficiency may also lead to mothers to attempt to schedule breast-feeds or give additional 'top-up' formula feeds, actions which diminish milk supply (Dewey et al., 2002). Therefore, lack of appropriate support in the early days of breastfeeding, accompanied by a belief (the mother's own belief or those of others) that breastfeeding is problematic is likely to contribute to exacerbation of breastfeeding difficulties, perceptions of poor milk supply, formula supplementation and ultimately breastfeeding cessation (Chantry, Dewey, Peerson, Wagner, Nommsen-Rivers, 2014). Formula feeding may therefore provide reassurance and a route to regaining control for some women who may feel disempowered especially after a negative breastfeeding experience (Brown, 2016a).

Similarly, mothers who introduce complementary foods earlier than the recommended age of 6 months are more likely to report that they felt their child needed more than milk alone (Arden, 2010; Brown & Rowan, 2016). This may also be influenced by infant size, in both directions. For instance, babies who are perceived to be underweight may commence complementary foods younger due to maternal concern over poor intake (Wright, Parkinson & Drewett, 2004; Kramer, 2010; Brown & Rowan, 2016). Qualitative studies of parents of SGA infants show a desire for their baby to catch up on weight (Lucas et al., 2007; Bentley et al., 2017). On the other hand, bigger babies may be started on complementary feeding earlier due to maternal perceptions that their big baby is 'hungrier' and therefore requires complementary foods earlier (Anderson et al., 2001; Arden, 2010; Daniels, Mallan, Fildes & Wilson, 2015b; Brown & Rowan, 2015). Clinical data from a large cohort study in the Netherlands supported this, finding that before complementary foods were introduced, weight was greater amongst infants who were introduced to complementary foods early (3-6 months) compared to those who waited until 6 months. (van Rossem et al., 2013).

During complementary feeding, concern over weight has been linked to pressure to eat, with mothers who perceive their infants to be smaller reporting pressuring them to eat more food (Brown & Lee, 2011c). In terms of control and monitoring of intake, as in formula feeding, spoon-feeding also allows the mother greater ability to monitor how much her child eats and this may explain the relationship seen in several studies between formula feeding and spoon-feeding (Brown & Lee, 2010; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017). Conversely, mothers who follow BLW are more likely to say that they waited for motor signs of developmental readiness before introducing complementary foods and report lower levels of concern over child weight and intake and adopt a less pressuring feeding style (Brown & Lee, 2011; Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015)

2.11.3. Infant temperament, beliefs around baby behaviour and sleep

Beliefs that formula supplementation or the introduction of food will help to 'settle' fractious infants and promote sleep are also pervasive and thus infant temperament may also serve to drive mothers to encourage intake (Arden, 2010; Hoddinott et al., 2011; Clayton et al., 2013). Infants who are perceived as 'fussy' are more likely to be supplemented with formula and more likely to be started on complementary foods earlier (Anderson et al., 2001; Wasser et al., 2011). Other studies found that mothers who perceived their infant to have a 'difficult' temperament were more likely to add cereal to a bottle (Baughcum et al., 1998; Lucas et al., 2017).

Increased perceived infant fussiness has been linked to increased weight gain in infancy. An early study found that infants aged 6-12 months who gained the most weight, were perceived by their parents to be more difficult than average (Carey, 1985). Findings were similar in a more recent study, which found that infants who slept less, cried or fussed more had faster rates of weight gain (Darlington & Wright, 2006). The connection between temperament and weight gain perhaps comes from encouragement of intake to soothe; Stifter, Anzman-Fransca, Birch & Voegtline (2011) found that using food to soothe is common amongst parents of who rated their infants highly on items of temperamental negativity, and in line with this, pressure to eat was also higher amongst parents of infants perceived as 'difficult' in this study. Another study of 452 mothers found that those who reported a belief that crying is indicative of hunger were more likely to pressure intake (Gross et al., 2010).

These beliefs and perceptions of 'fussiness' may be affected by unrealistic expectations of infant behaviour and an over attribution of crying to hunger. However, crying and night waking is developmentally normal for infants and children up until age 2; in particular, breastfed babies feed frequently and night feeding is common (Elias, Nicolson, Bora & Johnston, 1986; Brown & Harries, 2015). However, an expectation for a baby to sleep through the night has long been a social norm in developed societies, perhaps created due practices of separated sleeping, the impact of night waking on maternal mood, and increased formula milk use (Elias et al., 1986; Hiscock & Wake, 2001).

It is possible that responsive feeding practices are only available to infants who are less fussy and where the mother has no concerns over weight or intake. However, the degree of subjectivity around 'settledness', normal infant behaviour and perceived weight is likely to be high, since studies have found incongruence between maternal reports and observations/measurements of these aspects (Stifter et al., 2011; Harrison, Brodrib, Davies & Hepworth, 2018).

2.11.4. Maternal personality and beliefs

Parents' tendency towards a responsive or non-responsive feeding style may also be linked to personality, beliefs and general parenting style of the parent. For example, maternal desire to follow a structured parenting approach or routine has been associated with formula use from birth and and shorter breastfeeding duration (Brown & Arnott, 2014). A routine driven approach often stems from a prioritization of convenience in family life and maternal wellbeing (Brown, 2010; Shortt, McGorrian & Kelleher, 2013; Brown & Arnott, 2014; Carroll et al., 2015), and is commonly promoted by popular baby care books (Harries & Brown, 2019).

Mothers' beliefs in their baby's autonomy in feeding may also be influential. For example, whether or not a mother believes that the infant can regulate their own appetite has been linked to feeding style. Studies have shown that mothers who bottle feed were likely to believe that infants cannot regulate their own appetite and that this prompted them to follow restrictive feeding practices in infancy (Gross et al., 2011; Gross et al., 2014). On the other hand, breastfeeding mothers report learning to respond to baby hunger cues, believing that their baby knows how much they need, and they also cite increased confidence in their baby's ability to participate in the process (Crossley, 2009; Nelson, 2010; Kronborg et al., 2015). Maternal beliefs that a baby has an individual mind, rather than being a creature with purely functional needs, is known as 'mind-mindedness'. Parents with a higher degree of mind-mindedness have been shown to be more sensitive to feeding cues (Farrow & Blissett, 2014).

Being relaxed about intake requires a degree of maternal confidence in her ability to feed her baby; thus parental self-efficacy may predict feeding style. Low levels of confidence are linked to anxiety in feeding, greater formula use, breastfeeding cessation and earlier introduction of complementary foods (Meedya et al., 2010; Brown & Arnott, 2014; Rollins, et al., 2016). Breastfeeding mothers report lower levels of trait anxiety and greater confidence and self-efficacy in relation to feeding (Brown, 2014; Brown & Arnott, 2014). In complementary feeding, maternal anxiety in infancy has also been linked to a controlling feeding style, which can be persistent up to age 1 (Farrow & Blissett, 2005a). In terms of complementary feeding method, mothers who spoon feed also reported lower levels of confidence and higher anxiety when compared with mothers who adopt BLW, whereas mothers who follow BLW were reported to be less anxious either at mealtimes or as a general personality trait (Brown & Lee, 2011; Brown, 2014). Parents with lower levels of self-efficacy and higher anxiety may also be more attracted to a routine driven approach (Brown & Arnott, 2014; Brown & Harries, 2015).

Self-efficacy has been shown to mediate weight gain in one study. In a study of 110 children who were observed by researchers to be higher in negative emotional reactivity at age 1, showed greater weight gain up to age 3 years, but only where maternal self-efficacy was also reported to be low, but the relationship was the opposite where mothers had high self-efficacy (Anzman-Frasca, Stifter, Paul & Birch, 2013). This finding suggests maternal self-efficacy mediates the effect of infant temperament, perhaps because mothers with high self-efficacy feel more confident to respond to sensitively to cues to settle them, rather than assuming hunger, and they may thus be more likely to use techniques other than food to soothe. This dynamic of behaviour may continue into childhood; maternal use of food as an emotional regulating tool has been linked to eating in the absence of hunger and consumption of sweet foods in children aged 3-5 years (Blissett et al., 2010).

Maternal feeding style observed in infancy appears continue into childhood. In a large cohort study of 1160 mother-infant pairs, Taveras et al. (2004) found that breastfeeding mothers were less likely to show controlling feeding practices at age 1, compared to formula feeding mothers. Another study found that bottle-feeding mothers who encouraged bottle-emptying in infancy went on to encourage their child to finish the contents of a meal at age 6 (Li et al., 2014). Parental monitoring, restriction and pressure to eat have been observed to be stable in infancy (Blissett & Farrow, 2007) between ages 2-5 years (Farrow & Blissett, 2012) and 5-7 years (Faith et al., 2004).

It is important to note that the aetiology of maternal self-efficacy and confidence is often multifactorial and deep-rooted. Low self-confidence and self-efficacy in mothers can be affected by their own and others' experiences of feeding, and are also more common in women from socially disadvantaged backgrounds (Entwistle, Kendall, & Mead, 2010; Bartle & Harvey, 2017). Cultural expectations and parenting books may also exacerbate feelings of inadequacy (Brown & Arnott, 2014; Harries & Brown, 2019). Moreover, inappropriate advice from friends, family and health professionals may undermine maternal confidence and trigger anxiety, self-doubt and controlling feeding behaviour (Larsen, Hall & Aagard, 2008; MacGregor & Hughes, 2010; Shortt, McGorrian, & Kelleher, 2013).

Furthermore, a mother's perception of her own body image and eating practices has been shown influence infant feeding behaviour. Brown & Lee (2011c) examined this and found that mothers who demonstrate high levels of restrained, external or emotional eating, were more likely to demonstrate higher levels of control over their child's eating during complementary feeding, perhaps suggesting a maternal transference of body image concerns onto her infant. Similar associations have been found in studies with mothers and their older children (Johannsen, Johannsen & Specker, 2006; Rodgers et al., 2013b)

However, reasons for parent-led vary and not all centre on a maternal desire for control; for example, normative formula feeding in the woman's local community, lack of support, and stigma around feeding in public are key reasons for not initiating or stopping breastfeeding (Pain, Bailey & Mowl, 2001; McFadden & Toole, 2006). Likewise, mothers who choose to spoon-fed do not necessarily do so due to concerns over intake, as some report being worried about other aspects of infant self-feeding such as risk of choking or mess (Brown & Lee, 2011a).

2.11.5. Separating responsive feeding from feeding method

The tenets of responsive feeding are not exclusive to any one feeding method. For example, while controlling practices in bottle-feeding are higher than in breastfeeding (see section 2.8.3.) it is possible to bottle-feed responsively, and this is recommended practice (UNICEF UK, 2019). Maternal sensitivity to infant cues of satiety in bottle feeding can be modified and this has been demonstrated in research from as early as the 1960s. Fomon (1974) referred to earlier work (Brown, Tuholski, Sauer, Minsk & Rosenstern, 1960; and Fomon, Owen & Thomas, 1964) which demonstrated that bottle-fed infants if fed responsively drank around 20ml/kg/day less than if they were fed the greatest possible feed that they would accept. More recently, studies have tested feeding infants using opaque weighted bottles, so that mothers cannot see/feel how much their baby has drunk, taking away the temptation to encourage bottle-emptying, finding improved maternal sensitivity and reduced milk intake as a result (Ventura & Pollack Golen, 2015; Ventura & Hernandez, 2019).

Similarly, spoon-feeding may be undertaken responsively, by paying attention to infant cues and offering appropriate portion sizes (WHO, 2003b). For example, Black and Hurley (2017) offer practical strategies for responsive complementary feeding, such as ensuring the child eats with and facing others. However, much of the research on responsive complementary feeding has focussed on developing countries, where malnutrition (rather than prevention of overweight) is the pressing issue (Moore, Akhter & Aboud, 2006). There appears to be a fairly recent move towards a greater understanding responsive feeding specifically for the complementary feeding context in developed countries, following the development of new measuring tools such as the Responsiveness to Child Feeding Cues Scale (RCFCS) for 7-24 month olds (Hodges et al., 2013) and The Feeding Infants: Behaviour and Facial Expression Coding System (FIBFECS) (Hetherington et al., 2016).

Perhaps counter-intuitively, there is some potential for less responsive behaviours to occur in BLW. As Black and Aboud (2011) point out less responsive feeding may also include actions such as indulgence, where the child is allowed complete control, particularly in relation to 'giving in' to the child's preference for sweet or snack type foods. Critics of BLW have posited that there is a potential for BLW to allow babies to eat snacks, such as crisps and biscuits as finger foods (Cameron et al., 2012b). 'Indulgent' feeding styles, where infants are freely allowed to eat whatever and whenever they like are also problematic as parents who do this may misinterpret infant cues, indiscriminately attending to crying or protests with favoured foods (Black & Aboud, 2011), perhaps leading to a development of emotional eating (Blissett et al., 2010)

It is also important to consider the more intricate context of descriptors of maternal child feeding interactions, as the picture is not always clear. For example, Shloim and colleagues (2015) note that the term 'pressure to eat' requires some clarification, for example pressure to eat when not hungry (which may affect appetite regulation) ought to be considered separately from positive and relaxed encouragement to eat healthy foods as part of parental guidance in food choices. Similarly, restriction may be important in some situations around preventing over-consumption of energy dense snack foods. One study found that child BMI was inversely related to parental 'positive involvement' a term which the study authors defined as; encouragement of healthy eating, monitoring and limiting intake of high calorie foods and serving age appropriate portions (Tschann et al., 2013). Therefore, while the ethos of BLW means that the infant self-feeds, the role of the parent during feeding is also important, with parents playing a key part in what foods are offered, the portion size offered and positive interactions around mealtimes.

Some have also pointed out that BLW should not be tantamount to 'laissez-faire' feeding (Rapley et al., 2015). 'Uninvolved' feeding styles where the caregiver does not interact with the infant at all during feeding, or interacts in an age-inappropriate manner may put infants at risk of inadequate intake as has been reported in developing country settings (Engle, Bentley & Pelto, 2000; Black & Aboud, 2011). It is unlikely, however, in the common practice of BLW that infants are simply left to fend for themselves. A key tenet of BLW is eating with the family, and this naturally encourages parents and infants to interact during feeding. Responsive BLW involves observing the child's ability to eat, taking account of their preferences, and centres on enjoyment of family mealtimes. One study found that BLW infants were significantly more likely to eat with their family when compared with spoon-fed children (Morison et al., 2016). However, another pilot study of BLW found that the baby ate same time as other family members, on only around 50% of occasions, suggesting that the 'family mealtime' aspect of BLW may not be always adhered to (Rowan & Harris, 2012), but this did not necessarily mean that parents were uninvolved in the feeding. A qualitative study of UK mothers who define themselves as following BLW reported involvement in their baby's feeding, encompassing some level of control and compromise, such as deciding on the types of food offered, and the occasional use of spoon-feeding (Arden & Abbott, 2010). It is also important that throughout the BLW process parents are observant of the infants developing motor skills, as BLW may be more difficult for some infants (Rapley et al., 2015).

2.12. The Trust Model for child feeding

This literature review has presented literature which proposes some potential benefits of baby-led feeding approach for preventing childhood obesity. The opposite of a baby-led feeding approach is the parent-led approach, whereby parents control or manage their child's intake, and the reasons for this are widely variable. While parents may have well-meaning justifications for managing their child's food intake, many of these feeding behaviours are not responsive to children's internal appetite cues, potentially creating a reliance on external cues, and ultimately may lead to maladaptive eating in older childhood or later life.

Eneli, Crum and Tylka (2012) discuss the 'The Trust Model' paradigm for child feeding, which emphasises caregivers' role in nurturing or protecting children's internal hunger, appetite and satiety cues. The model encourages parents to 'trust' (hence the name given to the model) children to regulate their own eating allowing them to develop healthy relationships with food, greater self-esteem and responsibility. The Trust Model was first developed by American dietician and social worker Ellyn Satter (1996). Satter (1996) proposed that attempts to control weight in children are often counter-productive, and that maintaining children's internal regulatory responses is more likely to be effective, as well as being more holistically beneficial to the child's social and emotional wellbeing. Satter accepted that if children are trusted to eat according to their own appetite, there is a risk that some children may still become overweight, and that this may be attributed to genetic differences. However, parental attempts to control eating may exacerbate these predispositions. Rather, she suggested, the responsibility of parents is to manage the home food environment (in terms of what foods are available) and to promote positive experiences around food by establishing family mealtimes and parental modelling of healthy eating. The opposite paradigm to the Trust Model, Satter called the 'Control Model', which prioritises concern over child weight and focusses on interventions to address divergence from an accepted standardised 'normal' weight range. Within the Control Model parents may be tempted to restrict, control or manipulate food intake leading children to be at increased risk of developing disordered eating, and perhaps a greater risk of becoming overweight.

Satter (1996) and Eneli et al. (2012) suggested that application of The Trust Model can begin in infancy, as this allows the earliest possible opportunity for children to develop appetite regulation, before learned dysregulation has occurred. Feeding infants according to the The Trust Model therefore means feeding on demand, and in response to signs of hunger and satiety. This is the same as the 'responsive feeding' approach recommended by the WHO (2001b). In complementary feeding, the model recommends that children transition slowly onto family foods, in the context of a pleasant eating environment, and with parental modelling. This is reflected in the baby-led weaning method whereby infants progress slowly onto family foods (rather than 'baby' foods) and eat alongside the family (Rapley & Murkett, 2008). Also the ethos of BLW mirrors that of Satter's work, with the emphasis in BLW being on low maternal control, high child autonomy, and enjoyment of food being central to the process. The Trust Model therefore provides a broad paradigm view around child feeding within which a baby-led feeding approach sits perfectly.

The Trust Model relies on the assumption that children can regulate their own appetite and there is general agreement in the scientific community that this is the case (Anderson & Keim, 2016). Studies have demonstrated that given the opportunity most infants and children will self-regulate their appetite (Johnson, 2000; Farrow & Blissett, 2006). However, this ability may not be well recognized by mothers, with some studies reporting low maternal recognition of infant autonomy over appetite (Gross et al., 2011; Gross et al., 2014). Furthermore, concerns over infant and child weight and food intake are pervasive among parents (Redsell et al., 2010; Gross et al., 2011; Fildes et al., 2015). Perhaps these concerns are a product of a system which is predicated on a 'Control Model' which values surveillance and intervention. In the UK, babies and young children are weighed and measured frequently as part of child health programmes, and qualitative work has shown that growth monitoring is seen as valuable by parents (Lucas et al., 2007). Furthermore, poor understanding of 'normal' infant behaviour as well as lack of appropriate support are likely to fuel maternal worries, and undermine mothers' self-efficacy and ability to trust in her baby (Arden, 2010; Hoddinott et al., 2011; Clayton et al., 2013; Anzman-Frasca et al., 2013; Harries & Brown, 2019). A greater understanding of maternal drivers towards their feeding choices, as well as a recognition of wider cultural beliefs and social factors which perpetuate controlling feeding practices is therefore vitally important if The Trust Model is to be fostered as the predominant paradigm in infant feeding.

2.13. Summary and rationale for this research

Childhood obesity is a significant health problem globally and this chapter started by outlining the myriad factors that may influence childhood obesity. Evidence is building suggesting that the trajectory to obesity is likely to start as early as in infancy. While milk feeding and the timing of introduction to complementary foods are important factors which have received some research attention, there is a growing field of research exploring methods of complementary feeding as a potential way of reducing obesity risk. In particular, baby-led weaning has gained popularity in recent years in the UK and other developed countries around the world. It is unclear exactly the proportion of mothers who are adopting BLW, however interest in the method is evident from its large internet following and the commercial success of books on the topic (Jones, 2016).

Increasing research is showing that mothers are drawn to the method in part due to a perception that it will help their baby develop positive eating habits and be a healthy weight (Brown & Lee, 2012; Cameron et al., 2012; Arden & Abbott, 2015; D'andrea et al., 2016). However, although a number of research papers have explored maternal experiences of following the method, the data surrounding its impact upon childhood weight is sparse and most focusses on outcomes in toddlers (Townsend & Pitchford, 2012; Brown & Lee, 2015; Taylor et al., 2017) rather than growth during infancy. The previous research also has a number of limitations which provide the rationale for the SHIFT study:

Lack of researcher-led measurements

To date there have only been two published trials examining the effect of of a baby-led feeding approach upon growth, one from New Zealand (Taylor, et al., 2015) and one from Turkey (Dogan et al., 2018). These trials used researcher-led measurements, however both were limited by the fact that they only measured the effect of the BLISS BLW intervention (which was modified for energy and iron intake) and therefore the findings pertain only to the BLISS intervention and not BLW at large. Research that has examined the normal practice of BLW on weight outcomes has relied partly or fully on parental-report of child weight (Townsend & Pitchford, 2012; Brown & Lee, 2015), which may be unreliable (Huybrechts et al 2011; Gordon & Mellor, 2015; Wright, Glanz, Robson & Saelens, 2018).

Differing definitions of baby-led weaning

Measures of what constitutes a baby-led weaning have differed between studies, with different degrees of self-feeding/ puree use being accepted (Brown et al., 2017). Studies which asked parents to self-identify whether or not they were following baby-led weaning found that strict adherence to the method was variable (Cameron et al., 2013) In the BLISS study poor adherence within the BLISS group and self-selection of complementary feeding method within the usual care groups meant that cross-over between the arms of the study was an issue (Taylor et al., 2017).

Problems with retrospective recall

Prior research may have suffered from problems with retrospective recall of feeding data. Parental questionnaires surrounding infant feeding may occur months or years after infancy, which calls into question the accuracy of recollection of feeding information. For example, the Nurses Mothers' Cohort Study had a very long time lapse between feeding and the research; parents of nurses aged 37 to 44 were asked to recall breastfeeding duration and age of introduction to complementary foods (Michels et al., 2007). In baby-led weaning research Townsend and Pitchford (2012) asked parents to recall complementary feeding method up to four years later. Studies have suggested that maternal recall of milk feeding behaviour is valid if reported after a short duration (around 3 years), however validity and reliability of retrospective recall around complementary feeding is considered to be less accurate (Li, Scanlon & Serdula, 2005).

Lack of consideration for growth trajectories over time

Much of the research is cross sectional at one-time point, rather than considering growth over a period of time (Townsend & Pitchford, 2012; Brown & Lee, 2015). Dogan et al. (2018) recently explored trajectories of infants 6-12 months, however, this study did not adequately control for covariates and use of raw anthropometric data rather than z-scores limited its interpretation.

It is not clear which aspects of baby-led feeding are important

Research has simply considered the baby-led weaning method rather than considering what aspects of a baby-led approach might affect weight. Although some research controls for associated factors such as breastfeeding and timing of introduction to solid foods, some does not, or considers these factors solely as covariates rather than looking at any direct or combined effect. For example, Townsend and Pitchford (2012) did not account for milk feeding and in Dogan et al's (2018) study it was not clear how covariates (if any) were controlled for. Much of the research focuses on the concept of self-feeding, rather than the potential impact of the texture or type of diet offered or the maternal reasons for introducing complementary foods – which might also affect infant growth.

Lack of consideration of the potential for a combined effect

Although some research has controlled for the impact of milk feeding, despite recommendations that milk still forms a key source of nutrition during the first year, research has not considered whether baby-led feeding may have a different impact in breast and formula fed infants. Research looking at the age of introduction to complementary feeding has shown that outcomes differ dependent on milk feeding approach (Huh et al., 2011; Moss & Yeaton, 2014; Papoutsou et al., 2018). Thus is it possible that outcomes relating to the method to complementary feeding may similarly vary according to milk feeding type.

Furthermore, the majority of studies fail to consider the potential for a cumulative effect of milk feeding type, and timing of introduction to complementary foods, along with the complementary feeding method. This may be important for two key reasons:

a) Content of the diet.

Infants who are formula fed are known to incur higher intakes of protein than breastfed babies, stimulating growth (Heinig et al., 1993; Luque et al., 2015). In conjunction with infants who start complementary feeding early, and those who are spoon fed, they are also more likely to consume complementary diets high in cows' milk protein, such as infant cereals (Brown & Lee, 2011a; Komninou et al., 2019). Infants who start complementary foods earlier, and who are spoon-fed are also more likely to eat commercial baby foods, high in sugar (Erickson, 2015; Morison et al., 2016).

b) Feeding style of mothers:

These feeding choices, rather than causing increased weight per se, may be indicative of a controlling maternal feeding style, which is actually having the effect. Parents who are concerned about weight, intake or infant behaviour may encourage or pressure intake (Gross et al., 2011; Farrow & Blissett, 2006; Fildes et al., 2015). Pressuring feeding in infancy may increase intake (Thompson et al., 2013), heighten risk of overweight (Lumeng et al., 2012) and lead to later food fussiness (Ventura & Birch, 2008; Gregory et al., 2010)

There therefore appear to be two 'triads' of infant feeding behaviours; one which represents a more 'parent led' approach (formula feeding, early complementary feeding and spoon-feeding of complementary foods) and the other being indicative of more 'baby-led' approach (breastfeeding, delayed complementary feeding and infant self-feeding). However, these 'triads' are not mutually exclusive and aspects of them may be interchangeable and this is likely to depend on what is driving parents to adopt the behaviours. For example, breastfeeding mothers (initially baby-led) who become concerned about growth, may attempt to feed to a routine and/or introduce formula/complementary foods earlier (parent-led) and perhaps adopt a more pressuring spoon-feeding style in infancy (parent-led). Furthermore, it is not known whether a mothers who initially formula feed, may mediate risk of accelerated infant growth by delaying complementary foods introduction and following a BLW approach. Therefore, considering all three behaviours in relationship to each other may illuminate this.

Little understanding of the impact of what drives mothers towards a feeding approach

Although research has identified that mothers who choose to follow a baby-led approach are different in personality, and demonstrate different attitudes towards complementary feeding (Brown & Lee, 2011a; Brown & Lee, 2011b; Brown & Lee, 2013b; Arden &

Abbott, 2015) research has not examined the potential impact of the underlying drivers motivating mothers to choose a certain complementary feeding approach.

Length is often neglected

Across the infant feeding literature, much of the focus is on weight or BMI with very little consideration of infant length, as a measure of growth in its own right, or in conjunction with weight, which would allow a better reflection of body composition. Focus tends to consider the impact of weight or BMI alone (Gunnarsdottir & Thorsdottir, 2003) or if length is considered it is in regard to the impact of stunting, often primarily in developing regions (Prendergast & Humphrey, 2014). However, limited research with preterm infants suggests that rapid length gain from 4 – 12 months may also be a risk factor for later obesity (Belfort, Gillman, Buka, Casey & McCormick, 2013). High birth length has been associated with increased risk of overweight in adulthood (Rasmussen & Johansson, 1998), whilst in a Brazilian cohort study rapid gains in length-for-age were associated with rapid gains in weight-for-age and weight-for-length in overweight adolescents (Monteiro, Victora, Barros & Monteiro, 2003). Finally, in the ALSPAC cohort, infants with alleles associated with increased obesity risk showed faster length gain in the early months. These infants went on to be both heavier and taller by nine years old (Elks et al., 2010).

Longer length may also be influential in maternal feeding decisions; longer infants (in relation to weight) may give the appearance of being thinner, perhaps leading mothers to consider their child to be underweight and perhaps the tendency to pressure intake. Cow's milk protein in particular has been associated with linear growth, so infants fed formula or cow's milk powder (in infant cereals) may be subject to exacerbated length gains (Grenov & Michaelsen, 2018).

2.13.1. Research questions

Therefore, the SHIFT study seeks to explore the impact of a baby-led feeding style upon infant growth during complementary feeding by using researcher led, standardized anthropometric measures of growth incorporating both a cross sectional and longitudinal approach to examine the following broad questions:

1. Does the method of introducing complementary foods influence infant growth?

2. What elements of the method of complementary feeding affect infant growth? Is self-feeding important? Diet content? Texture of food? Timing of introduction to complementary feeding?

3. How does milk feeding affect this? Given that milk feeding is still a predominant part of the diet, does milk feeding predict or continue to affect growth in the latter half of infancy? And does a baby-led weaning method have a different impact upon growth in breast and formula fed infants?

4. What drives mothers to adopt a complementary feeding method? Do these driving factors appear to be influenced by infant weight or size, and do they influence infant growth?

Overall, this research seeks to go beyond asking simply whether a baby-led complementary feeding method impacts upon growth, exploring the individual and combined effects of different aspects of infant feeding, in order to understand why any differences might occur. The findings of SHIFT are likely to be important in helping both parents and professionals to adopt or recommend the elements of infant feeding, which appear to be beneficial.

CHAPTER 3: SHIFT study design and methodology

The primary aim and objectives of SHIFT were to explore infant growth in relation to infant feeding practices in the first year of life using researcher measured anthropometric data, with a particular focus on how growth might be related to different aspects of baby-led feeding. The study used a partially cross-sectional and partially longitudinal design to explore these aspects. Key factors will be examined one by one in the subsequent chapters (Chapters 4-10) in order to allow a deeper investigation of the research questions. They will finally be examined all together in the final findings chapter (Chapter 11).

This chapter presents the methodology of the SHIFT study; the design, sample, measures and tools used, the procedure, reliability and validity considerations, ethics and data analysis.

3.1. Study design

The aim of the study was to examine whether differences in infant growth could be identified at 6 – 12 months based on different baby-led feeding factors. Infants aged 6 – 12 months were weighed and measured by a trained researcher. This data set allowed for cross sectional analyses to be conducted for these one-off measurements for infants across the complementary feeding period. It allowed sub analyses to be conducted by splitting the sample into different age groups to compare infants who were at the start of the complementary feeding period (6 – 8 months) to infants who were at the latter stage of the period (9 – 12 months). Using this cross sectional approach allowed for a larger sample size to be collected.

However, within this sample a cohort of infants had two measures of growth taken, in order to examine growth over the complementary feeding period. These infants had one set of measurements taken at around 6 months (at the start of the complementary feeding period) and one at around 12 months (at the end of the complementary feeding period).

This approach was more time consuming for participants and required participant follow up. Therefore, numbers in this group were smaller than the overall sample.

In order to maintain independent samples only one of the measurements from the longitudinal cohort could also be included in the cross-sectional analyses. Therefore, for the infants with two measurements, only the second set of measurements was entered into the 'main data-set'. This was chosen as it gave the most even spread of ages allowing more infants in the data-set aged around 12 months, rather than being weighted towards earlier infancy and because overall recruitment of fewer infants aged towards 12 months was affected by lack of availability of parents to take part in the study as many of them had gone back to work and were less accessible. Boosting the sample at the older end of the 6-12-month range was seen as potentially important as older infants would have had longer exposure to the feeding behaviours, and therefore those later measurements would perhaps allow more time for any impact of the feeding behaviours to emerge.

A questionnaire was also developed in order to identify known maternal and infant demographic factors that may affect weight as well as to be able to measure and categorise infant feeding practices. These include, maternal age, parity, education, occupation, infant age, birthweight, type, mode and duration of milk feeding, age at introduction to complementary feeding, proportion of milk to foods offered, complementary feeding method and the texture and content of the infant diet. Mothers were also asked to give their reasons for choosing the complementary feeding method that they used.

3.2. Participants

Inclusion criteria

The SHIFT target population was healthy full-term infants aged 6-12 months and one of their parents (whichever parent was most involved in the baby's feeding). This age range was selected because it spans the latter half of infancy and complementary feeding period.

Other inclusion criteria were that parents must be aged over 18 and able to complete the English language questionnaire and to give informed consent. For feasibility for data collection, participants were recruited from the South and West Wales area, and the Bristol area.

Exclusion criteria

Exclusion criteria were infants born earlier than 37 weeks' gestation or with a low birth weight (born weighing less than 2500g), babies with significant health concerns or history of poor weight gain or feeding issues such as failure to thrive, severe colic or severe reflux (as reported by the parent).

Inclusion and exclusion criteria were checked on initial point of contact.

3.4. Tools

A questionnaire was developed to collect the following information regarding participant characteristics and infant feeding method:

- Maternal and infant background characteristics
- Infant birth weight
- Milk feeding history
- Timing of complementary feeding
- Complementary feeding method (including rationale for following)
- Infant diet

A questionnaire was chosen as the tool to collect the infant feeding data (as opposed to interviews) as most of the data required was simple and quantitative in nature.

Due to the extensive and interrelated variables involved in infant growth, a large a sample size as possible for statistical analysis was considered to be important. Group questionnaire administration can be a useful way to maximise recruitment and thus increase sample size (Birmingham & Wilkinson, 2003). Therefore, local mother and baby groups were intended to be a key source of recruitment for the study. It was thought that group recruitment would enable as large as possible sample size, as many mothers and babies might be able to take part at the same time, increasing efficiency and feasibility of data collection by one researcher.

The questionnaire was designed to be easy to understand and brief in order to be feasible for parents to complete whilst the baby is also present, which was especially important in busy baby group settings. It was thought that a long cumbersome questionnaire would be off-putting and might potentially incur a low recruitment and/or a high attrition rate. This meant however that the questionnaire did not include every possible factor influencing infant growth (for example, mode of delivery, antibiotic use, maternal gestational weight gain etc.). A decision was made, in order to maintain questionnaire brevity and to reduce respondent burden, to only focus on a few key elements relating to infant feeding. Birmingham & Wilkinson (2003) state that 20 minutes is the maximum ideal length for a questionnaire, therefore the questionnaire was designed and pilot-tested with parents to be able to be completed within 10-15 minutes. This then allowed for the additional time needed to weigh and measure the baby (which includes undressing).

Limitations of questionnaires as a data collection method are that they limit the scope of questioning, as questions need to be simple and quick to answer such as tick boxes (Walliman, 2006). However, this was not considered to be a drawback, as for this study most of the data required was simple and categorical in nature. Group questionnaire administration, especially in a baby group setting may also be limited by respondents feeling aware that others will know what they have written, and therefore the answers may be affected by social desirability bias, especially around sensitive topics (Wrieden, Peace, Armstrong & Barton, 2003; Krumpal, 2013). However, it was thought that a self-administered questionnaire, although completed in a group setting, allows a degree of individual privacy. Awareness of sensitivity around administering the questionnaire in a group setting was the reason why the questionnaire did not seek to ask about maternal weight status. Being distracted in a busy setting, and having the baby present may also have affected mothers' attentiveness to the questionnaire.

3.4.1. The questionnaire

Here, the rationale for the questions included in the SHIFT questionnaire (see Appendix 1 - questionnaire) will be presented.

Maternal and infant background

As identified in the literature review, maternal demographic background such as socioeconomic status can affect choice of milk feeding type, infant growth and later obesity (Wijlaars et al., 2011; Oakley et al., 2013, Pearce et al., 2013; Gibbs & Forste, 2014, NHS Digital, 2017). Studies have shown that mothers who breastfeed, introduce complementary foods later and who follow BLW are more likely to be older and have a higher level of education (Brown & Lee, 2011a). Details of maternal education and age were therefore collected. Infant age in weeks and sex were collected as these are necessary for the calculation of growth outcomes (see section 3.7.1)

Infant birth weight

Parents were asked to provide the infants birthweight. Birthweight is a known influence for overweight and obesity (Rogers, 2003; Monteiro & Victora, 2005; Baird et al., 2005; Chiavaroli et al., 2016). Infant birthweight also allowed weight gain trajectories over time to be calculated. Birth length data was not available as this is no longer routinely done in the UK.

Milk feeding at birth and at completion of questionnaire including details of any breastfeeding exclusivity

Milk feeding is an important factor in infancy growth, including duration and exclusivity (Dewey et al., 1992; Mihrshahi et al., 2011; Weng et al., 2012; Oddy et al., 2014). A number of questions were asked to determine milk feeding experiences:

- First milk feed: Breastmilk, expressed breast milk, formula milk (one choice only)
- Milk feeding at time of questionnaire: Breast, formula, expressed breast milk, cow's milk (multiple choices allowed in order to identify combination feeding and mode)
- Timing of any formula used in weeks (if relevant)
- Timing of stopping breastfeeding in weeks (if relevant)

This allowed duration of partial and exclusive breastfeeding to be computed. Defining breastfeeding exclusivity is important, because exclusive breastfeeding for 6 months is the current WHO (2001) recommendation, and because prior studies have related duration of breastfeeding exclusivity to differing rates of growth in infancy (Kramer et al., 2002; Oddy et al., 2014; de Beer et al., 2015).

Age of starting complementary feeding

Although the findings are mixed, some studies suggest that an early introduction of complementary foods can increase risk of overweight (EFSA, 2009; Moorcroft et al., 2011; Huh et al., 2011, Pearce et al., 2013; Barrera et al., 2016; Brown, 2017a). Furthermore, BLW has been associated with later introduction of complementary food (Arden, 2010; Brown & Lee, 2011a; Moore et al., 2014), so this information was used to determine if this association was present in this sample. Participants were asked to state how old their infant was in weeks when they first were given complementary foods. Complementary food was defined any food or drink that is not breast milk or infant formula, as per the WHO definition (2003b). Medications and vitamin drops were exempt.

Defining complementary feeding method

Complementary feeding method at the beginning of complementary feeding and again at the time of completion was identified through two questions used in previous research (Brown & Lee, 2011a; 2011b, Brown & Lee, 2015). There is no consensus on the definition of BLW (Brown et al., 2017). Some studies have asked parents to self-identify whether they are BLW or not, however this was found to be inconsistent and inaccurate. For example, in a study by D'andrea et al (2016) some mothers who identified as BLW still often offered pureed foods, however, in a different study by Cameron et al., (2013), those mothers who offered purees were classed as non-adherent to BLW. Studies by Brown and Lee (2011a; 2011b; 2015) however identified two key components that define BLW:

- Self-feeding (vs. spoon feeding)
- Consumption of whole foods (vs. pureed or mashed)

Brown and Lee's studies (2011a; 2011b; 2015) used these two key components in their research; they asked parents to self-identify whether they were BLW, but they stipulated that a BLW definition would allow a maximum of 10 % spoon feeding of puree because this allowed for the occasional use of spoon-feeding such as giving a yoghurt outside the home. Brown & Lee's work found similarities between infants who were never spoons-fed and those who were spoon fed 10% of the time, but found differences between these groups and those using spoon feeding 25% of the time or more (Brown & Lee, 2011a). In the SHIFT study questionnaire, the degrees of self-feeding and whole food consumption were graded into a 5 category Likert scale, with descriptions to aid understanding as in Figure 1 and Figure 2 below.

When your baby **FIRST STARTED SOLIDS** ….

a) Did your baby feed him/herself unaided? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
Every piece of food that went into his/her mouth was put there by baby.	Most of the time baby fed self but needed occasional help e.g. to eat a yoghurt.	About half the time baby fed self.	Most of the time an adult fed baby with a spoon. Baby occasionally fed self-e.g. a rusk or toast.	An adult always fed baby by putting the food into baby's mouth with a spoon.
BLW (Baby predominantly fed-self)		SCF (Baby was fed by adult 50% of the time or more)		

*Note the bottom row (in grey) was not on the questionnaire, but is shown here to identify how the groups were later defined.

Figur

b) Did your baby eat pureed or mashed food (rather than finger foods)? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
All food was of a pureed or mashed texture, this includes baby cereal/ rice.	Most food was of a pureed or mashed texture but occasionally baby ate finger-foods e.g. rusk or toast.	About half the time food was pureed or mashed, half the time baby ate finger foods.	Most of the time baby ate finger foods but occasionally baby ate something like yoghurt or baby cereal/rice.	Baby always ate finger foods in their whole form. E.g. sticks of carrot, toast, chunks of banana. No purees.
Puree group (Baby ate 50% or more of their diet from purees)			Whole food group (Baby predominantly ate whole foods)	

Figure 2: Extract from questionnaire. Texture

By breaking each key component of BLW down into 5 gradations, it was thought that this would allow for a more accurate representation of the spectrum of complementary feeding approaches. Many parents do not follow rigidly either BLW or SCF methods and often in reality the feeding behaviours falls somewhere in the middle. It was also designed to help parents to identify the principles of the complementary feeding method that they are actually doing, rather than asking them to self-identify with a label such as 'baby-led weaning'.

Participants completed these boxes twice – once for their behaviour at the start of the complementary feeding period and once for their behaviour at completion of the questionnaire. This allowed any changes in method over time to be examined.

Reasons for complementary feeding method

Participants were asked why they chose the complementary feeding method they did. A small free-text box was given for them to write their answer. Open ended questions allow participants to elaborate and provide more detail, without being restricted by closed questions specific to the research agenda (O' Caithan & Thomas, 2004).

This question was added to the questionnaire later during the data collection process, as it became apparent that mothers motivating factors for introducing complementary foods may influence what and how they feed their baby. This meant however, that not all participants have this data.

Exploring why mothers made the decision to introduce complementary foods in different ways is useful in understanding the motivating behaviour behind their decision that might in turn affect weight outcomes. Although some may adopt a baby-led complementary feeding method, waiting for infant readiness, many other reasons for introduction of food centre on persuading the infant to eat more food e.g. concerns around intake and weight, believing complementary food will help settle the infant or help sleep (Arden, 2010; Wasser et al., 2011; Clayton et al., 2013; Walsh et al., 2015; Brown & Rowan, 2015; Spence et al., 2016). These factors in themselves may affect weight gain as they may reflect an overall pressurising or controlling approach in the mother.

Proportion of milk versus complementary foods

Participants were also asked to estimate the proportion of their baby's diet that comes from milk as opposed to solid foods using to following options.

- All from milk. No solids.
- Mostly from milk. Small amount of solids.
- About half from milk/half from solids.
- Not much from milk. Mostly from solids.
- All from solids. No milk.

The purpose of this question was to identify whether complementary feeding method is associated with a different progression from milk onto complementary foods. This is because it has been suggested by BLW proponents that BLW encourages a slower transition from milk to complementary foods (Rapley, 2011). It has been proposed that while infants in the early stages of BLW may not consume large quantities of complementary foods, they continue to consume milk alongside food in order to meet their requirements and that this gradually reduces as food intake increases (Rapley, 2011).

The gradual transition from milk onto solid foods fits with the WHO report on the energy requirements of infants, which found that between ages 6 to 8 months the additional energy requirement from food is only around 196 kcal per day, increasing gradually with age, with the majority of an infant's energy intake (approximately 486 kcal per day) coming from milk, giving a total requirement of 682 kcal per day (Michaelsen et al., 2000). Proportionately, this means that just over a quarter of infants' intake needs to come from food at this age. By 9 to 12 months this proportion of food to milk increases to around 50% and, again, the emphasis is that this increase should occur gradually (Michaelsen et al., 2000). No studies so far have explored the relationship between the proportion of on-going milk-feeding in relation to solid foods and complementary feeding method, so it was hoped that this question would provide a unique insight in this area.

Infant diet

Several questions examined infant diet, including estimation of the proportion of the infant diet that was puree versus whole foods, a 24- hour dietary recall to examine content typically offered, and consideration of the proportion of the diet that was milk or complementary foods.

Collecting this data was important, as there is little evidence exploring infant diet and growth during the first year. Prior to commencing this research, no studies (apart from Erickson's (2015) unpublished Master's thesis as part of the BLISS study) had compared the differences in the content of the infant diet during complementary feeding in BLW and SCF. However, Erickson's study was an exploration of the BLISS intervention, and this may have contained higher amounts of energy dense foods in the diet as recommended in the intervention. This year, two more studies have been published exploring this (Rowan et al., 2019; Komninou et al., 2019), however, the evidence base remains very small. As outlined in the literature review, an understanding of diet offered may be interesting; first, in relation to the impact that dietary factors may have on growth and obesity risk, and second, in relation to concerns about BLW infants being offered appropriate foods. Therefore, it was decided that the questionnaire should also explore diet offered.

3.5. Procedure

3.5.1. Recruitment

Parents of infants aged 6-12 months were recruited via poster (see Appendix 2 - poster) advertisements in local baby groups and cafes, via social media (predominantly Facebook), via personal invitation at local baby groups, and some by word of mouth. Initial contact was made in the following ways:

- Poster or social media advertisement: Mother contacted the researcher by either telephone, text, email or Facebook messenger to express their interest.

- Personal invitation at baby groups: The researcher contacted the lead for the group and explained the background and aims of the study, requesting permission to attend the group to talk to mothers. If permission was granted, the researcher attended the group and gave a short presentation about the aims of the study and provided study information sheets. Those who wished to take part completed a consent form and then either participated in the study or arranged a convenient time for the researcher to visit.
- Word of mouth: Snowball recruitment occurred organically by word of mouth from previous research participants. The 'new' parents then contacted the researcher directly. Some parents offered to hold data collection 'sessions' at their home and invited their interested friends.

3.5.2. The process of a session

A data collection session involved 2 steps:

1) Parent completed questionnaire.
2) Child was weighed and measured by the researcher in accordance with procedure outlined below.

Each time, the parent was given the option to either complete the questionnaire first or for the child to be weighed and measured first. This was because the weighing and measuring was dependent on whether the child was awake/crying/contented etc. The parent judged the appropriate time for this to take place.

All infants were weighed and measured by the researcher using the following SECA® products; calibrated scales and length measuring mat. These are the products used by health care professionals in the local health board and the researcher is trained and experienced in their use, being a qualified health visitor.

At the end of the session parents were thanked for their participation. All questionnaires were anonymized with a codename and kept in a locked cabinet in Swansea University with a key held only by the researcher. The personal data (names, addresses, phone numbers and email addresses) were kept separately in a different locked cabinet and destroyed after the completion of the research and de-brief letters sent out.

The process of recruitment and participation is shown in Table 1.

Table 1: Initial contact and recruitment procedure

<table>
<tr><th>Recruitment in Baby Group</th><th>Advert Online or Word of Mouth</th></tr>
<tr><td>1. The researcher obtained permission to attend baby group from the organiser. The researcher introduced herself and the overview of the study to the whole group. Interested parents approached the researcher in person and expressed their interest in taking part</td><td>1. Parent saw advert on Facebook or was signposted to the study by another person who thinks they might be interested (word of mouth). The parent expressed interest by phone/text/email to the researcher.</td></tr>
<tr><td>2. Face to face discussion with the parent:
• Checked inclusion/ exclusion criteria
• Given paper copy of information sheet and consent form to parent. Allowed time to read information and decide on their involvement.</td><td>2. Phone call/text/email first contact:
• Checked inclusion/ exclusion criteria
• Parent was signposted to the study website address containing all the information sheets, questionnaires and consent forms. (If recruited online they may already have seen the website.)
OR
If preferred an information pack with paper copies of all of the above was sent out by email.</td></tr>
<tr><td>3. If parent consented to take part, they were given the option to start …
Session 1: straight away by completing the questionnaire in the baby group. Baby was weighed and measured at this time, with the parent present in an appropriate (and private if available) place in the baby group setting
OR
Arrangements were made to return to baby group another time (over the next few weeks)
OR
Arrangements were made to meet the parent at their home on another date if preferred.</td><td>3. Researcher contacted the parent via their preferred method (usually a few days later) and arranged an appointment for the first session.
Session 1 took place at a place of the parent's choice (usually at home). Parent completed questionnaire during the appointment. Baby was weighed and measured at this time with the parent present.</td></tr>
<tr><td colspan="2">4. Follow up sessions. Arranged with parent to take place either ongoing at baby group or at home as preferred. Ongoing baby group sessions arranged with group organisers, and text reminders sent to parents.</td></tr>
</table>

3.6. Reliability and validity

Reliability is the extent to which a measure can be repeated with accuracy (Heale & Twycross, 2015). In order ensure that the outcome measures of interest (anthropometric measurements of infants) were reliable, all infants were measured by one researcher in a standardised way thereby limiting variability as much as possible. All infants were weighed naked on a flat surface using calibrated scales. Length measurement was undertaken using a foldable length measuring mat. Parents were asked to assist in the length measurement by holding the infant's head still at the top headboard while the researcher gently released the infant's leg to a straight position. This method of measuring is common practice by health care professionals and the researcher (as a health visitor) is trained and competent in doing it. It was hoped that measuring in a standard way with the same instrument, by the same researcher this would address some of the concerns surrounding inconsistencies of growth data in the prior literature, which often use child health databases (Armstrong & Reilly, 2002; Grummer-Srawn & Mei, 2004) or parental self-report to acquire anthropometric data (Townsend & Pitchford, 2012; Brown & Lee 2015) which may contain inaccuracies (Huybrechts et al., 2011; Gordon & Mellor, 2015; Wright et al., 2018).

Birthweight data was collected by maternal recall which has been found to be accurate in prior UK studies across social class and independent of the age of the child (O'Sullivan, Pearce & Parker, 2000; Walton et al., 2000).

Validity describes the extent to which a concept is accurately measured (Heale & Twycross, 2015). The questionnaire sought to elicit key data on infant feeding practices. This information was simple, and categorical in nature, asking mothers to simply recall how they fed their baby. Therefore, a validated tool (as would be required to understand more complex patterns of behaviour or thinking) was not considered necessary. Despite this, when designing the questionnaire, it was important to consider if the validity of answers might be affected by inaccurate recall, as some behaviours which were asked about about occurred in the past (birth feeding type for example). Indeed, parental reporting of milk feeding data can be problematic if too much time has elapsed between the behaviour and the time of asking. For example, the Nurses Mothers' Cohort Study which asked for recall of feeding data up to 40 years later (Michels et al., 2007). In a less extreme example, Townsend and Pitchford (2012) asked parents to recall complementary feeding method up to four years later. While mothers seem to remember milk feeding information well if it is collected within around 3 years, retrospective recall around complementary feeding is considered to be less accurate (Li et al., 2005). Therefore, this study aimed to ask about infant feeding practices during the complementary feeding period while mothers are still actively feeding their infants, and when recall of earlier behaviour is still quite fresh (within 12 months).

24-hour dietary recall was used to explore frequency of exposure to food groups and infant growth. Participants were asked to list all food and drink their infant consumed in the previous 24-hour period. The strength of this method is that it provides a quick snapshot of participants' diet, it requires a low respondent burden and is suitable for large sample sizes, which were hoped for in this study (Wrieden et al., 2003). It was also deemed the most appropriate method as the questionnaire was designed to be brief (maximum 10-15 minutes) and may be completed in a busy setting such as a baby groups. 24-hour recall has long been considered a valid tool for measuring diet content (Karvetti & Knuts, 1985, Biro et al., 2002; Wrieden et al., 2003) and has been used in large scale studies exploring infant diet such as the FITS (Butte et al., 2010) and a recent study by Rowan et al., (2019).

It is important to note that there are some limitations of the 24 hour-recall method. First, that the respondent is only asked to estimate portion size (Wrieden et al., 2003), and this is further limited by the difficulties inherent in estimating infant food intake which may be spat out or dropped (Schramm, 2014). The 24-hour recall is therefore not considered to be an appropriate tool for estimating energy intake due to high levels of inaccuracy found in some studies (Fisher et al., 2008). This method also only provides a 'snapshot' of the previous day's intake and may not be representative of a typical day (Wrieden et al., 2003), which may vary dependent on the infant's temperament, daily activities, the weather, the caregiver (if in nursery or in the care of others for the day), and physical conditions such as teething. It also relies on the memory of the parent and may therefore be subject to recall error. Finally, there is potential for bias in recording what may be perceived to be 'good' or 'bad' foods (Wrieden et al., 2003; Hebert, Clemow, Pbert, Ockene & Ockene, 1995).

However, accurately measuring energy or nutrient intake of infants was not the primary aim of the SHIFT study, as the focus was mainly on anthropometric measurements, and was also not feasible within the study design. In order to obtain a large sample size, and to recruiting within busy baby group settings, a 24-hour recall was considered to be valid, convenient and feasible, incurring a lower burden on participants' time.

Consideration was also given to the potential for social-desirability bias in the data. It is well known across health and social research for people to present themselves in the best light possible, especially around sensitive topics (Fisher, 1993; Krumpal, 2013). Infant feeding can be a highly emotive topic, and parents may be affected by perceptions of what it means to be a 'good mother' (Murphy, 2000; Locke, 2015). Behaviours which 'go against' the current guidelines, such as early complementary feeding, may not have been reported accurately in favour of giving the perceived desired response, especially given that the researcher is a health professional (see section 3.7. for reflexive considerations).

A conscious decision was made not to allow participants to self-select whether they were baby-led weaning on the questionnaire. This was because the degree to which certain elements of the method were adopted is likely to have varied, and because definitions of BLW also vary across prior research (Brown et al., 2017). Studies have also found that mothers who self-select on a questionnaire that they follow BLW, actually were not when their feeding behaviours were explored further (Cameron et al., 2013).

3.6. Ethics

Ethical considerations were made in line with the principles outlined in the Declaration of Helsinki (World Medical Association, 2013). All parents were informed as to the purpose of the study and signed a consent form (See Appendix 3 – participant information pack and consent form). All parents were informed of their right to withdraw from the study at any time. Ethical approval was granted from the Swansea University Psychology Department Research Ethics Committee, for both the initial study, and any subsequent changes made to the questionnaire. No serious issues of concern arose in the duration of the study

The sensitive nature of infant feeding and growth was taken into consideration. Parents are often concerned about their baby's weight gain, and infant feeding is a topic on which parents routinely seek advice. It transpired during the process of recruitment that it was more difficult to recruit parents who were formula feeding, or who had introduced complementary feeding earlier, which inevitably affected the distribution of infant feeding behaviour in the sample. While this is commonplace in infant feeding research, I was led to consider that the reluctance to take part in the research for this group of mothers this may have been due to previous relationships with health professional, and myself being one. Qualitative studies have found that some women have had poor experiences with health professionals who they perceive to be too pushy and 'pro-breastfeeding' and in turn, less helpful with bottle-feeding matters (Hoddinott & Pill, 2001). This issue is discussed further below in my reflexive considerations.

The nature of this study involved weights and measurements that are extra to the routine health checks and in doing so there was a small risk that this could heighten parents' anxieties, especially if a problem was identified. Every effort was made to ensure that the research was undertaken sensitively. The researcher is a qualified health visitor and as such is used to dealing with these issues as they arise and reassuring parents. However, it was made clear that the purpose of the research visit was not to provide health visiting advice or services. Parents were signposted to their own health visitor or GP where appropriate.

Special attention was given in the ethics application given the requirement for contact with children and babies (See Appendix 4 – Ethical application). The researcher holds professional registration as a nurse, and a health visitor and has full clearance from the Disclosure and Barring Service (DBS) to work with children.

Reflexive considerations

I, as the researcher, was aware that my position as a nurse and health visitor may have influenced participants' agreement to take part, as well as their responses (Berger, 2015;

Pezella, Pettigrew & Miller-Day, 2012). Health professionals in general, and midwives and health visitors in particular, hold positions that may place them in a power dynamic with parents. Wilson (2002) has explored this with particular reference to the role that family health nurses (the New Zealand equivalent of a health visitor) hold in child health surveillance. Honesty around infant feeding was a theme in Wilson's qualitative study, where mothers were sometimes seen to conceal actions such as early complementary feeding from the nurse, revealing imbalances in the mother-nurse relationship, because as Wilson states, if the relationship had been equal, the mother should have been able to be frank with the nurse. Similarly, women in other qualitative studies have reported that that they have lied to health professionals in order to cover up the use of formula further evidencing the existence of a communication and trust imbalance between mothers and health professionals (Lee, 2007). I was therefore aware during data collection, that parents may have attempted to answer questions in a way that they felt would be accepted by a health professional. I also considered that some mothers might have had bad experiences with health professionals in the past (Hoddinott & Pill, 2001), leading them to be wary of involvement in the study. I emphasised during the data collection that I was a PhD student collecting data and not acting in the capacity of a health professional.

I also had to consider that I am not a mother myself, and have not fed children so have no experiential understanding of parenting or feeding behaviours. However, I feel that this might have been an advantage because it meant that I was less likely to bring personal biases or preferences into the design of the study or interpretation of the results (Berger, 2015). I also felt another advantage which is likely to have been important to mothers, was that my previous experience in infant growth measurement meant that I was competent to undertake the measurements of their baby quickly and sensitively.

3.7. Data Analysis

3.7.1. Anthropometric Measures

Primary outcomes of interest were z-scores. Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight gain velocity (WAZV) were the primary outcome measures. These measures were calculated using the WHO software *Anthro*.

Z-scores are a standardized index commonly used in research and clinical situations to assess and monitor growth of infants and children (de Onis & Blossner, 2000, Wang & Chen, 2012). A benefit of z-scores is that male and female infants of different ages can be analysed together as sex and age are taken into account during the calculation. A z-score represents the distance and direction of a measurement away from the population mean of a standard growth reference population (in this study, the *Anthro* package was used which makes calculations and produces z-score outputs based on the WHO child growth reference standards (WHO, 2006)).

For example, a weight-for-age z-score (WAZ) of 0 represents a measurement that is exactly the same as the reference population mean. A +1 WAZ score represents a measurement that is 1 standard deviation above the reference population mean and a WAZ of -1 represents a measurement that is 1 standard deviation below the reference population mean. Z-scores can also be easily translated into percentiles (see Figure 3). Wang and Chen (2012) explain this well:

'For normal distribution, the z-score of 0 divides the total area into two equal halves. Thus, the z-score of 1 corresponds to the 84^{th} percentile (=0.5 +0.34) i.e., 84% of the population are measured lower than a z-score of 1...' (p.33).

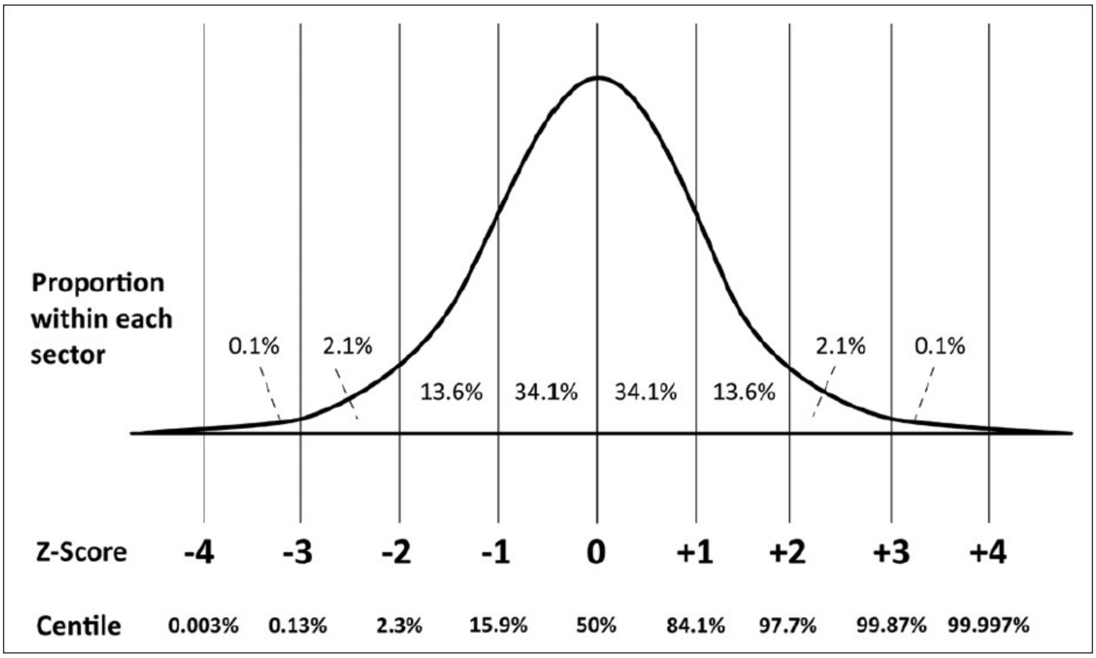

Figure 3: Z-scores as they relate to centiles

(Image taken from "Calculate probability of a range using z-score" by Wyman W, 2015, Access-Excel.tips, Retrieved September 20, 2018 from http://access-excel.tips/probability-range-z-score. Copyright, 2018 Access-Excel.tips)

BMI-for-age z-score (BMIZ) was chosen in preference to weight-for-length z-score as it has been shown to be more accurate than weight-for-length in identifying risk of overweight in children, and has been used in other large cohort studies of infant growth (Roy et al., 2016; Azad et al., 2018)

Defining overweight

BMI-for-age z-score was also categorized to define over and underweight for analysis. WHO defines cut-offs for BMI z-scores in children under 2 years. These are 'overweight' (Z-score > 2, equivalent to being above the 97.7th percentile), 'possible risk of overweight' (Z-score 1 to 2, equivalent to the 84.1st to 97.7th percentiles) and 'wasted' (Z-score < -2, equivalent to being below the 2.3rd percentile) (WHO, 2008; de Onis & Lobstein, 2010). Roy et al. (2016) found that BMI z-score in infancy had a positive predictive value for overweight in childhood using cut-offs of either the 85th percentile, or the 97.7th percentile.

Defining underweight

Underweight was categorised as having a WAZ of <-2, the equivalent to around the 5th percentile which is the cut-off defined by the WHO (2010) and which has been used in other large scale research in developed countries (Goyal, Fiks & Lorch, 2012).

Defining rapid weight gain

Weight gain velocity (WAZV) was calculated as the change in weight-for-age z-score (WAZ) from birth to age of measurement. WAZV was then dichotomised to define rapid weight gain as a velocity of greater than 0.67, as this is the definition used in other large cohort studies of infant growth (Ong et al., 2000; Monterio & Victora, 2005; Azad et al., 2018). This has been rationalised that a z-score increase of >0.67 represents an increase of one percentile band based on the WHO growth reference charts used by health professionals in the UK (which have percentile bands of 2, 9, 25, 50, 75, 91 and 98).

3.7.2. Analysis of the 24-hour diet diaries

The 24-hour diet diaries were analysed by hand by the researcher (i.e. not by a computerised programme), and the frequencies of each food type offered (exposures) to infants was coded numerically (0 = not offered, 1 = offered once, 2= offered twice and so on). Food groups examined were adapted from similar research (Wardle, Sanderson, Gibson & Rapoport, 2001; Brown & Lee, 2011a; Cameron et al., 2015; Erickson, 2015; Rowan et al., 2019; Komninou et al., 2019) focussing on food types which are thought to contribute to rapid infant growth; savoury snacks, sweet foods, protein, 'commercial baby foods' and 'commercial infant cereals' (see section 2.10.6.). Table 2 provides more detailed descriptors of the food groups.

Table 2: Food types and descriptors

Food Type	Examples

Savoury snacks	Crisps, breadsticks, crackers, rice cakes
Sweet foods	Biscuits, chocolates and puddings
Protein	Meat, fish, eggs, tofu, pulses
Commercial infant foods	Any jar, pouch or packet of food which is marketed specifically for babies' consumption (including infant crisps and processed dried fruit snacks)
Commercial infant cereal	Baby porridge and baby rice that typically contain cow's milk powder (not including standard porridge oats).

3.7.3. Analysis of free text answers

Directed content analysis was used to analyse the mothers' responses to the free-text open-ended question which asked to give a reason for the choice of complementary feeding method. The directed content analysis approach uses previous literature and theories to identify key concepts and apply them to qualitative data, categorizing responses accordingly, with the aim to support or add to existing literature on a theory (Hsieh & Shannon, 2005).

This method of analysing the free-text questionnaire data was chosen for a number of reasons. First, the free- text answers were often very brief (one or two sentences, or in some cases only one or two words) resulting in insufficient text to provide the depth and conceptual richness required for traditional inductive qualitative approaches such as thematic analysis (O'Cathain & Thomas, 2004). Second, O'Cathain and Thomas (2004) refer to open-ended questions on questionnaires as falling 'between two stools' (p.2) being neither quantitative nor qualitative and have been described by others as 'quasi-qualitative' (Murphy, Dingwall, Greatbatch, Parker & Watson, 1998, p.233). Therefore, by using directed content analysis it was thought that 'quasi-qualitative' answers could be transformed into quantitative data which could then be analysed alongside and against other variables in the data. Finally, this study had a clear aim, which was to compare baby-led and parent-led infant feeding approaches. Therefore, it was useful to categorise responses according to this theory. This is known as 'a-priori coding', as the categories were decided upon prior to analysis (Popping, 2015). According to Popping (2015) it is essential that the coder is able to apply the concepts to the data correctly. Coding in the study was therefore undertaken by hand by the researcher, using the knowledge of the background literature, theory and the hypothesis to categorize the data into themes accordingly.

Driscoll, Appiah-Yeboah, Salib & Rupert (2007) discuss some of the limitations of turning qualitative data into quantitative data, a process they term 'quantitizing' (p.25). The most obvious criticism is that quantitizing loses the depth and meaning of the original qualitative answer. However, in the case of short questionnaire answers, such as in the present study, there was little depth available for traditional qualitative analysis, so this was not considered to be a drawback.

3.7.4. Statistical tests

Data were analysed using IBM Statistical Package for Social Sciences (SPSS. Version 25).

Each potential influence on infant feeding was explored separately, one per chapter, to consider whether it affected growth (weight, length and BMI) in its own right.

For each chapter, analyses were undertaken in three ways:

1. Cross-sectional analyses were performed on the whole sample of infants aged 6-12 months.
2. The sample was split into age-subgroups at the time of measurement, 6-8 months and 9-12 months representing early and late complementary feeding. This was done to examine any differences occurring which might be affected by the age of the infant, or by length of time exposed to the feeding behaviour.
3. Subgroups were also created, where relevant, to explore if any effects of complementary feeding appear to differ among infants who were milk fed differently (e.g. by only looking at formula fed infants, or only looking at breastfed infants)
4. Longitudinal analyses were performed on the sub-sample of infants who had two measures (one at around 6 months and one at around 12 months).

Due to the complexity and interrelatedness of the factors affecting growth in infancy it was thought to be important to explore the influence of each factor in depth, in order to understand how the effects of each factor (e.g. milk feeding, timing of introduction to complementary foods) may play out individually and whether there were any notable interactions with any other key variables (i.e. do they affect different infants in different ways). Theoretical justifications for undertaking these analyses are presented in the chapters, and covariates are taken into account where possible.

However, these analyses are to be considered with caution firstly because they are looking at factors in isolation and may miss the 'bigger picture'. Second, when multiple analyses are performed on the same sample there is a risk of finding significant effects which have occurred by chance. This may happen because every data set will have some patterns, even if they are not meaningful (Davey-Smith & Ebrahim, 2002). Recently, more attention in the scientific community has been paid to the risks of practices known as 'p-hacking', 'data-dredging' and 'HARKing' (hypothesising after results are known) (Kerr, 1998; Davey-Smith & Ebrahim, 2002; Head, Holman, Lanfear, Khan & Jennions, 2015). This means that researchers may be indiscriminately applying a multitude of tests to the same data-set, without theoretical underpinnings, in an attempt to find a statistically significant result. This practice may not always be intentional or it is likely to be a consequence of pressure to publish and bias in publishing (in that nonsignificant findings are less 'interesting' and are disregarded) (Davey-Smith & Ebrahim, 2002). This is clearly problematic as it means that published findings may be representing an effect that does not really exist. However, in this study all analyses were based on theoretically informed hypotheses, defined before data analysis began, that each factor could affect infant growth.

To mitigate this further, once each factor had been explored individually, multiple regression analyses were conducted, exploring the impact of all factors together. Regression analyses were conducted for the sample as a whole, the sample split by infant age (e.g. the earlier and latter parts of the complementary feeding period) and in relation to growth over time for the longitudinal sample. The aim of the analyses presented in of each preceding chapter of the thesis, was to look at each factor separately in order to inform thinking, however the main discussion (Chapter 12) will focus on the findings of the regression analysis.

Considering the data analysis approach as a whole, where the data met parametric assumptions, t-tests and Analysis of Variance (ANOVA) and Multivariate Analysis of Co-Variance (MANCOVA) were used to explore between-subjects group differences. When parametric assumptions were not met, non-parametric equivalents were used (Mann-Whitney U or Kruskall-Wallis tests). Longitudinal data were analysed using two-way repeated measures ANOVA to explore interactions between within-subject (time points) differences and between-subjects (group) differences. In ANOVA/MANCOVA tests, post- hoc Bonferroni tests were used to compare the differences between groups of 3 or more. Pearson's or Spearman's correlations were used to explore associations between continuous and ordinal variables. Chi Square or Exact (Fisher's or with Monte Carlo simulation) tests were used to explore associations between categorical variables. Finally, to compare the influence of all the pertinent variables together, a multiple linear regression was performed.

Specific details of tests used will be described alongside the presentation of results within each results chapter. Covariates entered into the test models will be specified in the presentation of results.

3.7.5. Power calculations of required sample size

Two separate power calculations were calculated (using g-power) to examine sample size. The first, for the whole sample was based on a small effect size, powered at 95% required a sample size of at least 210. The second, for the repeated measures group required a sample size of 106 to detect a small effect size at 95% confidence.

CHAPTER 4: Maternal and infant demographic characteristics and associations with infancy growth

4.1. Rationale

This chapter first presents an overview of the participant characteristics which pertain to all the subsequent results chapters. It will go on to consider the characteristic variables which may influence growth and later obesity risk, in particular, maternal age, maternal socio-economic status (SES) and infant birthweight. Most studies in infant growth consider these factors only as covariates. However, exploration of these factors in a stand-alone chapter is important because:

1. Research shows that maternal characteristics are associated with infant growth. (Pilgrim et al., 2010; Wijlaars et al., 2011; Gibbs & Forste, 2014).

2. Infant birthweight is likely to be a significant influencing factor both for growth during infancy, and on maternal perceptions of infant size which affect feeding choices (Hediger et al., 1998; Ong & Dunger, 2004)

3. Often critics of the influence of infant feeding factors will state that maternal background (and its impact on health) leads to different feeding decisions rather than feeding decisions directly affecting outcomes. Therefore, background characteristics need to be considered in their own right, rather than 'just' as covariates.

It was therefore considered to be of interest to explore any associations related to these factors in the study sample which could explain growth differences, as well as to determine which covariates to use in later analyses.

4.2. Background

As discussed in the literature review (section 2.6.2.), maternal age may affect infant growth. Both younger mothers (especially adolescent mothers) and older mothers (>35 years) are more likely to have a low birthweight infant (Restrepo-Mendez et al., 2015). This may influence later growth because, infants born at a low-birth weight may be more likely to experience 'catch up growth' (Hediger et al., 1998; Singhal, 2017) which is known to increase risk of overweight in childhood (Ong et al., 2000). The age of the mother may also affect whether or not she breastfeeds; older mothers more likely to breastfeed than younger mothers (Oakley et al., 2013; McAndrew et al., 2012). Maternal age is therefore often controlled for in studies of infant growth (Dubois & Girard, 2006; Azad et al., 2018).

Differences seen infant growth according to maternal age may be due to the effect of socio-economic status as younger mothers are more likely to come from more deprived backgrounds (Pilgrim et al., 2010). Socio-economic status is also well known to affect birthweight, infant growth and later child weight status (see section 2.6.3). Lower maternal socio-economic status has been associated with increased odds of a low birthweight baby likely due to differences in gestational length, smoking during pregnancy, access to ante-natal care, maternal nutrition and maternal stress (Spencer et al., 1999; Joseph et al., 2007; Chevalier & O'Sullivan, 2007; Cantarutti et al., 2017). Lower SES has also been associated with rapid early infancy growth (Wijlaars et al., 2011). However, this could be attributed to the higher incidence of low birth weight (and resultant catch up growth) seen in lower SES groups, or may occur because of different infant feeding methods; mothers from lower socio-economic groups are less likely to breastfeed, for example (Oakley, et al., 2013; McAndrew et al., 2012).

It is also important to establish how infant birth weight might be associated with later growth. Several studies identify birthweight is a key predictor of infant growth (Rogers, 2003; Monteiro & Victora, 2005; Baird et al., 2005; Stettler, 2007; Yu et al., 2011; Ross & Desai, 2014; Wang et al., 2016; Chiavaroli et al., 2016). For example, smaller born infants have been shown to remain smaller and larger infants remain larger generally up to age 3-4 years, despite experiencing either catch up, or catch down growth respectively (Hediger et al., 1998). As well as influencing growth during the infancy period, birthweight has been associated with later risk of overweight or obesity. Studies have found that macrosomic babies (>4000g) or babies who are born born large for gestational age (LGA) (>90th percentile for weight) are more likely to be overweight or obese later in childhood and in adulthood (Rogers, 2003; Monteiro & Victora, 2005; Baird et al., 2005; Weng et al., 2012; Chiavaroli et al., 2016). However, evidence suggests that while higher birthweight is linked to higher BMI in childhood, this can be attributed to greater lean mass rather than fat mass (Ong, 2006). Other studies have found no association between high birthweight and later overweight (Stettler et al., 2002; Rogers et al., 2006), instead finding rapid growth in infancy to be more important (Stettler et al., 2002).

Birthweight may also influence later feeding choices, several studies have found that mothers of larger infants perceive that they need more food and move onto formula or solids sooner (Fewtrell et al., 2003; Kronborg, Foverskov & Vaeth, 2014; Anderson et al., 2001; Arden, 2010; Daniels et al., 2015b; Brown & Rowan, 2015). Conversely mothers of smaller infants also be tempted to encourage intake so that infants 'catch-up' on their growth (Kramer, Moodie, Dahhou & Platt, 2011).

It is difficult to tease apart the interrelated influences of maternal age, SES and other antenatal and pregnancy factors on infant birthweight. Nonetheless maternal characteristics, and infant birthweight appear to be key variables influencing infant growth in terms of weight gain in infancy relative to birthweight (i.e. that larger and smaller babies might continue along the same trajectories) as in Hediger et al's (1998) study, and in terms of risk of rapid growth, particularly amongst smaller born infants (Singhal, 2017), and because of different feeding methods among mothers of different backgrounds.

This chapter will first describe the general participant characteristics before answering the following key questions:

1) Is there a relationship between maternal characteristics and infant growth in the study sample?
2) Is there a relationship between infant birthweight and infant growth in the study sample?

3) Is there a relationship between maternal characteristics or infant birthweight and infant growth from birth to six months and from six to twelve months – longitudinal analysis?

4.3. Participants

The study sample was mothers of healthy full-term infants aged 6-12 months. No fathers took part in the study. Please refer to Chapter 3 for details on sample recruitment and inclusion/exclusion criteria.

4.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Maternal and infant characteristics

Mothers were asked to give their age, and their level of education. Infant sex and infant birthweight (as recalled by the mother) were also collected.

4.5. Data analysis

Data were analysed as described in Chapter 3 (section 3.7.4). Where the data met parametric assumptions Analysis of Co-Variance (ANCOVA) were used to explore between-subjects group differences. Pearson's correlations were used to explore relationships between continuous variables such as birthweight and growth outcome z-scores. Spearman's correlations were used to explore relationships between ordinal variables such as education level and growth outcome z-scores. Tests used will be described alongside the presentation of results

4.6. Results

Maternal characteristics

In the main sample there were 267 mothers (and two sets of twins giving 269 infants). Mean age of mothers was 31.7 (SD= 4.63; range: 21 to 51). One hundred and sixty were first-time mothers. Two mothers did not provide their education level so 265 mothers' data were analysed. In the longitudinal cohort there were 105 mother/infant pairs.

Descriptive statistics for maternal education level are shown below in Table 3.

Table 3: Descriptive statistics. Maternal education.

	Main sample		**Longitudinal cohort**	
Education level	*n*	%	*n*	%
Up to GCSE	20	7.5	8	7.6
A level	25	9.4	11	10.5
Diploma	33	12.4	10	9.5
Degree	113	42.3	37	35.2
Post-grad	74	27.7	37	35.2
Total	265	99.3	103	98.1
Missing	2	0.7	2	1.9

Mother & Baby Community Group Demographics

Most recruitment took place from baby groups across South Wales (and one in Bristol). Baby groups were approached from a wide range of geographical locations in order to encourage participation from parents from a broad spectrum of backgrounds. Deliberate attempts were therefore made to access groups located in areas which varied in 'level of deprivation' according to the Welsh Index of Multiple Deprivation (WIMD), which takes into account relative deprivation in small areas based on multiple indices of deprivation. Codes were assigned to identify most to least deprived areas. The locations of groups were in a variety of both urban and rural settings (see Tables 4 and 5). One group was in England and therefore a WIMD index was not available.

Table 4: WIMD ranking and codes given

WIMD Overall Ranking by Lower Super Output Area	**Code**
Among the 10% Most deprived in Wales	1 (most deprived)
Among the 10-20% Most deprived in Wales	2
Among the 20-30% Most deprived in Wales	3
Among the 30-50% Most deprived in Wales	4
Among the 50% Most deprived in Wales	5 (least deprived)

Table 5: Baby group locations. WIMD ranking.

Postcode	Predominantly Urban/Rural	Coded for WIMD
SA1 6BT	Urban	1
CF37 5HQ	Urban	1
CF33 4LW	Urban	1
SA11 1SS	Urban	1
SA6 6JR	Urban	2
CF34 0TW	Rural	2
CF31 4JR	Urban	3
CF31 1SU	Urban	3
SA5 5AR	Urban	4
SA18 2RA	Urban	4
SA14 8AG	Urban	4
SA1 3ST	Urban	4
SA1 3SN	Urban	4
SA38 9BX	Rural	4
CF83 1JL	Urban	4
SA2 8PP	Urban	5
CF14 1PT	Urban	5
SA34 0QB	Rural	5
CF729EH	Rural	5
CF35 5BP	Rural	5
SA2 0AY	Urban	5
CF62 4NA	Rural	5
BS13 8JR	Urban	N/A

Infant characteristics

There were 269 infants; 134 were male and 135 were female. Mean age was 42.5 weeks (SD=9.62; range: 26 to 59). Broken down into sub-groups by age, 125 were aged 6 – 8 months (46.5%), and 144 were aged 9 – 12 months (53.5%) (see Table 6).

Table 6: Infant demographics. Sex, birth weight and mean age, by age sub-group.

	N **(*n* Male/*n* Female)**	**Mean birth weight in kg (SD)**	**Mean age in weeks (SD)**
Whole sample	269 (134/135)	3.46 (0.49)	42.5 (9.62)
6 to 8 months	125 (65/60)	3.49 (0.52)	33.2 (4.93)
9 to 12 months	144 (69/75)	3.43 (0.46)	50.0 (4.12)

Longitudinal data analysis was also separately undertaken for infants for a sub-set of infants who had one measurement at around 6 months and another at around 12 months (*N*=105). The mean number of weeks between time point one and time point two was 26.6 weeks (SD: 7.09) (Table 7).

Table 7: Infant demographics. Longitudinal cohort. Sex, birth weight and mean age.

	N (*n* Male/ *n* Female)	**Mean birth weight in kg (SD)**	**Mean age in weeks (SD)**
Longitudinal cohort	105 (46/59)	3.47 (0.46)	24.88 (8.12) Time point one
			51.73 (7.47) Time point two

QUESTION 1: Is there a relationship between maternal characteristics and infant growth in the main sample?

Maternal characteristics were explored to identify any relationship to infant growth variables. Consideration of how maternal characteristics might interact with infant feeding variables will be addressed in the relevant chapters.

Maternal age

Pearson's correlations found no significant associations between maternal age and either birthweight [$r(265) = -0.10$, p=0.12], WAZ [$r(265) = -0.08$, p=0.19], LAZ [$r(265) = -0.11$ p=0.07], BMIZ [$r(265) = -0.04$, p=0.55], or WAZV [$r(265) = -0.03$, p=0.58].

Maternal education

An ANOVA found that mean birthweight did not significantly differ according to maternal education status [F (4, 260) = 0.15, p=0.96]. A Spearman's correlation revealed that birthweight was inversely associated with education level but that this was not statistically significant [r_s (265) = -0.003, p=0.96].

Looking at infant growth outcomes a series of ANOVAs found no significant differences in WAZ [F (4, 260) = 1.34, p=0.25], LAZ [F (4, 260) = 0.19, p=0.96], BMIZ [F (4, 260) = 2.07, p=0.08], or WAZV [F (4, 260) = 1.93, p=0.11] were observed according to maternal education status. Spearman's correlations however found significant negative associations between both WAZ [r_s (265) = -0.12, p=0.047] and BMIZ [r_s (265) = -0.17, p=0.01] and education level, with mothers of larger infants having a lower level of education. A significant negative association was also found between WAZV, indicating that infants of mothers with a lower level of education grew more rapidly [r_s (265) = -0.128, p=0.04]. No significant correlation was seen between maternal education and LAZ [r_s (265) = -0.015, p=0.80].

QUESTION 2: Is there a relationship between infant birthweight and growth in the main sample?

Significant positive Spearman's correlations were seen between birthweight both weight-for-age z-score (WAZ) [r_s (269)= 0.37, p<0.000] and length-for-age z-score (LAZ) [r_s (269)= 0.32, p<0.000], and BMI-for-age z-score (BMIZ) [r_s (269)= 0.16, p=0.009] with a greater birth weight being associated with greater WAZ, LAZ and BMIZ. WAZV was also associated with birthweight, but a negative correlation was found [r_s (269)= -0.53, p<0.000] meaning that infants with lower birthweights had a greater weight gain velocity.

QUESTION 3: Is there a relationship between maternal characteristics or infant birthweight and infant growth from birth to six months and from six to twelve months – longitudinal analysis?

These analyses explored the weight velocity of the longitudinal cohort of infants who had measurements at both 6 and 12 months (N=105). Weight gain velocity (WAZV) was explored from birth to six months, and then again from 6-12 months. This was in order to see whether the influence of maternal characteristics or birthweight on growth is more or less evident in early or late infancy.

Birth to 6 months

An ANOVA found that infant WAZV from birth to 6 months differed according to education status [F (4, 98) = 2.59, p=0.04]. However, following post-hoc Bonferroni tests, the significance disappeared. A Spearman's correlation revealed that WAVZ was inversely associated with education level but that this was not statistically significant [r_s (103) = -0.17, p=0.08]. Maternal age was also not significantly associated with WAZV from birth to 6 months [r_s (104) = -0.06, p=0.49].

A Spearman's correlation found a significant negative relationship between birthweight and WAZV from birth to 6-months [r_s (105)= -0.53, p<0.000] meaning that infants with lower birthweights had a greater weight gain velocity.

6 to 12 months

No significant differences were seen for WAZV from 6-12 months according to maternal education status or maternal age.

By 6-12 months the association between birthweight on weight velocity had also disappeared [r_s (105)= -0.54, p=0.58]. It therefore appears that birthweight was associated with rapid growth, but only in earlier infancy in this sample.

4.7. Discussion

The results presented in this chapter show that in the SHIFT study sample, mothers tended to be older and have a higher level of education and occupational status than the general UK population, however this is often the case in self-selected observational studies (Nilsen et al., 2009). For example, in the most recent Infant Feeding Survey, despite being a large population based survey, it still garnered a lower response rate amongst younger mothers and those from areas of higher deprivation (McAndrew et al., 2012).

Associations with growth outcomes were explored, due to suggestions from prior literature that maternal characteristics (specifically age and socio-economic status) and infant birthweight may influence infant growth, and later overweight/obesity risk. In the SHIFT sample, no associations were observed for maternal age, however, lower maternal education status was associated with increased BMI. Education is considered to be an acceptable proxy for SES in health research due to its ease of measurement, stability, and predictive value for income and neighbourhood residence (Shavers, 2007).

There are a number of factors which may explain the finding of greater BMI among infants with mothers with lower education (lower SES), for example mothers from lower SES backgrounds have a greater likelihood of being overweight, to gain weight during pregnancy and to formula feed (Baughcum, Chamberlain, Deeks, Powers & Whitaker, 2000; Oakley et al., 2013; McAndrew et al., 2012). Data on maternal pre-pregnancy and gestational weight gain was not collected in the SHIFT study so it was not possible to explore this, however differing infant feeding behaviours are likely to explain a proportion of the variation. A large longitudinal Swedish cohort study of over 11,000 children explored this and found that children born into lower SES families were born lighter on average but gained weight more rapidly in the first 9 months of life and were also heavier at age 3 years. They also reported that the risk of rapid growth was attenuated when adjustments were made for early infant feeding practices, indicating that differences in SES are likely to be explained by different feeding methods. However, this was not the sole explanation and in this study maternal pre-natal smoking was also considered to be an important contributory factor to the differences in growth observed between SES groups (Layte, Bennett, McCrory & Kearney, 2014).

In addition to differing milk feeding methods, mothers from lower SES backgrounds are more likely to introduce complementary food earlier (Tarrant et al., 2010; McAndrew et al., 2012) and are less likely to adopt baby-led weaning (Brown & Lee, 2010), which may further influence growth outcomes. Explanations for formula feeding and early complementary feeding among women of lower SES in the UK relate to historical normative infant feeding behaviours in low income communities, lack of experiential knowledge in the woman's family or peer group, poor relationships with health care professionals, low maternal self-efficacy and stigma (for example around breastfeeding in public) (Trickey et al., 2019).

Findings in this chapter also revealed that greater birthweight was associated with greater weight, length and BMI, reflecting prior studies which have found this (Hediger et al., 1998). Furthermore, weight gain velocity was significantly greater among smaller infants, and this finding is congruent with the known phenomenon of catch up growth (Jain & Singhal, 2012; Ong et al., 2000). While infants defined as having a low birthweight (<2500g) were excluded from the present study, it is feasible that infants on the smaller end of the normal range, or who are small for gestational age (<10^{th} percentile for weight, or WAZ <-2) who were included may also be at risk of catch-up growth. Catch-up growth is very common, with one Swedish birth cohort study reporting that it occurred in more than 86% of SGA infants by the time they reached 1 year (Karlberg & Albertsson-Wikland, 1995). While catch-up growth is generally considered to be advantageous for short-term infant health in terms of reductions in infant morbidity and mortality gained from putting on weight in infancy (Victora, Barros, Horta & Martorell, 2001; Martin, Connelly, Bland & Reilly, 2017), in light of the evidence surrounding the adverse effects associated rapid weight gain (see section 2.5.2.) researchers have expressed concern about the long term effects of catch-up growth on later risk of obesity (Singhal, 2017; Martin et al., 2017).

It has been suggested that part of the reason small infants catch up on growth may be due to an evolutionary adaptive biological response to ensure survival, as it is seen amongst animals as well as humans (Metcalfe & Monaghan, 2001). However, it may also be important to consider the implications of birthweight in the context of the social (as well as the biological) reasons why catch up growth occurs, in particular, in relation to maternal concerns surrounding low infant weight and subsequent feeding decisions and behaviours which may arise from that. Encouraging catching-up weight gain may be seen as desirable for mothers who are concerned about their baby's small size; in a systematic review of nineteen qualitative studies from the UK, US, Canada and Finland, mothers often associated infant size with health, expressed feeling responsible for infant weight gain (or lack thereof), and placed high value on growth monitoring (Lucas et al., 2007). Participants in another qualitative study regarded concern about infant underweight being more worrying than overweight, with mothers expressing high levels of anxiety about infant growth faltering especially in the early weeks (Bentley et al., 2017).

In the analysis of the longitudinal cohort of infants in the SHIFT sample, catch-up growth was only evident at 0-6 months, but disappeared by 6-12 months. This suggests that after around 6 months other factors may be more important. However, the effects of being born small and catching up on growth early on in life may have influenced maternal feeding decisions which have longer term impact. For example, Brown & Lee (2013) found that low birthweight associated with maternal reported concerns for infant weight and pressurising feeding, and an earlier study by Kramer et al. (2011) found that small infant size was significantly associated with early discontinuation of breastfeeding and supplementation. Feeding with formula feeding increases the likelihood of rapid weight gain (Appleton et al., 2018a), perhaps compounding an evolutionary propensity to gain weight in smaller infants. Furthermore, Kramer and colleagues (2011) consider that infants who grow quicker may be perceived to be less 'settled' (i.e. demonstrate more signs of hunger, crying or fussiness) than infants whose growth trajectories are slower, perhaps also prompting a choice to transition onto formula feeding. This may be relevant to smaller infants who are catching up their weight. A small evidence base suggests that

SGA infants have been demonstrated have higher states of arousal, feeding difficulties, and diminished responsiveness in feeding and other care interactions (Halpern & Garcia-Col, 2000). This effect of low child weight on maternal feeding interactions may continue into older childhood, as mothers of underweight children may be more likely to pressure intake (Webber et al., 2010; Gregory et al., 2010).

On the other end of the scale, large infant size may also be influential in infant feeding decisions. Bigger babies, while often seen as desirable (Baughcum et al., 1998; Redsell et al., 2010), may also be perceived as hungry and having excessive nutritional requirements (Anderson et al., 2001; Arden, 2010; Daniels et al., 2015b; Brown & Rowan, 2015) prompting cessation of breastfeeding and early complementary feeding. Studies have found significant associations between both higher birthweight (Fewtrell et al., 2003; Kronborg et al., 2014) and higher weight at 6 weeks with earlier introduction of complementary foods (Fewtrell et al., 2003).

This chapter has considered the potential influences of maternal age and SES and infant birthweight on infant growth, in particular how they may impact infant feeding decisions. While these characteristic factors all seem to play a role, they are often interrelated and mechanisms may be difficult to discern. A key modifiable factor emerging from the literature, which is linked to all three variables is that of differing infant feeding methods and that maternal concerns over infant size may be triggering decisions. The following chapters will therefore consider more closely the effects of infant feeding influences on infant growth.

Despite no significant findings relating maternal age to infant growth outcomes in the SHIFT study, it was determined that maternal age should be controlled throughout the analyses in the following chapters due to the precedence of prior literature (Restrepo-Mendez et al., 2015). In terms of SES, significant differences in BMI were observed here according to maternal education. Therefore, maternal education will be used as the indicator for SES covariance. Maternal education is considered to be a valid indicator of SES, and is often controlled for in studies of infant growth (Penny et al., 2016; Azad et al., 2018). Birthweight will also be controlled for throughout due to the significant findings presented above and prior literature.

CHAPTER 5: Exploring milk feeding and infancy growth during complementary feeding.

5.1. Rationale

This chapter will consider the role of milk feeding in infant growth once complementary foods have been introduced. It is important to establish the relationship between milk feeding and infant growth before examining the impact of complementary feeding method for three main reasons:

First, research shows that milk feeding is an important influencing factor for infant growth (Armstrong & Reilly, 2002; Huang & Wang, 2014; Oddy et, al, 2014; Horta et al., 2015).

Second, during the period of complementary feeding milk should still be a significant component of the infant diet (WHO, 2003) and therefore is still likely to be having an influence (Huh et al., 2011; Moss & Yeaton, 2014; Papoutsou et al., 2018).

Third, studies that have examined a baby-led method of introducing complementary foods have found that it is strongly associated with mothers who have or are still breastfeeding (Brown & Lee, 2011a; Cameron et al., 2013).

Although most studies use a measure of milk feeding as a covariate in any research on the impact of complementary feeding upon infant growth, the potential impact of milk feeding is so important that it deserves greater consideration on its own. This will help understand the impact of milk feeding upon overall growth and also help to establish what covariates or sub groups are needed in further analyses

5.2. Background

Milk feeding in infancy is known to influence growth and risk of obesity. As explained in more detail in the literature review, breastfeeding has been associated with lower infant weight by 12 months, more gradual weight gain trajectories and reduced risk of overweight in later childhood (Armstrong & Reilly, 2002; Huang & Wang, 2014; Oddy et, al, 2014; Horta et al., 2015). In particular, a longer duration of breastfeeding and prolonged exclusivity of breastfeeding is thought to provide greater benefits (Grummer-Strawn & Mei, 2004; Harder et al., 2005; Oddy et al., 2014; Yan et al., 2014; de Beer et al. 2015; WHO, 2016b).

Conversely formula feeding can have the opposite effect, encouraging more rapid weight gain in infancy through both physiological and behavioural pathways. For example, the higher protein content of formula (Luque et al., 2015), and the lack of presence of the appetite regulating bioactive compounds found in breastmilk (Alderete et al. 2015; Chan et al., 2017) may encourage growth.

However, mode of feeding may also be important due to the behavioural differences between bottle feeding and breastfeeding; studies have observed that bottle feeding (regardless of milk type) has been associated with higher BMI in infancy compared to direct breastfeeding (Li et al., 2012; Azad et al., 2018). Bottle fed babies may drink more due to the ease of drinking from a bottle compared with the breast (Daley & Hartmann, 1995; Moral et al., 2010; Huang et al., 2018) and the increased tendency for mothers to encourage infants to finish a bottle (Li et al., 2012).

Maternal controlling behaviours (such as delaying or scheduling feeds) may also have an impact on infant growth. Studies have shown that breastfeeding mothers have a feeding style that is lower in control and more responsive to babies' hunger and satiety cues (Brown et al., 2011a; Brown & Lee, 2013a). On the other hand, bottle fed babies, are more likely to be exposed to controlling feeding practices, such as scheduling feeds and encouragement to finish a bottle, and these practices have been linked to a reduced capacity for self-regulation of appetite (Li et al., 2010; DiSantis, Collins, Fisher & Davey, 2011b; Brown & Lee, 2012; Li et al., 2014; Reyes et al., 2014), though not all studies have found this (Hathcock et al., 2014).

Milk feeding during the first six months may therefore already be having an impact on growth from the start of complementary feeding, setting infants up on a particular weight gain trajectory or eating style (Mihrshahi et al., 2011; Li et al., 2010). Ongoing milk feeding method may also play a role through the content or mode of feeding (Azad et al., 2018). The IDEFICS study found that, ongoing breastfeeding up to 12 months, alongside complementary feeding was linked to a lower risk of overweight and obesity in childhood compared to those who had stopped breastfeeding before 12 months (Papoutsou et al., 2018). As milk feeding plays a substantial role in the diet even after complementary foods are introduced, it is likely that these mechanisms are still having an influence during the complementary feeding period.

For example, it is possible that bio-active properties of breastmilk may encourage appetite regulation even after complementary foods are introduced. It is also likely that the behavioural aspects developed during milk feeding affect complementary feeding behaviours e.g. if a mother is already trusting her breastfed infant to control their own intake of milk she may be less likely to adopt a controlling feeding approach for introducing complementary foods. Yet, conversely, if a mother is used to feeding set amounts of milk at a set time, her approach to giving complementary foods may continue to be more controlling. This pattern has been identified in a number of studies over time showing mothers who breastfeed go on to be less controlling during the period complementary foods are introduced and beyond (Fisher et al., 2000, Taveras et al., 2004; Blissett & Farrow, 2007; Brown & Lee, 2011b)

It has been suggested that the differences in growth attributed to milk feeding type may be explained by the type of mothers that breastfeed, for example, mothers who are older and who have a higher level of education are more likely to initiate breastfeeding and continue for longer (McAndrew et al., 2012). Links between maternal characteristics and infant growth were explored in chapter four, with significant associations being found; mothers with lower levels of education were likely to have babies who were heavier and who grew more rapidly. This may be accounted for by milk feeding type. Likewise, the relationship between SES and obesity is well established (Wijlaars et al., 2011; Gibbs & Forste, 2014). Furthermore, birthweight appears to an important factor influencing infancy growth and possibly infant feeding decisions (see Chapter 4).

The aim of this chapter is therefore to explore the impact of milk feeding type (breast, formula, combination) and duration of any or exclusive breastfeeding upon infant weight, length, BMI, and weight gain velocity in the study sample. Therefore, the relationships between maternal characteristics, birthweight and milk feeding are explored here.

This chapter will address the following key questions:

1) Is there a relationship between maternal age, education, or infant birthweight and milk feeding type?
2) Is there a relationship between milk feeding at birth or at the time of measurement and infant growth?
3) Is there a relationship between milk feeding and growth trajectories between birth to 6 months and 6-12 months? – Longitudinal data analysis.
4) Is there a relationship between duration of any (partial) or exclusive breastfeeding and infant growth?

5.3. Participants

For full details of participants please refer to chapter four.

5.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Milk feeding

Participants provided information on milk type at birth (two groups: breastmilk (including expressed) or formula) and milk type at the time of measurement (three groups: breastmilk (including expressed), combination of breastmilk and formula, or only formula). Duration of any breastfeeding/exclusive breastfeeding was calculated by categorizing the infant as yes/no for any and exclusive breastfeeding at birth, two weeks, six weeks, seventeen weeks and twenty-six weeks. Exclusive breastfeeding was defined as only breastmilk (including expressed), no formula, complementary foods or cow's milk.

5.5. Data analysis

Data were analysed as described in chapter three. Where the data met parametric assumptions, Multivariate Analysis of Co-Variance (MANCOVA) were used to explore between-subjects group differences. When parametric assumptions were not met, non-parametric equivalents were used (Mann-Whitney U or Kruskall-Wallis). Chi Square or Exact tests with Monte Carlo simulations were used to explore associations between categorical variables. Tests used will be described alongside the presentation of results.

Longitudinal data for infants with measurements at 6 and 12 months were analysed using two-way repeated measures ANOVA to explore the interactions between within-subject (time points) differences and between-subjects (group) differences. Weight-for-age velocity was also examined from birth to 6-months among this group of infants.

5.6. Results

Table 8 outlines the descriptive statistics of the sample in relation to milk feeding type at birth and at the time of measurement. Frequencies of infants breastfeeding until to 6 months and beyond, or exclusive breastfeeding until 6 months are also shown.

Table 8: Descriptive statistics. Milk feeding at birth and status at the time of measurement.

		n	%
Milk type at birth	Breast milk	226	84%
	Formula fed	43	16%
Milk type at the time of measurement	Breast milk	141	52.4%
	Formula milk	99	36.8%
	Combination	29	10.8%
Breastfeeding (any) to 6 months or beyond.	Yes	189	70.3%
	No	80	29.7%
Exclusively breastfed to 6 months (no formula or complementary foods)	Yes	66	24.5%
	No	203	75.5%

QUESTION 1: Is there a relationship between maternal age, education, or infant birthweight and milk feeding type?

In this study maternal age did not significantly differ between milk feeding at birth groups as seen in a Mann Whitney U test [U= 4124.0 p=0.16] but a Kruskall-Wallis test [X^2 (2) = 7.07, p=0.03] found that mothers who were currently breastfeeding were older than those who were combination or formula feeding.

Exact tests with Monte Carlo simulation found no significant association with maternal education and milk feeding type at birth [p=0.07] or at the time of measurment [p=0.47]

An ANOVA found that birthweight did not significantly differ between milk feeding at birth groups [F (1, 267)= 0.82 p=0.37] or at the time of measurement [F (2, 266)= 0.60 p=0.55]

QUESTION 2: Is there a relationship between milk feeding at birth or at the time of measurement and infant growth?

Milk type at birth

A series of MANCOVAs were conducted to explore differences in WAZ, LAZ, BMIZ and WAZV between milk type at birth (breastmilk (whether direct or expressed) or formula). Mode of feeding was not examined due to a very small numbers of infants receiving expressed breast milk in a bottle (N=6). Analyses first examined the sample as a whole and also looked at the sample split into two age sub-groups. Maternal age, education and infant birthweight were controlled for.

Weight-for-age z-score

For WAZ, infants who had formula milk at birth were found to be significantly heavier at measurement age than those who had breastmilk at birth [F (1, 258) = 12.94, p<0.000]. As seen in Table 9, sub group analyses by infant age group found a significant difference among infants aged 9 – 12 months at measurement.

Length-for-age z-score

No significant difference in LAZ were found for the whole sample [F (1, 258) = 3.72, p=0.06], nor for any age group.

BMI-for-age z-score

For BMIZ, formula fed infants had a greater BMI than breastfed infants for the whole sample [F (1, 258) = 4.02, p=0.046]. Again, the difference in BMIZ was only significant among infants aged 9-12 months.

Table 9: Milk type at birth and growth outcomes by age group.

Age group at the time of measurement			*n*	Mean WAZ (SD)	ANCOVA WAZ	Mean LAZ (SD)	ANCOVA LAZ	Mean BMIZ (SD)	ANCOVA BMIZ
6 – 8 months	Milk Type	Breast milk	104	0.22 (1.05)	F (1, 116) = 1.83, p=0.18	-0.04 (1.30)	F (1, 116) = 1.52, p=0.22	0.42 (0.95)	F (1, 116) = 0.000 p=0.99
		Formula	21	0.48 (0.66)		0.28 (0.97)		0.43 (1.13)	
9 – 12 months	Milk Type	Breast milk	122	0.02 (0.96)	F (1, 137) = 12.2, p=0.001*	-0.25 (1.02)	F (1, 137) = 1.70 p=0.19	0.26 (1.08)	F (1, 137) = 7.12 p=0.01*
		Formula	22	0.67 (0.55)		0.03 (1.29)		0.83 (0.46)	

*p<0.05

Overweight or underweight

An Exact test with Monte Carlo simulation found no significant differences for frequencies of observed over or underweight between infants who had been breastfed or formula fed at birth [p=0.91]. Thirteen (5.8%) infants in the breastfed group were classed as overweight (BMIZ >2) compared with two (4.7%) in the formula fed group. Forty-five infants (19.9%) in the breastfed group were classed as 'possible risk of overweight' (BMIZ between 1 and 2) compared to 10 (23.3%) in the formula fed group. Combined, therefore a greater proportion of formula fed infants (28%) had a BMIZ of greater than 1 (equivalent to being above the 84.1st percentile) categorised as being overweight or at risk of overweight, compared to (25.7%) of breastfed infants. However, this difference is still quite small and combining groups did not alter the significance of the Exact test [p=0.85]. Four infants were classed as underweight (WAZ <-2) and they were in the breastfed group (1.8%). No infants in the formula fed group were underweight. This result was also non-significant [p=1.0].

Rapid weight gain

Infants who were formula fed at birth had a greater mean WAZV from birth to age at the time of measurement than breastfed infants [F (1, 258) = 8.06, p=0.01]. WAZV was then grouped into whether weight gain was deemed rapid (WAZV >0.67) or not (see section 3.7.1. for explanation). A cross-tabulation revealed that 34.9% of infants' formula fed at birth showed rapid growth compared with 23.0% of infants who received breast milk at birth. However, a Chi Square test found this difference to be statistically non-significant [X^2(1, N=269) =2.72, p=0.09].

Milk feeding at the time of measurement

A series of MANCOVAs were used to explore differences in WAZ, LAZ, BMIZ and WAZV for milk type at the time of measurement (see Table 10) for the whole sample and when split into age sub-groups. Milk type was grouped into three categories based on milk type; breastmilk (directly breastfed or expressed), combination fed (breast milk and formula) and formula only. Mode of feeding was not separately explored, due to only 2 infants being solely fed expressed breastmilk in a bottle and only 14 infants receiving any degree of expressed breast milk in bottle.

Weight-for-age z-score

A significant difference in WAZ was found between the milk feeding groups for the whole sample [F (2, 257) = 3.28, p=0.04]. However, when post-hoc Bonferroni tests were performed, adjusting for multiple comparisons a significant difference was no longer apparent. Sub group analyses again (see Table 10) found only a significant difference amongst infants age 9 – 12 months. Post-hoc Bonferroni tests highlighted that formula fed infants were significantly heavier than combination fed infants [p =0.02].

Length-for-age z-score

No significant difference in LAZ was found in the whole sample according to milk type at the time of measurement [F (2, 257) = 2.51, p=0.08] or when split into age groups (see Table 10).

BMI-for-age z-score

BMIZ did not significantly differ according to milk type at the time of measurement for the whole sample [F (2, 257) = 2.38 p=0.09]. When the sample was broken down by age group BMIZ significantly differed for infants aged 9-12 months (see Table 10). As with WAZ, post-hoc Bonferroni comparisons found this difference was between formula and combination fed infants [p =0.04].

Table 10: Milk type at the time of measurement and growth outcomes by age group.

Age group		**Milk type at the time of measurement**	***n***	**Mean WAZ (SD)**	**MANCOVA WAZ**	**Mean LAZ (SD)**	**MANCOVA LAZ**	**Mean BMIZ (SD)**	**MANCOVA BMIZ**
6 – 8 months	Milk Type	Breast milk	71	0.26 (1.07)	F (2, 115) = 0.08, p=0.92	-0.09 (1.30)	F (2, 115) = 0.45, p=0.64	0.51 (1.01)	F (2, 115) = 0.88, p=0.42
		Formula	39	0.32 (0.89)		0.20 (1.20)		0.34 (0.99)	
		Combination	15	0.15 (0.89)		0.02 (1.19)		0.22 (0.80)	
9 – 12 months	Milk Type	Breast milk	70	0.04 (0.94)	F (2, 136) = 4.8, p=0.01*	-0.37 (0.96)	F (2, 136) = 2.29, p=0.10	0.36 (1.06)	F (2, 136) = 3.17 p=0.045*
		Formula	60	0.31 (0.94)		-0.05 (1.15)		0.44 (0.97)	
		Combination	14	-0.25 (0.85)		-0.09 (1.17)		-0.18 (1.01)	

*p<0.05

Overweight and underweight

In terms of overweight and underweight, an Exact test with Monte Carlo simulation found no significant differences between the groups [p=0.63]. Ten (7.1%) of infants in the breastfed group were classed as overweight compared with 4 (4.0%) in the formula fed group, and 1 (3.4%) in the combination fed group. Twenty-seven infants (19.1%) in the breastfed group were classed as 'possible risk of overweight' compared to 24 (24.2%) in the formula fed group, and 4 (13.8%) in the combination fed group. Combining overweight and possible risk of overweight categories did not alter the significance [p=0.52]. Four infants were classed as underweight, one was in the breastfed group and three were in the formula fed group. No combination fed infants were underweight. An Exact test with Monte Carlo simulation found this difference not to be statistically significant [p=0.43].

Rapid weight gain

WAZV did not significantly differ according to milk type at the time of measurement for the whole sample [F (2, 257) =2.26, p=0.11]. When WAZV was then grouped into rapid weight gain (WAZV >0.67) or not, 31.3% of infants who were currently formula fed showed rapid growth compared with only 22.7% of infants who were currently being fed breastmilk and 13.8% who were currently being combination fed. However, a Chi Square test found this difference to be non-statistically significant [X^2(2, N=269) =4.45, p=0.11).

QUESTION 3: Is there a relationship between milk feeding and growth trajectories between birth to 6 months and 6-12 months? – Longitudinal data analysis.

Longitudinal data analysis was also separately undertaken for infants who had one measurement at around 6 months and another at around 12 months (N=105). Associations between milk feeding type and weight velocity were explored between 0-6 months, and then at 6-12 months. The purpose of looking at the two distinct time periods was in order to explore whether milk feeding appears to have more or less of an influence on growth in early or later infancy (Table 11). One infant had missing data for milk feeding at birth.

Table 11: Milk feeding at birth, 6 months and 12 months. Longitudinal participants.

Time-point	Breastfeeding (*n*)	Formula feeding (*n*)	Combination feeding (*n*)

Birth	92	12	n/a
6 months	67	29	9
12 months	54	37	14

Birthweight

First, a t-test and an ANCOVA were performed to see if differences in birthweight were associated with later feeding behaviour. Infant birthweight significantly differed according to feeding method at birth, with those breastfed having a greater mean birthweight z-score (*M*=0.03, SD: 1.01) than those formula fed at birth (*M*=0.23, SD: 0.58) [*t* (102) = -0.28, *p*=0.04]. Birthweight z-score did not significantly differ according to milk feeding type at 6 months [*F* (2, 102) = 1.91, *p*=0.15].

Birth to 6 months

An ANCOVA compared weight gain velocity (WAZV) from birth to to age 6 months between infants milk fed in different ways. Milk feeding at birth, and milk feeding type at 6 months were examined. Maternal age, education and infant birthweight were controlled for.

Infants formula fed at birth had a significantly greater WAZV from birth to 6 months (*M*=0.26, SD: 1.00) compared to infants breastfed at birth (*M*=-0.47, 1.04) [*F* (1,96)= 5.92, *p*=0.02].

Infants formula fed at 6 months, had the greatest mean WAZV (*M*=0.05, SD: 0.79) when compared with breastfed (*M*=-0.54, SD: 1.08) and combination fed infants (*M*=-0.67, SD: 1.34). However, this difference was not statistically significant [*F* (2, 95) = 2.71, *p*=0.07].

6 to 12 months

Again, an ANCOVA compared weight gain velocity (WAZV) from six to twelve months between infants' milk fed in different ways. Milk feeding at birth, at 6 months were examined. Maternal age, education and infant birthweight were controlled for.

No significant differences were observed in WAZV from 6 to 12 months among infants breastfed at birth (*M*=0.24, SD: 0.63) compared with infants formula fed at birth (*M*=0.24, 0.63) [$F(1, 96)=0.29$, $p=0.59$].

Similarly, no significant differences in WAZV from 6-12 months were seen between infants who were breastfed at 6 months (*M*=0.25, SD: 0.71) compared with those were were formula fed (*M*=0.26, 0.47) or combination fed (*M*=0.13, 0.50) [F (2, 95) =0.46, $p=0.63$].

Repeated measures ANOVAS were then used to explore the trajectory differences of WAZ, LAZ and BMIZ between ages 6 and 12 months. The trajectory examined was between 6 months (time point one) (mean age 24.9 weeks, SD=8.12) and 12 months (time point two) (mean age 51.7 weeks, SD=7.47). The mean number of weeks between first and second measurements for longitudinal participants was 26.6 (SD 7.09) weeks (see Table 7 in Chapter 4).

Milk feeding practices change over time. Therefore, infants were then grouped according to milk type at both time one and time two as follows. (Table 12).

Table 12: Descriptive statistics. Milk feeding time one to time two. Longitudinal data.

Group	**Milk feeding group**	***n***	**%**

1	Breastmilk (time1) Breastmilk (time2)	52	49.5
2	Breastmilk (time1) Formula (time2)	5	4.8
3	Breastmilk (time1) Combination (time2)	10	9.5
4	Formula (time 1) Formula (time 2)	29	27.6
5	Combination (time 1) Formula (time 2)	3	2.9
6	Combination (time 1) Combination (time 2)	4	3.8
7	Combination (time 1) Breastmilk (time 2)	2	1.9
	Total	105	100.0

Due to small group sizes in many of the groups, the two biggest groups were compared. Group 1: infants who were breastfed from time one to time two i.e. breastfed throughout complementary feeding (no formula) [BF (t1) BF (t2)] (n=52), and Group 4: infants who were formula fed from time one to time two [FF (t1) FF (t2)] (n=29).

Weight-for-age z-score (WAZ)

The infants who were formula fed at both time points had a greater WAZ at both time points when compared with the breastfed infants and this between subjects' difference was statistically significant [F (1, 73) =4.45, p=0.04]. However, the interaction effect between time and milk feeding type was not statistically significant [p=0.94], implying that the degree of increase in WAZ between the two groups was similar between the time points. This can be seen below in the profile plot (Figure 4).

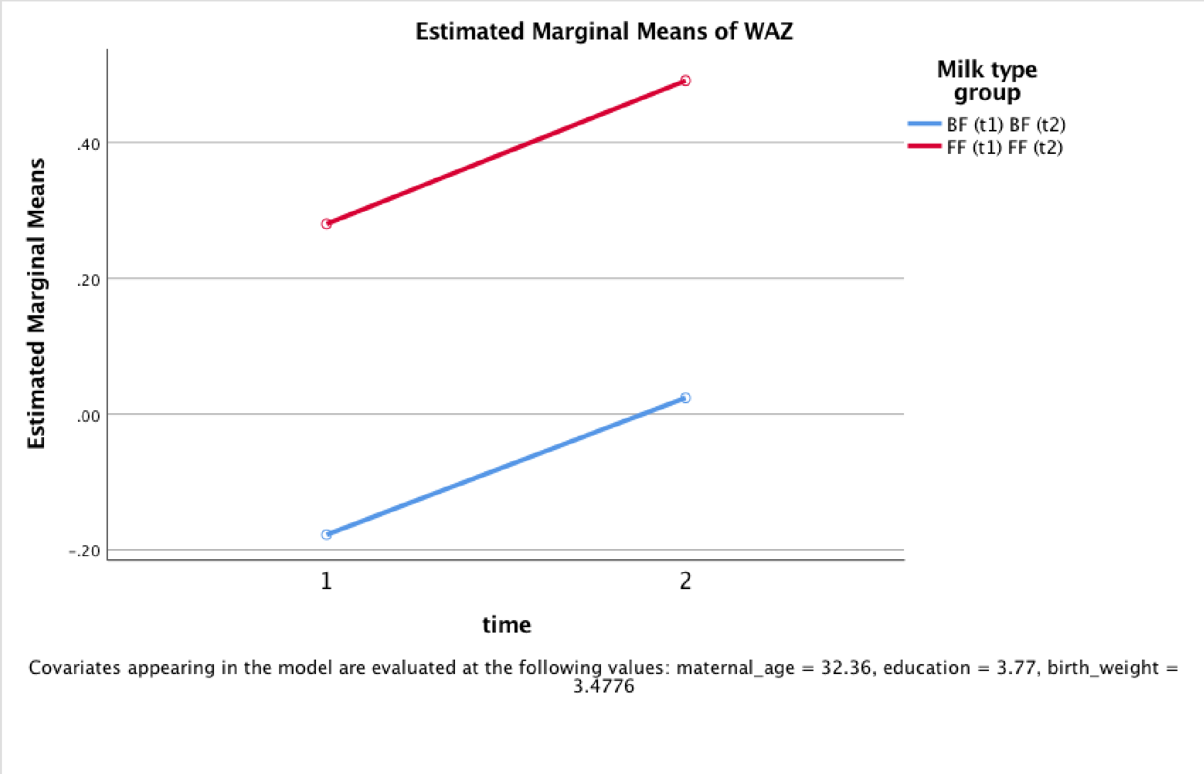

Figure 4: WAZ. Longitudinal analysis.

As Figure 4 shows by time point two (around 12 months) breastfed infants' mean weight was closest to the z-score median of zero, the WHO population mean and equivalent to the 50th percentile. Formula fed infants, on the other hand, started with WAZ above 0.2 at time one (around 6 months) which increased to above 0.4 by time two (around 12 months), the equivalent of the 63rd percentile.

Length-for-age z-score (LAZ)

The difference in LAZ between the milk feeding groups was statistically significant [F (1, 73) =6.71 p=0.01]. However, the interaction effect between time and milk feeding type was not statistically significant [p=0.69], because both groups demonstrated similar decline in LAZ between the two time points. This can be seen below in the profile plot (Figure 5). Considering this alongside the WAZ graph. Both groups gained more weight relative to their length gain, indicating that both groups got "fatter" between the two time points.

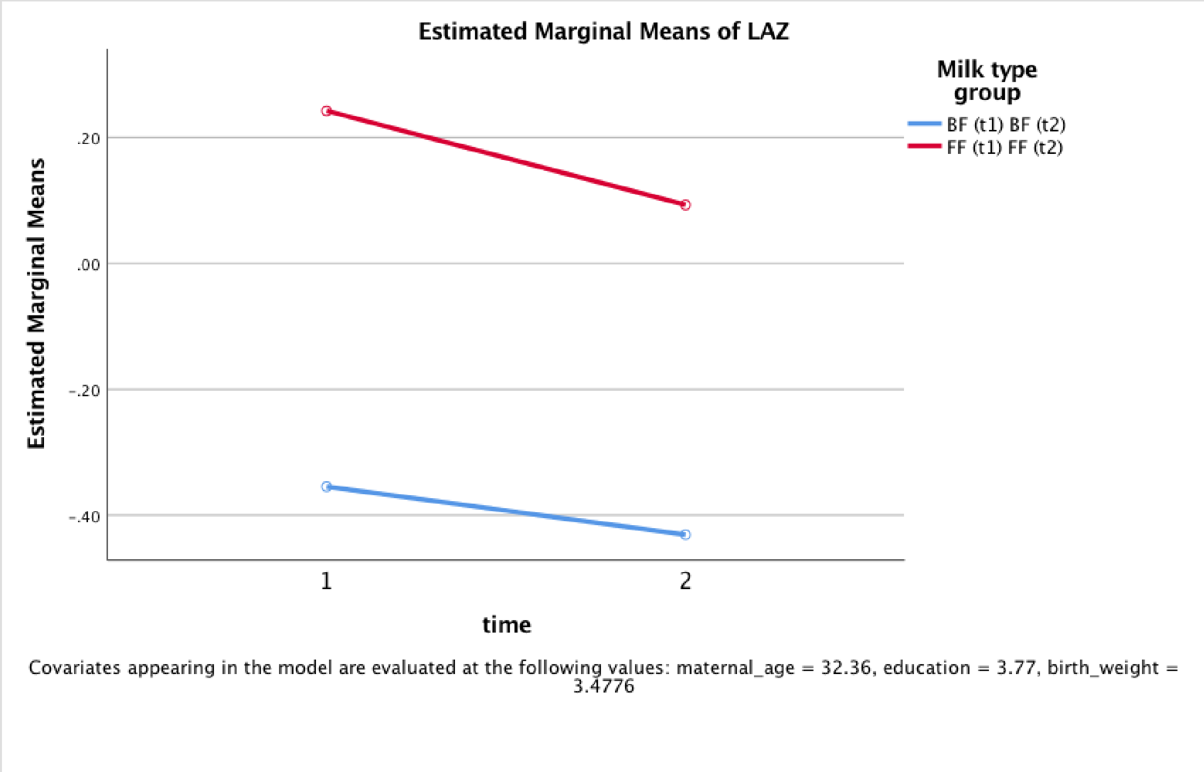

Figure 5: LAZ. Longitudinal analysis.

BMI-for-age z-score (BMIZ)

As expected therefore, both groups BMI increased from time one to time two. The between groups differences in BMIZ were not statistically significant [$F(1,73)$ =0.68, p=0.41] and also the interaction effect between time and milk feeding type was also non-significant [p=0.78], as the profile plot (Figure 6) demonstrates the increase in BMI for both groups was about the same.

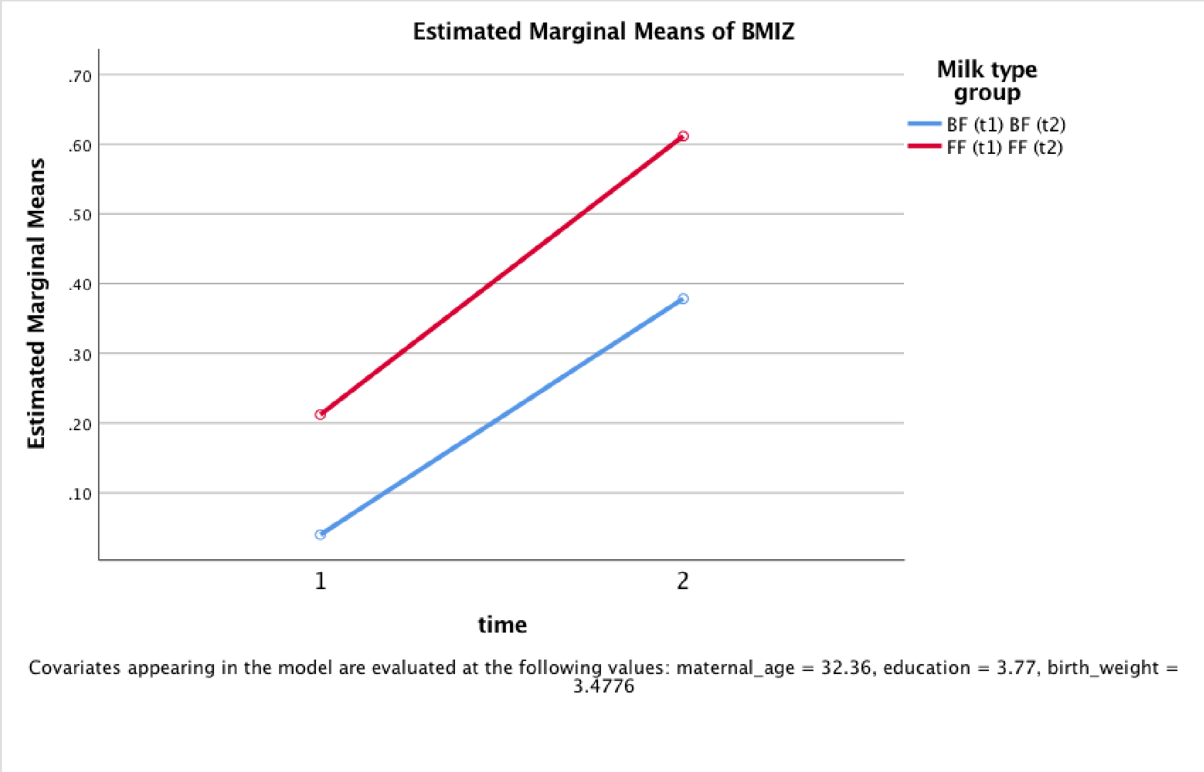

Figure 6: BMIZ. Longitudinal analysis.

QUESTION 4: Is there a relationship between duration of any (partial) or exclusive breastfeeding and infant growth?

Duration of any (partial) breastfeeding

A MANCOVA was used to explore differences in WAZ, LAZ, BMIZ, and WAZV for increasing durations of any breastfeeding (yes/no) at different infant ages up to six months (Table 13). Infants who were breastfed had a significantly lower WAZ at every milestone for duration of breastfeeding compared with fully formula fed infants (or infants who breastfed for shorter duration). No significant differences in LAZ or BMIZ occurred.

Duration of exclusive breastfeeding

A further MANCOVA was conducted to examine impact of exclusive breastfeeding duration (Table 13). Infants who were combination fed, bottle fed or who had commenced complementary foods were grouped as ‘no’ whereas infants who were only breastfed at that stage were grouped as 'yes'. Significant differences were found in WAZ for infants who were exclusively breastfed for 2 weeks or more, compared to those who were not. BMIZ was greater among infants who exclusively breastfed to 6 months, but this may be accounted for by them also having shorter length (even though LAZ was not significant), rather than due to heavier weight.

Table 13: Breastfeeding duration of partial or exclusive breastfeeding and growth outcomes.

Duration	Breast-feeding	Group	*n*	Mean WAZ (SD)	MANCOVA WAZ	Mean LAZ (SD)	MANCOVA LAZ	Mean BMIZ (SD)	MANCOVA BMIZ
>=2 weeks	Partial	Yes	224	0.14 (0.99)	*F* (1, 258) = 4.93, *p*=0.03*	-0.11 (1.15)	*F* (1, 258) = 0.09, *p*=0.76	0.33 (1.01)	*F* (1, 258) = 2.41, *p*=0.12
		No	45	0.41 (0.18)		-0.11 (1.23)		0.62 (0.92)	
	Exclus-ive	Yes	206	0.12 (0.97)	*F* (1, 258) = 6.05, *p*=0.02*	-0.15 (1.14)	*F* (1, 258) = 1.66, *p*=0.20	0.34 (1.01)	*F* (1, 258) = 1.78, *p*=0.18
		No	63	0.41 (0.92)		0.04 (1.23)		0.53 (1.00)	
>=6 weeks	Partial	Yes	213	0.13 (1.00)	*F* (1, 258) = 4.60, *p*=0.03*	-0.13 (1.15)	*F* (1, 258) = 0.53, *p*=0.47	0.35 (1.02)	*F* (1, 258) = 1.18, *p*=0.28
		No	56	0.40 (0.79)		-0.02 (1.21)		0.52 (0.94)	
	Exclus-ive	Yes	190	0.13 (0.99)	*F* (1, 258) = 3.51, *p*=0.06	-0.18 (1.13)	*F* (1, 258) = 2.86, *p*=0.09	0.38 (1.00)	*F* (1, 258) = 0.003, *p*=0.96
		No	79	0.33 (0.92)		0.05 (1.22)		0.38 (1.02)	
>=12 weeks	Partial	Yes	208	0.12 (1.01)	*F* (1, 258) = 5.18, *p*=0.02*	-0.15 (1.15)	*F* (1, 258) = 1.05, *p*=0.31	0.34 (1.02)	*F* (1, 258) = 0.98, *p*=0.32
		No	61	0.41 (0.78)		0.02 (1.17)		0.51 (0.93)	
	Exclus-ive	Yes	177	0.14 (0.99)	*F* (1, 258) = 1.33, *p*=0.25	-0.17 (1.15)	*F* (1, 258) = 1.44, *p*=0.23	0.40 (1.00)	*F* (1, 258) = 0.19, *p*=0.66
		No	92	0.27 (0.92)		0.00 (1.18)		0.34 (1.00)	
>=17 weeks	Partial	Yes	199	0.11 (1.02)	*F* (1, 258) = 5.70, *p*=0.02*	-0.16 (1.15)	*F* (1, 258) = 2.00, *p*=0.16	0.35 (1.03)	*F* (1, 258) = 0.76, *p*=0.38
		No	70	0.41 (0.77)		0.05 (1.17)		0.48 (0.93)	
	Exclus-ive	Yes	164	0.15 (0.99)	*F* (1, 258) = 0.97, *p*=0.33	-0.18 (1.15)	*F* (1, 258) = 1.88, *p*=0.17	0.42 (1.01)	*F* (1, 258) = 0.67, *p*=0.41
		No	105	0.24 (0.93)		0.00 (1.17)		0.31 (0.98)	
>=26 weeks	Partial	Yes	189	0.10 (0.99)	*F* (1, 258) = 6.52, *p*=0.01*	-0.18 (1.14)	*F* (1, 258) = 2.58, *p*=0.11	0.34 (1.02)	*F* (1, 258) = 0.82, *p*=0.37
		No	80	0.39 (0.89)		0.05 (1.20)		0.47 (0.97)	
	Exclus-ive	Yes	66	0.18 (1.01)	*F* (1, 258) = 0.07, *p*=0.79	-0.37 (1.17)	*F* (1, 258) = 3.82, *p*=0.051	0.63 (1.00)	*F* (1, 258) = 5.99, *p*=0.02*
		No	203	0.19 (0.96)		-0.02 (1.14)		0.30 (0.10)	

Age of formula introduction

A Spearman's correlation was performed on the whole sample of infants who had had any formula, either from birth or at any age (n=138) and a significant negative association was found between the age of formula introduction and WAZ [r_s (138) -0.20, p=0.02], BMIZ [r_s (138) -0.18, p=0.04] and WAZV [r_s (138) -0.18, p=0.04] indicating that younger age of formula introduction is associated with increased weight, BMI and greater weight gain velocity.

5.7. Discussion

This chapter explored the association between milk feeding and infant growth. Overall it supports previous research in the area that shows that formula fed infants are heavier and have a higher BMI than infants who are breastfed (Armstrong & Reilly, 2002; Baird et al., 2008; Horta et al., 2015; Oddy et al., 2014). However, this study explored this relationship in greater depth, and in a UK sample, by examining milk type at birth and at time of measurement, durations of any and exclusive breastfeeding, and timing of infant formula introduction.

This chapter found that weight and BMI were significantly increased in infants who were formula fed at birth and who were being formula fed at the time of measurement. When the sample was split to explore early (6-8 months) and late (9-12 months) complementary feeding, mean weight and BMI was greater amongst formula fed infants throughout. This demonstrates a clear trend; however, the association became marked and statistically significant at 9-12 months. For example, 9-12 month old infants who were formula fed at birth had a mean WAZ of 0.67, equivalent to the 65th percentile, compared with infants' breastfed at birth, who had a mean WAZ of 0.02, equivalent to the 52nd percentile. This difference equates to a weight difference of around 540g, which is approximately 5-6% of the average infants' bodyweight at this age. This could have implications if weight gain continues to track into childhood, as previous research has shown (Wang et al., 2016).

A number of mechanisms could explain these relationships. Formula milk has a greater protein content compared to breast milk, with higher levels of protein associated with greater weight gain (Luque et al., 2016). Breast milk also contains a number of bio-active properties that are present in breast milk that help to control appetite and weight gain (Chan et al., 2017). Emerging research also suggests that differences in the microbiome of breast and formula fed infants may play a potential role in weight gain (Emmanouil & Raoult, 2018). Although further research is needed, Bifidobacterium which is considered to be influential in reducing risk of overweight and obesity is present in greater amounts in the gut of exclusively breastfed infants (Lewis & Mills, 2017; Korpela et al., 2016; Moosavi et al., 2019).

Behavioural differences also occur. Intake is typically greater and quicker amongst formula fed infants, due to the biomechanical differences between bottle and breast-feeding (Heinig et al., 1993). Mothers who bottle feed are less likely to use a responsive feeding style, encouraging infants to finish a feed or not heeding subtle cues of satiety (Brown & Lee, 2013; Shloim et al., 2017; Disantis et al., 2011b; Brown et al., 2011). Small scale research shows that when bottle fed infants are encouraged to finish a feed they consume more milk than when they are fed responsively (Agras et al., 1990; Li et al., 2010). Infants who are bottle fed are rated as less satiety responsive as toddlers (Brown & Lee, 2012; Bartok & Ventura, 2009). Finally, although the research is very new at this stage, recent research shows that the microbiome of infants fed directly at the breast is different to that of infants fed expressed milk in a bottle. Infants who are given expressed milk have lower levels of Bifidobacterium – a type of bacteria associated with breastmilk – compared to those fed directly from the breast (Moossavi et al., 2019).

The increase in weight gain in formula fed infants but not until 9 – 12 months is interesting. Weight gain can take time to be significant – a few extra calories each day add up over time. Infants also increase their intake of food as they move from the earlier stages of complementary feeding (Rowan et al., 2019). Formula fed infants might be less likely to adapt to this change. For example, in the DARLING study in the USA, infants who were formula fed did not naturally cut down on their intake of milk when introduced to complementary foods. Conversely, infants who were breastfed appeared to self-regulate and reduce milk intake according to food calories consumed (Heinig et al., 1993).

Similarly, in the ALSPAC study in the UK, breastfed infants reduced their intake of milk when complementary foods were introduced but formula fed infants did not. Combined with complementary food given, this led to four month old infants who were formula fed and eating complementary food having the highest intake of protein compared to all other feeding combinations. Infants who were formula fed also had a lower intake of fruit and vegetables, suggesting differences in dietary intake between breast and formula fed infants (Noble & Emmett, 2006). Finally, in another study using ALSPAC data amongst infants introduced to complementary foods before six months, formula fed infants were consuming more calories overall compared to breastfed infants (Ong et al., 2006).

Mode of feeding is also thought to be important. Research in Canada and the USA, where rates of feeding expressed breastmilk in a bottle are far higher than in the UK (Johns, Forster, Amir & McLachlan, 2013) found that mode of feeding breast milk affected weight gain. Infants who were bottle fed were more likely to have a higher weight than infants fed directly at the breast regardless of whether breast milk or formula was in the bottle (Azad et al., 2018; Li et al., 2010; Li et al., 2012). As exclusive feeding of expressed breast milk is rare in the UK, and low in this sample, this relationship was not able to be examined.

Infants who were combination fed (e.g. having both breast and formula milk) at the time of measurement rather than exclusively breast or formula fed, had significantly lower WAZ and BMIZ, but only among the older infants (aged 9-12 months at the time of measurement). It is unlikely that combination feeding promotes lower weight gain. Instead, may be that that low weight gain is driving the decision to combination feed. Decision to 'top up' with formula is often driven by concerns over low milk intake or weight gain (Odom et al., 2013). Potentially these babies may have had early issues with feeding or weight gain that led to supplementation out of need or maternal anxiety (Chantry, Dewey, Peerson, Wagner & Nommsen-Rivers, 2014) that was continued. Birth complications can lead to a delayed or reduced milk supply (Jonas et al., 2009), increasing the risk of infant weight loss and the decision to supplement with (Dewey et al., 2003). Supplementing with breastmilk however is possibly affected by different drivers. It is not usual that a mother herself will breastfeed directly but then express further milk for a feed, for her to also give her infant. It is likely that someone else is involved in feeding the baby

– who may adopt a more controlling feeding style. It is also possible that mothers do not like to see their breastmilk go to waste, or it is in limited supply in expressed form, and therefore the infant is encouraged to finish the feed. Again numbers in this analysis were too small to explore this but it warrants further investigation.

Longitudinal analyses explored growth between 0-6 months and 6-12 months. Formula fed infants at birth had significantly greater weight gain velocity from 0-6 months, but not between 6-12 months, perhaps due to the influence of complementary feeding factors. Breastfed infants continued to have the lowest weight and length at both 6 and 12 months when compared with formula fed infants and these differences were statistically significant. However, the 'slope' of the trajectories between 6 and 12 months did not significantly differ between the groups. Visual examination if the graphs showed similar inclines in weight-for-age and BMI-for-age between the formula and breastfed groups.

Previous research has found slower rate of weight gain amongst breastfed infants when compared with formula fed infants (Dewey et al., 1992) especially during the second six months of infancy (Kramer et al., 2002). Furthermore, Wang et al (2016) found that rapid infancy weight gain resulted in weight 'tracking' (following the same upward trajectory) up to the age of two. This study did not find a statistically significant difference in the trajectory (rate) of weight gain, however the weight of breastfed infants was significantly lower than the formula fed infants at both time points. By 12 months the breast-fed babies mean weight-for-age was equivalent around the z-score of 0 (the 50th percentile) indicative of adequate growth. However, the formula fed babies WAZ increased by 12 months to the 63rd percentile. If the trajectory lines continue to track at the same rate and in the same direction, this could have important consequences for later childhood, especially for the formula fed infants starting at this higher baseline.

Finally, looking at duration of partial and exclusive breastfeeding, partial breastfeeding was associated with reduced weight when compared to full formula feeding (or those with a shorter breastfeeding duration). As in previous research (Grummer-Strawn & Mei, 2004; Harder et al., 2005; Yan et al., 2014), longer breastfeeding durations were associated with a lower weight. No further protection was seen in this sample for exclusive over partial feeding. It may be that mothers who breastfeed partially may have a more responsive feeding style than those who choose to move fully to formula, or that the properties of breastmilk itself (to any degree) has a protective effect. Further research is needed.

There are limitations to the data. Although a range of demographic backgrounds and feeding experiences were found in the study, mothers were generally older, with a higher level of education and a longer breastfeeding duration than average. The majority of infants (*n*=257; 95.5%) were also within a normal weight range with weight-for-age z-scores between -2 (equivalent to the .2nd percentile) and 2 (equivalent to the 97.7th percentile). However, this is typical of almost all infant feeding research, and the average UK infant population (Cole, Freeman & Preece, 1998).

Secondly, the research would have benefitted from a larger sample size. It is possible that some calculations were under-powered (particularly the longitudinal group, see section 3.7.5. for power calculations), thus not finding a significant difference. For example, when calculating weight-for-age-velocity despite 34.9% of formula fed infants at birth showed rapid weight gain compared with just 23% of those who were breastfed at birth, this was not statistically significant, despite those percentages showing a potentially considerable real-life significance. However, the sample size (for the main analyses) was deemed adequate for the study type and enabled all measurements to be taken by one researcher experienced in infant measurement, reducing inter-measurer bias.

Limitations aside, the findings of this chapter make an important addition to the literature on infant feeding and weight gain. Further research may also wish to explore wider infant feeding factors such as mode of feeding (and how that impacts on the infant microbiome), degree of breast/formula feeding amongst those combination feeding, antibiotic use and other factors. The next chapter will explore the relationship between the age of introduction to complementary foods and infant growth.

CHAPTER 6: Exploring timing of introduction to complementary foods and infancy growth

6.1. Rationale

As described in the literature review (section 2.10.), a baby-led feeding approach consists of a number of factors that might affect any differences in growth between baby-led and traditionally spoon fed infants. The first of these is the decision on when to first introduce complementary foods. Previous research has shown that mothers who adopt a baby-led weaning tend to introduce complementary foods later than those who spoon feed. This may be in part due to the impossibility of a very early introduction to solid foods amongst self-feeding infants for developmental reasons, or conversely due to a general maternal desire to follow infant led feeding cues.

Previous research has shown that timing of complementary foods may be associated with infant growth (Sloan et al., 2007; Azad et al., 2018). Therefore, determining whether this aspect of baby-led feeding is directly associated with infant growth on its own is an important step towards conducting the overall regression analysis (in Chapter 11).

6.2. Background

The recommended age for introducing complementary foods in the U.K. is 6 months (WHO, 2001). However, the most recently available statistics in the U.K. suggest that although some mothers wait until this time, many start complementary feeding much earlier, with around 30 per cent starting before 4 months and 75 per cent by 5 months (McAndrew et al., 2012).

Timing of introduction to complementary foods may be an important influencing factor on infant growth and later obesity risk, in particular review papers have concluded that generally very early introduction has been shown to increase obesity risk in some studies

(Moorcroft et al., 2011; Pearce et al., 2013; Daniels et al., 2015b). Studies which looked at infancy weight gain found a relationship between very early complementary feeding (<4 months) and overweight and rapid weight gain to 7 months (Sloan et al., 2007) and weaning before 5 months and increased BMI at 12 months (Azad et al., 2018). This effect may also continue into later childhood, for example, one large US study found increased odds of obesity at aged three if the infant had been started on complementary foods before 4 months (Huh et al., 2011).

While overall the evidence points towards an association between very early complementary feeding (<4 months) and later obesity risk, the evidence is limited or weak supporting a link between complementary feeding between 4 and 6 months and obesity (Moorcroft et al., 2011; Pearce et al., 2013; Daniels et al., 2015a).

As noted in the literature review, a number of factors could explain the association between age of introduction to complementary foods and risk of overweight. For example, infants exposed to complementary foods earlier may be simply consuming more in the first year of life in terms of energy and protein especially if milk intake is not reduced (Robinson et al., 2007; Garcia et al., 2013; Thompson & Bentley, 2013).

However, as well as differing diet content, there may be behavioural differences in feeding between mothers who introduce complementary foods early and those who wait (Brown & Lee, 2013). The feeding style of mothers who introduce complementary foods earlier is likely to be less responsive to babies and hunger and satiety cues and they may exercise a more pressuring attitude towards feeding during complementary feeding and beyond, due to concerns over weight, intake or perceptions of hunger (Arden, 2010; Brown & Rowan, 2016).

It is important to also be aware of reverse causality here (Vail et al., 2015). Some authors have pointed out that 'bigger' babies may be started on complementary food at a younger age due to maternal perceptions that their 'big baby' is 'hungrier' and therefore requires food earlier (Anderson et al., 2001; Arden, 2010; Daniels et al., 2015b; Brown & Rowan, 2015). Clinical data from a large cohort study in the Netherlands supported this, finding that before complementary foods were introduced, weight gain was greater amongst infants who were introduced to complementary foods early (3-6 months) compared to those who waited until 6 months. (Van Rossem et al., 2013). Equally, low child weight may affect maternal feeding interactions as mothers of underweight children may be more likely to pressure intake (Webber et al., 2010; Gregory et al., 2010).

Milk feeding may also play a role in the relationship between timing of introduction to complementary food and weight. Recently, the European IDEFICS study of over 10, 000 children age 2 to 9 years, found that amongst infants introduced to complementary foods at six months, infants who continued to receive breastmilk for >=12 months had a reduced risk of overweight compared to those who discontinued breastfeeding before 12 months (Papoustou et al., 2018). In an earlier birth cohort study in the US of 847 children, among formula fed infants, infants who were introduced to complementary foods before four months (versus at 4-5 months), had a six-fold increase in odds of obesity at age three. However, among breastfed infants no significant increase in odds of obesity at age three were seen in relation to age of complementary food introduction (Huh et al., 2011).

One explanation for the relationship between the timing of complementary foods, milk feeding and growth is an increased consumption of overall energy and protein intake in formula fed infants. For example, the ALSPAC study identified that breastfed infants reduced their milk intake when complementary foods were introduced but formula fed infants did not (Noble & Emmett, 2006). Similar findings were found in the DARLING study (Heinig et al., 1993).

However, there are a number of limitations with the current data on this topic. Research from the UK is sparse, especially in terms of considering any interaction with milk feeding. Again, data is prone to inconsistencies with variations in accuracy of measures of infant growth including a reliance on maternal report of weight (Rogers & Blissett, 2017). Little consideration is given to infant length

The aim of this chapter is to therefore understand the association between the first step of a baby-led approach – the timing of introduction to complementary foods - and infant growth, taking into consideration whether this relationship differs between breast and formula fed infants. This chapter will address the following key questions:

1) Is there a relationship between milk feeding type and timing of introduction to complementary foods?
2) Is there a relationship between when infants are introduced to complementary foods and infant growth?
3) Is there a relationship between when infants are introduced to complementary foods and growth trajectories between birth to 6 and 6 to 12 months? – Longitudinal data analysis.
4) Does the association between timing of complementary foods and growth differ dependent on milk feeding?

6.3. Participants

For full details of participants please refer to chapter four.

6.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Timing of complementary food introduction

Parents who had started complementary feeding were asked to provide the age at which they introduced complementary food in weeks. Very early introduction to complementary foods may have an effect on infant weight, however the evidence is not as clear in relation to 4-6 months, or 6 months and beyond. Therefore, in order to explore this further the data were coded into three 'timing groups' for analysis, 'Very Early' <=17 weeks, 'Early' 18-25 weeks and 'On Time' >=26 weeks.

Milk feeding

As described in Chapter 5, parents were asked how they were milk feeding their baby, at birth and at the time of measurement. Birth milk feeding type was grouped into two groups; breastfeeding (directly from the breast or expressed) or formula feeding. Current milk feeding type was grouped into three groups; breastfeeding (directly from the breast or expressed), combination feeding of breast milk and formula or formula feeding (or cow's milk). Data on duration of any or exclusive breastfeeding was also collected.

6.5. Data analysis

Data were analysed as described in Chapter 3. Where the data met parametric assumptions, Multivariate Analysis of Co-Variance (MANCOVA) were used to explore between-subjects group differences. When parametric assumptions were not met, non-parametric equivalents were used (Mann-Whitney U or Kruskall-Wallis). Chi Square or Exact tests with Monte Carlo simulations were used to explore associations between categorical variables. Tests used will be described alongside the presentation of results.

Longitudinal analyses

Longitudinal data analysis was also separately undertaken for infants with more than one measurement. Longitudinal data were analysed using two-way repeated measures ANOVA to explore the interaction between within-subject (time points) differences and between-subjects (group) differences.

6.6. Results

Mean age of starting complementary foods in the sample was 23.5 weeks (SD:3.63); the youngest started complementary foods at 10 weeks and the oldest started complementary foods at 40 weeks.

Table 14: Descriptive statistics. Timing groups.

Timing Group	***n***	**%**
'Very Early' <=17 weeks	23	8.6%
'Early' 18-25 weeks	150	55.8%
'On Time' =>26 weeks	96	35.7%

As seen in Table 14, the most infants started complementary feeding between 18 and 25 weeks and the majority (64.4%) commenced on complementary foods before the recommended age of 6 months (26 weeks).

Controlling for covariates

As in Chapter 5, maternal age, education and infant birthweight were controlled for. Milk feeding type at the time of measurement was also included as a co-variate in the main analysis due to significant associations between milk feeding and infant growth being found (reported in Chapter 5) and the precedence of prior literature. The categorical variable of milk feeding type at time of measurement was chosen as the covariate, rather than duration of breastfeeding as some infants never breastfed and some were still breastfeeding, and including this reduced the sample size.

Early introduction to complementary feeding is associated with younger maternal age, lower educational attainment and socio-economic status (Tarrant et al., 2010; McAndrew et al., 2012). Therefore, the relationships between timing of complementary feeding and maternal demographic background were explored. In this sample no significant associations were found between age of complementary feeding and maternal age and education.

QUESTION 1: Is there a relationship between milk feeding type and timing of introduction to complementary foods?

The literature suggests that formula fed infants are often started on complementary foods earlier than breastfed infants (Fewtrell et al., 2003; Scheiss et al., 2010; Clayton et al., 2013).

Milk type at birth

In the SHIFT study infants breastfed at birth were more likely to start complementary feeding slightly later (M=23.7 weeks; SD: 3.45) than infants who were formula fed at birth (M=22.7 weeks; SD: 4.46) and a Mann Whitney U test showed that this difference was statistically significant [U=3822.0, p=0.02]. A cross-tabulation was also performed exploring associations between the timing groups and milk feeding at birth groups. A greater proportion (38.5%) of infants who were breastfed at birth waited until 26 weeks to start complementary foods compared with only 20.9% of infants who were formula fed at birth. Furthermore, 16.3% of infants' formula fed from birth started complementary feeding before 17 weeks, compared with 7.1% of infants' breastfed at birth. A Chi square test found these differences between the two groups to be statistically significant [$X^2(2, N=269) = 7.15, p=0.03$].

Milk feeding at the time of measurement

Similarly, breastfed infants at the time of measurement were more likely to start complementary feeding later (M=24.7 weeks; SD: 2.54) than both the combination fed infants (M=22.9 weeks; SD: 3.93) and the formula fed infants who started the earliest (M=21.9 weeks; SD: 4.21). A Kruskall-Wallis test found this difference to be significant [$X^2(2)= 39.4, p<0.000$]. Table 15 below shows the result of a cross-tabulation of milk feeding type at the time of measurement, by timing of complementary foods group.

As seen in Table 15, a greater proportion (47.5%) of breastfed infants' mothers waited until 26 weeks to start complementary foods, compared with 31% of combination fed infants' mothers and 20.2% of formula fed infants' mothers. On the other hand, formula fed infants were more likely to start complementary feeding at or before 17 weeks, with

73.9% of infants in this 'Very Early' timing group being formula fed. A Chi square test showed this difference to be significant [$X^2(4, N=269) = 31.68, p<0.000$].

Table 15: Cross tabulation. Milk feeding type at the time of measurement and timing of complementary feeding.

		Very Early <=17 weeks	**Early 18-25 weeks**	**On Time >=26 weeks**
Breast feeding	*n*	2	72	67
	% within milk group	1.4%	51.1%	47.5%
	% within timing group	8.7%	48%	69.8%
Formula feeding	*n*	17	62	20
	% within milk group	17.2%	62.6%	20.2%
	% within timing group	73.9%	41.3%	20.8%
Combination feeding	*n*	4	16	9
	% within milk group	13.8%	55.2%	31.0%
	% within timing group	17.4%	10.7%	9.4%

It is important to note here that those introducing complementary foods Very Early is small (*n*=23) and those breastfeeding with this group is very small (*n* =2) limiting the usefulness of interpretation of these data.

QUESTION 2: Is there a relationship between when infants are introduced to complementary foods and infant growth?

Spearman's correlations found no significant associations between the age at which complementary feeding commenced and WAZ [r_s=-0.09, p=0.07]. However, a significant negative correlation was found for LAZ [r_s=-0.25, p<0.000], meaning that babies introduced to complementary foods at a younger age were longer. BMIZ did not significantly correlate with age of complementary feeding [r_s=0.10, p=0.08]. It is also important to note that Spearman's correlations do not account for covariates, in particular birthweight, which may influence later weight.

A series of MANCOVAs were performed to explore any differences in WAZ, LAZ, BMIZ and also WAZV between the three timing groups, controlling for maternal age, education, birth weight and milk feeding type at time of measurement. Analyses were also run throughout without milk feeding type as a co-variate, but this did not change the outcomes.

Weight-for-age z-score (WAZ)

No significant differences were found in WAZ between the three timing groups in the whole sample of infants over 6 months [F (2, 254) =0.36, p=0.70]. Infants who started complementary foods 'On Time' at 26 weeks or later had the lowest mean WAZ (M = 0.11, SD:1.13). This is compared to the 'Early' group who had a mean WAZ of 0.21 (SD:0.85) the 'Very Early' introducers (<=17 weeks) who were the heaviest with a mean WAZ of 0.38 (SD:0.92) and, though these differences were statistically non-significant, there appears to be a trend that weight-for-age decreased the later that complementary foods were introduced.

All measurements were then used for age group analysis. Table 16 presents the results of the ANCOVAs, controlling for maternal age, education, birth weight and milk feeding type at the time of measurement. No significant differences in WAZ were seen within the age group analyses.

Length-for-age z-score (LAZ)

A significant difference in LAZ was found between the three timing groups in the whole sample [F (2, 254) =4.83, p=0.01]. Mean LAZ for each timing group is shown below.

Length-for-age decreased the later complementary foods were introduced. The infants who started complementary feeding 'Very Early' were the longest (*M*=0.26, SD:1.08) compared to the 'Early' (*M*=0.08, 1.07) and 'On Time' groups (*M*=-0.46, SD:1.23). Post hoc Bonferroni tests found that the significant difference was between the 'Very Early' group who were the longest and the 'On Time' group who were the shortest [p=0.01]. As Table 16 shows this significant difference in length was only evident in the 9-12-month old group.

BMI-for-age z-score (BMIZ)

A significant difference in BMIZ was found between the three timing groups in the whole sample [F (2, 254) =4.13, p=0.02]. Mean BMIZ was the greatest amongst the 'On Time' group (*M*=0.60, SD:1.06) followed by the 'Very Early' group (*M*=0.26, SD:0.86) and the 'Early' group who had the lowest BMIZ (*M*=0.25, SD:0.97). Post-hoc Bonferroni comparisons revealed the difference lay between the 'Early' and the 'On Time' groups only [p=0.01]. This higher BMI is likely to be due to shorter length in the 'On Time' group rather than increased weight. Broken down by age sub-group, the difference in BMIZ was not evident (see Table 16).

Table 16: Timing of introduction to complementary foods groups and growth outcomes.

Age group		Timing group	*n*	Mean WAZ (SD)	MANCOVA WAZ	Mean LAZ (SD)	MANCOVA LAZ	Mean BMIZ (SD)	MANCOVA BMIZ
6 – 8 months	Timing group	Very Early <=17 weeks	10	0.50 (1.18)	*F* (2, 114) = 0.86, *p*=0.42	0.32 (1.45)	*F* (2, 114) = 0.57, *p*=0.57	0.46 (0.82)	*F* (2, 114) = 2.25, *p*=0.11
		Early 18-25 weeks	72	0.28 (0.81)		0.12 (1.08)		0.31 (0.91)	
		On Time >=26 weeks	39	0.15 (1.26)		-0.28 (1.46)		0.63 (1.10)	
9 – 12 months	Timing group	Very Early <=17 weeks	11	0.28 (0.65)	*F* (2, 133) = 0.16, *p*=0.85	0.20 (0.67)	*F* (2, 133) = 4.73, *p*=.01*	0.08 (0.88)	F (2, 133) = 2.23, p=0.11
		Early 18-25 weeks	73	0.13 (0.89)		0.03 (1.06)		0.19 (1.02)	
		On Time >=26 weeks	56	0.07 (1.05)		-0.57 (1.03)		0.57 (1.04)	

*$p<0.05$

An Exact test with Monte Carlo simulation found no significant differences for frequencies of observed overweight in the timing groups [*p*=0.10]. Ten (10.4%) of infants who delayed complementary feeding until 26 weeks were classed as overweight (BMIZ >2) compared with four (2.7%) in Early group and 1 (4.3%) in the Very Early group. Fifteen (15.6%) in the On Time group were classed as 'possible risk of overweight' (BMIZ between 1 and 2) compared with 33 (22%) in the Early group and 5 (21.7%) in the Very Early group. Four infants in total (1.4%) came into the category of underweight (WAZ<-2), and they were all in the On Time group, comprising 4.2% of this group. This finding was however, not statistically significant [*p*=0.051].

Weight-for-age-velocity z-score (WAZV)

No significant difference was found in WAZV (change in weight-for-age-z-score from birth to measurement age) between the three timing groups in the whole sample [F (2, 254) =0.80, p=0.45]. WAZV was then grouped into whether they showed rapid weight gain (an increase in WAZ of > 0.67) or not. Cross tabulation showed that 34.8% of infants who were started on complementary foods 'Very Early' showed rapid weight gain, compared to 22.7% of those who started complementary foods 'Early', and 26% who started 'On Time'. However, a Chi Square test found that this difference was not statistically significant [X^2 (2, N=269) =1.67, p=0.43].

QUESTION 3: Is there a relationship between when infants are introduced to complementary foods and growth trajectories between birth to 6 and 6 to 12 months? – Longitudinal data analysis.

Longitudinal data analysis were performed for infants who had one measurement at around 6 months and another at around 12 months (N=105). Weight velocity was also explored from birth to six months. The purpose of this analysis was in order to see whether how rapidly infants grow in early infancy, predicts the age at which they are started on complementary foods. Then, weight velocity and growth trajectories were explored for infants aged 6-12 months based on the age of introduction to complementary foods.

Birthweight

First, the data were explored to see if birthweight predicted age of introduction to complementary food. A Spearman's correlation was performed and no significant association was found [r_s=0.07, p=0.47].

Birth to 6 months

A Spearman's correlation did not find a significant association between the age at which infants were introduced to complementary foods and their weight gain velocity from birth to six months [r_s=-0.13, p=0.20].

6 to 12 months

Similarly, at 6-12 months no significant association was seen between the age at which infants were introduced to complementary foods and their weight gain velocity from six to twelve months [r_s=-0.05, p=0.59].

Repeated measures ANOVAS examined the growth trajectories of infants from 6 to 12 months. Longitudinal data were explored to discover if there is a difference in WAZ, LAZ or BMIZ trajectories between time point one (6 months) and time point two (12 months) based on timing of complementary feeding, controlling for maternal age, education, infant birth weight and milk feeding type (at time two).

Weight-for-age z-score

Table 17 shows the mean WAZ for each timing group. The between subject effect was not significant [F (2, 94) =0.48, p=0.63] and interaction effect between time and timing group was also not statistically significant [F (2, 94) =0.26, p=0.76]. Profile plots (Figure 7) demonstrate the trajectories for the three groups.

Table 17: Longitudinal differences in WAZ and timing of complementary feeding.

Timing group	***n***	**Time point One Mean WAZ (SD)**	**Time point Two Mean WAZ (SD)**
<17 weeks	11	0.06 (0.93)	0.38 (0.84)
18-25 weeks	57	-0.05 (0.93)	0.18 (1.00)
>=26 weeks	37	-0.17 (1.12)	0.14 (0.98)

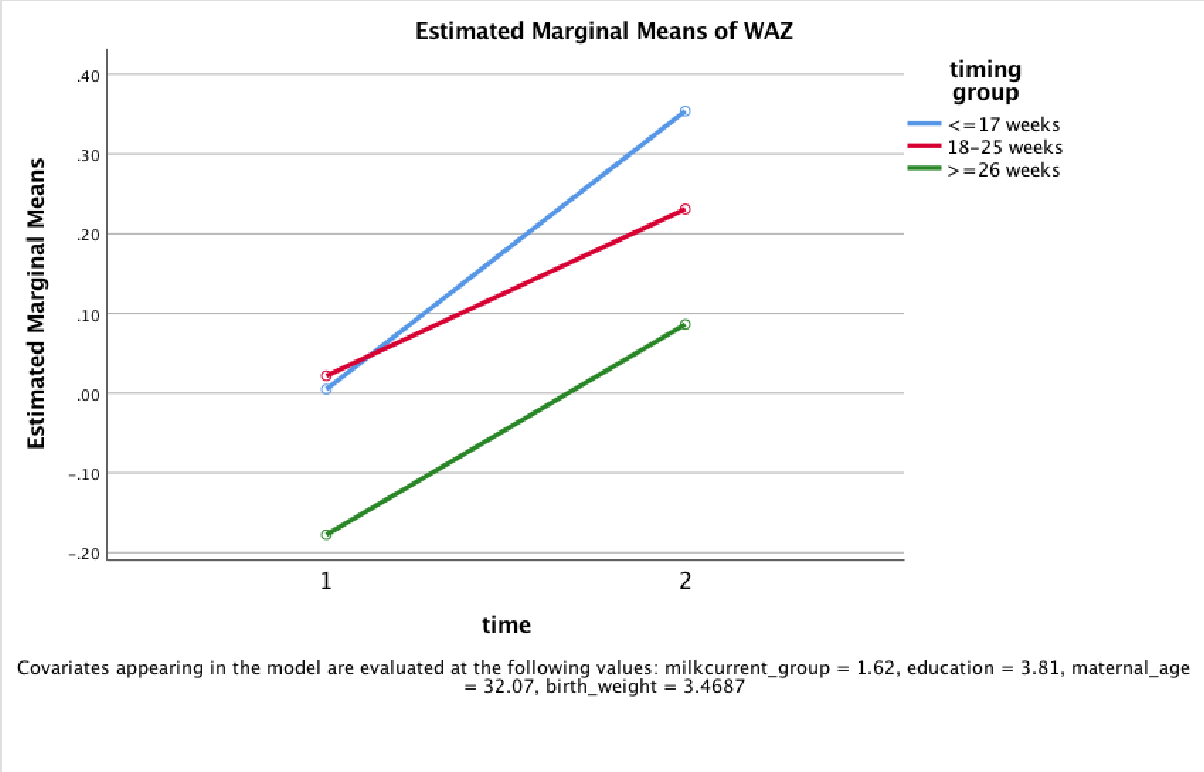

Figure 7: Longitudinal trajectories of WAZ and timing of complementary feeding.

All groups gained weight for their age between time point one and time point two. The group with the steepest trajectory was the <=17 week group. Those infants who waited until 26 weeks to start complementary foods had the lowest WAZ at both time points, but by time point two they had a WAZ just above 0 (closest to the 50th percentile).

Length-for-age z-score

Table 18: Longitudinal difference in LAZ and timing of complementary feeding.

Timing group	***n***	**Time point One Mean LAZ (SD)**	**Time point Two Mean LAZ (SD)**
<17 weeks	11	0.19 (.096)	0.33 (0.75)
18-25 weeks	57	0.02 (0.99)	0.01 (1.07)
>=26 weeks	37	-0.43 (0.83)	-0.52 (0.94)

The between subject effect was statistically significant [F (2, 94) =3.98, p=0.02] however interaction effect between time and timing group was not significant [F (2, 94) =0.35, p=0.71]. This means that the differences in LAZ between the groups was significantly different but that the slope of the trajectories from time one to time two did not significantly differ. Though the <17-week group were the longest at both time one and time two, Bonferroni comparisons showed that the significance of the between group difference lay between the 18-25-week group who were significantly longer than the >=26 week group who were the shortest. Profile plots (Figure 8) demonstrate the trajectories for the three groups.

As Figure 8 shows, length-for-age decreased amongst all infants who commenced complementary foods at 18 weeks or later. Only those in the early group showed an increase in LAZ, however the group size was small (N=11).

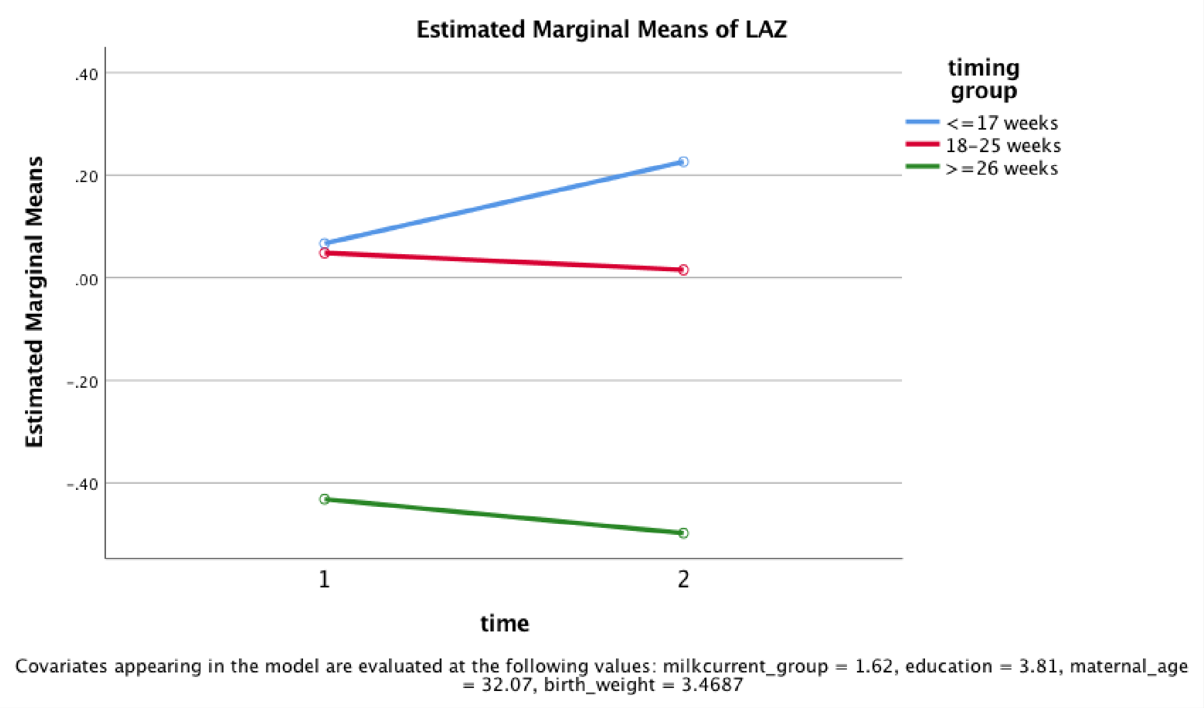

Figure 8: Longitudinal trajectories of LAZ and timing of complementary feeding

BMI-for-age z-score

Table 19: Longitudinal differences in BMIZ and timing of complementary feeding.

Timing group	***n***	**Time point One Mean BMIZ (SD)**	**Time point Two Mean BMIZ (SD)**
<17 weeks	11	-0.01 (1.02)	0.27 (0.83)
18-25 weeks	57	0.02 (1.17)	0.26 (1.18)
>=26 weeks	37	0.15 (1.27)	0.62 (0.97)

A repeated measures ANOVA found that the between subject effect was not statistically significant [F (2, 94) =0.16, p=0.85]. Furthermore, the interaction effect between time and timing group was not significant [F (2, 94) =0.43, p=0.65]. This means that the differences in BMIZ between the groups were not significantly different and that the slope of the trajectories did not significantly differ. As seen in the profile plot (Figure 9), the group that started complementary foods 'On Time' at 26 weeks or after had the greatest BMI increase over time, however on examining the WAZ and LAZ results, this appears to be due to shorter length rather than heavier weight.

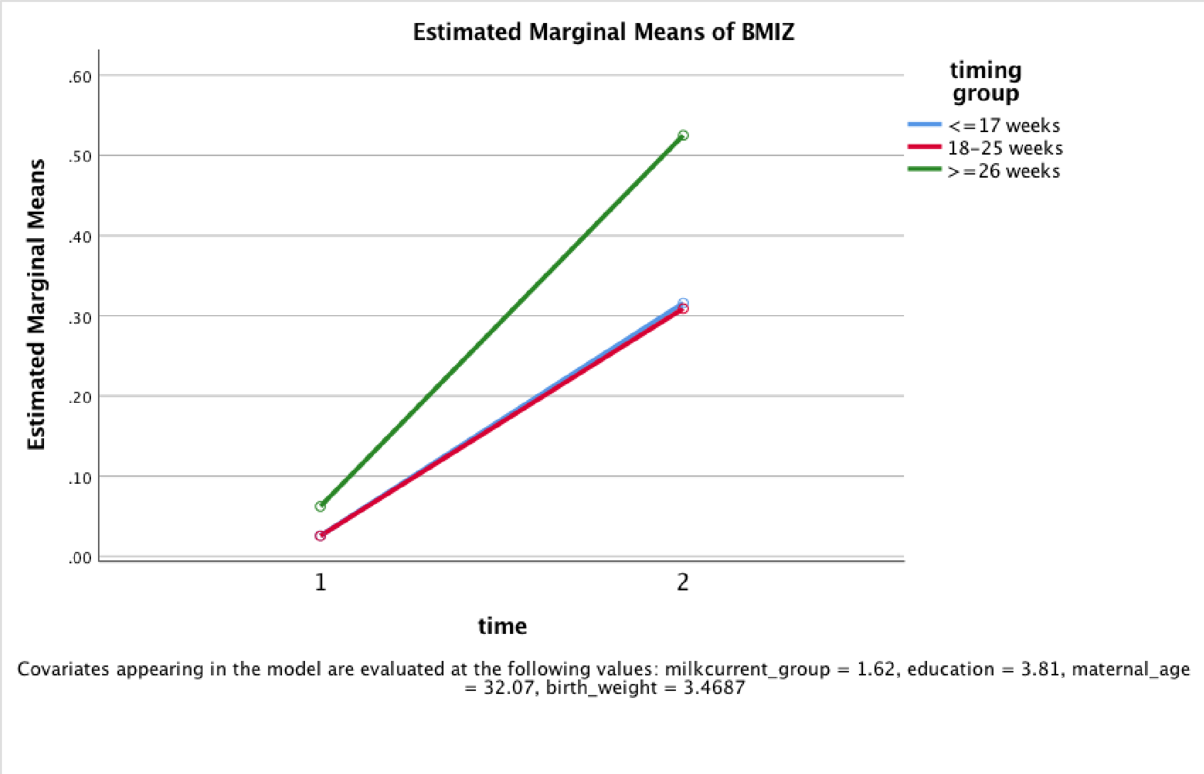

Figure 9: Longitudinal trajectories of BMIZ and timing of complementary feeding.

QUESTION 4: Does the association between timing of complementary foods and growth differ dependent on milk feeding?

The cumulative impact of timing of introduction to complementary foods and milk feeding was examined. Within each timing group, differences in growth between breast and formula fed infants were examined. Any breastfeeding versus exclusive formula feeding and exclusive breastfeeding versus any formula feeding were both examined.

For those who introduced complementary foods < 17 weeks, numbers were small so only infants receiving any breast milk (*n*= 6) versus only formula milk (*n*=15) were compared.

No significant difference was found for WAZ [*F*(1,16) = 0.004, *p*=0.95], LAZ [*F*(1,16)= 1.59, *p*=0.23], or BMIZ [*F*(1,16) = 1.26, *p*=0.27]. However, this sample size is very small.

For those who introduced to food between 18 – 25 weeks, a significant difference was found in WAZ [*F*(1,140) = 8.70, *p*=0.004] and LAZ [*F*(1,140) = 6.11, *p*=0.015] for infants receiving any breast milk (*n*=86) versus only formula (*n*=59). Infants receiving any formula were both longer and heavier, but no significant difference was found in BMIZ [*F*(1,140) = 0.84, *p*=0.36]. For infants receiving only breast milk (*n*= 75) versus any formula (*n*=70), no significant difference was found in WAZ [*F*(1,140) = 1.80, *p*=0.18] or BMIZ [*F*(1,140) = 0.39, *p*=0.54]. However, infants receiving any formula were significantly longer [*F*(1,140) = 6.06, *p*=0.015].

For those who started complementary foods at 26 weeks or more, no significant differences were seen between infants receiving any breastmilk (*n*= 75) or only formula (*n*= 20) for WAZ [*F*(1,90) = 0.56, *p*=0.81], [*F*(1,90)= 0.49, *p*=0.49], or BMIZ [*F*(1,90) = 0.23, *p*=0.64]. Similarly, no significant differences were seen in WAZ [*F*(1,90) = 0.331, *p*=0.57], LAZ [*F*(1,90)=1.35 *p*=0.25], or BMIZ [*F*(1,90) = 0.07, *p*=0.80] for infants receiving only breast milk (*n*= 29) or any formula milk (*n*= 66).

6.7. Discussion

This chapter explored the impact of the timing of introduction to complementary foods upon growth, considering also how timing interacted with milk feeding type. It confirmed existing research that the majority of mothers are introducing solid foods before six months old (McAndrew et al., 2012) and that formula fed infants are often started on complementary foods earlier than breastfed infants (Fewtrell et al., 2003; Scheiss et al., 2010; Clayton et al., 2013; Helle, Hillesund & Overby, 2018).

The SHIFT study found no significant differences in weight in relation to timing of introduction to complementary foods. This reflects the body of prior evidence which has found no strong association between timing of solid food introduction and weight (Pearce et al., 2013; SACN, 2018). However, the profile plots revealed the 6-12-month weight gain trajectories of infants who introduced before 4 months; while statistically non-significant there were quite dramatic increases in weight relative to those who introduced after 4 months. Given that weight gain is known to track reliably over time (Wang et al., 2016), this may be concerning if this group of infants continue to gain weight at this rate.

Differences in infant length growth were found according to timing of introduction. For the whole sample, age of introduction in weeks was inversely associated with length. Likewise, introduction before 26 weeks was associated with greater length, but only in infants aged 9 – 12 months. There are a number of explanations for why length may be associated with early introduction of complementary foods both in the direction of earlier introduction increasing length and / or a longer infant triggering earlier introduction of solid foods. The differences in LAZ were also significant among the longitudinal data set with the very early group (<17 weeks) being the only group showing increases in LAZ from 6-12 months. However, when Bonferroni comparisons explored this further, the early group (18-25 weeks) were found to be significantly shorter than those who started complementary feeding after 26 weeks.

One explanation for these length gains amongst those who are introduced to foods earlier could be the content of the complementary feeding diet. A common first food is fortified infant cereals particularly amongst early introducers; over half of infants in the FITS study in the US weaned between 4 and 5.9 months ate iron fortified infant cereal (Roess et al., 2018). Fortified infant cereals are also prevalent in the UK (McAndrew et al., 2010; Maslin & Venter, 2017). One study has linked iron fortification in cereal with increased gains in length-for-age at 12 months in a developing country setting (Diana et al., 2017). However, the literature is inconsistent with other studies have found that iron fortification either had no effect or impaired growth (of both length and weight) particularly in iron-replete infants (Pasricha, Hayes, Kalumba & Biggs, 2013; Lonnerdal, 2017). However, it may be more likely that cow's milk powder in the infant cereals, is exacerbating length gains, rather than the iron fortification (Diana et al., 2017; Grenov & Michaelsen, 2018). Infants who are also being fed formula milk, may have even greater intakes of cow's milk protein. Indeed, the SHIFT study found that when compared to exclusively breastfed infants, formula fed infants who were introduced to complementary foods 18-15 weeks had significantly greater linear growth.

It is also possible that infant body composition is driving early introduction of solid foods. The longer length in relation to weight, seen in infants introduced to complementary foods early, resulted in lower BMI, possibly giving the appearance of a 'thinner' baby. Mothers of thinner looking babies may therefore choose to introduce complementary foods earlier because of perceptions of insufficient satiety and growth from milk feeding alone. Conversely, babies with a 'chubbier' appearance may be perceived by the mother to be growing well and more satisfied by milk feeding. Misconception of hunger, readiness for complementary foods or concern over infant size are recurrent themes amongst mothers who introduce complementary foods early (Anderson et al., 2001; Arden, 2010; Brown & Rowan, 2015).

This consideration of length as a variable of growth in its own right is important not only because it might help us understand outcomes or drivers of timing of infant feeding upon length but because of the relatively sparse evidence considering the impact of length gains. As discussed in the literature review (section 2.13.), length gains in infancy have been associated with later risk of overweight obesity in some studies (Rasmussen & Johansson, 1998; Monteiro et al., 2003; Elks et al., 2010; Belfort et al., 2013), but the evidence is limited due to lack of attention to length as an aspect of growth in most studies.

The data also highlighted a notable interaction between timing of complementary foods and milk feeding. Infants who were formula fed had a greater length and weight compared to breastfed infants when introduced to complementary foods at 18 – 25 weeks but not if introduction occurred after 26 weeks. In the SHIFT study sample the group of infants who were introduced to complementary foods before four months and also breastfed was too small to confidently explore this relationship.

Previous research has suggested that timing of introduction of complementary foods may interact with milk feeding type to affect growth, for example, Huh and colleagues (2011) also found that timing of solid food introduction was not associated with odds of obesity at age 3 among breastfed infants, however among formula fed infants early introduction of complementary foods was associated with a four-fold increase in odds of obesity. A more recent study of over 2500 infants found that associations between early complementary foods introduction and BMI were attenuated when adjustments were made for breastfeeding duration in a dose dependent association (Azad et al., 2018). Other studies have found that delaying complementary feeding, combined with ongoing breastfeeding up to 12 months confers a lower risk of overweight and obesity in childhood at 2-4 years (Moss & Yeaton, 2014) and up to 9 years (Papoutsou et al., 2018). However as is often the case in research in this field, length was not considered.

It appears therefore, that the combination of formula feeding and early complementary feeding exacerbates early growth, which may potentially continue onto childhood. Previous research has shown that infants who are formula fed and introduced to complementary foods before six months have larger intakes of protein (Noble & Emmett, 2006). In a Danish cohort, higher protein levels in the infant diet at 9 months were associated with increased growth in both length and weight (Hoppe, Molgaard, Thomsen, Juul & Michaelsen, 2004). Protein intake stimulates insulin-like growth factor, increasing infant growth (Luque et al., 2016).

While formula exposure itself may be attributed to increases in weight, it may also be the case that breastfeeding is having a protective effect. This may be due to the effects of bio-active appetite regulation hormones contained within breastmilk (Ballard & Morrow, 2013; Chan et al., 2017) or the early differences in the infant microbiome that may protect breastfed infant against risk of overweight (Korpela et al., 2017) which may continue to protect the baby once complementary foods are introduced. Studies have found that the respective microbiomes of breastfed and formula fed infants continue to differ even after complementary foods are introduced although these findings are preliminary and need further investigation (Fallani et al., 2011; Pannaraj et al., 2017). Very recent research (published a couple of weeks before this thesis submission) from the US appears to support this hypothesis (Ville, Levine, Zhi, Lararia & Wojcicki, 2019).

It is also likely that the behavioural differences between breastfed and bottle-fed babies continue into the complementary feeding period. Mothers who bottle-feed are more likely to have a controlling feeding style, and bottle fed babies are often encourage to finish the contents of a bottle (Brown et al., 2011a; Li et al., 2012). Similar maternal controlling feeding behaviours may continue into complementary feeding mealtimes, meaning that infants consume more. A pressuring feeding style in infancy has been associated with greater energy intake (Thompson et al., 2013) and in toddlers has been associated with increased weight (Lumeng et al., 2012). Earlier introduction of solid foods is often driven by a belief that an infant need to consume more and therefore may also lead to a more pressurising feeding approach (Brown & Lee, 2010; Brown & Rowan, 2015). Conversely, in line with a more responsive feeding style, breastfeeding mothers may be more likely to be more in tune with their baby's subtle cues of hunger and satiety throughout the complementary feeding period (DiSantis, Hodges & Fisher, 2013). Breastfeeding may also be involved in early learning of satiety and infant self-regulation of intake. The 'baby-led', on demand nature of breastfeeding means that the infant gets used to controlling the amount consumed. Studies have shown that when complementary foods are introduced breastfed infants adapt and reduce their milk intake accordingly, whereas formula fed infants do not (Heinig et al., 1993; Noble & Emmett, 2006; Ong et al., 2006). Breastfed infants have been shown to be more satiety responsive in older childhood (Brown & Lee, 2012).

These data add to the evidence that delaying complementary feeding until 26 weeks does not appear to be detrimental to infant growth, which was the finding of the latest UK SACN review (2018). Longitudinal analyses found that while those who waited until 26 weeks to start complementary foods had the lowest weight at 6 months, by 12 months these infants were the closest to the mean WAZ of 0 (the 50th percentile). On the other hand, infants who introduced to complementary feeding before the recommended age, had already acquired a greater weight by 6 months. While the trajectory rate of growth from 6-12 months was similar, the early complementary feeding groups were starting from a higher baseline at 6 months, and therefore had the greatest weight-for-age by 12 months. This finding was not statistically significant in this study, probably due to small sample sizes, but does show a potentially concerning trend in the growth trajectories of infants introduced to complementary feeding early.

The limitations of this research, as in Chapter 4 were that the demographic background of the mothers was generally older, with higher levels of education and breastfeeding than the general population, limiting the generalizability of these results however this is a common occurrence across health research (Nilsen et al., 2009). Breastfeeding initiation and continuation rates were also higher compared to UK averages (McAndrew et al., 2012) although this enabled differences in milk feeding groups to be analysed. While sample size and power were broadly deemed adequate (see section 3.7.5.) sample sizes in some sub-groups were relatively small, in particular, the older more educated demographic of the sample resulted in low numbers of infants being introduced to complementary foods 'Very Early' (<=17 weeks) meaning that calculations in this group were sometimes not possible or likely underpowered.

To sum up, the findings presented in this chapter revealed that breastfed infants are more likely to start complementary feeding later than formula fed infants. Mean weight and length were greater among infants who were introduced to complementary foods before 4 months, though this was only statistically significant for length. However, those who delayed complementary feeding until 6 months had a significantly greater BMI (perhaps due to having shorter length). It was suggested that longer length in early introducers may be as a result of greater protein intake (from formula or infant cereals) or that these babies had a thinner appearance, prompting mothers to encourage intake by introducing food earlier. The consideration of length was therefore highlighted as an aspect that is not often explored in prior literature. Longitudinal analyses revealed non-significant but interesting trends, with those introducing very early (<17 weeks) having steep inclines in both weight and length, which could be problematic if continued. The steep BMI trajectory amongst those who delay complementary feeding until 6 months, again appears to be due to shorter length rather than greater weight. The implications of this are not clear and further research is needed to explore the long term effects of decreased length gains relative to weight.

However, the number introducing complementary foods before 4 months was low in this sample, and are getting fewer in the general population, while early introduction (between 4-5 months) appears to be prevalent (McAndrew et al., 2012). This chapter revealed that within this group of infants (who introduced complementary foods between 18-25 weeks), those who were also fully formula fed were heavier and longer indicating that there may be a combined effect of formula feeding and early complementary feeding which is exacerbating overall growth. This was not seen in those were formula fed but who delayed complementary feeding, perhaps suggestive of a mitigating effect of delaying complementary feeding, or that there is a difference in the feeding style of mothers who delay.

The method of complementary feeding (BLW or SCF) is likely to have differed between infants which will have also inevitably affected the age at which complementary feeding can begin, and it is not known how much of the difference seen can be attributed to the feeding method rather than the age of introduction. Likewise, the degree of complementary feeding may have varied. Infants may have been introduced to complementary foods very gradually, with only a couple of spoons of food/ finger foods per day for many weeks, whereas others may have progressed more quickly. Furthermore, the content of the complementary diet may differ between infants. An infant introduced to complementary foods with fruit or vegetables may grow differently to an infant starting on baby porridge containing cow's milk powder. The associations between these factors will therefore each be explored in the following chapters, beginning with an exploration of complementary feeding methods.

CHAPTER 7: Exploring complementary feeding methods and infancy growth

7.1. Rationale

The next aspect of a baby-led approach is how the infant is introduced to complementary foods – are they allowed to self-feed family foods or do mothers adopt a standard complementary feeding method and spoon-feed purees to their infant?

This is often the key focus of previous research that has examined the impact of the baby-led weaning method to complementary feeding, considering the element of self-feeding of whole foods to be the only or primary interest, with other factors such as timing of introduction to complementary feeding and milk feeding perhaps controlled for. Self-feeding is indeed an important part of BLW, but not the only one.

Previous research on baby-led weaning has often grouped both self-feeding and texture of food together as forming the BLW method. Although these two behaviours are obviously linked (it is difficult to spoon feed a sandwich for example) they are, in terms of understanding more about how BLW might work, two distinct behaviours.

Therefore, this chapter will examine whether this aspect of BLW – degree of infant self-feeding – is associated with infant growth. Again, how this interacts with the rest of their feeding experience i.e. milk feeding will be considered. Texture (puree or whole foods) will be considered along with the content of the diet in chapter 9.

7.2. Background

In terms of how infants are introduced to complementary foods, a baby-led weaning (BLW) method, where infants self-feed family foods has been proposed to promote healthier weight gain trajectories when compared with a standard complementary feeding (SCF) approach, which tends to comprise more spoon-feeding. Research with mothers who follow baby-led weaning highlights a perception that infants have greater control over their intake of food and therefore demonstrate greater satiety responsiveness (regulation of food intake), supporting a healthy weight (Brown & Lee, 2013; Rapley, 2015; Arden & Abbott, 2015).

Research examining the impact of BLW upon satiety responsiveness is mixed. In one study infants aged 18 – 24 months who followed a baby-led method of introducing complementary foods were rated as more satiety responsive compared to those who had been spoon-fed (Brown & Lee, 2015). Conversely in a more recent study no significant difference was found between weaning approach groups (Komninou et al., 2019) and in a trial of a baby-led versus standard weaning approach, baby-led weaning was associated with reduced satiety responsiveness at 24 months (Taylor et al., 2017).

Research into BLW is relatively new and has often been exploratory and there have been very few published studies directly exploring the association between a BLW approach and childhood overweight. In two cross-sectional studies based in the UK, a BLW approach was associated with a lower weight and reduced incidence of overweight amongst infants aged 18 – 24 months (Brown & Lee, 2015) and in preschool children (Townsend & Pitchford, 2012). However, in both studies mothers who participated were self-selecting and both relied on maternal self-report of infant weight of many of the infants.

Conversely, one study which looked at the infancy growth period specifically, found no difference in growth measures between BLW and SCF infants at 12 months (Taylor et al., 2017). However, there were adaptations made to the baby-led feeding approach examined in the BLISS study (the BLISS intervention) and this means that the intervention may have differed from how many families practice BLW in the community. Families were encouraged to offer their infants iron-containing and energy dese foods at every meal, as there was concern that infants may not self-feed sufficient calories. Additionally, some cross over between the arms occurred as would be expected with any behavioural based trial. At seven months 47% of BLISS infants were being 'fed by adult and child' compared to 52% in the control group (Taylor et al., 2017).

Infant growth is affected by many factors and it is unlikely that any one behaviour in insolation will affect weight trajectories. As noted, considerable research has shown the protective impact of breastfeeding upon infant weight. Although differences in milk content partly explain this, through breast milk having a lower protein content alongside bio-active properties that can support appetite regulation (Chan et al., 2017), differences in feeding style have also been identified. Compared to bottle feeding, breastfeeding is associated with a more responsive feeding style (Brown et al., 2011a), lower intake of milk (Hester, Husted, Mackey, Singhal & Marriage, 2012) and greater satiety responsiveness (Brown & Lee, 2012).

Research has not considered how milk feeding and method of introduction of complementary foods might interact to affect weight gain trajectories. In the BLISS trial, breastfeeding rates were higher than average, with New Zealand breastfeeding rates considerably higher than UK breastfeeding rates. In the cross-sectional studies, breastfeeding duration was either used as a control variable (Brown & Lee, 2015; Komninou et al., 2019) or not considered (Townsend & Pitchford, 2012).

Milk feeding method has been shown to interact with timing of complementary feeding to affect weight, in prior research (Huh et al., 2011 Papoustou et al., 2018) and in the SHIFT study (see chapter 6). This impact has been attributed to bottle fed infants being less likely to reduce their intake of milk when complementary foods are added to the diet (Noble & Emmett, 2006; Heinig et al., 1993), but may also be due to the differences in feeding style among mothers who formula feed or breastfeed. Therefore, it is possible that milk feeding may continue to interact with method of introducing complementary foods to affect infant growth.

The aim of this chapter is to examine the impact of method of complementary feeding and how it interacts with milk feeding upon infant growth during the first year using solely researcher led measurements.

This chapter will address the following key questions:

1) Is there a relationship between infant self-feeding and infant growth?
2) Is there a relationship between infant self-feeding and growth between 6 and 12 months? – Longitudinal data analysis.
3) Is there an interaction between feeding method, milk feeding type and growth? Separating breastfed and formula fed infants.

Note: An edited version of this Chapter has been submitted as: Jones, S., Lee, M. & Brown, A. Spoon-feeding is associated with increased weight compared to baby-led weaning in formula–fed but not breastfed infants. Submitted to Maternal and Child Nutrition. July 2019

7.3. Participants

For full details of participants please refer to chapter four.

7.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Defining BLW: The self-feeding aspect.

As discussed in Chapter 3, a common problem in BLW research is that the definition of BLW can vary between both researchers and parents. In particular, when parents are asked to self-identify with a BLW approach, actual practices can vary widely (Cameron et al., 2013). Brown and Lee (2010; 2011; 2015) have highlighted two key principles of BLW, which must be present from the start of complementary feeding:

- Infant self-feeding.
- Consumption of foods in their whole form.

In the SHIFT study, parents were therefore not asked to self-define whether they followed a BLW but to select the degree of infant self-feeding and texture of foods offered at the start of the complementary feeding process (see Chapter 3).

This chapter will focus only on the self-feeding aspect.

However, texture in itself may also be important. The texture of the foods offer can affect food familiarity, acceptance and speed of consumption (Rapley, 2015b). Therefore, texture of foods offered will be returned to later in Chapter 9, alongside the exploration of the content of diet offered.

7.5. Data analysis

Data were analysed as described in Chapter 3. Where the data met parametric assumptions, Multivariate Analysis of Co-Variance (MANCOVA) were used to explore between-subjects group differences. When parametric assumptions were not met, non-parametric equivalents were used (Mann-Whitney U or Kruskall-Wallis). Chi Square or Exact tests with Monte Carlo simulations were used to explore associations between categorical variables. Tests used will be described alongside the presentation of results.

Longitudinal analyses

Longitudinal data analysis was also separately undertaken for infants with more than one measurement. Longitudinal data were analysed using two-way repeated measures

ANOVA to explore the interaction between within-subject (time points) differences and between-subjects (group) differences.

7.6. Results

As seen in Table 20, 109 infants were defined as being predominantly self-feeding and 160 were predominantly being spoon-fed.

Table 20: Descriptive statistics. Method groups by self-feeding.

Method group	*n*	%
Self-feeding (BLW)	109	40.5%
Spoon-fed (SCF)	160	59.5%
Total	269	100%

Controlling for covariates

Maternal age, education and infant birthweight were covariates throughout. Mothers who follow BLW tend to be older and have a higher educational level (Brown & Lee, 2010) although this is not consistent across all studies (Cameron et al., 2013). In this sample however, no significant associations were found for either maternal age [U=7763, p=0.24] or maternal education [X^2(4)=2.28, p=0.68] and feeding method.

Prior research has found that mothers who follow a baby-led weaning method are more likely to breastfeed (Brown & Lee, 2010; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017). In the SHIFT study infants who self-fed were more likely to be breastfed, and spoon-fed infants were more likely to be formula fed. A Chi-square test found that this relationship was statistically significant [X^2 (2) =46.2, p<0.000]. Furthermore, baby-led weaning is thought to encourage later introduction of complementary foods as it depends upon babies' developmental readiness to self-feed which usually occurs at around 6 months (Arden, 2010; Brown & Lee, 2010; Moore et al., 2014, Erickson, 2015). In the SHIFT study a Mann-Whitney test showed that BLW infants started complementary feeding at a later age (*Mdn*= 26 weeks) than the SCF infants (*Mdn*= 23.5 weeks) and this difference was statistically significant [U=4420.5, p<0.000]. Therefore, due to these associations and the precedence of prior literature, milk feeding type at time of measurement and age of introduction to complementary foods were also controlled for.

QUESTION 1: Is there a relationship between infant self-feeding and infant growth?

A series of MANCOVAs were performed to explore any differences in WAZ, LAZ, BMIZ and also WAZV between the two method groups controlling for maternal age, education, birth weight, milk feeding type at time of measurement and age of introduction to complementary foods.

Weight-for-age z-score (WAZ)

No significant differences in WAZ were found according to feeding method [F (1, 254) = 3.34, p=0.07]. However, the BLW group had a lower mean WAZ (M=0.05, SD:1.05) compared with the SCF infants (M=0.28 SD:0.90). All measurements were then used for age group analysis (Table 21). No significant differences in WAZ were seen within the age group analyses.

Length-for-age z-score (LAZ)

LAZ significantly differed between the groups [F (1, 254) = 6.25, p=0.01]. The SCF infants had the greatest mean LAZ (M=0.11, SD:1.08) and the BLW infants were the shortest (M=-0.42, SD: 1.20). However, when broken down by age group (Table 21) the differences in LAZ disappeared.

BMI-for-age z-score (BMIZ)

BMI did not significantly differ between the groups [*F* (1, 254) = 0.29, *p*=0.59], though the BLW infants had the greatest BMI (*M*=0.48, SD:0.97) compared to the SCF infants (*M*=0.30, SD:1.03). The lower BMI in the spoon-fed infants appears to be as a result of longer length rather than lower weight. No significant differences in BMIZ were seen within the age group analyses (Table 21).

Table 21: Method groups (at time of introduction to complementary foods) and growth outcomes.

Age group	**Method group**	***n***	**Mean WAZ (SD)**	**ANCOVA WAZ**	**Mean LAZ (SD)**	**ANCOVA LAZ**	**Mean BMIZ (SD)**	**ANCOVA BMIZ**
6 – 8 months	BLW	54	0.08 (1.06)	*F* (1, 114) = 1.60, *p*=0.21	-0.35 (1.32)	*F* (1, 114) = 3.42, *p*=0.07	0.50 (0.92)	*F* (1, 114) = 0.06, *p*=0.80
	SCF	67	0.41 (0.94)		0.30 (1.14)		0.36 (1.00)	
9 – 12 months	BLW	53	0.03 (1.06)	*F* (1, 133) = 0.88, *p*=0.35	-0.49 (1.07)	*F* (1, 133) = 2.53, *p*=0.11	0.46 (1.03)	*F* (1, 133) = 0.32, *p*=0.57
	SCF	87	0.18 (0.86)		-0.02 (1.03)		0.26 (1.03)	

The finding that the difference in LAZ disappeared when broken down into sub-groups, prompted further exploration. Due to the fact that there is a relatively large age range of infants in the study sample (*M*=42.5 weeks, SD=9.62; range: 26 to 59), and that there may be differences in feeding in the early complementary feeding period (6-8 months) and later complementary feeding period (9-12 months), and in addition there may be a potential effect of length of time of exposed to the feeding method, it was considered that growth outcomes might differ dependent on the age of the infant at the time of measurement. Therefore, within each feeding method group, partial correlations between each growth outcome and the age of the infant at the time of measurement were undertaken (controlling for maternal age, education, infant birthweight, age of introduction to complementary foods and milk feeding type at the time of measurement).

Amongst infants who were BLW at introduction to complementary foods (n=109), no significant associations seen for WAZ [r=0.019, p=0.85], LAZ [r=0.029, p=0.77], or BMIZ [r=0.014, p=0.89] and infant's age at the time of measurement. Similarly, amongst infants who were SCF at introduction to complementary foods (n=160), no significant associations were found for WAZ [r=0.027, p=0.75], LAZ [r=-0.017, p=0.84], or BMIZ [r=0.048, p=0.56] and infant's age at the time of measurement.

Rapid weight gain

No significant difference was found in WAZV (change in weight-for-age-z-score from birth to measurement age) between the two method groups in the whole sample [F (1, 254) =1.38, p=0.24]. WAZV was then grouped into whether they showed rapid weight gain (an increase in WAZ of > 0.67) or not. Cross tabulation showed that 26.3% of infants in the BLW groups showed rapid weight gain, compared to 22.9% of those in the SCF group. However, a Chi Square test found that this difference was not statistically significant [X^2 (2, 269) =0.38, p=0.54].

Feeding method at the time of measurement

Complementary feeding method may change across the complementary feeding period. In particular, infants who start complementary feeding by spoon feeding may progress onto self-feeding as they get older. The data were therefore analysed again to explore whether infants' complementary feeding method, at the time of measurement, rather than that at introduction, was associated with growth. 182 infants were predominantly self-feeding at the time of measurement and 86 were being spoon-fed 50% of the time or more. One infant had missing data for self-feeding status at time of measurement. No statistically significant differences were seen in relation to self-feeding and WAZ [F (1, 253) = 0.54, p=0.47], LAZ [F (2, 253) = 2.96, p=0.09], or BMIZ [F (1, 253) = 1.50, p=0.22]. No significant differences were seen when the sample was broken down by age group (see Table 22).

Table 22: Method groups (at the time of measurement) and growth outcomes.

Age group	Method group	*n*	Mean WAZ (SD)	ANCOVA WAZ	Mean LAZ (SD)	ANCOVA LAZ	Mean BMIZ (SD)	ANCOVA BMIZ
6 – 8 months	Self-feeding	72	0.20 (1.04)	*F* (1, 114) = 0.16, *p*=0.69	-0.16 (1.34)	*F* (1, 114) = 1.62, *p*=0.21	0.49 (0.92)	*F* (1, 114) = 0.33, *p*=0.57
	Spoon-feeding	49	0.35 (0.95)		0.27 (1.08)		0.32 (1.07)	
9 – 12 months	Self-feeding	103	0.11 (1.02)	*F* (1, 132) = 0.03, *p*=0.87	-0.24 (1.11)	*F* (1, 132) = 0.48, *p*=0.49	0.40 (1.04)	*F* (2, 132) = 2.53, *p*=0.11
	Spoon-feeding	36	0.11 (0.66)		0.04 (.93)		0.12 (0.99)	

Rapid weight gain

No significant difference was found in WAZV (change in weight-for-age-z-score from birth to measurement age) between the two method groups in the whole sample based on feeding method at time of measurement [*F* (1, 253) =0.37, *p*=0.54]. WAZV was then grouped into whether they showed rapid weight gain (an increase in WAZ of > 0.67) or not. Cross tabulation showed that 22.1% of infants who were being spoon fed showed rapid weight gain, compared to 26.4% of those who were self-feeding. However, a Chi Square test found that this difference was not statistically significant [X^2 (1,268) =0.73, *p*=0.45].

Overweight and underweight

According to feeding method at the introduction of complementary foods, eight (7.3%) of infants were classed as overweight (BMIZ>2) compared with seven in the SCF group (4.4%). A greater proportion of infants were classed as 'possible risk of overweight' (BMIZ>1) in the SCF group (*n*=35, 21.9%) compared with only 16.5% (*n*=18) in the BLW group. An exact test did not find significance [*p*=0.38].

In terms of feeding method at time of measurement, twelve infants (6.6%) were overweight in the self-feeding group, compared with three (3.5%) in the spoon-feeding group. Proportion of infants at risk of overweight was also greater in the self-feeding group (n=38, 20.9%) compared with fourteen (16.3%) in the spoon-feeding group. However, this finding was statistically not significant [p=0.40].

Underweight was also explored, by looking at infants with a WAZ of less than -2. A cross tabulation and Exact test was performed and found significant differences in underweight according to method group as defined at the introduction to complementary feeding [p=0.03]. Four infants (1.5% of all infants) who self-fed from the start of complementary feeding (BLW group) (3.7% of this group) were categorised as underweight compared to 0 infants from the SCF group. However, when feeding method at time of measurement was explored, similarly four infants were classed as underweight, and all were within the self-feeding group, however as a proportion of the group this equated to only 2.2% (due to more infants self-feeding by the measurement age, n=182) and as a result, the significance disappeared [p=0.31].

QUESTION 2: Is there a relationship between infant self-feeding and growth between 6 and 12 months? – Longitudinal data analysis.

Longitudinal data analysis examined the trajectory of infants who were weighed and measured once at around 6 months and once at around 12 months (N=105).

Table 23: Self feeding at introduction to complementary feeding and at 12 months. Longitudinal participants.

Time-point	**Self-feeding (*n*)**	**Spoon-feeding (*n*)**
At introduction to complementary feeding	32	73
At 12 months	74	31

Birthweight

First, a t-test was performed to explore whether infant birthweight was associated with complementary feeding method (at introduction to complementary feeding). No significant difference was found [t (103) = 0.04, p=0.97].

Birth to 6 months

An ANCOVA compared weight gain velocity (WAZV) from birth to age 6 months between who were introduced to complementary food via different methods. The purpose of this analysis was to explore whether how rapidly infants grow appeared to predict the complementary feeding method chosen. Maternal age, education, infant birth weight and milk feeding type at birth were covariates.

No significant differences in WAZV were observed between ages 0-6 months, between infants who went on to either BLW (M-0.41, SD: 1.09) or SCF (M=-0.36, 1.05) [F (1, 97)= 0.03, p=0.87].

6 to 12 months

Again, an ANCOVA compared weight gain velocity (WAZV) from six to twelve months between infants fed using different complementary feeding methods. Maternal age, education, infant birth weight and milk feeding type at 6 months were covariates.

No significant differences in WAZV were observed between ages 6-12 months, between infants who went on to either BLW (*M*=0.15, SD: 0.61) or SCF (*M*=0.29, 0.59) [F (1, 97) =1.31, p=0.25].

Repeated measures ANOVAS were also performed, to find out if there was any difference in WAZ, LAZ or BMIZ based on feeding method at the start of complementary feeding, whether self-feeding (BLW) or spoon-feeding (SCF). Analyses controlled for maternal age, education, birth weight and milk feeding type (at time two) and age of introduction to complementary feeding.

Weight-for-age z-score

Table 24 shows the mean WAZ for each method group. The between subject effect was not significant [F (1, 94) =0.03, p=0.86] and interaction effect between time and method group was also not statistically significant [F (1, 94) =1.79, p=0.18]. While no statistically significant differences were found, the profile plot (Figure 10) demonstrates an increase in WAZ trajectory between both groups with the sharpest incline observed in the SCF group. On the other hand, infants in the BLW group demonstrated a more gradual weight-for-age increase.

Table 24: Longitudinal differences in WAZ and method group at introduction to complementary feeding.

	n	**Time point One Mean WAZ (SD)**	**Time point Two Mean WAZ (SD)**
BLW	30	-0.04 (1.07)	0.09 (0.94)
SCF	71	-0.05 (0.97)	0.24 (0.99)

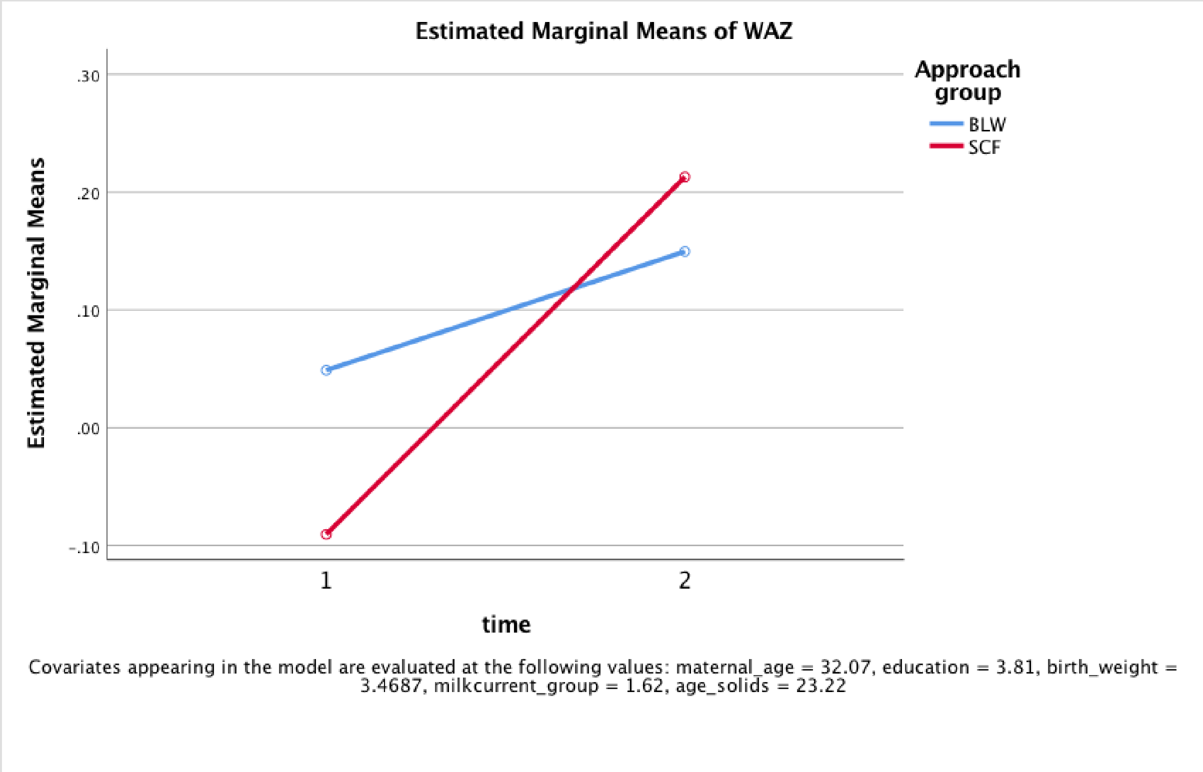

Figure 10: Longitudinal trajectories of WAZ and feeding method group at introduction to complementary feeding.

Length-for-age z-score

Table 25 shows the mean LAZ for each method group. The between subject effect was not significant [F (2, 94) =0.22, p=0.64] and interaction effect between time and method group was also not statistically significant [F (2, 94) =0.12, p=0.73]. The profile plot (Figure 11) shows that SCF infants had a decline in their length-for-age while the BLW length-for-age stayed about the same.

Table 25: Longitudinal differences in LAZ and method group at introduction to complementary feeding.

	n	**Time point One Mean LAZ (SD)**	**Time point Two Mean LAZ (SD)**
BLW	30	-0.38 (0.72)	-0.39 (0.87)
SCF	71	-0.002 (1.02)	-0.03 (1.08)

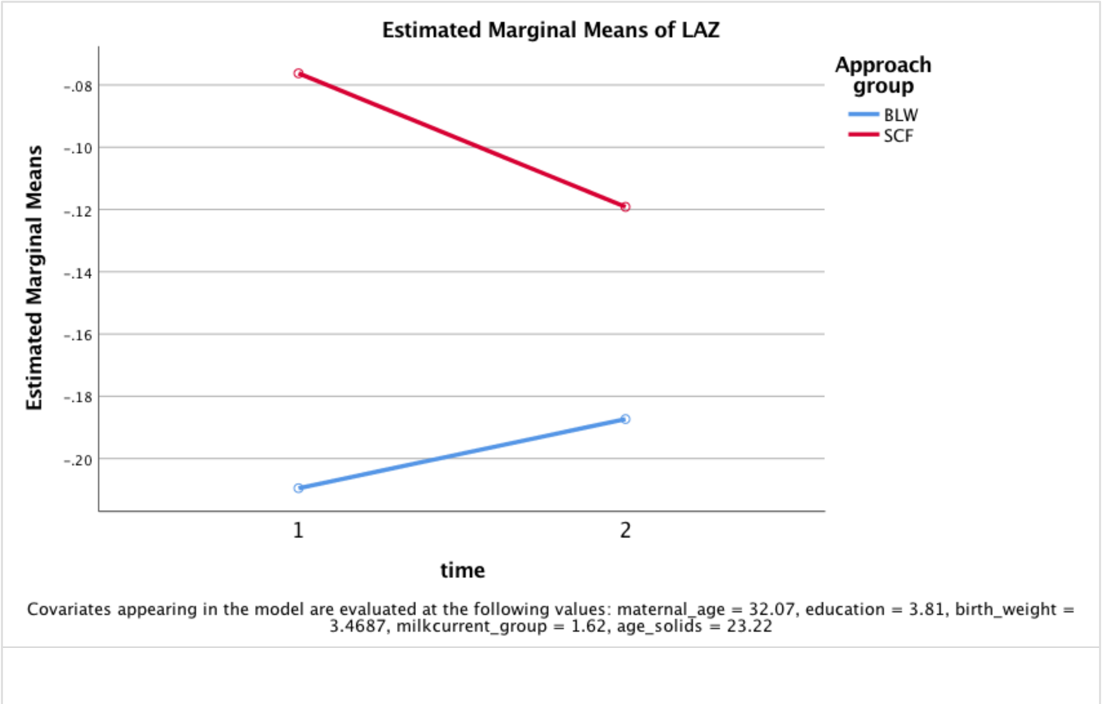

Figure 11: Longitudinal trajectories of LAZ and feeding method group at introduction to complementary feeding.

BMI-for-age z-score

BMIZ was explored for each method group (Table 26). The between subject effect was not significant [F (2, 94) =1.003, p=0.32] and interaction effect between time and method group was also not statistically significant [F (2, 94) =3.34, p=0.07]. The profile plot (Figure 12) shows that the SCF group showed the sharpest increase in BMI. BLW infants showed a very slight and gradual increase in BMI-for age. However, these differences were not statistically significant.

Table 26: Longitudinal differences in BMIZ and method group at introduction to complementary feeding.

	n	Time point One Mean BMIZ (SD)	Time point Two Mean LAZ BMIZ (SD)
BLW	30	0.32 (1.11)	0.49 (0.97)
SCF	71	-0.08 (1.19)	0.34 (1.13)

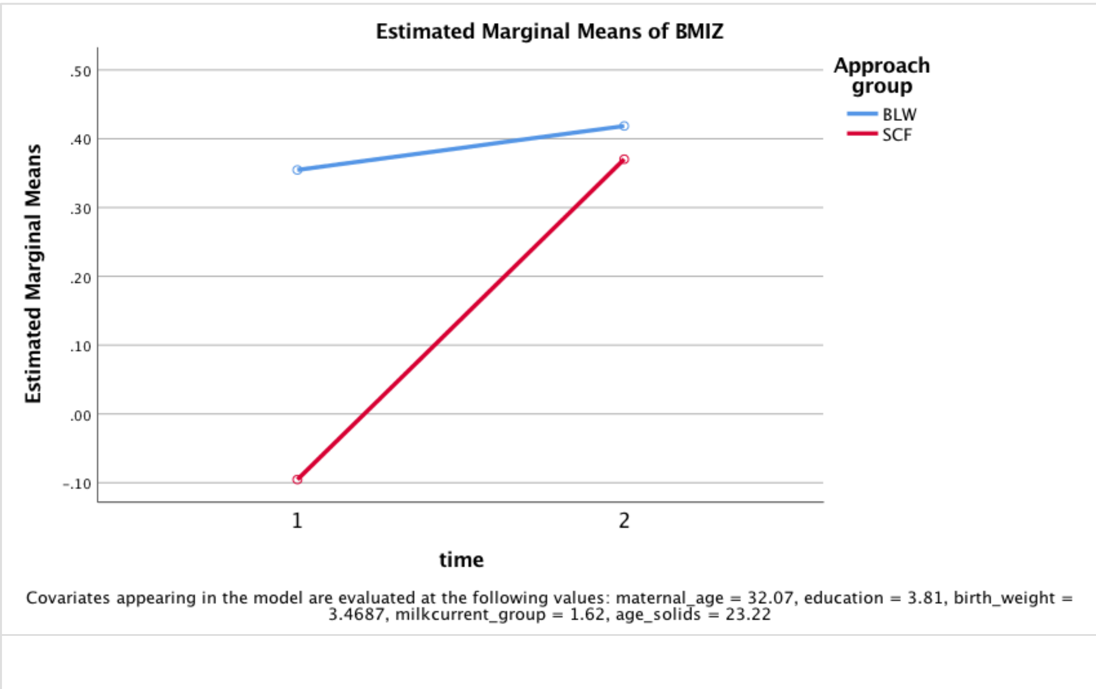

Figure 12: Longitudinal trajectories of BMIZ and feeding method group at introduction to complementary feeding.

QUESTION 3: Is there an interaction between feeding method, milk feeding type and growth? Separating breastfed and formula fed infants.

Within each feeding method group, differences in growth between breast and formula fed infants were examined. Any breastfeeding versus exclusive formula feeding and exclusive breastfeeding versus any formula feeding were both examined. Control variables were maternal age, education, birth weight and timing of complementary foods introduction.

Within the BLW group, no significant growth differences were found for WAZ [$F(1,101) = 0.018$, $p=0.89$], LAZ [$F(1,101)= 0.008$, $p=0.93$] or BMIZ [$F(1,101) = 0.004$, $p=0.95$] based on whether the infant had received any breastmilk ($n=93$) or were fully formula fed ($n=14$). No significant differences were seen for WAZ [$F(1,101) = 0.003$, $p=0.96$], LAZ [$F(1,101)= 0.08$, $p=0.78$] or BMIZ [$F(1,101) = 0.02$, $p=0.89$] in infants who were exclusively breastfed ($n=82$) versus any formula feeding ($n=25$).

However, a significant difference in WAZ was seen amongst the SCF infants [$F(1,148) = 4.65$, $p=.03$]. Fully formula fed infants ($n=80$) were found to be significantly heavier ($M= 0.38$, SD:0.81) than infants who had received any breastfeeding ($n=74$) ($M=0.17$, SD:0.98). No significant differences were seen for LAZ [$F(1,148)=0.42$, $p=0.52$] or BMIZ [$F(1,148) = 2.43$, $p=0.12$] between full formula feeding and any breastfeeding. No significant differences were seen in relation to exclusive breastfeeding ($N=56$) versus any formula feeding ($n=98$) for WAZ [$F(1,148) = 0.47$, $p=0.50$], LAZ [$F(1,148)= 0.07$, $p=0.79$]or BMIZ [$F(1,148) = 0.03$, $p=0.85$].

7.7. Discussion

This chapter explored the impact of method of introducing complementary foods upon growth at 6 – 12 months, considering further how this might interact with milk feeding method. It found no significant differences in weight or BMI between infants introduced to complementary foods via spoon or self-feeding but found that infants who were spoon-fed were significantly longer than those who were self-feeding. However, no significant differences were found for method of feeding at time of measurement. Trajectories of infant growth between 6-12 months, while non-significant, revealed trends of infant growth, with SCF infants showing sharp inclines in both weight and BMI. Although no significant difference was seen in the growth of infants who were self-feeding according to milk type, infants who were both spoon-fed and exclusively formula fed were significantly heavier than those spoon-fed alongside being breastfed. The findings have important considerations for how responsive feeding may be a key aspect of growth in the latter part of infancy.

First, infants who were following a traditional complementary feeding method were longer than those that were self-feeding. It is possible that method of complementary feeding is affecting length gains due to differences in infant diet. Spoon-fed infants are more likely to consume fortified infant cereals when compared with self-feeding infants, especially when introduced to solid foods at an earlier date; as discussed in prior chapters, cow's milk infant cereals may be promoting growth in length (Diana et al., 2017; Roess et al., 2018; Grenov & Michaelsen, 2018). High protein intake has been associated with rapid increases in weight and length during infancy (Heinig et al., 1993) and is a risk factor for later overweight and obesity (Hoppe et al., 2004; Michelsen & Greer, 2014).

As highlighted in the discussions arising in the previous two chapters, length growth in itself can be a predictor of later obesity, and is often neglected in research (Monteiro et al., 2003; Elks et al., 2010; Belfort et al., 2013). Therefore, it would be interesting for future research to consider the longer-term growth trajectories of infants who are longer in the early months of life.

However, a number of aspects in the data suggest that infant length may be determining complementary feeding method. LAZ was associated with method of introducing complementary food but not method at the time of measurement. LAZ was greater at time one (6 months) amongst those who introduced complementary foods with SCF, compared to those who introduced using a BLW method (however this difference did not reach significance). It may be the 'thinner' appearance of a longer baby may be prompting the decision to start complementary feeding earlier. Research has shown that concerns over infant weight and energy intake are associated with an earlier introduction of complementary foods (Arden, 2010; Brown & Rowan, 2016), which for infant developmental reasons would require a spoon-feeding approach. Indeed, in one study mothers reported that one reason they chose to spoon-feed was that they were worried their baby wouldn't eat enough (Cameron et al., 2013), whereas mothers who chose a baby-led method may be less concerned around intake of food (Brown & Lee, 2012).

Neither weight nor BMI differed between introduction groups, supporting the BLISS study findings (Taylor et al., 2017). There are a number of reasons why a baby-led method might not be affecting weight gain. First, the 6 – 12-month period may be too early for differences to emerge and the percentage of overweight children in the study was small. This may change over time and one study has shown that pre-school children who followed a baby-led weaning method were less likely to be overweight compared to those spoon-fed, although retrospective recall and some self-reporting of weight limit these findings (Townsend & Pitchford, 2012). Indeed, although in this study longitudinal analysis did not reach significance, the difference in weight change and BMI change was greater in the SCF group. If these infants followed on the same trajectories, these differences are likely to become significant over time.

Second, as baby-led weaning grows in mainstream popularity, the method may become less 'healthy'. Critics of BLW have posited that there is a potential for BLW to allow babies to eat snacks as finger foods such as crisps and biscuits (Cameron et al., 2012b) and research in larger samples exploring a 'looser' version of baby-led weaning where infants self-fed most of the time, highlighted an increased intake of such snack foods in this group (Rowan et al., 2019).

However, it might also be that examining method of introducing complementary foods in isolation is not enough and this is highlighted by differences in weight found in the sample when both milk feeding and method of complementary feeding were considered together. Although no significant difference in the overall sample for weight or BMI was seen between the method groups, infants who were spoon fed and fully formula fed were significantly heavier than those exclusively or partially breastfed, but no impact of milk feeding was seen for baby-led infants. This suggests that infant opportunity to regulate their intake of food may be playing an important role.

Breastfed infants typically have more control over their intake of milk as the amount consumed is not visible, whereas formula fed infants can be encouraged to finish a bottle (Li et al., 2012). Mothers who breastfeed are more likely to adopt a responsive feeding approach, letting their infant set the pace of feeds and worrying less around monitoring intake of milk (Brown et al., 2011a; Brown & Lee, 2013). Breastfed infants have been identified as better able to regulate their appetite as toddlers (Brown & Lee, 2012) and adolescents (Reyes et al., 2014) although not all studies are conclusive (Hathcock et al., 2014). Additionally, mothers who follow BLW have been shown to be more responsive in their feeding style showing lower control in terms of restriction, pressure to eat and monitoring (Brown & Lee, 2011).

Therefore, infants who are both spoon and bottle fed may have lower opportunity to regulate their own intake compared to infants who can regulate over different meals even if one aspect of their feeding approach (e.g. spoon or bottle) is more 'controlling'. This may be affecting weight, although research examining the longer term impact of responsive feeding in infancy is sparse. However, a large body of literature suggests that for older children, a responsive feeding style is associated with the most positive weight outcomes. For example, in a 2015 systematic review of the literature, the authors concluded that restrictive and controlling feeding practices were associated with higher child BMI at ages 4-12 years (Shloim et al., 2015).

It is also possible that mothers who are formula feeding and whose infant is already at increased likelihood of being heavier (Dewey et al., 1992; Li et al., 2012) are drawn to spoon-feeding. In this study and others there is a strong association between spoon-feeding and bottle feeding (Brown & Lee, 2010; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017), potentially due to preferred overall maternal feeding style. Both bottle feeding (Brown et al., 2011) and spoon- feeding (Cameron et al., 2013) are associated with maternal concerns around intake. Maternal general feeding style appears to be stable over time (Black & Aboud, 2011) with longitudinal research showing that mothers who encouraged their infant to finish their bottle as a baby were more likely to use higher pressure to eat at age 6 (Li et al., 2014). It would be interesting in future research to explore whether mothers who bottle feed but follow baby-led weaning were more responsive than average in their bottle feeding approach.

Finally, this chapter explored a key concern about baby-led weaning; that infants could be at greater risk of underweight due to inadequate energy intake. In terms of underweight, this study adds to finding by Taylor et al (2017) which found no concerning increased risk of underweight in the BLISS version of BLW. While higher incidence of underweight was found in BLW infants (*n*=4, 3.7%) numbers were extremely small and therefore not appropriate to draw conclusions from. The vast majority of BLW infants in the study were not underweight which is reassuring. Rapley and Murkett (2008) suggest that while it is likely that BLW might eat less than spoon-fed infants in the early stages of complementary feeding because they need time to learn the skills of handling and chewing food, they argue that lower energy intake from complementary foods may be supplemented by ongoing milk feeding. In another arm of BLISS study Erickson (2015) explored energy intake from complementary foods at 7 months and found no-statistically significant differences between the BLISS BLW approach and SCF, indicating that adequate energy intake from complementary foods is feasible with a BLW approach.

Furthermore, infants do not require as much energy from complementary foods as may often be perceived. The WHO states that for babies aged 6-8 months, 196 calories per day is sufficient from complementary foods, with a far greater proportion (486 calories) coming from milk (Michaelsen et al., 2000). Many infants may exceed this the FITS study found that infants aged 7-11 months were reported to have exceeded their energy intake by 23%, though this study was limited by self-report (Butte et al., 2010). Increased energy consumption may be more likely in spoon-feeding as discussed above. BLW, on the other hand is naturally more conducive to lower energy intake from complementary foods, and greater intake from milk, resulting in a slower rate of growth. While the longitudinal data in the SHIFT study showed no statistically significant findings, the profile plots showed that BLW babies had notably slower (but adequate) increases in weight, length and BMI. Slower rates of weight gain are thought to present a lower risk of overweight, when compared with rapid weight gain (Ong & Loos, 2006; Druet et al., 2011; Wang et al., 2016).

As mentioned previously, a key limitation of this study was self-selection; participants were older with a higher level of education and breastfeeding rates were higher than within the general population, although this enabled stronger milk feeding group analyses. While broadly the sample size met power calculation requirements (see section 3.7.5.), breaking down the sample into groups is likely to have affected power. Additionally, the majority of infants were considered a healthy BMI/weight, meaning that analysis of weight groups (under, normal, over weight) would have been underpowered.

Limitations aside this chapter explored a so-far under-researched area, highlighting a possible cumulative effect of bottle feeding which is followed by spoon feeding for increasing weight gain in infancy. This may be because both bottle feeding and spoon-feeding are likely to negatively impact satiety responsiveness due to a tendency towards a less-responsive maternal feeding style.

The following chapter will examine how infants fed in different ways transition from a diet of predominately milk onto complementary foods, and whether the proportion of milk to solids within the diet affects growth.

CHAPTER 8: Exploring the transition to complementary feeding and infancy growth

8.1. Rationale

The previous chapter looked at the impact of self-feeding aspect of BLW. However, it may be that, regardless of method of introduction (self-feeding or spoon-feeding), what is important for healthier weight gain trajectories is a more gradual introduction of moving onto complementary food, with milk remaining a large proportion of the diet, as recommended by the WHO (Michaelsen et al., 2000; WHO, 2001).

It has been suggested that BLW may offer a slower transition from milk to solid foods because the method encourages ongoing frequent milk feeding and frequent small offers of food. (Rapley & Murkett, 2008). This might be important for healthy weight trajectories because a 'little and often' approach to eating such as this has been seen to be helpful in reducing risk of overweight in children (Kaisari, Yannakoulia & Panagiotakos, 2013). However, in infancy parents are often concerned about their babies' weight and intake which may be leading to a pressurising feeding style (Anderson et al., 2001; Redsell et al., 2010), where the transition from milk to food may occur more rapidly. No published research has yet explored the impact that complementary feeding approaches may have on the transition from milk to food.

Therefore, the aim of this chapter is to examine whether this aspect of BLW – a likely slower transition from milk to food – is associated with infant growth. As it is known that milk feeding type may play a role in this, interactions with milk feeding will also be explored.

8.2. Background

WHO reports on complementary feeding support a gradual increase in food alongside milk, which should continue to comprise a large part of an infant's diet up until 12 months (Michaelsen et al., 2000; WHO, 2001). Michaelsen et al. (2000) estimated that the energy from complementary food for babies aged 6-8 months should be just over a quarter of their daily intake. The energy requirement from complementary foods should then increase gradually over time to just over half of the infant's daily energy intake by 9-12 months with decreasing requirements from breast milk. However, studies suggest that infants may be eating more energy than recommended from complementary foods, perhaps placing infants at greater risk of overweight. For example, the FITS study in the US estimated that infants aged 7-11 months exceeded their required energy intakes by 23% (Butte et al., 2010). Similarly, a Canadian study found that infants aged 7-12 months consumed over the daily recommended energy intake from complementary foods (Friel, Hanning, Isaak, Prowse & Miller, 2010).

Differences in milk feeding may contribute to how much energy infants consume once complementary foods are introduced. For exclusively breastfed infants, reducing milk feeding rapidly or stopping breastfeeding once complementary foods are introduced may pose a risk of overweight, as one study found that breastfed infants who exclusively breastfed up to 6 months and who continued breastfeeding alongside complementary foods up until 12 months had a lower risk of overweight in childhood compared with those who discontinued breastfeeding after 6 months (Papoutsou et al., 2018). This may indicate a possible protective effect of prolonged breastfeeding on appetite regulation once complementary foods have been introduced.

In terms of infancy weight gain, Azad et al (2018) found that introduction of formula to a breastfed infant (rather than complementary foods) was associated with faster weight gain from 6-12 months and increased weight and BMI at 12 months. This is again indicative of a protective effect of ongoing breastfeeding once complementary foods are introduced (but not when formula is introduced). A further explanation for this difference may be that the transition from breastfeeding to complementary foods tends to be more gradual than the transition from breastfeeding to formula which is usually abrupt (Hornell et al., 2001).

The transition from formula feeding onto solid foods is also thought to different than for breastfed infants. For example, in the DARLING study breastfed infants appeared to reduce their milk intake according to solid food calories consumed, indicating infant self-regulation of intake. Comparatively, infants who were formula fed did not reduce their intake of milk when introduced to solid foods (Heinig et al., 1993). Similar results were found in the ALSPAC study which found that breastfed infants reduced their intake of milk when complementary foods were introduced but formula fed infants did not (Noble & Emmett, 2006). Finally, in another study using ALSPAC data, infants introduced to complementary foods before six months found that formula fed infants were consuming more calories overall compared to breastfed infants (Ong et al., 2006).

There may be several explanations for differences between how breastfed and formula fed infants transition onto solid foods. First, ongoing breastfeeding may promote better appetite regulation (Li et al., 2010; DiSantis, Collins, Fisher & Davey, 2011), perhaps allowing infants to naturally cut down on how much they drink in relation to complementary foods consumed (Heinig et al., 1993; Noble & Emmett, 2006; Ong et al., 2006). However, it may also be that the feeding styles of the mothers are having an effect. For example, as discussed in the literature review, breastfeeding mothers demonstrate lower levels of control over feeding, both in terms of milk feeding, complementary feeding and beyond (Taveras et al., 2004; Farrow & Blissett, 2007; Brown & Lee, 2012). Conversely, mothers who are concerned about infant weight or intake, tend towards formula feeding, early introduction to complementary foods, spoon feeding and a more controlling feeding style (Arden, 2010; Brown et al., 2001b; Redsell et al., 2010; Brown & Lee, 2011b). Controlling feeding styles such as pressure to eat have also been linked to increased intake in infancy (Thompson et al., 2013), and increased weight in toddlers (Lumeng et al., 2012). In terms of dietary content, infants who are formula fed and also transitioned onto complementary foods quickly may also consume higher levels of protein, because of consumption of infant cereals (containing cow's milk protein), which are thought to exacerbate rapid early growth (Luque et al., 2016; Roess et al., 2018; Grenov & Michaelsen, 2018). Indeed, both the DARLING study and the ALSPAC study found that infants who were formula fed and eating complementary foods had the highest intakes of protein (Heinig et al., 1993; Noble & Emmett, 2006).

The approach taken to the introduction to complementary foods may also affect how the transition occurs. It has been suggested that spoon-feeding infants may contribute to larger intakes of food from a young age because pureed foods can be slurped off a spoon and swallowed easily, increasing speed and volume of consumption (Gisel, 1991; Rapley et al., 2015). Conversely, baby-led weaning may help encourage a slower transition onto complementary foods, first because the nature of the method is that infants must be developmentally ready to self-feed, necessitating later introduction, and second because the infant is allowed to take time to learn and practice moving food to his/her mouth, chewing and swallowing, meaning that overall intake from complementary food is lower, especially early on in the process. This is thought to be beneficial for satiety recognition, as faster speed of eating has been associated with higher energy intakes and BMI in children (Fogel et al., 2017). While some have recently suggested that this slow transition may problematic for infants' nutritional intake (Cichero, 2016), Rapley & Murkett (2008) argued that the main source of infants' energy should come from milk, supporting the WHO recommendation (2001).

Only the BLISS study has explored energy intakes from milk and complementary foods in a BLW approach. Erickson found that at 7 months, total energy intakes between the BLISS BLW group and the control group were about the same, both were slightly lower than the WHO recommendations. Furthermore, both the BLISS group and the control group consumed very little of their calories from complementary foods (less than a fifth) with the rest coming from milk (Erickson, 2015). This study therefore did not find a difference in the proportion of energy from milk or complementary foods based on feeding method, however, there was some cross-over of behaviour between the BLISS and control groups. Despite this, the study does indicate that adequate energy intake is possible with BLW even if milk is the main component of the diet.

Very little research has examined whether infants who are fed milk in different ways and then introduced to complementary foods in different ways also differ in how gradually they transition to complementary foods. Furthermore, no research has explored feeding type (specifically looking at BLW), and combined this with information on the proportion of milk to complementary foods offered, and infant anthropometric data. The aim of this chapter is therefore to explore the impact of milk feeding type, age of introduction to complementary foods, and complementary feeding method, upon infant weight, length, BMI, and weight gain velocity in the study sample.

This chapter will address the following key questions:

1) Does the transition to complementary feeding differ according to feeding method?
2) Is there a relationship between how infants transition to complementary feeding and infant growth?
3) Is there an interaction between milk feeding type and the transition to complementary foods on growth? Separating breastfed and formula fed infants.
4) Is there a relationship between how infants transition from milk to solids and growth trajectories from birth to 6 months and from 6 to 12 months? – Longitudinal data analysis.

8.3. Participants

For full details of participants please refer to chapter four.

8.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Degree of milk/complementary food offered

Mothers were asked to estimate the proportion of their infant's dietary intake that comes from milk and how much comes from food (See Figure 13).

IN THE PAST WEEK: Please describe a **typical day's** feeding:

a) How many milk feeds does your baby have in 24 hours?

b) How many times does your baby eat solids per day (meal or snack)?

c) How much of your baby's food intake comes from milk **or** solids? **Please tick one option**.

☐	☐	☐	☐	☐
All from milk. No solids.	Mostly from milk. Small amounts of solids.	About half from milk/half from solids.	Not much from milk. Mostly from solids	All from solids. No milk.

Figure 13: Extract from questionnaire. Proportion of milk to complementary foods.

Feeding variables

As described in Chapter 5 milk feeding was defined at birth (breastfeeding or formula feeding) and at the time of measurement (breastfeeding, formula feeding or combination feeding). As described in Chapter 7, feeding approach was grouped into two main approaches by degree of self-feeding at introduction to complementary feeding: baby-led weaning versus standard complementary feeding.

8.5. Data analysis

The frequencies of milk or complementary foods exposures in relation to feeding approach group were explored using Mann-Whitney U or Kruskall-Wallis tests. Associations between milk and complementary foods frequencies and continuous variables (growth outcomes, age of introduction to complementary foods, age of infants) were analysed using Spearman's correlations. Chi square or Exact tests explored relationships between categorical variables. MANCOVAs were used to analyse the differences within groups based on the proportion of milk to food offered, and growth outcomes.

8.6. Results

QUESTION 1: Does the transition to complementary feeding differ according to feeding method?

One hundred and nine infants in the sample had been introduced to complementary foods using BLW, and 160 were classed as SCF. Infants in the BLW group consumed significantly more milk feeds per day at the time of measurement (M= 6.37, SD: 2.74) infants in the SCF group (M= 4.64, SD:2.66) [U=4980.0, p<0.000]. Exposures to complementary food did not significantly differ (M= 4.00, SD: 1.45) compared to SCF infants (M=3.70, SD: 1.07) [U=7835.5, p=0.15].

These analyses were repeated by age at the time of measurement sub-group (Table 27). At 6-8 months, BLW infants received significantly more milk feeds that the SCF infants, but the number of times complementary foods did not significantly differ. However, by 9-12 months, BLW infants received significantly more offers of both milk and solid feeds.

Table 27: Feeding method and number of milk feeds/ occasions food offered.

Age	Feeding method at introduction to complementary feeding	*n*	Mean number of milk feeds (SD)	Mann Whitney U	Mean number of occasions complementary food offered (SD)	Mann Whitney U
6-8 months	BLW	55	7.11 (2.71)	*U*= 1143.0, *p*<0.000*	3.44 (1.35)	*U*=1792.0, *p*=0.48
	SCF	70	5.49 (2.60)		3.17 (0.87)	
9-12 months	BLW	54	5.62 (2.58)	*U*= 1335.5, *p*<0.000*	4.57 (1.32)	*U*= 1966.0 *p*=0.047*
	SCF	90	3.97 (2.52)		4.11 (1.03)	

* $p<0.05$

A Cross-tabulation was performed to explore the proportion of milk/complementary foods infants were consuming, as estimated by the mother, according to feeding method. An Exact test (with Monte Carlo simulation) found a statistically significant relationship [*p*=0.01]. A greater proportion of the infants in the BLW group were reportedly consuming mostly milk, compared with the SCF infants who appeared to be consuming 'not much milk- mostly food' (see Table 28)

Table 28: Cross-tabulation complementary feeding method group and parental estimation of proportion of infant diet coming from either milk or food.

		Proportion milk/food				
Method group		**Mostly milk, small amount of food**	**About half milk, half food**	**Not much milk, mostly food**	**All food, no milk**	**Total**
BLW	*n*	35	48	25	0	108
	%	32.4%	44.4%	23.1%	0.0%	40%
SCF	*n*	31	66	61	2	160
	%	19.4%	41.3%	38.1%	1.3%	100.0%
Total	*n*	66	114	86	2	268
	%	24.6%	42.5%	32.1%	0.7%	100.0%

Within the age at measurement sub-groups, separate cross-tabulations looked at the estimated proportion of milk or food offered based on the method groups. Exact tests (with Monte Carlo simulation) were performed and found no significant differences between the timing of introduction and proportion of milk to complementary foods offered to infants aged 9-12 months. However, a significant result was found among infants aged 6-8 months [p=0.02]. The majority of infants in in the BLW group (57.4%) at age 6-8 months were consuming 'mostly milk, small amount of food', compared with only 35.7% of infants in the SCF group. This means that around two-thirds of SCF infants were reported to be consuming at least half of their diet from food rather than milk at this age (see Table 29).

Table 29: Cross-tabulation complementary feeding method group and parental estimation of proportion of infant diet coming from either milk or food at age 6-8 months.

		Proportion milk/food				
Method group		**Mostly milk, small amount of food**	**About half milk, half food**	**Not much milk, mostly food**	**All food, no milk**	**Total**
BLW	*n*	31	20	3	0	54
	%	57.4%	37.0%	5.6%	0.0%	100.0%
SCF	*n*	25	33	12	0	70
	%	35.7%	47.1%	17.1%	0.0%	100.0%
Total	*n*	56	53	15	0	124
	%	45.2%	42.7%	12.1%	0.0%	100.0%

Question 2: Is there a relationship between how infants transition to complementary feeding and infant growth?

Weight-for-age z-score (WAZ)

Spearman's correlations revealed that WAZ was significantly negatively correlated with the number of milk feeds [r_s = -0.158, p= 0.01] and number of food exposures [r_s = -0.134, p= 0.03], meaning that infants who were fed more frequently (both milk and food) had a lower weight at the time of measurement.

Length-for-age z-score (LAZ)

A significant negative association was also found between LAZ the number of milk feeds [r^s= -0.168, p= 0.01], but no significant association was found between LAZ and number of exposures to complementary foods [r^s= -0.106, p= 0.08].

BMI-for-age z-score (BMIZ)

No significant associations were seen between BMIZ and either number of milk feeds [r^s= -0.059, p= 0.34] or the number of exposures to complementary foods [r^s= -0.091, p= 0.18].

Weight-for-age velocity (WAZV)

WAZV was significantly negatively associated with the number of milk feeds [r^s= -0.154, p=0.01]. No association was found for the number of exposures to complementary foods [r^s= -0.04, p= 0.55].

These analyses show that the more milk feeds an infant receives, the lower the weight, length and slower the weight gain velocity. The more exposures to complementary foods had an impact on lower weight only but not any other growth measure.

When split by age-sub group, among infants age 6-8 months, the only significant association was between LAZ and the number of milk feeds, with increased number of milk feeds being associated with shorter length [r^s= -0.22, p= 0.01]. Among 9-12 month old infants, several significant differences were found. WAZ was negatively associated with increased number of milk feeds [r^s= -0.24, p= 0.01] and complementary food exposures [r^s= -0.20, p= 0.02]. LAZ was significantly negatively correlated with number of milk feeds [r^s= -0.20, p= 0.02] but not complementary food exposures [r^s= -0.16, p= 0.06]. WAZV was significantly negatively associated with number of milk feeds [r^s= -0.19, p= 0.02] and complementary food exposures [r^s= -0.17, p= 0.04]. No significant associations were found for BMI.

Proportion of milk to complementary foods and growth

MANCOVAs compared the proportion groups ('mostly milk, small amount food', 'about half milk/ half food' and 'not much milk/ mostly food' 'all food, no milk) in relation to growth outcomes controlling for maternal age, education, infant birth-weight, age of introduction to complementary feeding and milk feeding type. No significant differences were found for WAZ [F (3, 253) = 0.64, p=0.59], LAZ [F (3, 253)= 0.46, p=0.71], BMIZ

[F (3, 253)= 0.26, p=0.86], or WAZV [F (3, 253)= 0.23, p=0.88]. When the sample was further broken down by age at the time of measurement (6-8 months, 9-12 months), no significant differences were found within any age group for any growth measure.

Overweight and underweight

Cross tabulation and Exact tests explored the relationship between the proportion groups and overweight/underweight classifications, as described in Chapter 3 ('overweight' = BMIZ>2; 'possible risk of overweight' = BMIZ between 1 and 2; 'underweight' = WAZ <-2). No significant differences were seen between groups based on proportion of milk to complementary foods and risk of overweight, either for the whole sample [p=0.20], or within the age sub-groups; 6-8 months [p=0.10]; 9-12 months [p=0.86]. Similarly, no differences were seen for incidence of underweight in relation to the reported proportion of milk to complementary foods, for the whole group [p=0.58], or within any age sub-groups; 6-8 months [p=0.61], 9-12 months [p=1.00].

QUESTION 3: Is there an interaction between milk feeding type and the transition to complementary foods on growth? Separating breastfed and formula fed infants.

Differences in growth between any breastfeeding versus full formula feeding and exclusive breastfeeding (including those on complementary foods) versus any formula feeding were examined. Spearman's correlations and MANCOVAs (controlling for maternal age, education, infant birthweight, and age of introduction to complementary foods) explored this.

WAZ [r_s= -0.15, p= 0.02] and BMI [r_s= -0.14, p= 0.03] were significantly negatively correlated with number of complementary food exposures, and LAZ [r_s= -0.19, p= 0.01] was significantly negatively correlated with the number of milk feeds among infants who had received any degree of breastfeeding. Number of milk feeds of complementary food exposures did not not significantly correlate with any growth outcomes among exclusively breastfed infants, or fully formula fed infants.

MANCOVAs also explored differences within the milk feeding groups based on parental estimations of the proportion of their baby's diet coming from milk/food. No significant differences were found among breastfed infants for WAZ [F (3,215) = 0.60, p=0.61], LAZ [F (3,215) = 0.95, p=0.42], BMIZ [F (3,215) = 0.49, p=0.69], or WAZV [F (3,215) = 0.61, p=0.61]. Nor were any significant differences within the fully formula fed infants based on proportion of milk/food and WAZ [F (3,30) = 1.03, p=0.39], LAZ [F (3,30) = 0.05, p=0.98], BMIZ [F (3,30) = 0.72, p=0.55], or WAZV [F (3,30) = 0.89, p=0.46].

Similarly, for exclusively breastfed infants MANCOVAs found no significant differences based on proportion of milk/food for WAZ [F (2,119) = 0.45, p=0.64], LAZ [F (2,119) = 0.65, p=0.52], BMIZ [F (2,119) = 0.19, p=0.83], or WAZV [F (2,119) = 0.18, p=0.84]. Finally, no significant differences were revealed among infants receiving any formula based on proportion of milk/food for WAZ [F (3,126) = 0.32, p=0.81], LAZ [F (2,126) = 0.25, p=0.86], BMIZ [F (2,126) = 0.20, p=0.90], or WAZV [F (2,126) = 0.26, p=0.85].

QUESTION 4: Is there a relationship between how infants transition from milk to solids and growth trajectories from birth to 6 months and from 6 to 12 months? – Longitudinal data analysis.

Longitudinal data analyses were performed for infants who had one measurement at around 6 months and another at around 12 months (N=105). The purpose of this analysis was to look at any associations between the degree of milk to complementary foods and infant growth trajectories. The number of milk to food exposures and the proportion of milk/food in the diet at 6 months (rather that at 12 months) were examined. This was chosen as it was though that 6 months represents the early transitionary period onto complementary foods.

Birthweight

First, birthweight was explored to see if it was associated with later transition from milk to food (at 6 months). Spearman's correlations found no significant associations between infant birthweight and number of milk feeds [r_s=0.07, p=0.48] or exposure to complementary foods at 6 months [r_s=0.03, p=0.73]. An ANOVA found no significant differences in birthweight according to the 'proportion of milk/food' groups at 6 months [F (2, 102) =2.59, p=0.08].

Birth to 6 months

Growth between birth and 6 months (WAZV) was explored to see if this predicted the number of milk feeds or exposure to complementary foods given at 6 months. Spearman's correlations revealed significant associations. The lower the WAZV (slower weight gain velocity), the greater the number of milk feeds given at 6 months [r_s=-0.23, p=0.02]. No significant association was seen for the number of complementary food exposures and WAZV [r_s=-0.05, p=0.64].

6 to 12 months

Spearman's correlations were performed to explore whether the number of milk feeds, or frequency of exposure to food at 6 months was linked to weight-for-age-velocity (WAZV) between 6 and 12 months. No significant associations were seen for either number of milk feeds [p=0.92] or number of exposure to complementary foods [p=0.88] and WAZV from 6-12 months.

At 6 months, there were 43 mothers reporting that their baby was consuming 'mostly milk, small amount of food', 44 reported that their baby was consuming 'about half milk, half food', and 14 were consuming 'not much milk, mostly food'.

An ANCOVA, controlling for maternal age, education, infant birthweight and milk feeding type at time of measurement, explored any differences between the groups on proportion of milk to food at 6 months and WAZV between 6 and 12 months. Those who were eating 'not much milk, mostly food' at 6 months had the greatest weight gain velocity (M=0.11, SD: 0.90), compared with those eating 'about half milk, half food' (M=-0.52, SD: 1.13), or those eating 'mostly milk, small amount of food' (M=-0.41, SD: 0.99). However, this difference was not significant [F (2, 94) = 0.74, p=0.48].

Repeated measures ANOVAs were then performed to explore trajectories of WAZ, LAZ and BMIZ between 6 months (time point one) and 12 months (time point two) based on the proportion of milk to complementary foods that mothers reported that their baby was eating at 6 months. Maternal age, education, infant birthweight and milk feeding type at time of measurement, and age of introduction to complementary feeding were controlled for.

Weight-for-age z-score (WAZ).

Table 30 shows the mean WAZ for each ‘proportion group’. The between subject effect was not significant [F (2, 93) =0.38, p=0.68] and interaction effect between time and proportion group was also not statistically significant [F (2, 93) =0.51, p=0.59]. Profile plots (Figure 14) demonstrate the trajectories for the groups.

Table 30: Longitudinal differences in WAZ and the proportion of milk to food at 6 months

Proportion group	***n***	**Time point One Mean WAZ (SD)**	**Time point Two Mean WAZ (SD)**
Mostly milk, small amount of food	43	-0.14 (0.89)	0.12 (1.03)
About half milk, half food	44	0.04 (1.03)	0.29 (0.94)
Not much milk, mostly food	14	-0.05 (1.2)	0.10 (0.95)

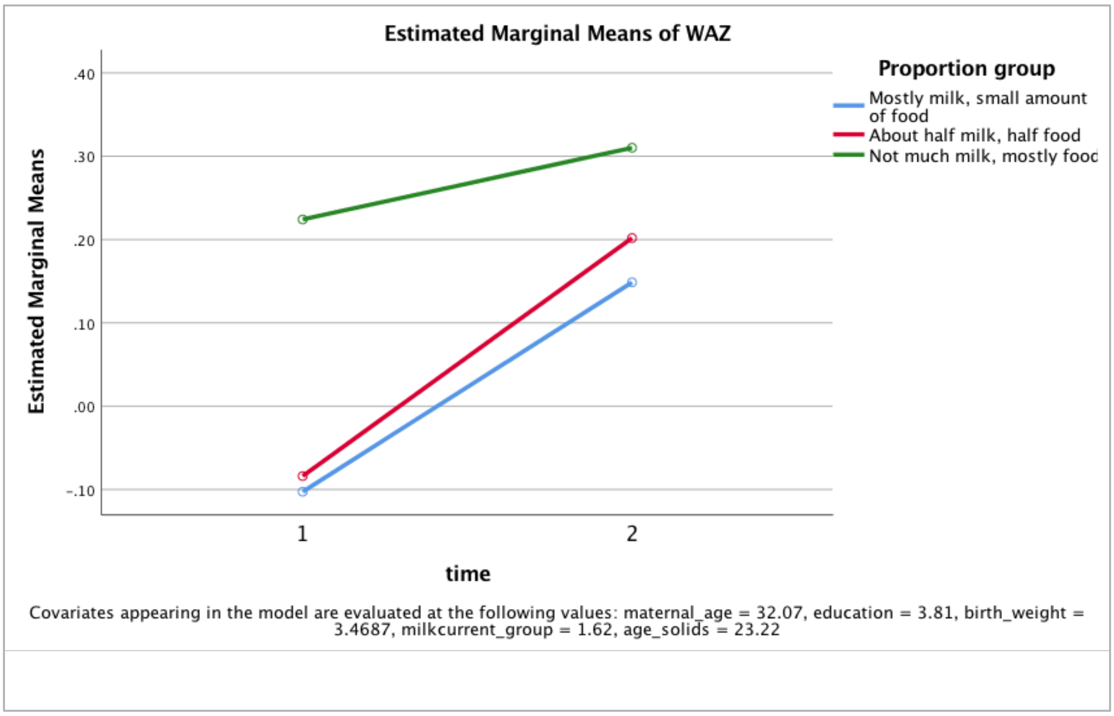

Figure 14: Longitudinal trajectories of WAZ and proportion of milk to food group at 6 months

Length-for-age z-score (LAZ).

Table 31 shows the mean LAZ for each 'proportion group'. The between subject effect was not significant [F (2, 93) =0.79, p=0.46] and interaction effect between time and proportion group was also not statistically significant [F (2, 93) =0.17, p=0.85]. The profile plot (Figure 15) demonstrates the trajectories for the groups.

Table 31: Longitudinal differences in LAZ and the proportion of milk to food at 6 months

Proportion group	***n***	**Time point One Mean LAZ (SD)**	**Time point Two Mean LAZ (SD)**
Mostly milk, small amount of food	43	-0.23 (0.98)	-0.19 (1.19)
About half milk, half food	44	0.10 (1.01)	-0.02 (0.96)
Not much milk, mostly food	14	-0.38 (0.51)	-0.34 (0.69)

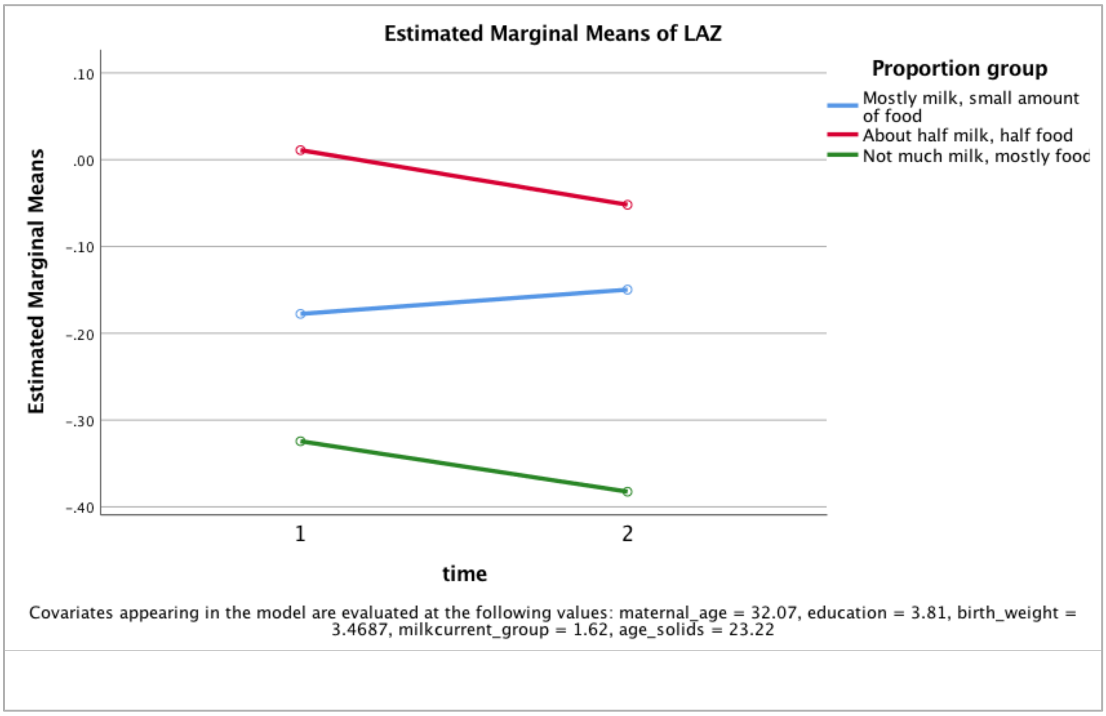

Figure 15: Longitudinal trajectories of LAZ and proportion of milk to food group at 6 months

BMI-for-age z-score (BMIZ).

Table 32 shows the mean BMIZ for each 'proportion group'. The between subject effect was not significant [F (2, 93) =1.49, p=0.23] and interaction effect between time and proportion group was also not statistically significant [F (2, 93) =0.96, p=0.37]. The profile plot (Figure 16) demonstrates the trajectories for the groups.

Table 32: Longitudinal differences in BMIZ and the proportion of milk to food at 6 months

Proportion group	***n***	**Time point One Mean BMIZ (SD)**	**Time point Two Mean BMIZ (SD)**
Mostly milk, small amount of food	43	0.40 (1.10)	0.30 (1.08)
About half milk, half food	44	-0.03 (1.19)	0.46 (1.02)
Not much milk, mostly food	14	0.25 (1.43)	0.40 (1.32)

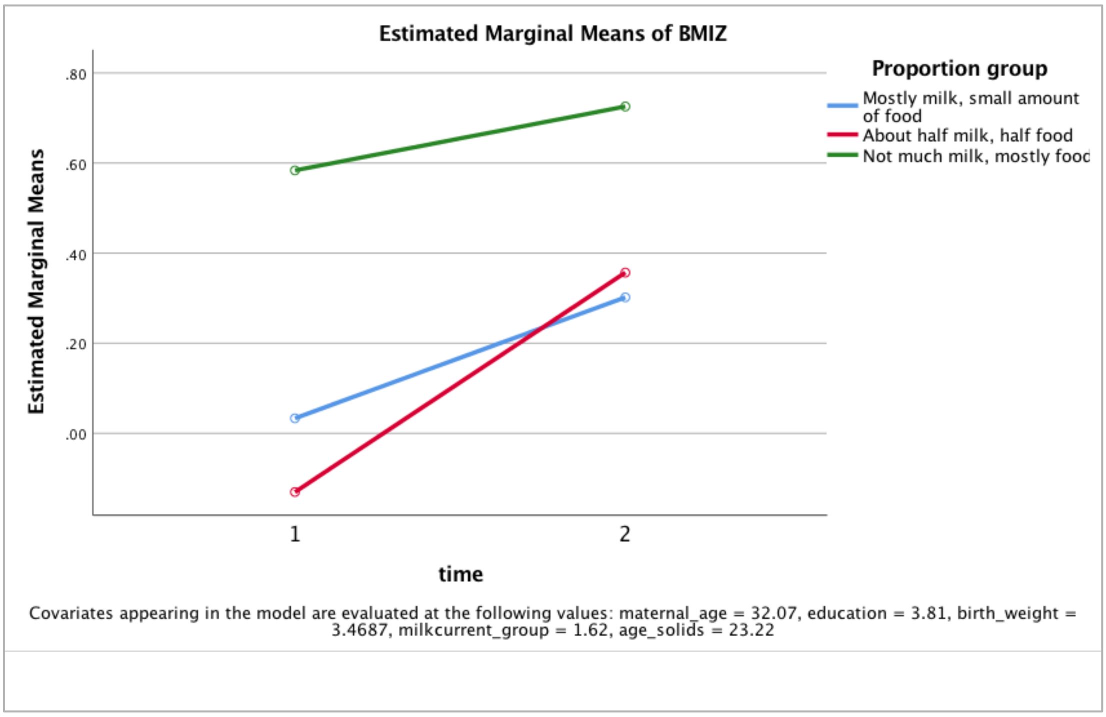

Figure 16: Longitudinal trajectories of BMIZ and proportion of milk to food group at 6 months

8.7. Discussion

This chapter explored the relationship between transition from milk to complementary foods and growth, considering also interaction with milk feeding type and complementary feeding method.

Breastfed infants (either at birth or at the time of measurement) received significantly greater numbers of milk feeds, but not complementary food exposures throughout infancy. While the number of milk exposures does not equate to how much milk they consumed, two thirds of breastfed infants' mothers reported they felt that most of their baby's diet came from milk and not food. Breastfed infants are thought to be more satiety responsive than formula fed infants (Disantis, 2011b; Brown & Lee, 2012), so it is possible that while number of milk feeds was greater in breastfed infants, the volume consumed may have decreased in response to the complementary food consumed. This phenomenon has been observed in other studies where energy intakes have been measured between breastfed and formula fed infants. For example, in the DARLING and the ALSPAC studies infants who were formula fed did not reduce their intake of milk when introduced to solid foods, whereas as breastfed infants appeared to reduce milk intake according to solid calories consumed (Heinig et al., 1993; Noble & Emmett, 2006; Ong et al., 2006). Breastfed infants who continue to consume regular milk feeds alongside food have been found to have lower risk of overweight in childhood (Papoutsou et al., 2017). This may be due to the actions of bio-active components such as appetite regulating hormones, and differences in gut bacteria, which are thought to promote metabolism and satiety (Fields & Demerath, 2012; Alderete et al. 2015, Chan et al., 2017). Furthermore, by continuing breastfeeding the baby will receive ongoing health and immunity benefits (Field, 2005: Grummer-Strawn & Rollins, 2015).

This chapter found that as early as 6-8 months, two-thirds of mothers in the SCF group reported that over half of their baby's diet came from food, rather than milk, probably because they had started the transition from milk to complementary foods at a much younger age. It is perhaps easier to displace milk intake with food in SCF because infants who are introduced to complementary foods early, and via a spoon are more likely to consume energy dense foods. These are commonly fortified infant cereals (McAndrew et al., 2012; Maslin & Venter, 2017) which contain high amounts of cow's milk protein, prompting faster growth. Infants who grow fast may be perceived by their parent to be 'doing well' on complementary foods, thus the mother may reduce milk feeds in preference for complementary foods.

Faster growth and the subsequent dropping of milk feeds amongst those who start complementary foods earlier, may account for the finding that overall having fewer milk feeds (but not number of complementary food exposures) was associated with greater WAZ, LAZ and weight velocity. However, it was notable that when breastfed and formula fed infants were examined separately, growth outcomes differed. Among partially breastfed infants, length was significantly negatively associated with increased milk feeds. Again among those partially breastfeeding, increased exposure to complementary foods was significantly associated with lower weight and BMI. However, this was not seen among fully formula fed infants. This implies that feeding of some breastmilk, alongside increased exposure to complementary food, slows growth. Conversely, among the fully formula fed infants the association between milk feeds and exposure to complementary feeds showed positive associations (increased feeding of formula milk increased length, and increased exposure to complementary food increased weight and BMI), however, these associations did not reach significance.

Looking at infants fed using different methods, a greater number of milk feeds was associated with lower BMI among BLW infants and lower WAZ among SCF infants. Ongoing milk feeding may therefore protect against overweight, regardless of complementary feeding method. In addition, the vast majority of infants were within normal anthropometric ranges, indicating that prolonged milk feeding is not detrimental to growth.

Infants who were fed using a BLW method, alongside having greater number of milk feeds, also had a significantly greater number of complementary food exposures, and both increased milk feeds and increased complementary food exposure were associated with lower BMI in BLW infants. It seems logical that more opportunities to eat would result in greater intake and therefore increased BMI, however this was not the case for BLW infants in this sample. This study measured 'exposure' not consumption of foods; therefore, just because these infants had more opportunities to eat, it does not mean that they did so. The feeding style of BLW mothers is unlikely to be pressuring, due to the nature of the method and this has also been confirmed by prior studies which have found lower levels of maternal control in BLW (Brown & Lee, 2011a; 2011b).

It may also mean that BLW infants do eat when food is offered, but in a 'little and often' fashion. A large meta-analysis of nearly 19,000 participants found that higher eating frequency was associated with lower weight status in children and adolescents (aged 2-19) (Kaisari et al., 2013), so developing this way of eating from a young age may be protective against overweight.

Conversely, it may be argued that mothers who feed their child little and often may do so because their baby is small and that offering food frequently is similar to pressuring intake, perhaps indicating reverse causality. However, it does not necessarily follow that frequent offerings of food equate to pressure to eat, as the context of the interaction is unknown

(Shloim et al., 2015; Galindo et al., 2018; Tshann et al., 2013). Early work by Klesges (1983, 1986) and more recent studies (Lumeng et al., 2012) indicate that frequent maternal prompts to eat increase the risk of obesity. Others have found the opposite, with children who were pressured to eat being more likely to be lower in weight (Shloim et al., 2015). Divergence in the literature suggests that the context and definition of 'pressure to eat' may be crucial. For example, Galindo and colleagues (2018) found that pre-school children who were prompted to eat a different food (rather than pressured to eat more of the same food), ate more in an EAH experiment. The authors suggest that prompts to eat a different food are representative of a more controlling maternal behaviour, as the child has to stop what they are doing to eat the new food, whereas pressure to eat the same food means that the child simply continues with a behaviour that they are already engaged in.

It is not possible to know from the SHIFT data whether parents who frequently offered food also prompted, encouraged or pressured intake. It is also not known whether the infants were offered new foods or the same foods each time. Frequent offering of food (but without prompting) in relation to intake or weight gain has not been explored in infant feeding research, but frequent exposure to a wide variety of foods has been shown to be beneficial for improving acceptance of new foods and reducing fussiness (Maier, Chabanet, Schall, Issanchou & Leathwood, 2007; Coulthard, Harris & Emmett, 2010.). Frequent offering of food, without pressure, is a key element of BLW Rapley & Murkett, 2008). Rapley and Murkett's popular BLW book explicitly states 'don't try and persuade your baby to eat more than she wants' (2008, p.110). In the wider practice of BLW it is not clear whether mothers who adopt the method adhere to the 'no-pressure' aspect; it is, of course, possible for coaxing or prompting to take place.

However, this seems unlikely due to the lower level of maternal control seen in BLW (Brown & Lee, 2011a; 2011b). It is possible that parents who feed responsively respond in a timely fashion to infants' apparent hunger cues, resulting in more frequent offers of food, but without pressuring consumption, meaning that overall actual intake is lower. Furthermore, greater satiety responsiveness may be involved. Infants who are BLW are more likely to have been breastfed, which is thought to contribute to satiety responsiveness (Brown & Lee, 2012), meaning that perhaps during complementary feeding they continue to be satiety responsive, eating less despite increased offerings of food. Moreover, BLW infants have been found to be more satiety responsive in toddlerhood (Brown & Lee, 2015).

Conversely, SCF infants received fewer offers of complementary foods and were more likely to have been formula fed. Formula feeding mothers may be more keen to adopt a feeding routine (Brown & Arnott, 2014), and more likely to monitor intake (Brown & Lee, 2013), and encourage bottle-emptying (Ventura & Herndandez, 2019). In the same way, mothers who choose to adopt SCF may also continue practicing a routine-driven approach, and thus may offer food less often in preference for structured mealtimes, but may then encourage intake during mealtimes. This is easier to do in an SCF approach where the parent controls the amount on the spoon and where there may be an inclination to finish the portion prepared.

Finally, the longitudinal trajectories provided some insight. Slower growth from birth to 6 months predicted greater milk feeds at 6 months, however, this may be accounted for by differences in milk-feeding type (i.e. breastfed infants have slower weight gain from birth to 6 months and also have more milk feeds). Number of milk feeds or exposures to complementary foods at 6 months did not seem to predict later weight gain velocity from 6-12 months. The trajectories of growth from 6 to 12 months were not significant. However, the profile plots, again, show potentially interesting trends. Infants who were reportedly consuming 'not much milk, mostly food' at 6 months had greater weight-for-age at 6 months which continued to track upwards until 12 months, compared to those consuming a greater proportion of their diet from milk, who showed more gradual weight gain trajectories. Length trajectories were equivocal. BMI trajectory differences were stark; again infants on a diet predominantly of food at 6 months had a greater BMI at 6 months which continued to increase until 12 months. Those on a half food/half milk diet at 6 months had the lowest BMI at 6 months, but showed the steepest incline to 12 months. Those consuming mostly milk showed the most gradual BMI trajectory. However, these results must be interpreted with caution as power analyses revealed a slight lack of power in the longitudinal group (see section 3.7.5.)

This chapter explored important differences in the way infants grow relative to the proportion of milk/food they consume in complementary feeding process. Differences in milk feeding type and complementary feeding method used may dictate how this transition occurs. Regardless of milk feeding type or complementary feeding method used, it appears that slower transition to complementary feeding, which incorporates a large proportion of milk in the diet up until 12 months may be beneficial for healthier (i.e. less rapid) infant growth trajectories. However, the content and texture diet consumed in complementary feeding may also play a role in infant growth, and this will be the focus of the next chapter.

CHAPTER 9: Exploring the content and texture of diet offered and infancy growth.

9.1. Rationale

So far, this research has attempted to explore the different aspects of a baby-led feeding approach which are impactful. The self-feeding aspect of BLW was considered in chapter 7, however it is not clear whether any differences are due to the behaviour of self-feeding, or due to the consumption of whole foods. While, these behaviours are likely to be highly correlated (it is surely difficult for an infant to self-feed a pureed food, or for a parent to spoon-feed a sandwich) the distinct impact of eating purees or whole foods, rather than the impact of self-feeding or spoon-feeding is not clear. The degree of consumption of pureed versus whole food use will therefore be examined in its own right.

The content of the infant diet is also an important consideration. As in adults, what infants eat affects growth. In particular consumption of a high protein diet is thought to stimulate growth (Koletzko et al., 2009b; Haschke et al., 2016). Concern has been raised about infants consuming diets high in sugar and fat, in particular in relation to commercial baby foods and processed snacks (Crawley & Westland, 2017, Sparks & Crawley, 2018). Furthermore, consumption of diets high in commercial infant foods may affect later liking of food as composite meals do not allow for discernment of different flavours (Garcia et al., 2016; Chambers et al., 2016). It has also been previously highlighted that commercial infant cereals may be high in cow's milk protein (Cow & Gate, 2018; Heinz, 2019) which may exacerbate growth (Ziegler, 2006; Thorisdottir et al., 2014; Luque et al., 2016; Grenov & Michelsen, 2018). Diet has been shown to differ between BLW and SCF infants in prior research (Brown & Lee, 2011a; Erickson, 2015; Rowan et al., 2019; Komninou et al., 2019), for example, SCF infants are more likely to consume commercial infant foods and cereals (Brown & Lee, 2011a; Komninou et al., 2019). It is therefore possible that any differences in growth or obesity risk attributed to complementary feeding method, may simply be explained by differences in diet consumed.

The aim of this chapter is to examine whether the texture or content of food offered is associated with infant growth. As it is known that milk feeding type may play a role in infant growth, interactions with milk feeding will also be explored.

9.2. Background

BLW encourages consumption of food in its whole form, rather than the traditional method of starting complementary feeding with purees, before moving onto whole foods. It has been proposed that a diets high in pureed food may lead to over consumption of energy, as it is easier for a baby to slurp and swallow a puree off a spoon, encouraging a faster pace of eating (Gisel, 1991; Rapley et al., 2015). Conversely it has been suggested that the slower oral processing time associated with eating whole foods may improve satiety recognition, as this has been seen in studies with adults (Smit et al., 2011; Higgs & Jones, 2013).

Eating whole foods rather than purees may also facilitate liking of new foods, because due to eating whole foods, single flavours can be tasted, as opposed to being blended together in composite (Rapley & Murkett, 2008; Cameron et al., 2012a; Brown & Lee, 2013b; Arden & Abbott, 2015; D'Andrea et al., 2016). Furthermore, BLW encourages the sensory exploration of food. Handling and playing with fruit and vegetables has been demonstrated to improve their acceptance in a number of studies with toddlers (Dazeley & Houston-Price, 2015; Coulthard & Sealey, 2017). Mothers who follow a BLW have reported that infants are less fussy in toddlerhood (Brown & Lee, 2015).

Type of foods offered may also vary according to method of introduction, primarily because the consistencies of the foods differ. Consuming a diet of whole foods provides an alternative to the use of commercially prepared baby food and infant cereals (Brown et al., 2017). This may be important in terms of weight and obesity risk since commercial baby foods tend to be high in sugar, even the savoury options, which are often sweetened (Wlaker & Goarn, 2015; Crawley & Westland, 2017). Commercial infant cereals also may promote increased cow's milk protein consumption as they often contain large proportions of cow's milk powder (Cow & Gate, 2018; Heinz, 2019). High consumption of cow's milk protein has been associated with accelerated growth (Ziegler, 2006; Luque et al., 2016; Grenov & Michelsen, 2018). Prior research has found that infants fed via SCF were more likely to be offered infant cereals, when compared with those fed using BLW (Brown & Lee, 2011; Komninou et al., 2019).

Studies have explored prevalence of commercial food in SCF compared with BLW with mixed results. Morison et al (2016) found no significant difference in exposure to commercially prepared baby-foods between BLW and SCF groups. However, other studies have found a difference. In Erickson's (2015) exploration of the BLISS study data infants in the usual care group consumed significantly more commercial infant foods that infants in the BLISS BLW group. Rowan et al (2019) also found that traditionally weaned infants were more likely to consume 'infant meals', compared with BLW infants. However, these were defined in this study as being composite meals with a variety of ingredients and were not necessarily processed or shop-bought.

Concerns have been raised about the potential for inappropriate finger foods to be offered in BLW, such as crisps, chips, chocolates and biscuits (Cameron Heath and Taylor, 2012b). BLW encourages eating with the family, and therefore the healthfulness of the diet offered depends on what the family eat. One study found the infants' diets often closely reflected the family diet (Robinson et al., 2007). Eating lots of energy dense processed snacks, could lead to an overconsumption of energy (Adams & White, 2015). An examination of infant processed snacks in the UK has revealed that many contain extremely high sugar contents similar to that of confectionary (Sparks & Crawley, 2018). However, while it is true that BLW may be at increased risk of eating sugary processed infant snacks, infants who are predominantly spoon-fed (but offered some finger foods) may also consume them, alongside processed infant purees which are equally high in sugar (Walker & Goran, 2015; Westland & Crawley, 2018).

Studies have also found increased protein intake amongst infant fed using a BLW method (Erickson, 2015; Rowan et al., 2019). This may be concerning as protein is often highlighted as a growth stimulant in infancy (Koletzko et al., 2009b; Haschke et al., 2016). However, the type of protein consumed is likely to be important, for example, the

DONALD study found that consumption of dairy protein (but not meat or vegetable protein) in infancy was linked to later overweight (Gunther et al., 2007).

Considering the interactions with milk feeding may also be interest. Dupont (2003) pointed out that protein intake for breastfed infants may be low, therefore protein requirements must be met from the complementary feeding diet. If BLW infants are breastfed (and they usually are) then consuming protein in the complementary feeding period may be a good thing. However, if infants are formula fed, protein consumption in complementary feeding may lead to excessive intake. As seen in the DARLING and ALSPAC studies, formula fed infants who were complementary feeding had the highest overall intakes of protein (Heinig et al., 1993; Noble & Emmett, 2006). Interactions with milk feeding was therefore of interest.

This chapter will address the following key questions:

1) Is there a relationship between complementary feeding method and texture of diet offered?
2) Is there a relationship between texture of food and diet offered and growth?
3) Is there any relationship between diet offered and infant growth trajectories from birth to 6 months or six to twelve months? – Longitudinal data analysis.

9.3. Participants

For full details of participants please refer to chapter four.

9.4. Measures

Anthropometric measurements

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Food texture

As described in chapter 3 (section 3.4.1.) definitions of baby-led weaning centre on two key aspects:

- Self-feeding (vs. spoon feeding)
- Consumption of whole foods (vs. pureed or mashed)

In Chapter 7, when exploring both these aspects (see section 7.4.) it was decided that degree of self-feeding would be used to define BLW and SCF within this research. This was chosen because there is a high degree of congruence between self-feeding and whole food consumption and between spoon-feeding and puree use, and choosing one aspect only prevented unnecessary repetition. However, exploring texture independently was also deemed to be potentially interesting because texture of food may influence both speed of consumption (and thus possibly the amount consumed), type of food offered and food acceptance (Gisel, 1991; Rapley et al., 2015).

Parents were asked to choose one option which best describes the degree of whole food versus puree/mashed foods in their baby's diet (see Chapter 3) both at introduction to complementary foods and at the time of measurement. They were grouped into whether they ate predominantly whole foods or predominantly purees.

Foods types offered

The 24-hour diet diaries were analysed by hand by the researcher and the frequencies of each food type offered to infants was coded numerically (0 = not offered, 1 = offered once, 2= offered twice and so on). Food groups examined were adapted from similar research focussing on food types which are thought to contribute to rapid infant growth; savoury snacks, sweet foods, protein, 'commercial baby foods' and 'commercial infant cereals' (Wardle et al., 2001; Brown & Lee, 2011a; Cameron et al., 2015; Erickson, 2015; Rowan et al., 2019; Komninou et al., 2019). Table 2 (Chapter 3) provides more detailed descriptors of the food groups.

9.5. Data Analysis

Relationships between categorical variables (complementary feeding method group by texture group) were explored using a Chi Square test. Frequencies of food type in relation to feeding method group were explored using Mann-Whitney U tests. Associations between growth outcomes and texture groups were analysed using MANCOVAs. Relationships between food frequencies and continuous variables (age of introduction to complementary foods, age of infants, growth outcomes) were analysed using Spearman's correlations.

9.6. Results

QUESTION 1. Is there a relationship between complementary feeding method and texture of food or diet offered?

Complementary feeding method (BLW or SCF) was defined by self-feeding as in Chapter 7.

Texture

Ninety-seven infants were offered predominantly whole foods at the introduction to complementary feeding, and 172 were offered predominantly purees (Table 33).

Table 33: Descriptive statistic. Texture groups

Texture group	***n***	**%**
Whole foods	97	36.1%
Purees	172	63.9%
Total	269	100%

As expected infants in the self-feeding (BLW) group were significantly more likely to be offered foods in their whole form, compared with the spoon-feeding (SCF) group who were more likely to have been offered purees. A Chi-square test found these associations statistically significant [X^2 (1, 269) =165.2, p<0.000] (see Table 34).

Table 34: Cross-tabulation. Feeding method group by texture group.

Texture group		**Feeding method group**		
		BLW (Self-feeding)	**SCF (Spoon-feeding)**	**Total**
Whole foods	*n*	89	8	97
	% within texture group	91.8%	8.2%	100%
	% within feeding method group	81.7%	5%	36.1%
	% of Total	33.1%	3%	36.1%
Purees	*n*	20	152	172
	% within texture group	11.6%	88.4%	100%
	% within feeding method group	18.3%	95%	63.9%
	% of Total	7.4%	56.5%	63.9%
Total	*n*	109	160	269
	% within texture group	40.5%	59.5%	100%
	% within feeding method group	100%	100%	100%
	% of Total	40.5%	59.5%	100%

Food types offered

Infants in the BLW group were significantly more likely to have been offered protein, whereas SCF infants were significantly more likely to have been offered commercial baby foods and commercial infant cereals. No significant differences were observed in relation to exposure savoury snacks or sweet foods. Table 35 shows the mean exposures to the food groups between the BLW (*n*=109) and SCF (*n*=160) groups and the outcome of the Mann-Whitney tests.

Table 35: Food types offered according to feeding method group.

Food Type	**Feeding method group**	**Mean exposures (SD)**	**Range**	**Mann Whitney**
Savoury Snacks	BLW	0.35 (0.54)	0-2	*U*=8581.5,
	SCF	0.35 (0.56)	0-3	*p*=0.79
Sweet foods	BLW	0.33 (0.53)	0-2	*U*=8576.0,
	SCF	0.29 (0.60)	0-3	*p*=0.26
Protein	BLW	1.26 (0.95)	0-4	*U*=6984.5,
	SCF	0.93 (0.87)	0-4	*p*=0.003*
Commercial baby foods	BLW	0.26 (0.66)	0-4	*U*=7155.5,
	SCF	0.62 (1.05)	0-5	*p*=0.001*
Commercial infant cereals	BLW	0.02 (1.13)	0-1	*U*=7731.5,
	SCF	0.12 (0.35)	0-2	*p*=0.003*

*$p<0.05$

Age of introduction to complementary foods

Infants fed whole foods at the introduction to complementary feeding were more likely to start complementary feeding later (*M*=25.4 weeks; SD: 2.24) than infants fed purees (*M*=22.4 weeks; SD: 3.82). A Mann Whitney test found this difference to be significant [*U*= 3821.0, *p*<0.000].

A Spearman's correlation was undertaken to explore whether diet offered was associated with age of introduction to complementary foods. Significant negative correlations were observed in relation to 'commercial infant foods' [r_s (269) = -0.155, p=0.01] and 'commercial infant cereals' [r_s (269) = -0.155, p=0.01] indicating that infants who were younger at age of introduction to complementary feeding were more likely to be offered commercial infant foods and commercial infant cereal. None of the other food groups had significant associations with age of introduction to complementary feeding.

Age of the infant at the time of measurement

A Spearman's correlation was undertaken to explore whether diet offered was associated with age of the infant at the time of questionnaire/measurement. As seen in Table 36 older infants were more likely to be offered savoury snacks, sweet foods, protein, and commercial infant cereals.

Table 36: Food types (frequency of exposure) and age of infant at time of questionnaire. Spearman's rho correlations.

Food types	**Infant age in weeks**
Savoury snacks	r_s (269) = 0.129, p=0.035*
Sweet foods	r_s (269) = 0.268, p<0.000*
Protein	r_s (269) = 0.301, p<0.000*
Commercial infant foods	r_s (269) = 0.056, p=0.39
Commercial infant cereals	r_s (269) = -0.136, p=0.03*

* p<0.05

QUESTION 2: Is there a relationship between texture of food and diet offered and growth?

Texture of food offered at introduction to complementary foods

A series of MANCOVAs were performed to explore any differences in WAZ, LAZ, BMIZ and WAZV between the texture of foods offered at the introduction to complementary feeding (whole foods group vs. purees group) controlling for maternal age, education, birth weight, milk feeding type at time of measurement and age of introduction to complementary foods.

Weight-for-age z-score (WAZ)

No significant differences in WAZ were found according to texture group [F (1, 254) = 1.04, p=0.31]. However, the whole foods group had a lower mean WAZ (M=0.05, SD:1.01) compared with the puree group (M=0.27 SD:0.94). All measurements were then used for age group analysis (Table 37). No significant differences in WAZ were seen within the age group analyses.

Length-for-age z-score (LAZ)

LAZ did not significantly differ between the texture groups [F (1, 254) = 2.59, p=0.11]. The puree texture group had the greatest mean LAZ (M=0.08, SD: 1.13) and the infants fed whole foods were the shortest (M=-.41, SD: 1.15). No significant differences in LAZ were seen within the age group analyses (Table 37).

BMI-for-age z-score (BMIZ)

BMI did not significantly differ between the texture groups [F (1, 254) = 0.53, p=0.47], though the whole foods group had the greatest BMI (M=0.47, SD: 0.97) compared to the puree group (M=0.32, SD:1.03). The lower BMI in the puree group appears to be as a result of longer length rather than lower weight. No significant differences in BMIZ were seen within the age group analyses (Table 37).

Table 37: Texture groups at introduction to complementary feeding and growth outcomes.

Age group	**Texture group**	***n***	**Mean WAZ (SD)**	**MANCOVA WAZ**	**Mean LAZ (SD)**	**MANCOVA LAZ**	**Mean BMIZ (SD)**	**MANCOVA BMIZ**
6 – 8 months	Whole foods	46	-0.01 (1.00)	$F(1,114) =3.31$, $p=0.07$	-0.43 (1.28)	$F(1,114) =2.77$, $p=0.10$	0.45 (0.88)	$F(1,114) =2.52$, $p=0.62$
	Purees	75	0.43 (0.97)		0.28 (1.17)		0.41 (1.04)	
9 – 12 months	Whole foods	49	0.10 (1.02)	$F(1,133) =0.29$, $p=0.59$	-0.40 (1.04)	$F(1,133) =0.19$, $p=0.67$	0.49 (1.05)	$F(1,133) =1.82$, $p=0.18$
	Purees	91	0.13 (0.90)		-0.09 (1.07)		0.25 (1.01)	

Rapid weight gain

No significant difference was found in WAZV (change in weight-for-age-z-score from birth to measurement age) between the texture groups in the whole sample [F (1, 254) =0.18, p=0.73]. WAZV was then grouped into whether they showed rapid weight gain (an increase in WAZ of > 0.67) or not. Cross tabulation showed that 20.6% of infants in the whole foods group showed rapid weight gain, compared to 27.3% of those in the purees group. However, a Chi Square test found that this difference was not statistically significant [X^2 (1, 269) =1.49, p=0.24].

Texture of food offered at the time of measurement

Whole food or puree use is likely to change across the complementary feeding period, for example, infants who start complementary feeding on purees, may progress onto whole foods as they get older. The data were therefore analysed again to explore whether texture of the infants' diet at the time of measurement (rather than that at introduction) was associated with growth. 133 infants were predominantly eating whole foods at the time of measurement and 135 were eating predominantly purees. One infant had missing data for current texture of foods offered.

Weight-for-age z-score (WAZ)

The whole foods group had a lower mean WAZ (*M*=0.06, SD: 1.01) compared with the puree group (*M*=0.30 SD: 0.91) however this difference was not statistically significant [F (1, 253) = 2.64, p=0.11]. All measurements were then used for age group analysis (Table 38). No significant differences in WAZ were seen within the age group analyses.

Length-for-age z-score (LAZ)

LAZ significantly differed between the texture groups [F (1, 253) = 5.47, p=0.02]. The puree texture group had a significantly greater mean LAZ (*M*=0.12, SD: 1.11) than the infants fed whole foods (*M*=-.33, SD: 1.17). When the sample was broken down by age sub-group, LAZ remained significantly different with infants aged 9-12 months currently eating purees being significantly longer than the whole food group within the age group analyses (see Table 38).

BMI-for-age z-score (BMIZ)

BMI did not significantly differ between the texture groups [F (1, 254) = 0.53, p=0.47], though the whole foods group had the greatest BMI (*M*=0.42, SD: 0.99) compared to the puree group (*M*=0.33, SD: 1.06). However, as before, the lower BMI in the puree group is likely to have occurred due to longer length rather than lower weight. No significant differences in BMIZ were seen within the age group analyses (Table 38).

Table 38: Texture groups at time of measurement and growth outcomes.

Age group	**Texture group at time of measurement**	***n***	**Mean WAZ (SD)**	**ANCOVA WAZ**	**Mean LAZ (SD)**	**ANCOVA LAZ**	**Mean BMIZ (SD)**	**ANCOVA BMIZ**
6 – 8 months	Whole foods	48	0.13 (1.04)	*F* (1, 114) = 0.74, *p*=0.39	-0.23 (1.37)	*F* (1, 114) =1.06, *p*=0.31	0.47 (0.94)	*F* (1, 114) =0.001, *p*=0.97
	Purees	73	0.35 (0.95)		0.17 (1.15)		0.39 (1.01)	
9 – 12 months	Whole foods	82	0.02 (0.98)	*F* (1, 132) = 2.19, *p*=0.14	-0.38 (1.04)	*F* (1, 132) =0.42, *p*=0.04*	0.40 (1.04)	*F* (1, 132) = 2.56, *p*=0.61
	Purees	57	0.24 (0.88)		0.06 (1.07)		0.12 (0.99)	

**p*<0.05

Rapid weight gain

No significant difference was found in WAZV (change in weight-for-age-z-score from birth to measurement age) between the two texture groups [*F* (1, 253) =2.31, *p*=0.13]. WAZV was then grouped into whether infants showed rapid weight gain (an increase in WAZ of > 0.67) or not. Cross tabulation showed that 27.4% of infants who were currently eating purees showed rapid weight gain, compared to 22.6% of those who were currently eating whole foods. However, a Chi Square test found that this difference was not statistically significant [X^2 (1,268) =0.84, *p*=0.36].

Overweight and underweight

According to texture group at the introduction of complementary feeding, seven (7.2%) infants fed whole foods at the introduction to complementary feeding were classed as overweight (BMIZ>2) compared with eight in the puree group (4.7%). A greater proportion of infants were classed as 'possible risk of overweight' (BMIZ 1-2) in the puree group (*n*=40, 23.3%) compared with the whole foods group (*n*=15, 15.5%). A Chi-Square test did not find this difference to be significant, however [X^2 (2, 269) =2.80, *p*=0.26].

Again, according to texture group at time of measurement, seven infants (5.3%) were overweight in the whole foods group, compared with eight (5.9%) in the puree group. Proportion of infants at risk of overweight was also greater in the puree group (*n*=28, 20.7%) compared with the whole foods group (*n* = 26, 19.5%). However, this finding was statistically not significant [X^2 (2, 268) =0.13, *p*=0.94].

Underweight was also explored (classed as WAZ <-2). A cross tabulation and Exact test was performed and found significant differences in underweight according to texture group as defined at the introduction to complementary feeding [*p*=0.016]. Four infants (1.5% of all infants) who were fed whole foods from the start of complementary feeding (4.1% of this group) were categorised as underweight compared to no infants from the puree group. However, when texture at the time of measurement was explored, three infants (2.3%) in the whole food group were classed as underweight and one in the puree group (0.7%) and this was not statistically significant [*p*=0.37].

Food types offered

Spearman's correlations found no significant associations with WAZ, LAZ, BMIZ and WAZV and frequencies of foods offered. Table 39 shows the results of these analyses.

Table 39: Food type (frequency of exposure) and growth outcomes, Spearman's rho correlations.

Food type	**WAZ**	**LAZ**	**BMIZ**	**WAZV**
Savoury snacks	r_s (269) = -0.11, *p*=0.07	r_s (269) = -0.10, *p*=0.10	r_s (269) = -0.06, *p*=0.35	r_s (269) = -0.07, *p*=0.23
Sweet foods	r_s (269) = -0.03, *p*=0.54	r_s (269) = -0.49, *p*=0.43	r_s (269) = -0.01, *p*=0.96	r_s (269) = 0.01, *p*=0.86
Protein	r_s (269) = 0.09, *p*=0.14	r_s (269) = 0.07, *p*=0.24	r_s (269) = 0.04, *p*=0.52	r_s (269) = 0.06, *p*=0.31
Commercial infant foods	r_s (269) = -0.05, *p*=0.39	r_s (269) =-0.04 , *p*=0.49	r_s (269) =-0.06 , *p*=0.31	r_s (269) = -0.02, *p*=0.70
Commercial infant cereals	r_s (269) = 0.02, *p*=0.72	r_s (269) = 0.07, *p*=0.25	r_s (269) = -0.04, *p*=0.53	r_s (269) = -0.02, *p*=0.79

QUESTION 3: Is there any relationship between diet offered and infant growth trajectories from birth to 6 months or six to twelve months? – Longitudinal data analysis.

Longitudinal data analyses were performed for infants who had one measurement at around 6 months and another at around 12 months (*N*=105). The purpose of this analysis was to look at any associations between the texture and content of diet offered infant growth trajectories. Diet was explored at 6 months (rather that at 12 months). This was chosen as it was though that 6 months represents the early transitionary period onto complementary foods, whereas by 12 months most infants should be on a family diet.

Birthweight

Birthweight was explored to examine associations with later texture and content of diet offered at 6 months. A t-test did not find a significant difference between the birthweight of the groups, according to texture of food at introduction of complementary feeding [t (103) =0.95, p=0.86].

Spearman's correlations were performed on frequencies of types of food offered at 6 months. The only dietary variable that was significantly associated with birthweight was that of savoury snacks; infants with a lower birthweight appeared to have a greater exposure to savoury snacks at 6 months [r_s= -0.29, p=0.002].

Birth to 6 months

Weight gain velocity between birth to 6 months (WAZV) was explored to see if the speed of infant weight gain in early infancy predicted the the texture or type of food given at 6 months. An ANCOVA explored differences in WAZV from birth to six months, and the texture of diet offered at introduction to complementary feeding. Maternal age, education and milk feeding type and age of introduction to complementary feeding were controlled for. The mean WAZV between the puree and whole food groups did not significantly differ [F (1, 94) =0.78, p=0.38]. Spearman's correlations revealed no significant associations between any food type and infant WAZV from birth to six months.

6 to 12 months

An ANCOVA was again performed on differences in WAZV from 6 to 12 months, based on puree to whole food use at introduction to complementary feeding. No significant differences were seen [F (1, 94) =1.64, p=0.20].

Spearman's correlations were performed to explore whether frequency of exposure to any food types at 6 months was linked to weight-for-age-velocity (WAZV) between 6 and 12 months. A significant negative association was seen for commercial infant meals, with more exposure commercial meals at 6 months being associated with lower weight gain velocity from 6 to 12 months [r_s = -0.20, p=0.044].

Trajectories of WAZ, LAZ and BMIZ were then examined based on texture of food offered at introduction to complementary feeding using repeated measures ANOVAs. The trajectory examined was between 6 months (time point one) and 12 months (time point two). Maternal age, education, milk feeding type and age of introduction to complementary feeding were controlled for.

Weight-for-age z-score (WAZ)

Table 40 shows the mean WAZ for each texture group. The between subject effect was not significant [F (1, 94) =0.48, p=0.49] and interaction effect between time and texture group was also not statistically significant [F (1, 94) =1.77, p=0.38]. While no statistically significant differences were found, the profile plot (Figure 17) demonstrates an increase in WAZ trajectory between both groups with the sharpest incline observed in the puree group. On the other hand, infants in the whole food group demonstrated a more gradual weight-for-age increase.

Table 40: Longitudinal differences in WAZ and texture group at introduction to complementary feeding.

	n	**Time point One Mean WAZ (SD)**	**Time point Two Mean WAZ (SD)**
Whole	28	-0.01 (0.99)	0.09 (0.91)

Purees	73	-0.06 (1.00)	0.22 (1.01)

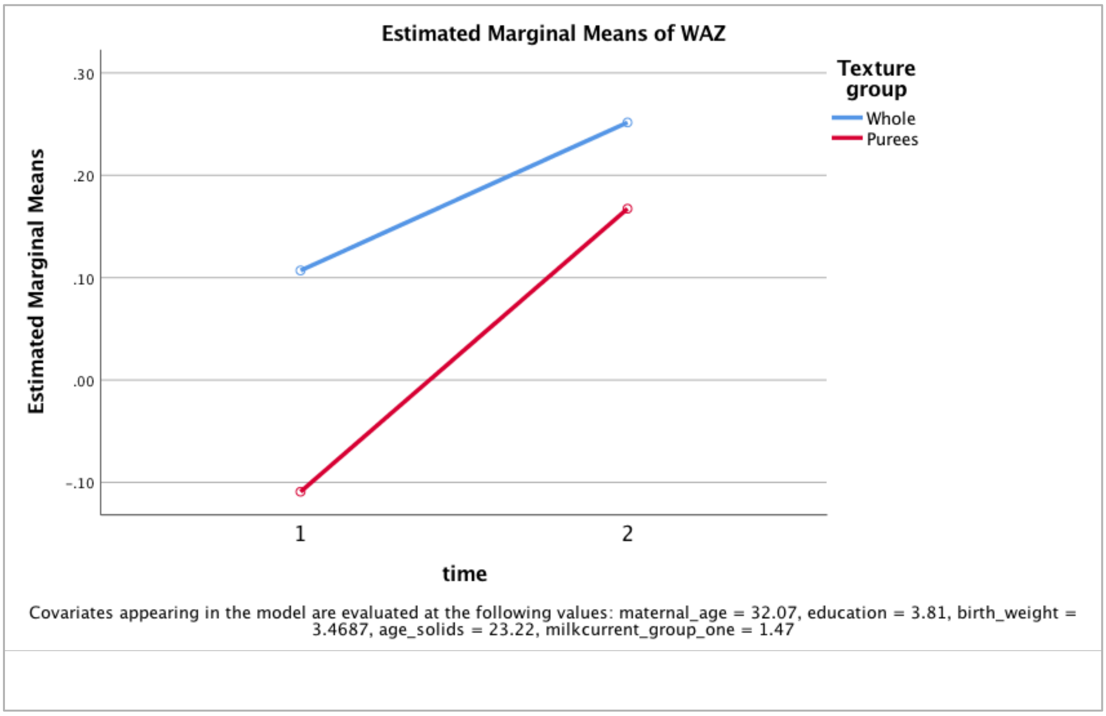

Figure 17: Longitudinal trajectories of WAZ and texture group at introduction to complementary feeding.

Length-for-age z-score (LAZ)

Table 41 shows the mean LAZ for each texture group. The between subject effect was not significant [F (1, 94) =0.01, p=0.92] and interaction effect between time and texture group was also not statistically significant [F (1, 94) =0.08, p=0.76]. While no statistically significant differences were found, the profile plot (Figure 18) demonstrates a sharp decrease in LAZ trajectory in the puree group and a slight increase for the whole food group.

Table 41: Longitudinal differences in LAZ and texture group at introduction to complementary feeding.

	n	**Time point One Mean LAZ (SD)**	**Time point Two Mean LAZ (SD)**
Whole	28	-0.35 (0.57)	-0.38 (0.80)
Purees	73	-0.03 (1.05)	-0.04 (1.10)

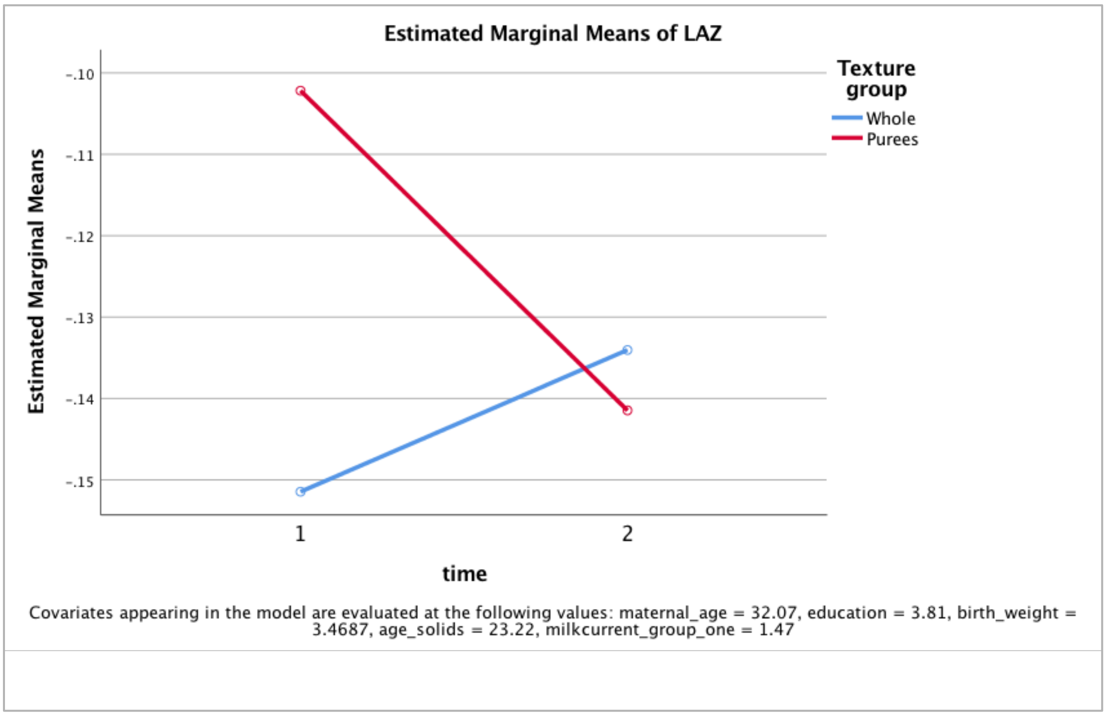

Figure 18: Longitudinal trajectories of LAZ and texture group at introduction to complementary feeding.

BMI-for-age z-score (BMIZ)

Table 42 shows the mean BMIZ for each texture group. The between subject effect was not significant [F (1, 94) =1.25, p=0.26] and interaction effect between time and texture group was also not statistically significant [F (1, 94) =0.76, p=0.36]. While no statistically significant differences were found, the profile plot (Figure 19) demonstrates that overall those consuming whole foods at the introduction to complementary feeding had the greatest BMI at both 6 and 12 months however the group consuming purees at the start of complementary feeding, showed a steeper trajectory in BMI gain from 6-12 months.

Table 42: Longitudinal differences in BMIZ and texture group at introduction to complementary feeding.

	n	**Time point One Mean BMIZ (SD)**	**Time point Two Mean BMIZ (SD)**
Whole	28	0.23 (1.12)	0.48 (0.99)
Purees	73	-0.04 (1.20)	0.35 (1.12)

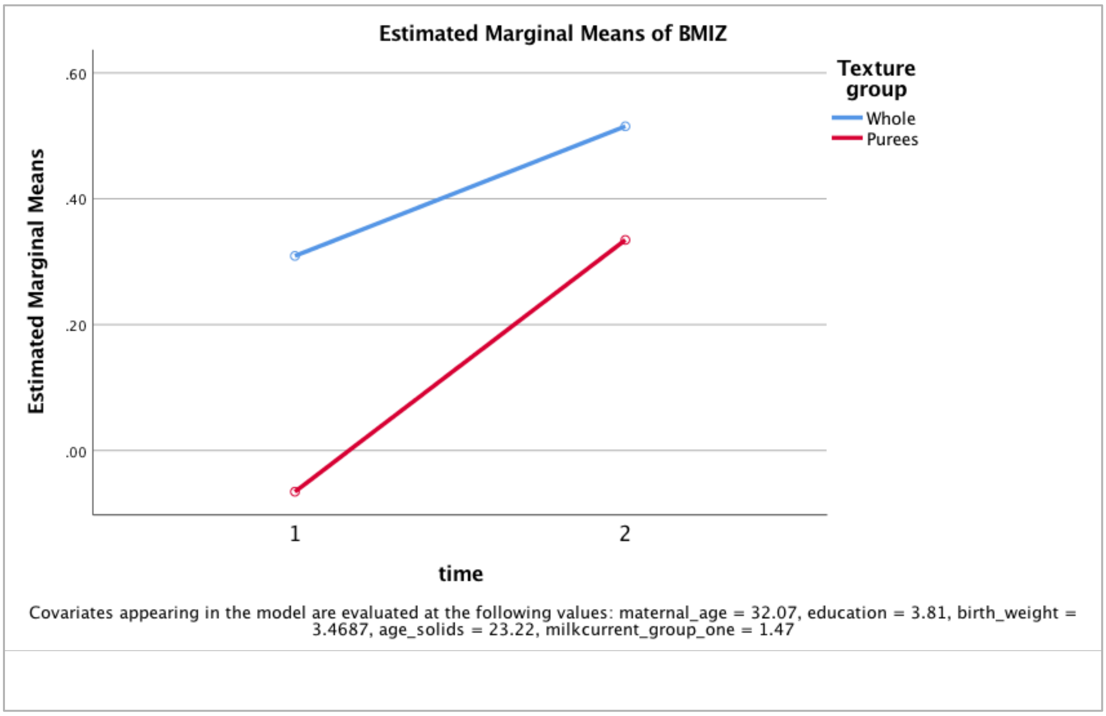

Figure 19: Longitudinal trajectories of BMIZ and texture group at introduction to complementary feeding.

9.3. Discussion

This chapter examined the differences in texture and food types offered to infants aged 6-12 months, and associations with growth outcomes. Overall the findings showed several significant differences. As expected, BLW infants were predominantly fed foods in their whole form from the start of complementary feeding (as whole food consumption is a key part of the definition of the method) and SCF infants were more likely to eat pureed or mashed foods.

Texture may be an important factor in determining types of foods offered to infants, and this was evident in the SHIFT study. For example, the SCF group consumed more composite meals, commercial infant foods (such as jars and pouches) and commercial infant cereals. These differences are likely to have arisen due to the differing textures of foods eaten by BLW and SCF infants because these foods usually exist in a pureed/mashed format. Studies suggest that these commercial infant foods can be high in sugar or cow's milk protein (Westland & Crawley, 2018; Sparks & Crawley 2018; Cow & Gate, 2018; Heinz, 2019) and consumption of these foods may therefore be conducive to weight gain. This study did not find statistically significant increases in growth outcomes based on texture of foods given at the start of the complementary feeding process. The only significant finding was that of longer length in infants fed purees at the time of measurement (average age around 9 months). As highlighted in previous chapters, increased consumption of cow's milk protein in this group could account for linear growth gains, especially if the infant is also formula fed.

Infants in the BLW group on the other hand were more likely to eat protein. Higher consumption of protein in the BLW group may be initially concerning because excessive protein in infancy can promote rapid growth, increasing the risk of later overweight and obesity (Koletzko et al., 2009b; Pearce & Langley-Evans, 2013; Haschke et al., 2016). The SHIFT study finding supports prior research; BLW infants in the BLISS study (Erickson, 2015) and in Rowan et al.'s (2019) study consumed higher levels of protein than SCF infants. However, this is likely to be more of a problem in formula fed infants who are already receiving high levels of protein from formula milk (Luque, et al., 2016; Haschke et al., 2016). Since BLW infants are more likely to be breastfed (Brown & Lee, 2010;

Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017), and this was also the case in this sample (section 7.6.), they are likely to benefit from eating more protein from complementary foods. Indeed, it may be reassuring that BLW might encourage protein intake, which may be low in 6-12 month old breastfed infants (Dupont, 2003). They type of protein consumed may also be important. For example, the DONALD study in Germany found that consumption of dairy protein, but not meat or vegetable protein (such as from pulses or legumes) at 12 months was associated with higher adiposity at age 7 years (Gunther et al., 2007). Similarly, others have reported, higher intake of animal protein at 12 months and increased BMI in later childhood (Thorisdottir et al., 2014). Not all studies have found this association, for example, a systematic review (funded by the National Dairy Council in the US) reported a beneficial relationship between dairy consumption and body composition in children (Spence, Cifelli & Miller, 2011). This review focused on older children, however, rather than infants and the potential for conflict of interest warrants caution.

As well as considering diet texture and content in relation to infancy growth, it is important to pay attention the impact that differing textures and foods may have on later child eating behaviour. For example, texture of food may affect later enjoyment of food, fussiness and preferences which may affect childhood overweight and obesity. Early introduction of lumpier textures is thought to improve acceptance of a wider variety of food (in particular of fruit and vegetables) in toddlerhood (Northstone et al., 2008; Werthmann et al., 2015; Emmett, Hays & Taylor, 2018). Indeed, Townsend & Pitchford (2012), found increased liking of fruits and vegetables in toddlers who had been fed using a BLW method in infancy. Others have found reduced child fussiness reported by mothers who followed BLW (Brown & Lee, 2015; Taylor et al., 2017).

Infants in this study who were fed using a SCF method were more likely to eat commercial infant meals, where different food types were mixed. This may be problematic for flavour learning as children are less likely to be able to discern the flavours of distinct food types. In particular baby foods which contain a mixture of fruit and vegetables may mask the taste of the vegetable, meaning that children do not learn to like vegetables (Garcia et al., 2016; Chambers et al., 2016). One study has suggested that mixing a liked flavour (sweet) with vegetable increases later acceptance of the unsweetened vegetable (Havermans &

Jansen, 2007). However, systematic reviews on the subject have concluded that repeated exposure of single vegetables and parental/peer modelling are effective strategies for encouraging vegetable consumption in young children (Appleton, Hemingway, Rajska & Hartwell, 2018b; Holley, Farrow & Haycraft, 2017). Recent ALSPAC data findings support this, finding that children offering of fresh whole fruit and the mother eating the same meal as the child were protective against later fussiness, whereas feeding ready-prepared food had the opposite effect (Emmett et al., 2018).

The development of food fussiness is not only distressing for parents (Taylor et al., 2015) it is detrimental to forming adaptive relationships with food and may increase risk of overweight and obesity in older childhood. The evidence linking food fussiness with weight status is mixed. Higher incidence of food fussiness has been found in obese and overweight children, compared with normal weight children aged 2-6 years (Finistrella et al., 2012), This maybe be due to rejection of healthier foods in preference for sweet or highly palatable, energy dense foods (Finistrella et al., 2012; Perry et al., 2015). Other studies have linked food fussiness with lower weight at age 2, but with increased parental use of non-responsive feeding practices, which in turn may increase obesity risk later on (Byrne, Jansen & Daniels, 2017).

Manual and oral exploration of foods may alter the experience of eating, overall consumption and perhaps satiety. Foods which are harder and require chewing are consumed more slowly and this is thought to reduce intake and improve recognition of satiety (Gisel, 1991; Bolhuis et al., 2014), though speed of consumption based on texture in relation to growth has yet to be explored in research with infants. As well as taste, touch, smell and consistency are all thought to contribute to overall enjoyment of meals and appetite control and may shape beliefs about the satiating effect of food (McCrickerd & Forde, 2016b). Babies who are allowed to handle, squash, lick and sniff food may be better able to detect and identify foods, improving recognition and familiarity; handling of whole food has also been found to be conducive to liking and later acceptance of foods, especially of fruit and vegetables in young children (Dazeley & Houston-Price, 2015; Coulthard & Sealey, 2017).

Finally, the potential effect of maternal-child interactions in relation to food offered is also worth considering. Purees, especially commercial foods in jars or pouches are often available in portion sizes which exceed infants' requirements for the advertised age of the product (Crawley & Westland, 2017). The fact that these products come in pre-determined portion sizes opens up the risk for a tendency for parents to encourage their child to finish the portion rather than paying attention to subtle hunger and satiety cues. In bottle feeding this phenomenon has been seen; when larger bottles are used formula intake is increased (Wood et al., 2016) likely due to a maternal temptation to encourage bottle-emptying (Ventura & Hernandez, 2019). McConahy and colleagues (2002) found that larger portion size was associated with increased energy intake and body weight in 1-2 year-olds.

To conclude this chapter, broadly, in this study sample infant growth did not appear to be significantly affected by the texture or type of food offered. There was a slight increase in underweight (weight-for-age z-score <-2) amongst infants who had been fed whole foods at the start of complementary feeding. However, the numbers were very small (BLW *n*=4, 1.5%; SCF *n*=0) and the findings therefore indicate that that initiating complementary feeding with whole foods is feasible for adequate growth for the vast majority of infants. This chapter has outlined some of the potential benefits of eating food in their whole form, in relation to content of the diet, and the importance of handling and chewing food. Other advantages of infants eating foods in their whole form include, hand-eye co-ordination, the development of chewing and swallowing skills and neuro-developmental benefits of exploratory play (Rapley & Murkett; 2008). Therefore, findings reported here may add to the body of evidence supporting whole food consumption for infants.

CHAPTER 10: Exploring maternal reported reasons for the chosen approach to complementary feeding.

10.1. Rationale

This research has shown that aspects of the approach to infant feeding may have some impact upon infant growth. Breastfeeding, delayed complementary feeding, and self-feeding of whole foods all may play a role, and appear to be interrelated. What connects these behaviours is that they all represent aspects of a baby-led feeding approach, which is low in maternal control. Conversely, formula feeding, early complementary feeding and spoon-feeding of purees may represent a more 'parent led' approach, and higher maternal control.

Rather than the behaviours having an impact per se, it may be that it is the attitude of the mother which predicts a feeding style which is either low or high in control. Thus the way an infant is fed (breast or formula, self-fed or spoon-fed) may not be as important as whether the overall feeding style is characterised by a maternal desire for control. With this in mind, it is possible for a mother to formula feed and then spoon-feed complementary foods in a manner which is low in control, responsive to the baby's cues and thereby protects the baby's internal appetite regulation.

The aim of this chapter is to explore the maternal driving factors towards a particular feeding approach, which may reflect either a responsive or non-responsive attitude which may in turn potentially affect infant intake and weight. Understanding these factors is important for understanding the context influencing infant feeding decisions.

10.2. Background

It appears that maternal-infant feeding practices are likely to shape growth and eating behaviour, however, there is very little research exploring maternal drivers towards their feeding choices. These reasons are important to explore because they may point towards a general tendency towards a more or less responsive feeding style (see section 2.11.).

While BLW has been associated with a more responsive feeding style, compared with SCF (Brown & Lee, 2011b), it is not clear whether it is the method which determines the feeding style, or whether mothers are attracted to a particular feeding method because it reflects mothers' tendency towards control (Brown et al., 2017). For example, there are strong links between breastfeeding, delaying complementary feeding and BLW (Brown & Lee, 2010; Townsend & Pitchford, 2012; Morison et al., 2016; Taylor et al., 2017). It is possible that through breastfeeding mothers learn to develop a trust in their baby's appetite, and relax about intake and weight because they are unable to measure how much is going in. Through this experience of breastfeeding, mothers may feel more comfortable adopting BLW and continue with a more responsive feeding style. On the other hand, it might be that a mother with less controlling attitude from the outset may be more attracted to both breastfeeding and BLW because they fit with her underlying ethos of allowing the baby to take the lead. Equally, it is not clear whether formula feeding, early complementary feeding and spoon-feeding create an attitude of maternal control within the mother, or whether she is attracted to these feeding approaches because of a desire for control.

There are a number of reasons that mothers cite around when or how to introduce complementary foods, and often these are driven by concerns over weight and intake, and a belief that their baby needs to consume more (Arden, 2010; Brown & Rowan, 2016). Perceived infant size may also influence maternal use of pressure to eat (Brown & Lee, 2011c). Moreover, concerns around infant sleep and fussiness may also lead to mothers encouraging intake in order to settle a fractious infant (Baughcum et al., 1998; Arden, 2010; Hoddinott et al., 2011; Clayton et al., 2013; Lucas et al., 2017). These beliefs may predicate a more pressurising feeding approach (Brown & Lee, 2010).

While pressure to eat has been broadly linked to lower child weight (Shloim et al., 2015), very little research has explored this in infancy, where the nature of pressure to eat may be different. As discussed in the literature review, infants may be more easily pressured to eat than older children, and the type of foods which are encouraged are likely to differ (in infancy mothers are more likely to encourage satiating foods to help settle).

Conversely, prior research has found that mothers who follow BLW are more likely to say that they waited for motor signs of developmental readiness before introducing complementary foods and report lower levels of concern over child weight and intake and adopt a less pressuring feeding style (Brown & Lee, 2011; Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015)

The aim of this chapter was to explore differences in reasons for introducing complementary foods and maternal concerns between mothers choosing to follow either BLW or SCF.

This chapter will address the following key questions:

1) What reasons do mothers give for choosing a particular complementary feeding method and are these reasons associated with milk feeding type or complementary feeding method?
2) Are the reasons for choosing the complementary feeding method associated with infant birthweight or infant size at the time of measurement/questioning?

10.3. Participants

For full details of participants please refer to chapter four. However, not all mothers were given the opportunity to answer this question as it was added into the questionnaire mid-way through the data collection process.

10.4. Measures

Mothers were provided with a free text box to give a reason why they chose the complementary feeding approach.

10.5. Data analysis

As described in Chapter 3 (section 3.7.3.), sub-themes were created and then grouped into whether they represented broadly, a 'baby-led' approach, broadly 'parent-led approach', were simply following the guidelines or were motivated by other factors (see Table 43).

Table 43: Broad themes and sub-themes

Broad Themes	**Baby-led**	**Parent-led**	**Following guidelines**	**Other**
Sub Themes	Parent reported signs of appropriate developmental readiness	Concerns about weight or intake	Health professional advice	Worried about choking
	Beliefs about benefits of BLW e.g. for motor control, appetite control or later eating behaviour	Beliefs around sleep	Awareness of public health recommendations	Own previous experience or influenced by family/friends
	Consideration of baby's enjoyment or preferences	Parental did not feel confident or reported anxiety		Mess – a belief an approach is either more or less messy
				Convenience

Some answers referred to multiple themes and it was not always clear which, if any, was the primary influencing factor (see example in figure 20). One single participant's answer could therefore appear in one or more sub-themes or broad themes, and could appear twice in one broad theme (as in the case for the theme 'other' in the example). Therefore, for analysis, each sub-theme and theme was created as a separate independent variable. Whether or not an answer matched to a sub-theme variable was coded in a binary fashion (1= yes and 0= no) to identify the frequency of the appearance of this sub-theme. For the broad themes the appearance of any of the subthemes within that broad theme (1 or more) was coded as 1.

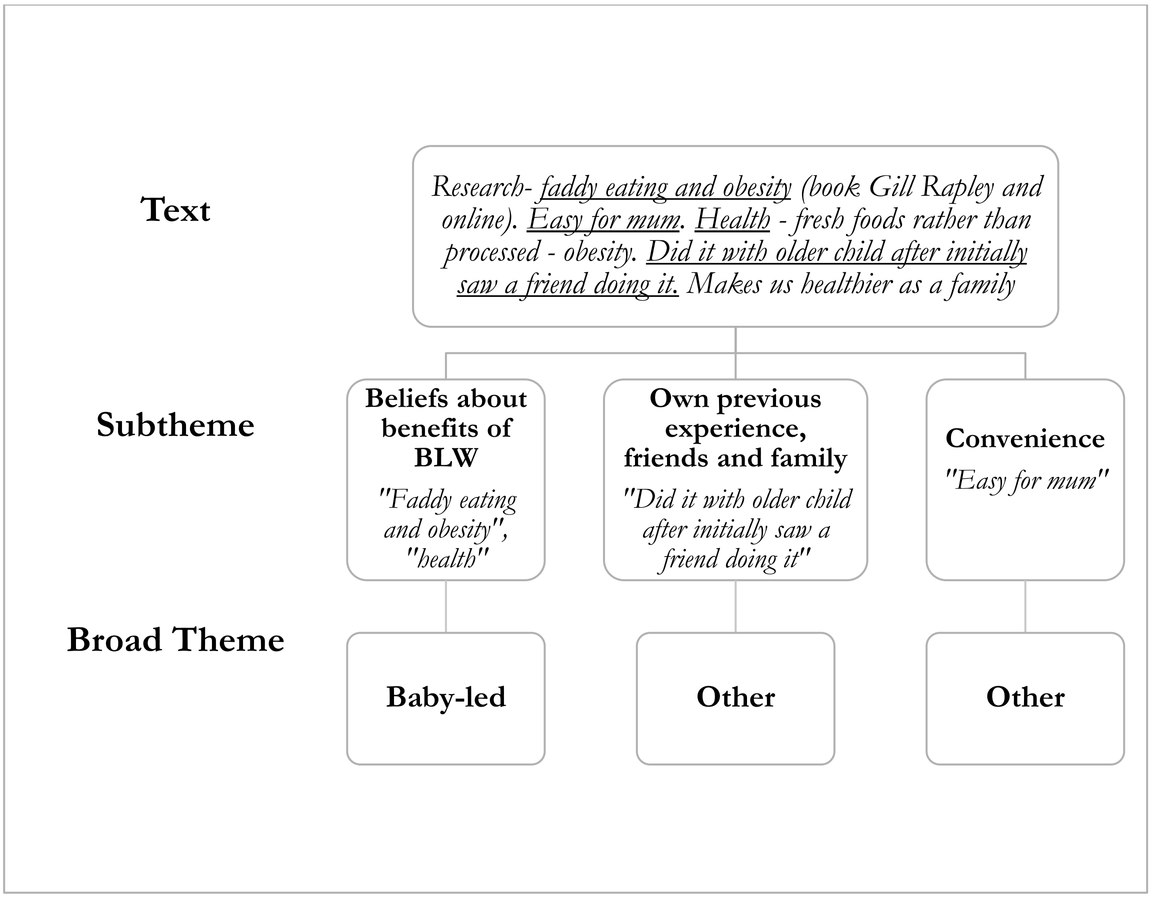

Figure 20: Example of coding of a free-text answer.

So for the example in Figure 20, this answer was coded as follows:

- For the subthemes it was given a 1 for 'beliefs about the benefits of BLW', 1 for 'own experience, friends and family' and 1 for 'convenience'.
- For the broad themes it was given a 1 for 'baby-led' and 1 for 'other'.

Anthropometric measures

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV) were calculated as described in Chapter 3.

Statistical tests

Chi-square or exact tests were used to identify any relationships between the frequency of sub-themes or broad themes and either milk feeding type or complementary feeding approach. Spearman's correlations explored frequencies of themes against growth measures. Verbatim extracts from the data were used to illuminate themes.

10.6. Results

One hundred and twenty-three mothers gave a reason why they had chosen a particular complementary feeding method (mean infant age was 41.7 weeks, SD: 11.0, range 18-59 weeks). Of these 17 formula fed their infants at birth, and 106 breastfed their infants at birth. Forty were formula feeding at the time of measurement, 67 were breastfeeding, and 16 were combination feeding. Forty-seven had adopted BLW (self-feeding) and 76 had adopted a SCF (spoon-feeding) approach.

QUESTION 1: What reasons do mothers give for choosing a particular complementary feeding method and are these reasons associated with milk feeding type or complementary feeding method?

Broad themes

Fifty-nine mothers (48%) reported reasons which fit with a broad 'baby-led' theme. Forty-one (33.3%) gave broadly 'parent-led' reasons'. Only three (2.4%) stated that they were following guidelines or health advice. Sixty (48.8%) gave 'other' reasons. (n.b. as described in section 10.5. some single answers matched with multiple themes, which is why these percentages do not add up to 100%).

Chi square or exact tests were run on each broad theme to find out if any associations could be found between the frequency of occurrence of a broad theme and milk-feeding type either at birth or at the time of measurement. No statistically significant associations were found.

The same analyses were run to find associations between the broad themes and complementary feeding method (BLW or SCF).

A chi square test showed that mothers significantly differed in frequency of reporting 'baby-led' reasons for choosing a complementary feeding method. A significantly greater proportion of mothers who chose BLW (*n*=35, 74.5%) reported being motivated by reasons within the broad 'baby-led' theme, when compared to the mothers who adopted a SCF method (*n*=24, 31.6%) [X^2 (1,123) = 21.4, $p<0.000$]. On the other hand, mothers who adopted a SCF method were more likely to report factors within the 'parent-led' broad theme (SCF, *n*=36, 47.4%; BLW, *n*=5, 10.6%) [X^2 (1,123) = 17.6, $p<0.000$]. As only three reported referring to health professional guidance this could theme not be analysed. The groups did not significantly differ in relation to the broad theme 'other', with around half of mothers in both the BLW (*n*=23, 48.9%) and SCF (*n*=37, 48.7%) groups reporting being influenced by 'other' factors.

Sub-themes

Table 44 shows the frequencies of sub-themes and percentages of parents in the whole sample giving reasons which fit with these themes (n.b. as above some single answers were coded into multiple sub-themes, which is why the *n* in the table adds up to more than the sample size of 123. Likewise, the percentages in the table represent the % of *n* within the whole sample (*N*=123) for each theme and therefore add to more than 100%).

Table 44: Sub-themes. Frequencies.

Sub-theme	*n*	% of total sample
Parent reported signs of appropriate developmental readiness	13	10.6%
Beliefs about benefits of BLW e.g. for motor control, appetite control or later eating behaviour	33	26.8%
Consideration of baby's enjoyment or preferences	24	19.5%
Concerns about weight or intake	32	26%
Beliefs around sleep	6	4.9%
Parent did not feel confident or felt anxious	6	4.9%
Health professional advice	2	1.6%
Awareness of public health recommendations	1	0.8%
Worried about choking	25	20.3%
Own previous experience or influenced by family/friends	13	10.6%
Mess – a belief a method is either more or less messy	4	3.3%
Convenience	33	26.8%

Chi square and exact tests were run on each sub-theme to find out if any significant associations could be found between the frequency of occurrence of a sub-theme and milk-feeding type (either at birth or at the time of measurement) and the chosen complementary feeding method. No significant associations were found between the frequencies of any sub-theme and milk feeding type at birth.

Exact tests (with Monte Carlo simulation) found a significant association between milk feeding type at the time of measurement and the sub-theme 'beliefs around sleep' [p=0.04]. Mothers whose infants were being combination fed were more likely to report beliefs around sleep as a motivating factor for choosing a complementary feeding method (n=3, 18.8%), compared with breastfed (*n*=2, 3%) or formula fed infants (*n*=1, 2.5%), however overall numbers were very small within this theme, limiting interpretation.

'Worried about choking' was also a significant sub-theme. Mothers of infants who were being formula fed (*n*=15, 37.5%) were more likely cite being worried about choking in complementary feeding, when compared with combination fed infants (*n*=2, 12.5%) and breastfed infants (*n*=8, 11.9%).

Looking at sub-themes in relation to the chosen complementary feeding method, some significant differences arose. Around a fifth of mothers who adopted BLW reported looking for signs of appropriate developmental readiness (*n*=9, 19.1%), compared with a lower proportion of mothers who adopted SCF (*n*=4, 5.3%) and an exact test was significant [p=0.03]. However, numbers were low overall for this theme with only 10.6% of all mothers reporting waiting for developmental readiness.

Unsurprisingly, beliefs about the benefits of BLW were more likely to be cited by mothers who adopted BLW (*n*=23, 48.9%), compared with mothers who adopted a SCF method (*n*=10, 13.2%), and a chi square test found this to be significant [X^2 (1, 123) =18.9, p<0.000]. The latter group were likely to be following a mix of spoon-feeding and self-feeding, due to how the method groups were defined within this study (see Chapter 3). Mothers reported beliefs around better appetite control, for example:

"Prevents obesity and later diabetes. Controls own appetite, Independence in feeding. Improves dexterity and motor skills."

"Health i.e. fullness cues"

"I believe baby-led is better to teach baby how to chew and manage his own food intake for his needs - seems to be doing well so far."

They also cited perceived benefits around encouraging a wide variety of tastes and textures and reduced risk of fussiness, for example:

"To improve the chances of her eating a wide variety of foods. To ensure she could tolerate a variety of tastes and textures. So she could participate in family meal times."

"My (older) daughter is a really fussy eater and she was fed puree. We decided to go for a different approach to see if he would be a better eater."

Concerns about weight or intake were significantly more common among mothers who adopted a SCF method [X^2 (1, 123) =12.1, p=0.001]. Over a third of mothers in the SCF group (n=28, 36.8%) stated that concerns about their baby's intake or weight prompted their choice to adopt SCF, compared with only four mothers (8.5%) within the BLW group. Examples of answers given in relation to this include:

"To ensure he was eating enough when being fed by me"

"If he has a bowl of mash/puree food I know what he's had whereas with finger foods it's everywhere"

"Best of both. Able to track amount with spoon fed but baby enjoyed feeding herself and found it easier when introducing new foods"

"He began taking food from mine my husband and my 2 –year-old son's plates. He also dropped from the 75th to below the 50th centile (discovered on his 6-month check-up) so we had to start feeding him more"

"Baby getting hungry. I think this (approach) is best. I can monitor how much he eats."

Being worried about choking was a significant sub-theme [X^2 (1, 123) =19.4, p<0.000], but it was only evident within the SCF group with 25 (32.9%) mothers in this group reporting concerns around choking as influencing their choice of feeding method. No mothers within the BLW group cited concerns about choking.

A greater proportion of mothers within the BLW group cited convenience as a motivating factor towards BLW (*n*=20, 42.6%) compared with 13 (17.1%) in the SCF group [X^2 (1, 123) =9.58, *p*=0.002]. Mothers in both groups felt their choice was easier for them and their family, for example one mother felt BLW was easier for example:

"It's easier than having to mash or puree foods"

Conversely, another felt SCF was more convenient:

"We wanted (baby) to be able to manage with feeding himself and being spoon fed so that we could feed him a range of foods in a range of places. Felt it would be harder out and about if solely baby led weaning"

No significant associations were found between the following sub-themes and the chosen complementary feeding method: 'consideration of baby's enjoyment or preferences', 'beliefs around sleep' 'parent did not feel confident or felt anxious', 'health professional advice', 'awareness of public health recommendations', 'own previous experience or influenced by family/friends' or 'mess'.

QUESTION 2: Are the reasons for choosing the complementary feeding method associated with infant birthweight or infant size at the time of measurement/questioning?

Spearman's correlations were performed. Infant birthweight was not significantly associated with frequency of 'baby-led', 'parent-led' or 'following guidelines' or 'other' broad themes. Infant WAZ, LAZ or BMIZ at the time of measurement were not significantly associated with the frequency of appearance of any of the broad themes or sub-themes. However, WAZV was significantly positively correlated to the frequency of the 'baby-led' broad theme [$r_s = 0.15, p=0.01$] and the 'consideration of baby's enjoyment or preferences' sub-theme' within this [$r_s= 0.12, p=0.04$].

Examples of answers which reflect this sub-theme were:

"I hadn't thought he was ready but he really enjoyed the experience of food"

"I wanted to see what she preferred doing"

"(I wanted) to allow baby to choose what to eat himself. I didn't want to feel like I was force-feeding him"

10.7. Discussion

In line with prior thinking, BLW mothers' reasons for introducing complementary foods were less likely to centre around 'parent-led' reasons such as concern over child intake or weight, rather, BLW mothers were significantly more likely to introduce food because of reasons of developmental readiness, and this has been seen in prior research (Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015). Qualitative work has found that mothers who choose a BLW method also refer to 'trust' in relation to their baby showing them they are ready for solids, and how much they need to eat (Arden & Abbott, 2010).

On the other hand, as hypothesised, mothers in the SCF group were more likely to report concerns about weight or intake as prompting their decision to spoon-feed with over a third of mothers in the SCF group saying this. Findings in Chapter 7, revealed that in the SHIFT sample, no significant differences in WAZV were observed between ages 0-6 months, between infants who went on to either BLW or SCF. This indicates that the mothers' concerns are likely to be perceived rather than actual. Studies have found that perceived infant size influences infant feeding decisions; for example, mothers of infants who they deem to be 'bigger' may encourage intake due to a belief that a bigger baby is hungrier and requires more food (Anderson et al., 2001; Wright et al., 2004; Carroll et al., 2015; Brown & Rowan, 2016). Similarly, mothers of smaller infants report a desire for their infant to put on weight (Redsell et al., 2010; Gross et al., 2001; Fildes et al., 2015). It is unclear why the mothers' perceptions of their infants' size were inaccurate, but it is perhaps related to the cultural view of the desirable 'bigger baby' (Baughcum et al., 1998; Lucas et al., 2007; Redsell et al., 2010; Bentley et al., 2017) and a tendency towards inaccurate estimation of infants' size and healthy growth trajectories (Laraway, Birch, Shaffer & Paul, 2010).

In terms of growth, birthweight or growth outcomes at the time of measurement did not predict the reasons parents gave for the complementary feeding method, however, weight gain velocity from birth to measurement age was greater amongst those who gave reasons in the 'baby-led' theme and specifically the sub-theme 'consideration of baby's enjoyment or preferences'. This may be explained by a reverse causal relationship; it may be that babies who are perceived to be growing 'well' (i.e. gaining weight rapidly in earlier infancy) may be those who their parents deem them suitable to try BLW, because there is less concern about their weight. Similarly, babies who enjoy food or prefer to feed themselves may be more likely to be considered suitable for BLW by their parent, compared to a baby who seems less interested whom the parent may try to spoon feed for example. Conversely, the relationship may be more straightforward in that a baby who enjoys food and prefers to feed themselves may actually eat more, thus gaining weight more rapidly. Food responsiveness (the urge to eat when exposed to food) and enjoyment of eating has been linked to overweight in children (Webber et al., 2009; Spence, Carson, Casey & Boule, 2010). It is also worth considering the genetic propensity for a baby to overeat, whether following the BLW method or SCF. For example, one large cohort study of over 1700 children found links between the FTO genetic allele and food responsiveness in young children (Velders et al., 2012).

It was noteworthy that reasons differed among infants who were milk-fed differently perhaps highlighting a tendency towards a parent-led or baby-led complementary feeding style that is evident from early in infancy. Although numbers were very small, limiting interpretation, mothers of who were combination feeding were more likely to cite beliefs around infant sleep as prompting their choice of complementary feeding method. Perhaps, the same beliefs led to the introduction of formula to a previously breastfed infant? Indeed, studies have found that mothers stop breastfeeding and move to formula because of a belief that it will help them sleep (Hoddinott et al., 2011; Brown & Harries, 2015; Rudzik & Ball, 2016).

Infant behaviour and perceived weight may therefore be predictive of the way they are fed throughout infancy. Some authors have noted that BLW may only be available to a certain cohort of infants, those with the developmental readiness to self-feed, who are 'settled' generally and who are a normal weight (actual or perceived) to begin with, leading parents to identify with BLW as a viable option (Brown et al., 2017) and also indicating that perhaps this 'type' of baby would induce less anxiety in the parent anyway. Notwithstanding this, anxiety about infant feeding is very commonplace even if infant behaviour is normal. For example, chewing fists or watching adults eating is often cited by parents as an indication of readiness for solids (Arden, 2010; Begley, Ringrose, Giglia & Scott, 2019), however these not considered to be true signs of physical developmental readiness (Naylor & Morrow, 2001; NHS, 2019). Infants who receive solids earlier are also not necessarily likely to be less wakeful at night (Brown & Harries, 2015).

Research has explored the ongoing impact of infant behaviour on infant growth and feeding decisions. For example, Darlington & Wright (2006) found that infants who slept less and fussed and cried more, were more likely to grow more rapidly. This may be explained by attempts to soothe infant behaviour with food which has been seen in other studies of fractious infants (Stifter et al., 2011). Another found that mothers who believed that crying is indicative of hunger were more likely to pressure intake (Gross et al., 2010).

Why mothers have so many concerns around their babies' behaviour might largely be explained by cultural perceptions of what is 'normal'. Pressure for the baby to be a 'good baby', who sleeps through the night and does not cry too often may be driving mothers to choose or change feeding behaviour, or adopt a strict routine in an attempt to reach this desired image (Redsell et al., 2010; Harrison, Brodribb & Hepworth, 2016; Harries & Brown, 2019). Maternal mood and mental health is also thought to play a role in how she perceives her infant's temperament, behaviour and in this way also may affect her feeding decisions (Farrow & Blissett, 2005b; McMeekin et al., 2013).

Limitations of the information around parents' choices presented in this chapter are that they were self-reported which may be affected by social desirability (Krumpal, 2013). Infant feeding is often an emotionally charged subject and because BLW is also not universally supported mothers who choose BLW may be more defensive of the method leading some mothers to cite the proposed benefits of the method (Locke, 2015). Nevertheless, the results of this chapter show that maternal concerns, beliefs and anxieties appear to be related to feeding method chosen, and addressing parents' worries about infant feeding may help to reduce the influence of these drivers, and promote more responsive feeding.

The next chapter will explore all the infant feeding factors that have been looked at so far and examine them all together in a regression analysis in order to identify which might be the most important for influencing infant growth.

CHAPTER 11: What are the key factors influencing infant growth? Exploration of the data using regression analysis.

11.1. Rationale

The previous chapters showed some significant results, which, in summary, were:

For Weight

- Birthweight was associated with greater weight.
- Formula feeding (both at birth and at the time of measurement) was associated with greater weight.
- Duration of any breastfeeding to 2, 6, 12, 17 and 26 weeks seemed to be protective against increased weight compared with full formula feeding, or breastfeeding for less than, 2, 6, 12, 17 and 26 weeks respectively. Duration of exclusive breastfeeding had no significant effect on weight.
- Early introduction of complementary feeding (at 18-26 weeks) was associated with greater weight but only in infants who were also formula fed. This association was not seen for breastfed infants or if complementary feeding was delayed until 26 weeks (regardless of milk type).
- Increased frequency of milk feeding and increased exposure to complementary foods was associated with lower weight but only at 9-12 months.
- Breastfed infants who had more frequent exposure to complementary foods had a lower weight. This association was not seen for formula fed infants.

For Length

- Greater birthweight was associated with greater length.
- Early introduction to complementary feeding (before 26 weeks) was associated with increased length, but only in infants 9-12 months.

- Combination of formula feeding and early introduction to complementary feeding resulted in greater length. This association was not seen for breastfed infants, or if complementary feeding was delayed until 26 weeks (regardless of milk type).
- Spoon-fed infants were longer than self-fed infants.
- Increased frequency of milk feeding was associated with shorter length, particularly among breastfed infants.
- Infants currently consuming purees at 9-12 had significantly greater length compared with those eating whole foods.

For BMI

- Lower maternal education was associated with increased infant BMI.
- Greater birthweight was associated with increased BMI.
- Formula feeding from birth was associated with increased BMI. Formula feeding at the time of measurement was associated with increased BMI at 9-12 months.
- Exclusive breastfeeding to 6 months was associated with increased BMI (this seemed to be due to shorter length rather than increased weight).

For Weight-for-age velocity

- Lower birthweight was associated with increased weight for age velocity (catch-up growth)
- Increased frequency of milk feeding and increased exposure to complementary foods was associated with slower weight gain.

Due to the often interrelated nature of factors affecting infant growth it was important to analyse them all together in order to identify the key influencing factors, and to ensure that the effects of confounding were accounted for. As discussed in Chapter 3, section 3.7.4), this was also needed to mitigate against the discovery of false positive results due to multiple analyses (Davey-Smith & Ebrahim, 2002; Head et al., 2015) A regression analysis including all the key factors was therefore undertaken.

11.2. Background

Several factors were identified as being influential on infant growth, based on prior literature and the findings of previous chapters. To briefly reiterate the rationale for each of these:

- **Maternal age.** Research has found that both younger mothers and older are more likely to have a smaller baby (Pilgrim et al., 2010; Restrepo-Mendez et al., 2015). Infant feeding practices also differ according to age, with older mothers more likely to breastfeed, introduce food later and adopt BLW (Oakley et al., 2013; McAndrew et al., 2012).

- **Maternal education (SES)** Mothers from more deprived socio-economic backgrounds are more likely to have a small baby at birth, but to go on to have infants who grow rapidly (Wijlaars et al., 2011; Cantarutti et al., 2017). Mothers from more deprived communities are also less likely to breastfeed, and to introduce complementary food earlier (Tarrant et al., 2010; McAndrew et al., 2012; Trickey et al., 2019)

- **Infant birthweight.** Many studies have identified birthweight as a significant predictor of infant growth and later weight status (Ross & Desai, 2014; Wang et al., 2016; Chiavaroli et al., 2016). Smaller infants may undergo catch-up growth (Jain & Singhal, 2012; Ong et al., 2000) Maternal feeding practices also may differ according to perceived or actual infant size (Kramer et al., 2011; Brown & Lee, 2013; van Rossem et al., 2013).

- **Milk feeding type.** Milk feeding is a well-established predictor of infant growth, with breastfeeding being protective and formula feeding thought to exacerbate growth (Horta et al., 2015; WHO, 2016b; Rito et al., 2019).

- **Age of introduction to complementary feeding.** Studies are mixed, however broadly very early introduction to complementary food (<4 months) has been linked to risk of overweight and rapid infant growth (Sloan et al., 2007; Pearce et al., 2013; Azad et al., 2018). Reviews continue to advise delaying complementary feeding until 6 months (Kramer & Kakuma, 2012; Smith & Becker, 2016; SACN, 2018).

- **Complementary feeding method (self-feeding or spoon fed) at introduction to complementary feeding and at the time of measurement.** A self-feeding approach (BLW) has been proposed as beneficial to prevent against excessive weight gain in infancy (Brown et al., 2017). However, research in this area is sparse and limited by self-report or lack of consideration of covariates (Townsend & Pitchford, 2012; Brown & Lee, 2015; Taylor et al., 2017; Dogan et al., 2018)

- **Number of milk feeds in 24-hours (breast or formula) and number of exposures to complementary feeds in 24-hours, and the estimated proportion of milk to food in the diet.** Milk should continue to be a key source of nutrition and energy for infants during complementary feeding (Michaelsen et al., 2000; WHO, 2001). BLW may offer a slower transition from milk to solid foods (Rapley & Murkett, 2008). The transition from milk to food has also been seen to differ among infants' milk fed differently; breastfed infants have been seen to reduce their milk feeds in relation to food intake when formula infants do not (Heinig et al., 1993; Noble & Emmett, 2006; Ong et al., 2006). Frequent milk feeding and frequent small offers of food may assist appetite regulation because a little and often approach to eating has been seen to be helpful in children for maintaining healthy weight (Kaisari et al., 2013)

- **Texture of food offered (Predominantly whole foods or predominantly pureed)**. Foods that are eaten whole take longer to chew and swallow as opposed to purees which can be slurped off a spoon and swallowed easily (Gisel, 1991; Rapley et al., 2015). Speed of eating may affect energy intake and weight gain, as has been found in studies of older children and adults (Fogel et al., 2017; Shah et al., 2014; Robinson et al., 2014). Foods of a pureed texture, if they are commercially prepared, can be high in sugar (Walker & Goran, 2015; Maslin et al., 2015; Crawley & Westland, 2017) or cow's milk protein (Cow & Gate, 2018, Heinz, 2019).

- **Exposure to protein.** Several studies have linked excess protein consumption in infancy with rapid growth and risk of overweight (Hoppe et al., 2004; Luque et al., 2016).

- **Exposure to sweet foods.** These are high in sugar which may exacerbate weight gain (Westland & Crawley, 2018; Sparks & Crawley 2018).

- **Exposure to savoury snacks.** These can be energy dense, high in fat and sugar, again, a risk for weight gain (Emmett & Jones, 2015; Rouhani et al., 2016; Sparks & Crawley, 2018).

- **Exposure to commercial infant foods.** Studies have shown these to be high in sugar (Walker & Goran, 2015; Westland & Crawley, 2018; Sparks & Crawley 2018).

- **Exposure to commercial infant cereals.** These may be high in cow's milk powder (Cow & Gate, 2018, Heinz, 2019) which has been found to exacerbate growth (Diana et al., 2017; Roess et al., 2018; Grenov & Michaelsen, 2018).

The analyses for this chapter sought to answer the following key questions:

1) Which factors, if any, predict infant growth outcomes?
2) Which factors, if any, predict infant growth trajectories from 0-6 months and 6-12 months?

11.3. Participants

For full details of participants please refer to chapter four.

11.4. Measures.

Predictor variables entered in to the model were:

- **Maternal age.**
- **Maternal education (SES).** Lowest=1, Highest =5
- **Infant birthweight.**
- **Milk feeding type at birth.** Breastfed (yes/no).
- **Milk feeding type at the time of measurement.** Partial breastfeeding (yes/no) and exclusive breastfeeding (for the purposes of this analysis exclusive breastfeeding meant no formula but having complementary food) (yes/no) were both entered in as separate independent variables.
- **Age of introduction to complementary feeding.**
- **Complementary feeding method.** Predominantly spoon-fed (yes/no)
- **Number of milk feeds in 24-hours.**
- **Number of exposures to complementary feeds in 24-hours**.
- **Proportion of milk to solids in the diet**. 1 =all milk, 5= all food
- **Texture of food offered.** Predominantly purees (yes/no)
- **Exposure to protein.**
- **Exposure to sweet foods.**
- **Exposure to savoury snacks.**
- **Exposure to commercial infant foods.**
- **Exposure to commercial infant cereals**

Outcome measures were:

Weight-for-age z-score (WAZ), length-for-age z-score (LAZ) and BMI-for-age z-score (BMIZ) and weight-for-age velocity (WAZV), calculated as described in Chapter 3.

11.5. Data analysis

A multiple linear regression analysis was calculated to investigate whether any of the predictor variables could significantly predict any of the outcome measures. Dichotomous categorical variables were coded as 1 for yes and 0 for no. For example, for spoon-feeding, a code of 1 indicated that 'yes' the infant was in the spoon-feeding group and 0 indicated that 'no' they were not in the spoon-feeding group (i.e. they were in the self-feeding group). The standard 'enter' method (rather than 'stepwise' or sequential selection) was used so that all predictor variables were considered at the same time. This was chosen as it was not clear from the analyses in the preceding chapters which factors were the most important in predicting infant growth. In terms of dealing with missing data, very few cases had any missing data (*n*=12). Therefore, as not many cases would be lost, cases with missing data were excluded list-wise (rather than pairwise) as recommended by Tabachnick & Fidell (2013). The data were checked and did not violate assumptions for regression (collinearity, outliers, normality, linearity homoscedasticity, and independence of residuals).

The sample was then split (as per previous chapters) into the age at measurement sub-groups (6-8 months, and 9-12 months) and exactly the same regression analyses were repeated for each. This was done in order to explore whether predictor variables appeared to have a greater or lesser effect dependent on the age of the infant, and the length of time exposed to feeding behaviours.

The longitudinal data-set explored predictors for WAZV from birth to six months, and from six to twelve months.

11.6. Results

QUESTION 1: Which factors, if any, predict infant growth outcomes?

Weight-for-age z-score

For the whole sample (*N*=257) the model explained 27.5% of the variance and the model was a significant predictor of infant weight [F (19, 238)= 4.76, p<0.000]. Several factors predicted infant weight. Greater infant birthweight predicted increased weight. Whether the infant was breastfed at birth was associated with lower weight. Increased frequency of exposure to complementary foods was associated with lower weight. Increased frequency of exposure to protein in the complementary diet was associated with increased weight. Table 45 shows the statistics for significant predictors (only the significant predictors are reported).

Table 45: Unstandardised and standardised regression coefficients for variables associated with WAZ. Whole sample.

Variable	***B***	**SE *B***	**β**	**Sig.**
Infant birthweight	0.815	0.111	0.416	p<0.000
Breastfed at birth	-0.450	0.172	-0.172	p=0.01
Frequency of exposure to complementary foods	-0.134	0.050	-0.173	p=0.01
Frequency of exposure to protein	0.154	0.065	0.146	p=0.02

B= unstandardized coefficient, β= standardised coefficient

When the model was applied to the age subgroups, at age 6-8 months (*n*=120), the model explained 35.6% of the variance in weight and the model remained significant [F (19, 100)= 2.91 p<0.000]. Amongst these younger infants, significant predictor variables were again, greater birthweight and higher exposure to protein in the diet, both predicting higher infant weight. In this group, infant feeding behaviours (milk or complementary feeding type) did not appear to have a significant effect. Significant predictive variables are shown in Table 46.

Table 46: Unstandardised and standardised regression coefficients for variables associated with WAZ. Age group 6-8 months.

Variable	***B***	**SE *B***	**β**	**Sig.**
Infant birthweight	0.817	0.164	0.430	$p<0.000$
Frequency of exposure to protein	0.273	0.114	0.224	$p=0.02$

B= unstandardized coefficient, β= standardised coefficient

At 9-12 months (n=138), the model's predictive value increased further, explaining 41.1% of the variance [F (19, 118) = 4.32, $p<0.000$]. More significant predictive variables emerged, indicating that perhaps the influence of the factors takes time to become apparent (i.e. as infants get older, and have been exposed to the complementary food or feeding practices for longer). Predictive factors for greater infant weight were; lower maternal education, greater birthweight, increased frequency of exposure to protein, and eating pureed food at the time of measurement. Conversely, being breastfed at birth, and any partial breastfeeding, having purees at introduction to complementary feeding, being spoon-fed and increased frequency of exposures to complementary foods were associated with lower infant weight. See Table 47.

Table 47: Unstandardised and standardised regression coefficients for variables associated with WAZ. Age group 9-12 months.

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal education	-0.269	0.065	-0.330	p<0.000
Infant birthweight	0.734	0.150	0.363	p<0.000
Breastfed at birth	-0.502	0.215	-0.192	p=0.02
Breastfed (any) at the time of measurement	-0.571	0.271	-0.299	p=0.04
Frequency of exposure to complementary foods	-0.173	0.062	-0.217	p=0.01
Frequency of exposure to protein	0.183	0.079	0.184	p=0.02
Purees at introduction to complementary feeding	-0.706	0.267	-0.360	p=0.01
Purees at the time of measurement	0.515	0.191	0.269	p=0.01
Spoon-fed at the time of measurement	-0.447	0.207	-0.208	p=0.03

B= unstandardized coefficient, β= standardised coefficient

Length-for-age z-score

For the whole sample the model explained 24.5% of the variance and the model was a significant predictor of infant length [F (19, 238) = 4.07, p<0.000]. Significant predictor variables for greater length were greater infant birthweight, earlier introduction to complementary foods, and increased exposure to protein. Table 48 shows the statistics for significant predictors.

Table 48: Unstandardised and standardised regression coefficients for variables associated with LAZ. Whole sample

Variable	*B*	SE *B*	β	Sig.
Infant birthweight	0.353	0.067	0.303	$p<0.000$
Age of introduction to complementary foods	-0.070	0.022	-0.207	$p=0.003$
Frequency of exposure to protein	0.185	0.080	0.145	$p=0.02$

B= unstandardized coefficient, β= standardised coefficient

At age 6-8 months the model explained 37.2% of the variance in length which was significant [F (19, 100) = 3.11, $p<0.000$]. Amongst these younger infants, the only significant predictor variables of greater length were greater infant birthweight and increased frequency of exposure to protein (see Table 49).

Table 49: Unstandardised and standardised regression coefficients for variables associated with LAZ. 6-8 months.

Variable	*B*	SE *B*	β	Sig.
Infant birthweight	0.969	0.205	0.404	$p<0.000$
Frequency of exposure to protein	0.355	0.142	0.231	$p=0.01$

B= unstandardized coefficient, β= standardised coefficient

At age 9-12 months the model explained 23.3% of the variance, and remained significant [F (19, 118) = 1.89, $p=0.02$]. Amongst these older infants, significant predictor variables of greater length were greater birthweight, and younger age of introduction to solids (see Table 50).

Table 50: Unstandardised and standardised regression coefficients for variables associated with LAZ. 9-12 months.

Variable	***B***	**SE *B***	**β**	**Sig.**
Infant birthweight	0.476	0.197	0.204	*p*=0.02
Age of introduction to complementary foods	-0.076	0.028	-0.258	*p*=0.01

B= unstandardized coefficient, β= standardised coefficient

BMI-for-age z-score

For the whole sample the model explained 14.8% of the variance and the model was a significant predictor of infant BMI [F (19, 238) = 2.18, p=0.004]. Significant predictor variables for increased BMI were lower maternal education and greater infant birthweight. Table 51 shows the statistics for significant predictors.

Table 51: Unstandardised and standardised regression coefficients for variables associated with BMIZ. Whole sample.

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal education	-0.131	0.053	-0.156	*p*=0.02
Infant birthweight	0.448	0.125	0.222	*p*<0.000

B= unstandardized coefficient, β= standardised coefficient

At age 6-8 months the model explained only 10.4% of the variance in BMI and the predictive value of the model failed to find significance [F (19, 100) = 0.61, p=0.89]. No variables were predictive of BMI within this age group.

However, by 9-12 months' factors in the model appeared to contribute to a greater proportion of the variance (34.1%), which was significant [F (19, 118) = 3.21, p<0.000]. As seen with WAZ this may indicate that it takes longer for the effects of the variables to emerge. Table 52 shows the significant predictive variables influencing greater BMI, which were lower maternal education, greater infant birthweight, and increased frequency of exposure to sweet foods. Increased frequency of exposure to complementary foods and being spoon-fed at the time of measurement were linked to lower infant BMI.

Table 52: Unstandardised and standardised regression coefficients for variables associated with BMIZ. 9-12 months.

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal education	-0.334	0.074	-0.378	$p<0.000$
Infant birthweight	0.576	0.172	0.263	$p=0.001$
Frequency of exposure to complementary foods	-0.144	0.071	-0.166	$p=0.046$
Frequency of exposure to sweet foods	0.296	0.126	0.191	$p=0.02$
Spoon-feeding at the time of measurement	-0.584	0.237	-0.250	$p=0.02$

B= unstandardized coefficient, β= standardised coefficient

Weight-for-age velocity (WAZV)

For the whole sample the model explained 39.1% of the variance and the model was a significant predictor of infant WAZV [F (19, 238) = 8.04, $p<0.000$]. Significant predictor variables were infant birthweight (however this time the association was inverse with lower birthweight predicting greater weight gain velocity). Earlier age of introduction to complementary foods, and increased frequency of exposure to protein were also associated with greater weight gain velocity. However, being breastfed at birth and increased exposure to complementary foods predicted slower weight gain. Table 53 shows the statistics for significant predictors.

Table 53: Unstandardised and standardised regression coefficients for variables associated with WAZV. Whole sample.

Variable	***B***	**SE *B***	**β**	**Sig.**
Infant birthweight	-1.180	0.110	-0.559	p<0.000
Breastfed at birth	-0.363	0.171	-0.129	p=0.03
Age of introduction to complementary foods	-0.036	0.018	-0.118	p=0.04
Frequency of exposure to complementary foods	-0.117	0.050	-0.141	p=0.02
Frequency of exposure to protein	0.165	0.064	0.145	p=0.01

B= unstandardized coefficient, β= standardised coefficient

When the sample was split by age group, among the younger infants aged 6-8 months, the model was predictive for WAZV, explaining 43.1% of the variance [F (19,100)= 3.99, p<0.000]. Predictive factors within this age group predicting greater weight gain velocity were younger maternal age, lower infant birthweight and increased exposure to protein (Table 54).

Table 54: Unstandardised and standardised regression coefficients for variables associated with WAZV. 6-8 months

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal age	-0.42	0.020	-0.179	p=0.04
Infant birthweight	-1.153	0.157	-0.598	p<0.000
Frequency of exposure to protein	0.316	0.109	0.255	p=0.01

B= unstandardized coefficient, β= standardised coefficient

Among the older infants aged 9-12 months, the model explained more of the variance (51.6%) [F(19, 118) = 6.63, p<0.000]. There were several significant factors contributing to the model; lower maternal education, lower infant birthweight, earlier age of introduction to complementary foods, increased frequency of exposure to protein, and puree consumption at the time of measurement, all predicted greater weight gain velocity. Increased frequency of exposure to complementary foods and being fed purees at introduction to complementary foods was linked to slower weight gain velocity (see table 55).

Table 55: Unstandardised and standardised regression coefficients for variables associated with WAZV. Age group 9-12 months

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal education	-0.253	0.067	-0.272	p<0.000
Infant birthweight	-1.263	0.155	-0.547	p<0.000
Age of introduction to complementary foods	-0.052	0.022	-0.179	p=0.02
Frequency of exposure to complementary foods	-0.151	0.064	-0.166	p=0.02
Frequency of exposure to protein	0.174	0.082	0.154	p=0.04
Purees at introduction to complementary feeding	-0.671	0.277	-0.300	p=0.02
Purees at the time of measurement	0.490	0.197	0.224	p=0.02

B= unstandardized coefficient, β= standardised coefficient

Table 56 below summarizes the significant findings of the above regressions. A plus (+) symbol represents a positive association of the variable with the outcome measure, and a minus (-) symbol represents a negative association.

Table 56: Summary of regression findings.

	Whole sample				6 – 8 months				9 – 12 months			
	WAZ	LAZ	BMIZ	WAZV	WAZ	LAZ	BMIZ	WAZV	WAZ	LAZ	BMIZ	WAZV
Maternal age								-				
Higher maternal education			-						-		-	-
Birthweight	+	+	+	-	+	+		-	+	+	+	-
Breastfed (birth)	-			-					-			
Partial breastfeeding at the time of measurement									-			
Age of introduction to complementary feeding		-								-		-
Spoon fed at the time of measurement									-		-	
Frequency of exposure to complementary feeds in 24 hours	-			-					-		-	-
Purees at introduction to complementary foods									-			-
Purees at the time of measurement									+			+
Exposure to protein	+	+		+	+	+		+	+			+
Exposure to sweet foods											+	

QUESTION 2: Which factors, if any, predict infant growth trajectories from 0-6 months and 6-12 months?

For infants in the longitudinal data set WAZV was calculated from birth to 6 months and again from 6 to 12 months. As above, regression analyses were undertaken for these WAZV scores.

WAZV – birth to 6 months

Only certain factors examined for WAVZ from birth to 6 months (those relevant to early infancy). These were:

- **Maternal age**
- **Maternal education**
- **Infant birthweight**
- **Breastfeeding at birth** (yes/no)
- **Breastfeeding (any) at 6 months** (yes/no)
- **Breastfeeding (exclusive - no formula, may have solids) at 6 months** (yes/no)

The model explained 34.5% of the variance and the model was a significant predictor of infant WAZV [F (19, 238) = 8.04, p<0.000] from birth to 6 months. However, only significant predictive variable was infant birthweight [B = -1.17, SE B =0.192, β = -0.515, p<0.000]. Lower birthweight predicted greater weight gain velocity from birth to six months.

WAZV – 6 to 12 months

For infants aged 6-12 months the following factors were included:

- **Maternal age**
- **Maternal education**
- **Infant birthweight**
- **Breastfeeding at birth** (yes/no)
- **Breastfeeding (any) at 6 months** (yes/no)
- **Breastfeeding (exclusive - no formula can have solids) at 6 months** (yes/no)

- **Age of introduction to complementary foods.**
- **Complementary feeding method.** Predominantly spoon-fed (yes/no) at introduction to complementary feeding and at 12 months.
- **Texture of food offered**. Predominantly purees (yes/no) at introduction to complementary feeding and at 12 months.
- **Frequency of of milk feeds** (at 6 months)
- **Frequency of exposure to complementary foods** (at 6 months)
- **Proportion of milk to complementary food** (at 6 months)
- **Diet at 6 months**. Frequency of exposure to protein, savoury snacks, sweet foods, commercial infant meals and commercial infant cereals (at 6 months).

The model explained 23.4% of the variance, however the overall model was not a significant predictor of infant WAZV [F (19, 79) = 1.27 p=0.23] from 6 to 12 months.

Significant predictors are shown in Table 57. In this model infant birthweight was no longer significant, perhaps indicating the influence of other factors after 6 months. Higher maternal education and partial breastfeeding at 6 months predicted greater weight gain between 6-12 months. Exclusive breastfeeding (except for complementary foods) and frequency of exposure to commercial infant meals at 6 months predicted lower infant weight gain from 6-12 months.

Table 57: Unstandardised and standardised regression coefficients for variables associated with WAZV. Longitudinal analyses of infants aged 6-12 months.

Variable	***B***	**SE *B***	**β**	**Sig.**
Maternal education	0.118	0.055	0.24	p=0.04
Partial breastfeeding at 6 months	0.671	0.298	2.25	p=0.03
Exclusive breastfeeding at 6 months	-0.581	0.234	-2.47	p=0.02
Frequency of exposure to commercial infant meals	-0.258	0.104	-2.49	p=0.02

B= unstandardized coefficient, β= standardised coefficient

11.7. Discussion

This aim of the regression analysis was to consider all the factors explored in the preceding chapters in order to look at which variables independently predict growth. This was considered to be important because of the issues that may occur from undertaking multiple analyses (ANOVAS etc.) on the same set of data, which may have identified patterns in the data which are not necessarily meaningful (Davey-Smith & Ebrahim, 2002). Multiple influences were identified as significant predictors of infant growth including maternal education, birthweight, milk feeding, timing of introduction to complementary foods, use of purees, frequency of exposure to complementary foods and protein intake.

The focus of the thesis was, initially, to examine the impact of a BLW method of complementary feeding on infant growth. The regression analyses found this was unclear; divergent results were found between the two key aspects of BLW (self-feeding and texture) which was surprising. Puree use into late infancy (9-12 months), but not earlier (6-8 months), was associated with greater weight. This may imply two things. It may be that the pureed food encourages a faster speed of eating resulting in greater intake, especially in later infancy (Gisel, 1991; Fogel et al., 2017). The risk for overeating may not be as great in early infancy when mothers are perhaps offering very small amounts of purees before moving on to whole foods. Mothers who continue to give purees until late infancy may be encouraged by their babies' ability to 'eat well' when offered purees and they may be more representative of a 'parent-led' approach, perhaps also pressuring intake. However, an incongruent finding in the regression analysis opposed this theory; spoon-feeding in later infancy (also considered to be 'parent-led') was associated with lower weight. Given the logical correlation between spoon-feeding and puree-use, this result led to some consideration about the appropriateness of a linear regression analysis for factors that are highly interrelated. Collinearity diagnostics, however, did not indicate that this should be a problem in the model. Due to this inconsistent finding, it is reasonable to conclude that the overall impact of the BLW method (in particular the self-feeding aspect) in the SHIFT sample is unclear. However, longitudinal analyses comparing self-feeding to spoon-feeding from a previous chapter (Chapter 7, Figures 10, 12) represented a concerning trend of increasing weight and BMI in spoon-fed infants.

While the findings are not able to confidently discern the impact of the BLW method on infant growth, other aspects which could arguably represent a broader 'baby-led' infant feeding approach transpired to potentially important. For example, breastfeeding and later introduction of complementary foods and whole food use in later infancy were associated with lower weight. In contrast, formula feeding, earlier introduction to foods and prolonged puree use were linked to increased weight. Therefore, rather than the BLW method, a baby-led approach from birth, starting with breastfeeding, may be more important. Breastfeeding is innately 'baby-led' in that it relies on infant being fed in response to appetite cues Daley & Hartmann, 1995; Brown et al., 2011a). Similarly, mothers who delay complementary feeding are more likely to look for signs of developmental readiness, rather than be driven by factors which are more 'parent-led', for example concerns over weight, intake behaviour or sleep (Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015). Offering a diet of predominantly whole-foods, especially as infants get older is also likely to reflect a baby-led approach which values infant development and exploration of food. Current UK infant feeding guidelines promote the use of whole food use as early in the complementary feeding process as possible (UNICEF UK, 2015). Puree use into late infancy on the other hand, may occur when mothers want to encourage intake.

The regressions found that these significant predictive factors had a greater influence on infant growth in later infancy (9-12 months). This may be due to the infants being exposed to the behaviours for longer. The impact of feeding behaviour may also take time to have an effect. For example, incremental increases in protein from formula feeding, or early introduction of complementary foods (where infant cereals may be prominent) may mount up over time. The DARLING study found that total protein intake (from either milk and complementary foods) was 66-70 % higher in formula fed babies than in breast fed babies age 3-6 months (Heinig et al., 1993). While the DARLING research is now fairly outdated because protein in formula milks has reduced (EFSA, 2017), recent research continues to show that formula contains higher protein levels than breastmilk (Ballard & Morrow, 2013). Over weeks and months consistently high protein consumption and subsequent growth is likely to add up. Similarly, the impact of a controlling maternal feeding style may take time to show an effect. Mothers who formula feed or introduce complementary food early may encourage or pressure intake (Brown et al., 2011a). Studies of formula fed infants have shown increased volume of milk consumption where bottle emptying is encouraged. Over time, even relatively few extra calories each day may amount to a large calorie increase.

The presence of this later effect of feeding variables on weight could also be explained by the possibility of a combined or cumulative effect of the factors, which only becomes apparent in older infancy. Previous chapters explored the potential for such a combined effect and found some noteworthy results. For example, in Chapter 6, analyses found that earlier introduction of complementary feeding was associated with greater weight and length, but only among infants who were also fully formula fed. Similarly, in Chapter 7 spoon-feeding of infants was associated with greater weight, but only amongst fully formula fed infants. Conversely, among infants who were breastfed, it did not seem to matter if complementary feeding took place before 26 weeks, or if they were subsequently spoon-fed. These findings appear to point towards an ongoing protective effect of breastfeeding once complementary feeding has commenced, as is also seen in the literature (Huh et al., 2011; Moss & Yeaton, 2014; Papoutsou et al., 2018). This protective effect could be due to differences in the microbiome which continue after food is introduced (Ville et al., 2019). Alternatively, the appearance of a combined effect could be accounted for by behavioural differences between mother-infant dyads, which start with milk feeding choice (Brown & Lee, 2012; Bartok & Ventura, 2009). Improved satiety responsiveness from breastfeeding and lower levels of maternal controlling behaviour seen in breastfeeding mothers among may thus play a role (Brown & Lee, 2011; Brown & Lee, 2013a).

The significant associations seen with lower maternal education and greater infant weight, BMI and weight gain velocity may therefore be explained by the effect of combination of feeding behaviours that are more prevalent in this group of mothers. For example, mothers with lower levels of education are more likely to formula feed and introduce complementary food early, necessitating a spoon-feeding approach (Brown & Lee, 2010; Oakley, et al., 2013; McAndrew et al., 2012).

Similarly, birthweight may trigger a trajectory towards behaviours aligned with a more controlling feeding style. Birthweight also stood out as being a highly influential factor on infant growth in the regression model, with greater infant birthweight predicting greater infant weight, length and BMI. While genetics are likely to be implicated in greater birthweight (Ong & Dunger, 2004), there may be ongoing effects that come from being born bigger. It seems logical that bigger babies would continue to be bigger in line with their birth trajectory, however, it is also possible that mothers of bigger infants exhibit a more controlling feeding styles, believing that a bigger baby is hungrier and needs more food. Such beliefs have been found in studies with mothers have reported that perceptions of their baby being big prompted them to start formula feeding (due to perceptions that breastmilk was insufficient) or to start complementary food earlier (Anderson et al., 2001; Arden, 2010; van Rossem et al., 2013; Daniels et al., 2015b).

Perhaps more concerning when considering ways to mitigate against excessive growth, is the now well-recognised adverse effect of catch-up growth among smaller-born infants (Ong et al., 2000; Stettler, 2007; Ross & Desai, 2014; Wang et al., 2016). In line with this, the SHIFT regression analyses revealed that smaller infant birthweight predicted faster growth velocity. However, as discussed in Chapter 4, it is not clear whether catch-up growth is a biological imperative for survival (Metcalfe & Monaghan, 2001) or whether it is influenced by feeding behaviour. For example, mothers who wish for their infant to gain weight may be more attracted to formula feeding and may encourage weight gain through a pressuring complementary feeding style. Whatever the cause, lower birthweight appears to trigger a trajectory for rapid weight gain.

As discussed in Chapter 8, a new and unique area of exploration in infant feeding which might be important was that of how infants move from milk onto complementary foods. When this was examined on its own, two factors stood out; prolonged frequent milk feeding was associated with lower weight, length and weight-velocity, and frequent exposure to complementary foods was linked to lower weight (see Chapter 8). However, once these factors were entered into the regression analyses the importance of frequent milk feeding disappeared. It may be that rather than frequent and prolonged milk feeding, it was breastfeeding (which was associated with frequent and prolonged milk feeding) which was having the effect. The influence of frequent exposure to complementary foods however, was a significant predictor in the regression for lower weight, BMI and weight velocity up to 9-12 months. It was suggested in the discussion of Chapter 8 (section 8.7.), that this may be because a 'little and often' approach may be more protective of appetite regulation as opposed to infants being fed fewer but larger meals. This may not be surprising, since this approach to eating has been seen to have beneficial effects in children for weight management (Kaisari et al., 2013).

Finally, apart from how babies are fed, the content of the diet may differ between BLW and SCF approaches (see Chapter 9). The most important dietary factor emerging from the regression analyses of the SHIFT data was protein. Increased exposure to protein in the complementary diet was linked to increased weight, length and weight gain velocity throughout infancy. Protein consumption is known to promote growth, however, as previously discussed in Chapter 9, this may be more concerning in formula fed infants who already consume higher levels of protein via milk. Breastfed infants who eat protein in the complementary feeding period may benefit from this (Dupont, 2003). It is not currently clear how much protein is too much, and recommendations vary (Michaelsen et al., 2012), which can be confusing for parents, which can potentially lead to a perception that infants need more protein than they do. Again, parents with a controlling feeding style may be tempted to encourage protein intake from 6 months when instead, it is likely that a gradual transition from milk to dietary sources of protein may be beneficial.

In the longitudinal sub-sample, exposure to commercial infant cereals at 6 months was associated with lower weight gain velocity from 6-12 months. This was surprising initially due to the suggestion made in previous chapters that infant cereals may exacerbate growth due to their cow's milk content. However, the cow's milk protein in these cereals is likely to promote linear (rather than weight) gains (Grenov & Michelsen, 2018). A reverse causality association ought to also be considered. It may be that mothers of infants who were concerned about their infant's small size were giving cereals to promote growth, as this has been reported in studies; however, this research is somewhat old (Baughcum et al., 1998) or not culturally relevant to the UK (Lucas et al., 2017). More recent research on reasons for mothers' use of commercial infant cereals is required.

Limitations of these analyses may be that they lacked power (as discussed in previous chapters) or there could be other factors to explain any variance, as the regression model only explained around 28-50% of the variance in weight with other influencing factors unknown or unaccounted for. For example, information on mode of birth, antibiotic use or maternal weight or infant physical activity was either not collected or not measureable (further discussion of confounding factors will be discussed in Chapter 12).

This chapter drew together all the factors from the SHIFT data and examined them using linear regressions. This was useful to illuminate key factors influencing infant growth and it appeared that rather the self-feeding aspect being important, key aspects of what may be considered part of a broader baby-led feeding approach, predicted healthier infant growth trajectories. Thus it may not be the BLW method, but an overarching 'baby-led' approach to infant feeding from birth which is effective. The final chapter, the general discussion, will explore this further, considering the practical applications of a baby-led feeding approach, the limitations of the research and suggestions for the future.

CHAPTER 12: General discussion, limitations of the research, conclusions and recommendations.

12.1. Key findings

This thesis examined the increasingly popular belief that the baby-led weaning (BLW) method of introducing complementary foods, by allowing infants to self-feed will encourage healthy weight gain trajectories. Building on previous research in the area, it used researcher led anthropometric measures of infant growth from 6 – 12 months, considering not only the behaviour of self-feeding but exploring how connected factors such as milk feeding, timing of introduction to complementary foods, and diet consumed may influence growth. Infant growth, as expected, could not be predicted by one single factor. Instead multiple influences including maternal education, birthweight, milk feeding type, timing of introduction to complementary foods, use of purees, frequency of exposure to complementary foods and protein intake all predicted infant weight and growth. Overall, the findings highlighted the complex nature of infant growth in the first year, suggesting that any interventions to support healthy weight gain trajectories must consider a multicomponent approach.

The original aim of the research was to explore whether a BLW method affected infant growth. Followers of BLW often state that allowing an infant to self-feed will promote healthier weight gain trajectories, yet this belief is largely untested. Only four previous studies have examined this, with mixed results and limitations in their designs. The SHIFT study was therefore designed to reduce these limitations (by collecting researcher-led anthropometric measurements) and to expand the question by asking whether any differences in growth that occurred from following a BLW method might be due not to infant self-feeding alone, but rather may be attributed to a collection of other associated behaviours that may be termed 'baby-led'. Therefore, the study explored each of these factors in its own right, before considering the factors together in a regression analysis.

Notably, in the final analysis, self-feeding itself was not associated with differences in infant growth; but other factors that are commonly related to a baby-led approach were.

Factors such as breastfeeding, delayed introduction to complementary foods, and a slow transition onto a diet consisting of mainly whole foods appeared to promote healthier growth and slower weight gain. Conversely, formula feeding, earlier introduction of solids and prolonged use of purees were associated with greater weight. These factors suggest that, perhaps, rather than the baby-led weaning method, with infant self-feeding being the key behaviour, being generally 'baby-led' (i.e. responsive) may be more important. Of course, allowing an infant to self-feed is the most obvious way of ensuring a feeding style is responsive as it would be very difficult to adopt a controlling feeding style if the infant is ultimately in control of food intake.

Together the feeding behaviours seem to represent broadly either a 'baby-led' or 'parent-led' approach, however, before now, research has not considered how these behaviours interact, and whether one behaviour is more important than another. Therefore, as well as looking at the whole sample, the sample was split by milk feeding type which enabled an exploration of complementary feeding outcomes between the infants who were milk fed differently. This was deemed important because milk should remain a large part of the infant diet throughout infancy (Michaelsen et al., 2000; WHO, 2001) and it was recognised that this is not often explored in research into which usually uses milk feeding data as a covariate only.

The SHIFT data therefore explored the potential for a combined or cumulative effect of all these factors and, indeed, combinations of factors did seem to exacerbate excess growth. For example, earlier introduction of complementary feeding and spoon-feeding were associated with greater weight and length, but only among fully formula fed infants. Conversely, when infants were breastfed, it did not seem to matter if complementary feeding took place before 26 weeks, or if they were subsequently spoon-fed. It may be that breastfeeding is having some protective effect either due to the properties of the milk or improved satiety responsiveness due to ongoing lower maternal control (Heinig et al., 1993; Brown & Lee, 2012; Ville et al., 2019). It is also thought that breastfed infants reduce milk intake in line with complementary food intake, where formula fed infants are less likely to adapt to this change (Heinig et al., 1993). These findings also suggest that it is not any one behaviour which is important rather that some or all of them together increase risk of excess growth. By this token, it may be possible to mitigate the effects of one behaviour by altering another.

Several other factors were associated with weight gain, which were maternal education, birth weight, protein intake. Although not immediately identifiable as being part of a baby-led approach, on reflection and in consideration of the literature, these factors may also be indicative of a generally more responsive feeding approach.

12.2. The central role of responsive feeding

Breastfeeding, delaying complementary feeding and a slow transition from milk onto a diet of predominantly whole foods all seemed to have a beneficial effect on weight trajectories, to a greater or lesser degree. While it is difficult to draw strong conclusions from the SHIFT data about which aspect is the most important, all of these behaviours are aligned with a baby-led paradigm which focuses on the infant controlling their intake. Conversely, more 'controlling' behaviours, such as using a bottle, encouraging early complementary feeding and moving quickly onto food, with prolonged use of purees were associated with greater weight.

These behaviours, taken together, represent a long term 'commitment' to an approach to nutrition in the first year which places the infant in greater control. Starting with milk feeding, the infant is afforded greater ability to regulate their appetite, followed by an introduction of solid foods at a stage where they are more developmentally ready, and ending with a more gradual transition from milk to solid foods. Each of these behaviours encourages the infant to be able to set their own pace, with the mother looking to infant cues of hunger and satiety; essentially being more 'baby-led' regardless of whether she is following the 'baby-led weaning' method.

For example, breastfeeding is by nature baby-led. For a sufficient breastmilk supply to be produced and sustained, infants typically need to feed on-demand (i.e. in response to infant need) (Daley & Hartmann, 1995; Brown et al., 2011a). Breastfeeding mothers are also unable to visualise how much milk their baby is getting, meaning that it is virtually impossible to monitor or control milk supply, and attempts to schedule feeds invariably result in damage to milk supply and cessation of breastfeeding (Dewey et al., 2002; Chantry et al., 2014). Breastfeeding mothers are therefore more responsive to infant feeding cues (Brown et al., 2011a). Whether it is the type of mother who is more relaxed about intake who is attracted to breastfeeding, or whether breastfeeding 'teaches' the mother to be responsive is unclear. However, breastfeeding mothers seem to continue to be responsive in their approach throughout infancy and childhood (Blissett & Farrow, 2007; Ventura, 2017b). Breastfeeding is therefore an important first step in providing a basis for ongoing baby-led responsive feeding. The findings in SHIFT where breastfed infants were examined separately did not find any effect on growth if they were introduced to complementary foods earlier (18-25 weeks) or if they were spoon-fed (see Chapter 6 and Chapter 7). One interpretation of these findings is that mothers who breastfeed continue with a responsive feeding style, regardless of age of complementary feeding or complementary feeding method.

Delaying complementary feeding also lends itself to being baby-led, primarily because infants' developmental status by 6 months allows them to have a greater control, particularly in terms of self-feeding (Wright et al., 2011). Mothers who delay complementary feeding report waiting for signs of readiness (Brown & Lee, 2011b; Brown & Lee, 2013b; Arden & Abbott, 2015). Conversely mothers who introduce food earlier cite their concerns around weight, intake or infant sleep patterns as driving their decision (Anderson et al., 2001; Arden, 2010; Brown & Rowan, 2015), indicating that their feeding style is more parent-led and perhaps therefore less responsive. Infants who are fed complementary food very early may also be more likely to passively consume spoon-fed food, where older infants are likely to demonstrate greater agency.

Finally, a slower transition from milk onto complementary foods also represents a baby-led approach whilst the infant experiments, learns and adapts to eating a solid diet. This may take place by continuing to offer milk as the key component of the diet, alongside small frequent offers of complementary food. This aspect of baby-led feeding has not been explored previously and the SHIFT study was unique in looking at this. It was suggested that mothers who offer food more frequently may be more responsive to babies' hunger cues (which may occur sporadically throughout the day), rather than sticking to set meal-times, where there may be a stronger inclination for the baby to be encouraged to finish the portion. A 'little and often' approach may be more protective of appetite regulation as opposed to infants being fed fewer but larger meals (Kaisari et al., 2013).

Taken together these behaviours illustrate the baby-led journey through the first year. However, a number of other factors were significant in affecting infant growth. At first glance these may not be apparently linked to responsive feeding but on deeper consideration they play an important role in the baby-led approach. For example, prolonged puree use was associated with greater weight gain. This is associated to the baby-led approach, because texture is linked to self-feeding. Whole foods are usually self-fed by the baby, however purees are invariably spoon-fed. This study found that puree use in early infancy did not result in later increased weight, however, feeding purees up until 9-12 months did. It appears therefore that starting off with purees may not be problematic, providing that progression to whole foods occurs as soon as possible, and this is the current recommendation in the UK (UNICEF UK, 2015) which advises finger foods alongside pureed or mashed food from the start of the complementary feeding process. Prolonged consumption of purees into late infancy (when it is no longer recommended that these foods make up a large part of the diet) may be indicative of a more parent-led approach, as parents who desire to encourage intake may continue to spoon-feed purees, perhaps as part of a concern that an infant who is left to self-feed whole foods will not eat enough. Ease of consumption of pureed food may also mean that infants eat more, and quickly, and thus may be at risk of not registering sensations of satiety. Research has found that satiety recognition in adults is improved with a slower pace of eating (Shah et al., 2014) and in children studies have found that rapid pace of eating at age 4 predicted BMI over 2 years (Berkowitz et al., 2010).

The impact of protein stood out in the SHIFT data. Increased exposure to protein in the complementary diet was linked to increased weight, length and weight gain velocity throughout infancy. Although protein as a food group is not itself inherently baby-led or not, the way in which it predominates in a diet may be. For example, parents who feed commercial infant cereals with cow's milk (which is high in protein) to 'fill up' their baby, or help them to sleep may be also placing them at risk of excess consumption of dairy protein. Some parents may therefore be inadvertently feeding their babies too much protein. Instead, it is likely that breastfeeding followed by a baby-led complementary feeding approach using whole foods, may facilitate a beneficial gradual transition from milk to non-dairy dietary sources of protein. The information on appropriate levels of protein consumption is not clear (Michaelsen et al., 2012), which may be confusing for parents, potentially leading to a perception that infants need more protein than they do. The effects of protein may also differ according to how infants were milk fed, and this is an important consideration. For example, increased protein consumption may be more concerning in formula fed infants who already consume higher levels of protein via milk, whereas breastmilk is low in protein so breastfed infants need to get their protein from food (Dupont, 2003). Furthermore, the type of protein may have a different effect; dairy protein promotes growth more than meat or plant proteins (Gunther et al., 2007).

Other factors that emerged from the study, those of infant birthweight and maternal education may at first not seem to be linked to responsive feeding, but they arguably represent key precursors of a tendency to be baby-led or not. Greater infant birthweight predicted greater later infant weight, length and BMI. Of course, it may be that bigger babies simply continued to be bigger in line with their birth trajectory (Hediger et al., 1998). What was perhaps of greater interest is that smaller infant birthweight predicted faster growth velocity which is now considered to be a risk factor for later overweight (Ong et al., 2000; Stettler, 2007; Ross & Desai, 2014; Wang et al., 2016). While genetics and maternal pregnancy factors certainly play a role in infant birthweight and later growth (Clausson et al., 2000; Santangeli et al., 2015), both small and large infant size may trigger feeding behaviours in the mother which are more parent-led (Brown et al., 2011a). Mothers of larger infants report perceptions that a big baby is hungrier and requires more food, prompting the introduction of formula and early complementary feeding (Anderson et al., 2001; Arden, 2010; van Rossem et al., 2013; Daniels et al., 2015b). On the other hand, mothers of smaller infants who wish for their infant to gain weight may be more attracted to formula feeding and a more pressuring feeding style in complementary feeding (Kramer et al., 2011). Pressure from others and the concept of a bigger baby being desirable might further add to the inclination to encourage weight gain (Baughcum et al., 1998; Lucas et al., 2007; Bentley et al., 2017). Nonetheless, lower birthweight appears to trigger a trajectory for rapid weight gain.

Associations between maternal education (a proxy for SES in this study) and infant growth were seen in this study. However, rather than directly influencing infant growth this was more likely to have been due to fact that mothers of lower education are more likely to formula feed, introduce complementary foods early and to adopt an SCF approach (Brown & Lee, 2010; Oakley, et al., 2013; McAndrew et al., 2012). However, it is also important to consider why these behaviours are more likely in mothers from lower SES backgrounds. The factors affecting mothers' feeding choices in this demographic are varied and complex, but centre on cultural norms, low maternal self-efficacy, and lack of experiential knowledge and support for a baby-led feeding approach from people around the mother (Trickey et al., 2019). Mothers from more socio-economically deprived backgrounds are therefore most 'at-risk' of adopting a parent-led approach, perhaps partly explaining the the higher incidence of childhood overweight and obesity in poorer communities (Lakshman et al., 2013; NHS Digital, 2017b).

The findings of SHIFT study therefore appear to support the recommendation for a responsive feeding approach (WHO, 2001b; Hurley et al., 2011; Shloim et al., 2015). However, it appears that responsive feeding does not need to be exclusive to breastfeeding or the BLW method. It is possible for mothers who formula feed to do so responsively and this is the current UNICEF UK (2019) recommendation. Studies, which have explored this have demonstrated that interventions such as weighted and opaque bottles can reduce the temptation to encourage bottle emptying and improve maternal sensitivity to infant feeding cues (Ventura & Pollack Golen, 2015; Ventura & Hernandez, 2019). Similarly spoon-feeding of infants may be undertaken responsively, by giving appropriate portion sizes and being aware of infants' cues of satiety (Hodges et al., 2013; Hetherington et al., 2016; Black & Hurley, 2017). Further research is needed to fully understand how a responsive bottle and spoon fed approach might affect infant growth.

Theoretically, adopting what would be typically considered to be a BLW method, lends itself to a more responsive feeding style, as it is more difficult for a mother to pressure a self-feeding infant. However, some aspects of non-responsiveness may occur in BLW for example by intrusively prompting a child to eat what is in front of them (Lumeng et al., 2012) or by adopting an indulgent style, 'giving in' to the child's preference sweet or snack type foods (Black & Aboud, 2011). An indulgent feeding style where parents indiscriminately attending to crying or protests with favoured foods may lead to the development of emotional overeating (Blissett et al., 2010; Black & Aboud, 2011).

It could be argued therefore, that the method of feeding does not matter so much as it does to feed infants in a responsive and sensitive manner. Notwithstanding this consideration, mothers who adopt BLW have been shown to be more responsive in research (Brown & Lee, 2011b), perhaps because the method emphasises key aspects of responsiveness. Parents who spoon-feed may not be as aware of the information around responsive feeding, and therefore may not be conscientious of it. Furthermore, as with many behaviours, parents are often unaware of their own controlling feeding style as found in a number of studies which have found discrepancies between parents' reports of their feeding style and observations (Sacco et al., 2007; Lewis & Worobey, 2011; Farrow et al., 2011).

12.3. Growth trajectories over time

One of the benefits of the SHIFT study was that it was able to track the growth of a sub-set of infants at the beginning and the end of the complementary feeding period. Although this sample size could have benefitted from being larger, this data revealed some noteworthy results in the graphs representing the longitudinal growth trajectories of infants aged 6-12months. Visual examination of the graphs of infant weight gain for 'parent-led' behaviours for example, formula feeding (Figure 4) early introduction to complementary foods, (Figure 7), and spoon-feeding (Figure 10) all showed steep inclines compared to the comparison groups. This was despite baseline 6-month measures between the two groups being equivocal (and covariates being controlled for). Although these were not significant at 12 months, if the trajectories continued, this could represent a large difference by for example, the time the infant reached 24 months.

The cross sectional nature of the larger data set also allowed comparisons to be made for infants at the start and end of the complementary feeding periods. Notably, the earlier analyses of separate factors and the results of the regression analysis found that the effect of a number of factors was not evident until 9-12 months. For example, milk feeding type, age of introduction to complementary foods, puree use and frequency of complementary meals were not significant in the 6-8-month old sub-group, but were significant in the 9-12-month old sub-group. The fact that the association appeared with older infant age (and thus longer experience of feeding influences), might evidence the suggestion that it is the behaviours having the effect upon infant growth rather than being due to reverse causality, or purely the influence of non-modifiable factors such as infant birthweight or maternal SES as many critics might suggest.

On this note, the influence of birthweight in the longitudinal cohort (in Chapter 4) and in the regression (Chapter 11) for example was only influential on weight gain velocity from birth to 6 months, and disappeared in later infancy. This might indicate that after 6 months' other factors (i.e. the feeding variables) may be more important. However, as discussed in (Chapter 4) lower birthweight may have been the trigger for feeding behaviours which promote catch-up growth in early infancy, but which then continue to have an effect later on. Low birthweight has been linked formula feeding (Appleton et al., 2018a), concern for infant weight and a more pressuring feeding style (Brown & Lee, 2013). Studies have found that infants who initially grow quickly might also be more likely to be perceived as 'fussy' or less 'settled' (Kramer et al., 2011), temperamental states which are linked to formula use and less responsive feeding styles (Darlington & Wright, 2006; Stifter et al., 2011; Wasser et al., 2011; Odom et al., 2013).

While the differences in the longitudinal trajectories were broadly non-significant, they represent a potentially concerning trends. If these trajectories were to continue at the same rate it could perhaps result in significant differences in late childhood, since studies have shown evidence of continuous upward tracking of weight gain from infancy until age 2 (Wang et al., 2016). It may be that the longitudinal SHIFT data provides an early snapshot of this upward trend. Furthermore, small differences of maybe a few hundred grams may not be great enough to produce statistical significance, however in real life the significance of a small increase in weight is likely to be consequential, especially relative to the body size of an infant. For example, 9-12 month old infants who were formula fed at birth had a mean WAZ of 0.67, equivalent to the 65th percentile, compared with infants' breastfed at birth, who had a mean WAZ of 0.02, equivalent to the 52nd percentile. This difference equates to a weight difference of around 540g, which is approximately 5-6% of the average infants' bodyweight at this age. Small but incremental increases such as this may become a large difference over time.

12.4. Practical implications of SHIFT

In the literature review, a 'Trust Model' for infant feeding was proposed, whereby, importance is placed on trusting the infant to know how much and when to eat, without too much intervention or monitoring from the parent in order to protect children's internal appetite regulation skills (Satter, 1996; Eneli et al., 2012). The recommendations of the Trust Model also fit widely with what is known about the negative impact of controlling feeding practices among older children (Hurley et al., 2011; Shloim et al., 2015) and also reflects the WHO (2003b) guidelines which emphasise responsive feeding. The SHIFT data appeared to support the Trust Model as a potentially beneficial approach for supporting healthy infant growth trajectories and reducing the risk of childhood overweight and obesity. However, despite the clear imperative for promoting such an approach, and mothers reported desire to be informed about healthy infant weight trajectories, many find responsive feeding difficult. Widespread adoption of the Trust Model (and a more baby-led approach to infant feeding) is therefore only possible, if there is an understanding of the reasons why this might be.

The reasons appear to be primarily two-fold:

1. In order to be able to trust that a baby can feed adequately and regulate their own appetite, the mother must believe that the baby 'knows what to do', and that this is beneficial for them in the long term. Differences in infant behaviour can lead to misconceptions of hunger, or readiness for food.
2. Mothers need to feel confident in their own ability to feed their baby without the need for over-monitoring and special foods. The influence of mothers' personal self-efficacy, her close relationships, the wider culture and baby food industry can undermine this. Therefore, environment around the mother must be conducive for responsive feeding for it to even be possible.

To explore the first point further, trusting in the infant is based on the idea that infants can and do regulate their own appetite. This concept may not be familiar for some; studies with mothers who formula feed has found the existence of a belief that infants cannot regulate their own appetite, resulting in a perceived need for the parent to control or monitor intake (Gross et al., 2011; Gross et al., 2014). Mothers who are more responsive in their feeding behaviour, on the other hand, are more likely to have a tendency to see the infant as a being with a mind of their own (Farrow & Blissett, 2014). Qualitative work with mothers who breastfeed and those who follow BLW have found trust (in the baby) to be recurring theme (Crossley, 2009; Kronborg et al., 2015; Arden & Abbott, 2015). Investigating and addressing what undermines trust is then surely vital. Babies who are less settled in temperament, feed frequently or watch parents eat may be perceived to be hungry and/or ready for food by the mother, when these may not be true signs of developmental readiness. It seems that 'trust' is being replaced by a projection of mothers' beliefs about what a behaviour means, for example, Gross et al (2010) found a higher prevalence of a pressuring feeding style among mothers who believed that crying is indicative of hunger. It is also commonly perceived that introducing formula or food will help to settle a fractious baby or promote longer sleep (Wasser et al., 2011; Clayton et al., 2013; Lucas et al., 2017).

Perceptions of infant behaviour are inevitably subjective, and misinterpretation of infant cues does not necessarily mean that parents lack responsiveness. Qualitative studies have found that mothers who introduce food early considered themselves to have acted responsively; reporting that they intuitively felt that their baby's behaviours (such as watching parents eat or chewing fists) were indicative of hunger or readiness for complementary foods (Anderson et al., 2001; Walsh et al., 2015). In Brown & Rowan's (2016) research some parents cited perceived developmental readiness as the reason for introducing complementary foods as early as 12 weeks, which is unfeasible according to what is known about infant development (Naylor & Morrow, 2001; Wright et al., 2011).

Very recent research, which has emerged just days prior to this thesis submission has explored the potential impact of what the authors term 'mother-child dyadic' pathways to obesity (Bergmeier et al., 2019). Bergmeier and colleagues posit that the research focus on mother child interactions is often on the mother, with very few studies examining the influence of the child's role in the dyad. The attachment style and the temperament of the child may shape the nature and quality of their relationship with their parent, which may in turn affect feeding behaviour and development of overweight. Bergmeier et al.'s paper also brings attention to the influence of maternal mental health on the parent-child relationship and responsiveness between the dyad. Poor mental health has been shown to negatively impact on maternal responsiveness to child cues and emotional states, leading to a more controlling approach (Farrow, 2005; Haycraft et al., 2008). It may be difficult in these circumstances for some mothers to feel confident to trust their babies' appetite cues and to respond appropriately.

This leads on to a second consideration, which concerns mothers' confidence in their ability to feed their babies. Factors influencing this can be viewed within a socio-ecological model (see Figure 21)

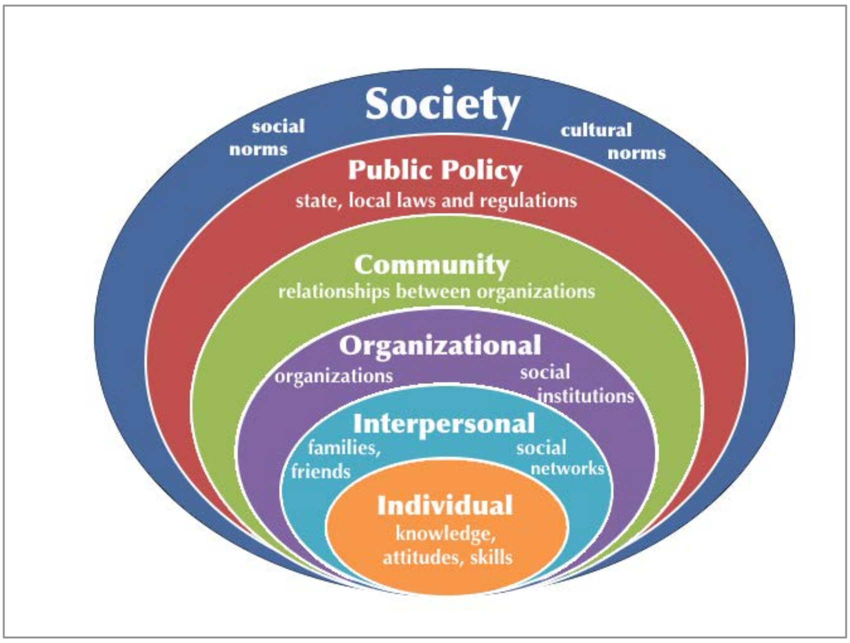

Figure 21: The socio-ecological model

(Image taken from "The Enough Abuse Campaign" by Massachusetts Citizens for Children, 2010, Retrieved September 25, 2019 from https://www.enoughabuse.org/the-campaign/stragegies-and-results.html)

In a report for Public Health Wales, Trickey et al. (2019) explored reasons for low breastfeeding rates in Wales from this 'whole system' perspective. The same could be applied to a baby-led feeding approach, in general. On an individual level, women require the knowledge and skills in order to responsively and confidently feed their babies. This requires self-efficacy, which is defined as the confidence and resilience to undertake a behaviour due to a belief that it is achievable and worthwhile (Bandura, 1994; Entwistle et al., 2010). Self-efficacy is fostered through practice of a skill and/or through social modelling (Bandura, 1994). However, as Trickey et al., (2019) note, opportunities for developing self-efficacy in baby-led feeding are few in a culture where routine-driven formula feeding and early, parent-led complementary feeding are the normative behaviours. This may be especially true when a mother or others around her have had negative experiences with breastfeeding or present a narrative that it is difficult, that babies should be fed to a schedule and/or that baby-led feeding is unsafe (Entwistle, 2010). An Australian systematic review found that if the maternal grandmother had a positive attitude towards breastfeeding, the mother may be up to 12 per cent more likely to initiate breastfeeding; conversely, if she had a negative opinion, this could reduce the likelihood of initiating breastfeeding by up to 70 per cent (Negin, Coffmann, Vizintin, & Raynes-Greenow, 2016). Similarly, mothers who introduce complementary foods early report having been influenced by family and friends (Tarrant et al., 2010; Spillman, 2012).

As well as influencing mothers' beliefs, the family around a mother may lack experiential knowledge of baby-led feeding and may be unable to effectively support her choice (McFadden & Toole, 2006). There are often competing sets of priorities within a family, and a woman's overall wellbeing is understandably important to those close to her. Family and friends may wish to relieve the mother of undue distress by 'solving' any difficulties that occur with feeding the baby by introducing formula or complementary food early (Hoddinott et al., 2011). Fathers who have negative views of breastfeeding, or who wish to be involved in the feeding of the baby may also influence the choice to formula feed (Scott, Binns & Aroni, 1997; Earle, 2000; Henderson et al., 2011). Convenience around going back to work, going out and/or going to childcare may also influence the age of introduction or method of introducing complementary food and convenience was cited as being important for many mothers in the SHIFT study.

On a wider cultural and societal level, frequent growth monitoring is normal in the UK health service and is often highly valued by parents (Lucas et al., 2007). However, parents commonly report feeling that they did not receive enough help to breastfeed (McInnes & Chambers, 2008; Schmeid, Beake, Sheehan, McCourt & Dykes, 2010). There is a paucity of research looking at the availability of professional complementary feeding support for parents, however inconsistency between sources of advice and food labelling is reportedly an issue (Harrison et al., 2016). The current situation of universal child health surveillance, with inconsistent or inadequate support, may therefore have created a climate of worry for parents, which is likely to impact on self-efficacy and potentially lead to controlling infant feeding behaviours. This suggestion is supported by referring back to key works by feminist authors in the 1980's who noted that the medicalisation of infant feeding had inevitably led to a prescriptive approach with the feeding of infants being a problem to be solved, rather than a natural process that requires support (Fildes, 1986; Apple, 1987, Palmer, 1988). Over thirty years on, the narrative around infant feeding remains dominated by the medical model (Qureshi & Rahman, 2017). Formula feeding in particular is the normative practice in much of the UK (McAndrew et al., 2012), and it has been argued that this stems in part from the medical stance which values measurement, control and surveillance (Qureshi & Rahman, 2017). Breastfeeding mothers may be tempted to feed to a routine (Brown & Arnott, 2014), attempt to monitor feeding, or to have their baby frequently weighed and measured causing anxiety and ultimately cessation of breastfeeding. Within a medical paradigm, behaviours which are undesirable (such as a baby that feeds frequently) may be considered to be evidence that there is something 'wrong', again leading to a perception that breastfeeding isn't working (Qureshi & Rahman, 2017)

The impact of medicalization has been further compounded by the effects of a powerful baby-food industry. As well as the ubiquitous influence of the infant formula companies (Palmer, 1988) the appearance of commercial baby-foods have arguably added to the pressure and confusion about when, how and what babies should eat (Palmer, 2011; Bentley, 2014: Jones, 2016). European Union (2006) regulations mean that infant foods can be labelled as being suitable from 4 months, even though health service recommendations continue to advise delaying complementary foods until 6 months (SACN, 2018; NHS Choices, 2019). The idea that babies need 'special' food, rather than the same foods as adults, is likely to have stemmed from the increased use and availability of these products (Jones, 2016; Rowan & Harris, 2012).

It is, of course, imperative that some growth monitoring takes place to provide a safety net for infants at risk of growth faltering. Prior to the increased involvement of doctors, nurses and health visitors in child health, child mortality was very high (Jones, 2016). Similarly, infant formula and some specialised baby-food products have their place. However, a service, which emphasises monitoring, but without adequate support is likely to be failing many women who wish to breastfeed, or may like to try a baby-led feeding approach but do not do so because of unfounded concerns or misdirected pressure from others.

These multiple factors therefore may create an environment where there is a tendency for mothers to be more parent-led in their feeding approach. However, in addition there are also some concerns related specifically to the baby-led weaning method which may be off-putting for parents, and which have prevented the method from being widely recommended.

12.5. Should we be recommending the BLW method?

In the literature and health services recommendations, there remain many reservations about the feasibility and safety of BLW. The lack of firm evidence to support the benefits of the method has meant that is not generally recommended by health visitors and other health advisory bodies (Jones, 2016). The advice from WHO (2003b) and the UK Department of Health (2018) to commence complementary feeding with pureed or mashed food has not changed, and in New Zealand the Ministry of Health (2018) issued a statement in 2018 saying that they explicitly do not recommend BLW until more research is done. While the findings of the SHIFT study do not wholly support the idea that BLW method reduces risk of overweight, the data did not appear to suggest that the method is unsafe as the vast majority of infants in the BLW group were within normal growth parameters. It is recognised, nonetheless, that BLW may only be suitable for infants who are developmentally able to self-feed, and the method may preclude infants with developmental delay for example (Wright et al., 2011; Rapley et al., 2015). The use of purees in early infancy did not appear to be a problem, only contributing to overweight if continued into late infancy. Therefore, a transition onto whole foods by by 9-12 months (as is currently advised) seems to be acceptable for healthy growth trajectories. What appeared to be more important overall, from the SHIFT data, and from the in-depth exploration of the literature was that of adopting a baby-led feeding approach throughout infancy, which focusses on responsive feeding. While theoretically a baby-led responsive feeding approach may be undertaken by mothers who spoon-feed, it makes sense that (for infants who are able to do so) the BLW method might be a simple and effective way of ensuring that the process of complementary feeding is controlled by the baby and not the parent. Notwithstanding these reassuring findings, it is important to understand the issues surrounding the lack of confidence in the BLW method, as they illuminate the key reasons that make adopting or promoting BLW worrisome for parents, professionals and advisory bodies.

The main concern surrounds the possibility that infants who self-feed may be at risk of not eating enough, leading to growth faltering (Cameron, Heath & Taylor, 2012b; Brown & Lee, 2013b; Cichero, 2016; D'Andrea et al., 2016). Concern over infant intake, or pressure for infants to gain weight is pervasive in infancy generally, and this was cited by mothers in the SHIFT study (chapter 10) as well as in previous research (Bentley et al., 2017). BLW depends on developmental readiness, so concerns have been cited that the method may not be feasible and that babies who have not achieved an adequate skill level for effective self-feeding may not consume sufficient energy for growth and development (Cameron, Heath & Taylor, 2012b; Brown & Lee, 2013b; Cichero, 2016; D'Andrea et al., 2016). Wright and colleagues (2011) found that 85% of babies aged 6-7 months were able to reach out and grasp food, indicating that the vast majority of babies of this age would indeed be able to self-feed. However, eating involves oral-motor skills as well as gross motor skills. Cichero (2016) posits that, like any other area in infant motor development such as crawling and walking, learning to chew and swallow takes months of practice and it is not until late infancy that effective chewing and swallowing takes place. Thus, in the early stages of complementary feeding babies may not be able to physically consume enough food if left to self-feed. BLW proponents counter this by arguing that on-going milk feeding alongside BLW provides adequate energy and nutritional needs of infants whilst they learn how to self-feed and to chew (Rapley & Murkett, 2008). However, it is well known that after 6 months of age breast-milk no longer supplies adequate energy and nutrients for growth and development (WHO, 2001; Butte, Lopez-Alarcon & Garza, 2002), which raises the question of how much energy babies actually require in the early stage of complementary feeding?

The subsequent WHO recommendations (2001) state that a gradual increase from 200kcal per day for infants aged 6-8 months, to 300kcal per day for infants aged 9-11 months, to 550kcal per day for children aged 12-24 months is appropriate. However, it has been noted that during the complementary feeding stage, infants often exceed their recommended energy intake. The Feeding Infants and Toddlers Study (FITS) in the US found that infants aged 7-11 months exceeded their required energy intakes by 23% (Butte et al., 2010). The potential for decreased energy intake in BLW may actually therefore, be beneficial in preventing over-consumption of energy beyond requirements at this time.

The BLISS study is the only study to have explored the energy intake of infants when following a BLW approach (Erickson, 2015). Erickson (2015) found that at age 7 months, there was no statistically significant difference for energy intakes between the BLISS group (2946kJ (704kcal) daily total; 586kJ (140kcal) from complementary food) and the control group (2815kJ (672kcal) daily total; 478kJ (114kcal) from complementary food). These data show that in both groups the mean energy intake from complementary food fell slightly short of the WHO recommendation, but their overall energy intake was approximately adequate. Although the finding was non –significant, it is also interesting to note that BLISS infants on average consumed slightly more energy both overall, and in terms of complementary foods than babies in the control group. A further study exploring BLISS data at 12 and 24 months, found no significant differences in energy intakes between the BLISS and control groups (Taylor et al., 2017). While findings may have been affected by the BLISS intervention, which encouraged a high energy diet, it implies that it is feasible for baby-led approach to allow adequate energy intake.

As discussed in the literature review studies, which have looked at BLW and child weight in toddlerhood have found a slightly higher incidence of child underweight in BLW; however small numbers in observational studies are difficult to draw conclusions from. For example, Townsend and Pitchford (2012) found a higher incidence of underweight in pre-school children who had been fed using BLW in infancy but this was only a very small number (n=3 out of 155) compared with none in the SCF group. Brown and Lee (2015) also found a slightly greater incidence of underweight in younger toddlers (defined as <5th percentile) in the BLW group (5.4%) compared with the SCF group (2.5%). It should be noted however, that no children in the BLISS study (N=206) showed signs of growth faltering (Taylor, 2017). The vast majority of infants in all studies were within the normal weight range. The SHIFT data also showed no evidence of growth deficits among infants who were fed using a BLW method, which may be reassuring for those concerned that BLW infants are at risk of poor intake and being underweight (see Chapter 7).

In terms of nutrients, one main concern is that BLW limits iron consumption (New Zealand Ministry of Health, 2016). Iron is well documented as being the most prevalent mineral deficiency in infants (Michelsen et al., 2000; Palmer, 2011) and is considered to be important for neurodevelopment (Baker, Greer & The Committee on Nutrition, 2010). The WHO therefore recommends that iron-rich foods should be included in the complementary feeding diet from 6 months (Michelson et al., 2000). The recommended iron intake for a 7-9-month old infant is 4.8mg (First Steps Nutrition Trust, 2017). To address the problem of iron deficiency, it is often recommended to give iron fortified cereals to infants and young children (NHS Choices, 2019; Baker et al., 2010; First Steps Nutrition Trust, 2017). However, since BLW promotes the consumption of foods in their whole natural form, it precludes the consumption of spoon-feeding cereals, and due to this it may limit iron consumption (Cameron, Taylor & Heath, 2015). Indeed, consumption of baby cereals was found to be lower in BLW in three studies (Brown & Lee, 2011a; Morison et al., 2016; Komninou et al., 2019). However, baby cereals may not be the best source of iron as it is not well absorbed since compounds in cereals known as phytates impede absorption. This is especially true if the cereal meal is made with milk or formula as the calcium in milk also reduces the bioavailability of iron (Hurrell, Reddy, Juillerat & Cook, 2003; National Institutes of Health, 2018).

Other sources of dietary iron may be better absorbed in the digestive tract, in particular, heme iron from animal sources such as meat fish and eggs. Non-heme iron from lentils, green leafy vegetables and beans are also a source of iron but this is less than heme iron sources (Abbaspour, Hurrell & Kelishadi, 2014; National Institutes of Health, 2018). These dietary sources of iron could be incorporated into a baby-led approach (Cameron et al., 2015; First Steps Nutrition Trust, 2017). However, healthcare professionals have posed concerns that BLW babies most commonly eat fruit and vegetables as first foods and therefore they may be limited in their consumption of iron rich foods (Cameron, Heath & Taylor, 2012). Morison and colleagues (2016) also explored iron intake and found that both BLW infants and SCF infants were limited in their iron intake, and indeed iron consumption was lower in the BLW than the SCF group (1.6mg vs. 3.6mg), and this finding was statistically significant. Both groups, however consumed sub-optimal levels of iron. Conversely Rowan et al's (2019) study found no significant differences between exposure to iron-containing foods between BLW and SCF.

The BLISS study intervention proposed encouraging an iron-rich food at each meal (Cameron et al., 2015). Daniels (2017) explored BLISS study data in relation to iron, and found no differences in iron intakes, or plasma ferritin levels at 7 and 12 months between the BLISS and the control group. In this study, once again, all babies were found to consume suboptimal levels of iron. What this study shows however, is that when iron rich foods are encouraged as part of the daily diet, BLW does not increase the risk of iron deficiency any more than SCF. Iron supplementation (drops) may therefore be a convenient source of addressing iron deficiency for all babies, regardless of feeding method and these are recommended by the WHO (2016c) in areas where anaemia risk is high, but it is not currently recommended in the UK by the NHS, which only advises supplements of vitamins A, C & D (NHS Choices, 2018).

Concern has also been raised around the potential for inappropriate diet to be offered in BLW. BLW encourages babies to eat family foods, along with the family. The healthfulness of the diet offered therefore depends on the diet consumed by the family. One study found that the consumption of high energy processed snack foods such as chips, crisps, sweets and biscuits in infancy was associated with parents who also ate these foods (Robinson et al., 2007). Health professionals in a qualitative study in New Zealand cited concerns about the potential for these types of snack foods being given as part of BLW (Cameron et al., 2012b). Consuming these foods may easily lead to an over consumption of energy as they tend to be higher in fat (Adams & White, 2015). These effects may also be long lasting as identified in Okubo et al.'s (2015) study that showed poor dietary quality (relatively low in fruit, vegetables and fish) in infancy persists into older childhood and that poor dietary quality at 6 months, 3 years and 6 years was also significantly associated with adiposity at age 6. Consuming the same foods as the family in BLW also poses a risk that babies may consume high levels of salt or sugar found in 'adult' foods (Rowan & Harris; 2012).

Despite these concerns there is limited evidence for either extent of adherence to family foods or whether inappropriate food is offered in BLW. Only one small pilot study has explored this specifically. Rowan and Harris (2012) found that having a baby in the family who was following BLW did not effect a change in the overall diet of the family. The authors found that only half of meals eaten by the infant were similar to the parents' meal, implying that around half the time babies were having a separate meal and parents in this study did not appear to strictly adhere to this principle of BLW. The study reported, however, that babies were offered a wide variety of foods including fruits (fresh and dried), vegetables (cooked and raw), sandwiches, bread, toast, crackers, rice, yogurt, tofu, cheese, eggs, hummus (and other bean spreads), nut butters, rice cakes, biscuits, hot cereal, soups, pasta, pork, beef, lamb, chicken, and fish (Rowan & Harris, 2012).

Finally, another point which may dissuade mothers from adopting BLW is the perceived possibility that it may increase the risk of choking. This was mentioned by mothers in the SHIFT study, and in previous research (Cameron et al., 2012b; Cichero, 2016; Fangupo et al., 2016), and therefore warrants some attention. Cichero (2016) argued that infants' oral-motor development is not usually developed enough at 6 months to chew and swallow effectively; chewing at this age is a simple up and down action, which is fine for soft food such as ripe avocado or banana, but not for particularly fibrous food such as strips of meat or for more textured foods such as toast. Furthermore, she argued that young babies may not have the stamina to break down foods and as a result may hold food in their mouth posing a choking risk. Conversely, BLW proponents suggest that babies who follow SCF do not have the opportunity learn to chew, but rather to suck semi-solid food from a spoon and swallow, and that this may increase choking risk when they are later introduced to more chewable, textured foods (Rapley, 2011; Rapley & Murkett, 2008). However, this was disputed by Cichero (2016) who argues that babies who are introduced to purees first, learn to practice moving an already formed food bolus (a spoonful of puree) to the back of their mouth and to swallow. This prepares them, once oral motor development is sufficient and the eruption of teeth occurs, to then learn to chew properly and swallow safely.

Two studies have explored this. As part of the BLISS study, Fangupo and colleagues (2017) found that the BLISS BLW approach (which included advice on minimizing foods thought to pose a high choking risk) did not result in an increased incidence of choking events. Brown (2017b) replicated this finding in a large survey of over 1100 mothers, and asked them to recall a choking event in relation to complementary feeding method and type of food offered. No significant association was found between BLW and choking and, as had been previously theorized, choking incidents were found to be significantly higher in the SCF group when starting to eat lumpy foods and finger foods.

12.6. Supporting parents with responsive feeding

Bringing the findings together, and reflecting on maternal and health professional concerns in the wider literature, the evidence suggests that at this stage of the research at least, that rather than promoting the BLW method per se, supporting parents to become more baby-led and responsive generally might be more appropriate. Strategies to promote responsive bottle feeding, such as advising mothers not to schedule feeds and to watch for hunger and satiety cues are already occurring (UNICEF UK, 2019). Research has found using weighted opaque bottles may also reduce the temptation to encourage bottle emptying (Ventura & Pollack Golen, 2015; Ventura & Hernandez, 2019), though these are not in widespread use. Similarly, in relation to spoon-feeding the UK guidance advises that there is "no rush to mush" emphasising whole food use and waiting for signs of developmental readiness before introducing complementary food (UNICEF UK., 2015). Black & Hurley (2017) cite several strategies to promote responsive feeding which may be useful (see Figure 22):

Domain	Description	Positive Strategies
Navigating the progression of the feeding development	1 Recognizing and responding to a child's signals of hunger and satiety 2 Providing healthy and developmentally appropriate complementary food 3 Promoting self-feeding	1 Assure Feeding context is pleasant with few distractions Child is seated comfortably facing others Expectations are communicated clearly 2 Offer Tasty, healthy, developmentally appropriate foods 3 Provide Emotional climate with parent modeling eating Encourage as needed Opportunity to self-feed with developmentally appropriate food
Providing responsive feeding context	1 Responsive (authoritative) feeding style 2 Predictable feeding practices (behaviors that parents use to organize meals and the meal structure)	1 Provide food In a prompt, emotionally supportive, contingent, and developmentally appropriate manner 2 Offer foods On a predictable schedule so the child is likely to be hungry
Prevent/resolve growth and feeding problems	1 Food refusal, food selectivity (pickiness), or disruptive mealtime behavior, resulting in growth, nutrition and behaviors problems	1 Provide Patience and adherence to a regular mealtime routine (2–3 h between meals, 20–30 min/meal) resolve transient feeding problems

Figure 22: Strategies for responsive feeding extracted from Black & Hurley (2017).

Research has explored interventions to promote responsive feeding. For example, one study delivered an education programme about child development and responsive feeding and found increases in children's self-feeding and maternal responsiveness following the intervention compared to a control group (Aboud, Shafiq & Akhter, 2009). However, this study examined a developing country sample, where the concern was undernutrition not overweight. In Australia, the NOURISH study also evaluated an educational intervention, delivered prior to complementary feeding. Mothers in the intervention group reported using more responsive and less controlling feeding practices up to age 2 (Daniels, Mallan, Nicholson, Battisutta & Margary, 2013). No impact was seen on weight in this sample, however. The INSIGHT trial in the US, looked more broadly at the impact of an intervention that promoted responsive parenting (rather than just responsive feeding, though feeding was a key element) in a sample of 291 mother-infant dyads. The intervention consisted of a video and hands-on demonstrations of the strategies by visiting nurses. Infants in the intervention group showed slower weight gain from birth to 6 months and lower weight status at age one compared to the control group (Savage, Birch, Marini, Anzman-Frasca & Paul, 2016) This type of intervention may therefore be promising.

While responsive feeding is now considered to be important by professionals and researchers in the field (WHO, 2003b; Black & Aboud, 2011; Hurley et al., 2011), it is not clear how parents view this. Changing health related behaviour is notoriously difficult and a key aspect is cultivating the desire to change (Kelly & Barker, 2016). Theories of health behaviour posit that for change to occur, the subject must first recognise the change to be worthwhile undertaking (Bandura, 1994; Fishbein & Cappella, 2006; Kelly & Barker; 2016). Therefore, for any interventions which promote responsive feeding to be successful, parents need to also deem it to be important. The literature shows that a maternal desire for appetite regulation in infancy does not appear to be a widely held belief, with many more studies finding that mothers are often far more concerned with infants being underweight (Lucas et al., 2009; Laraway et al., 2010; Bentley et al., 2017). While parental concern about overweight is evident in older childhood (May et al., 2007; Gregory et al., 2010), it is now believed that interventions targeted at older children are coming too late (Brown et al., 2019). It is imperative that awareness is raised and interventions are focussed on feeding behaviours in infancy which may increase risk of overweight.

In one recent qualitative study mothers stated that they 'would rather be told than not know' about the risks of childhood obesity stemming from excess weight in infancy (Bentley et al., 2017). However, it is unlikely that just informing mothers about the risks of rapid infant growth will create change. Understanding and working to address the socio-cultural influences affecting parents' feeding choices is clearly going to be important if a more responsive or 'baby-led' approach is to become normalised. Working towards changing culture however, takes time, and it needs to be focussed on young people because it has been found that decisions on how mothers will feed their baby often occur long before conception (Earle, 2000; Gale & Davies, 2013). A number of programmes are now teaching school children about infant feeding (Singletary, Chetwynd, Goodell & Fogelman, 2017). Adequate support around infant feeding during antenatal and post-partum care is then vital, not only to develop mothers' practical skills in feeding but also to build self-efficacy around 'trusting' that their baby knows how much to eat.

12.7. Limitations of the SHIFT study

The SHIFT study is a relatively small study for this type of research, however, it is the only one of its kind, which has specifically looked at all aspects of a baby-led feeding approach and used the measurements of one trained researcher.

In general, the analyses may have lacked power. Power analyses were conducted conducted (see section 3.7.5.) and revealed an adequate sample size for the main analyses, (the power calculation required a sample of 210 for a small effect size, and the final study sample size was 269), however when the sample was broken done into smaller groups and compared this may have limited power for those calculations. The longitudinal (repeated measures) sample size was also slightly too small (the power calculation called for a sample size of 106, and the final study sample size was 105).

There could also be other factors to explain any variance. Indeed, the regression model only explained around 28-50% of the variance in weight with other influencing factors unknown or unaccounted for (notwithstanding this, this extent of model fit is considered to be acceptable, if not fairly high, in behavioural research). For example, information on mode of birth, antibiotic use or maternal weight was not collected. Maternal weight and maternal gestational weight gain may have been particularly important, as children of mothers who are overweight or who gain weigh during pregnancy are more likely to be born bigger (Rode et al., 2007) and be overweight in older childhood (Oken et al., 2007). However, the reasons for not collecting this data were three-fold; first so that the questionnaires could be brief, being less burdensome to the participants, and second, because it would not have been appropriate to collect such sensitive information in a group setting, and finally that the data is likely to have been inaccurate, perhaps compromising the reliability of the study. Mothers' weight may fluctuate before, during and after pregnancy, and therefore, might not be accurately recalled (Natamba, Sanchez, Gelaye & Williams, 2016).

Other factors were simply not measureable, for example how physically active the infants were. Tummy-time, active-play, crawling and other physical activities consume energy, and there is evidence that some infants who do not expend enough energy in this way may be at risk of overweight (Wells & Ritz, 2001; Timmons et al., 2012; Ulrich & Hauck, 2013). However, not all studies have found a strong link between energy expenditure in infancy and overweight, rather finding that energy intake is more important (Stunkard, Berkowitz, Stallings & Schoeller, 1999).

The study design was also a limiting factor. As it was mainly cross-sectional (with a small longitudinal sample) the information only provided a snapshot of infant feeding behaviour, which was especially limiting for the diet diaries as infant diet is likely to change from day-to-day, and from week-to-week. The 24-hour recall may also not be considered to be a true reflection of the infant diet across the complementary feeding period. An alternative could have been Weighed Diet Record (of at least 3 days), which is considered to be the 'gold standard' for measuring infant food intake (Wreiden et al., 2003). However, it was not feasible to undertake this for the sample size within the time-frame of a PhD candidature. Furthermore, accurately measuring energy or nutrient intake of infants was not the primary aim of the current study, as the focus was mainly on anthropometric measurements and the influence of the baby-led feeding approach. A 24-hour diet diary was therefore chosen as it was feasible and incurred a low participant burden. When data collection commenced in 2015, only one published study (Brown & Lee, 2011a) and one Masters' dissertation (Erickson, 2015) had explored diet in relation to BLW, and thus this aspect of the SHIFT study was intended to be exploratory only. Given that very few studies have explored infant diet in relation to BLW, SHIFT added to this very small evidence base. In terms of measuring infant growth and feeding behaviour the sample size and design reflects other similar work (Farrow, 2005; Rogers, 2013).

The SHIFT study would also perhaps have benefitted from following up the infants for a longer time, however, this was not feasible within the PhD candidature. This would have been interesting in order to see whether the trajectories observed continued into childhood, and whether they later become significant. Furthermore, the mother-child dynamic may change as children get older. Children of mothers who previously showed a controlling feeding style, once parental control lessens, may demonstrate poor appetite regulation, leading perhaps to overeating. It was suggested in the literature review that pressure to eat and other maternal controlling feeding behaviours may look different in infants than they do in older children. In childhood pressure to eat is likely to entail encouraging the child to eat previously refused foods, in particular fruit and vegetables, which may increase food fussiness (Finistrella et al., 2012; Perry et al., 2015). However, in infancy pressure to eat may be more likely to centre on infants being encouraged to eat palatable 'filling' foods, to settle them, help them sleep or to help them gain weight. The effect of pressuring that may occur in infancy on later satiety responsiveness has not been well explored. Brown & Lee (2015) found decreased satiety responsiveness and higher risk of overweight in children who had been fed using a SCF approach in infancy, compared with BLW. However, Brown & Lee's research was limited by parental report of child weight. Additional measurements of satiety responsiveness within the SHIFT study sample, alongside the longitudinal anthropometric measurements would exhibit new data on this subject.

As with many studies in infant feeding, the SHIFT sample arguably lacks generalisability due to the higher proportion of older and well educated mothers, compared to the general population. Harder to reach groups such as those from more socio-economically disadvantaged backgrounds are well known to be difficult to recruit to research (Bonevski et al., 2014). In light of these considerations, efforts were made to attend groups in socio-economically varied locations. However, baby-group attendees are likely to have certain demographic characteristics, for example, younger mothers have reported a reluctance to attend groups (Action for Children, 2017). It may also be suggested that mothers who attend groups might also be more likely to have an interest in child health or development.

Growth data may also have been biased towards the normal range, because mothers who were concerned about their baby's weight may not have wanted to take part for fear of exposing a problem that they would prefer to keep private. Equally, mothers who were concerned about their baby's weight or who are keen on growth monitoring, may have been attracted to the study so that they could have their baby measured.

It was also more challenging to recruit mothers with certain feeding behaviours, for example who were formula feeding or spoon-feeding or who introduced complementary foods earlier. Mothers who formula feed or introduce complementary foods earlier may not wish to take part due to fear of judgement, especially as the researcher was a health professional. This was identified as a potential barrier in my reflexive account (see section 3.7.). The rhetoric around infant feeding is intricately tied to the notion of 'good' or 'bad' motherhood, with feeding choices often portrayed as a 'moral duty' where the mother is accountable for the ‘best’ course of action for her child (Murphy, 2000; Locke, 2015). Locke describes how parenting can be viewed by some as a ‘project’, where new or different parenting methods are tested out. In this sense, there may be some divergence between mothers who stringently follow BLW and those who don’t, with the former being portrayed as somewhat superior and self-sacrificial (Locke, 2015). Mothers who choose to adopt BLW are often confident in their choice of feeding method and are well read on complementary feeding. Indeed, the SHIFT data showed that many mothers in the BLW group cited their beliefs in the benefits of the method. This may have led mothers who chose BLW to be more keen to take part in the research, in order to ‘prove’ the proposed benefits of the method that they already believe in.

Finally, all research that uses self-selecting recruitment may incur these issues. Population level health record data can instead be used to glean limited information from a larger more generalizable sample. However, these can be inaccurate and do not record the specific data around baby-led feeding that the SHIFT study sought to measure.

12.8. Future research

Future research may wish to explore the observed (rather than reported) parental interactions in infant feeding between BLW and SCF methods of introducing complementary foods. This would perhaps illuminate whether it is the degree of responsiveness, rather than the method per-se which is important. Further insight into mother-infant dyadic interactions (see recent research from Bergmeier and colleagues, 2019) is also likely to be important.

Further research examining interventions, which support parents to become more responsive (such as the INSIGHT trial) would also be beneficial, in particular from a UK perspective, as culture and breastfeeding rates are different here compared to in the US. Interventions specifically for formula feeding mothers, to maintain responsiveness through milk feeding and complementary feeding might be particularly important as formula feeding appears to trigger a parent-led pathway of feeding.

As previously mentioned, weighed food records would help to more accurately determine type of food, amount and energy consumed by infants fed using different complementary feeding methods. This data could identify whether infants spoon-fed purees eat more than those who eat whole foods and could be compared to WHO guidelines. Protein, specifically types of protein (dairy, meat etc.) could also be calculated more accurately.

Infants who are breastfed are thought to be more satiety responsive (Brown & Lee, 2012) and the same has been reported by mothers who follow BLW (Brown & Lee, 2015). However, many studies rely on parental report of their child's eating behaviour. More robust experimental satiety responsiveness measures (for example those exploring eating in the absence of hunger or the compensatory regulation of food intake after a preload) alongside ongoing clinical anthropometric measurements in older childhood may also be useful to identify the long term impact of a baby-led feeding approach.

Gene-environment interactions are also likely to be high on the research agenda going forward since a baby-led feeding approach could mitigate against overweight among infants with a known genetic risk. The emergence of more genetic loci implicated in obesity and the possibility of a cumulative effect could help to identify the most 'at risk' infants' and therefore where interventions could be targeted. What may also be interesting is whether a baby-led feeding approach could have a negative effect in infants with a genetic predisposition to disinhibited eating. In these cases, perhaps allowing the infant to self-feed would place them at risk of overeating.

12.9. Conclusions

This aim of this research was to explore the role of a baby-led feeding approach on infant growth and its possible implications for childhood obesity. It investigated key aspects of a baby-led feeding approach in depth. While the data did not convincingly support or refute the suggestion that the BLW method (as promoted by Rapley and others) reduces the risk of overweight in infancy, behaviours which could be considered broadly baby-led such as breastfeeding, delayed complementary feeding and a slow transition from milk onto a diet of mainly of whole foods were found to be potentially beneficial for healthy weight gain trajectories. In contrast, behaviours such as formula feeding, earlier introduction of solids and prolonged use of purees, are likely to be more parent led in nature and were associated with greater weight. One key mechanism for these differences may be explained by the suggestion that infants who are fed in a baby-led way are better able to regulate their appetite, due to being in control of how much they eat (Brown & Lee, 2012). This seems to be affected by a maternal feeding style which is less controlling, which may also have long term effects on later relationships with food (Blissett & Farrow; 2007; Brown & Lee, 2013a; Farrow et al., 2015).

Promoting a baby-led approach to infant feeding which emphasises parental responsiveness may therefore be an important way to foster healthy weight gain in infancy and beyond. However, this is only possible if parents are able to feel confident and supported in feeding their baby since many parents report lack of support around the practicalities of infant feeding matters (McInnes & Chambers, 2008; Schmeid et al., 2010; Harrison et al., 2016). Concerns about infant weight and intake may be driving mothers to adopt a more parent-led approach, and perhaps to be less responsive in their feeding style. This pattern of behaviour begins early on, with many parents citing perceived insufficient milk supply as a reasons to stop breastfeeding and move to formula (Dewey et al., 2002; Meedya et al., 2010; Peacock–Chambers et al., 2017). Similar concerns influence the early introduction of complementary food (Redsell et al., 2010; Brown & Rowan, 2016) and spoon-feeding of purees as found in this study. The influence of friends and family, and cultural norms and the wider baby-food industry may add to this pressure.

This research provides an impetus for health services to support parents to become more responsive in feeding their babies. This needs to start as early in life as possible. Feeding behaviours once established have been shown to be stable over time as breastfeeding mothers appear to remain more responsive throughout infancy (Blissett & Farrow, 2007; Ventura, 2017b). Supporting women to initiate and continue breastfeeding is an important first step towards long-term responsive feeding. However, this is not easy, as wider cultural influences will inevitably take time to change and breastfeeding rates are especially low in the UK relative to the rest of the world (UNICEF, 2018). There will nevertheless always be mothers who choose to formula feed for a range of reasons. Next steps might comprise research on responsive feeding behaviours for all parents (regardless of milk feeding type or complementary feeding method). Additionally, experiential research is needed in order to examine more closely the effects of a baby-led feeding approach on intake and satiety.

Bringing this thesis to a close, it did not find a conclusive association between the baby-led weaning method (i.e. self-feeding) and infant growth. However, behaviours which could be considered to be more broadly 'baby-led' in approach appeared to foster healthier weight gain trajectories, supporting the WHO (2003b) recommendation for 'responsive' feeding. Why mothers choose a more baby-led or parent-led approach is complex; concerns around infant weight, intake and behaviour are commonly cited as driving parent-led behaviour (Clayton et al., 2013; Brown & Harries, 2015), and were also reported by mothers in this study. The SHIFT study highlights the need for effective support for parents in infant feeding, so that they feel confident adopting a baby-led, responsive approach.

References

Abbaspour, N., Hurrell, R. & Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of Research in Medical Sciences, 19*(2), 164-174.

Action for Children. (2017). *The Next Chapter: Young People and Parenthood.* Retrieved from https://www.actionforchildren.org.uk/media/9612/the-next-chapter.pdf

Adams, J. & White, M. (2015). Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *International Journal of Nutrition and Physical Activity, 12*, 1-11.

Agostini, A., Tamas, D., Fewtrell, M., Olivier, G., Kolacek, S., Koletzko, B.,… ESPGHAN Committee on Nutrition. (2008). Complementary feeding: a commentary by the ESPGHAN Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition, 46*(1), 99–110.

Agras, W.S., Kraemer, H.C., Berkowitz, R.I. & Hanmer, L.D. (1990). Influence of early feeding style on adiposity at 6 years of age. *Journal of Pediatrics, 116,* 805-809.

Ajslev, T.A., Andersen, C.S., Gamborg, M., Sorensen, T.I.A. & Jess, T. (2011). Childhood overweight after establishment of the gut microbiota: the role of delivery mode, pre-pregnancy weight and early administration of antibiotics. *International Journal of Obesity (London), 35,* 522-529.

Alderete, T.L., Autran, C., Brekke, B.E., Knight, R., Bode, L., Goran, M.I. & Fields, D.A. (2015). Associations between human milk oligosaccharides and infant body composition in the first 6 mo of life. *American Journal of Clinical Nutrition,* 102(6) 1381-1388.

Alvisi, P., Brusa, S., Alboresi, S., Amarri, S., Bottau, P., Cavagni, G…. Agostoni, C. (2015). Recommendations on complementary feeding for healthy full-term infants. *Italian Journal of Pediatrics, 41*(36) 1-9.

Amir, L.H. & Donath, S. (2007). A systematic review of maternal obesity and breastfeeding intention, initiation and duration. *BMC Pregnancy and Childbirth, 4,* 1-14.

Anderson, A.S., Guthrie, C.A. Alder, E.M., Forsyth, S., Howie, P.W. & Williams, F.L.R. (2001). Rattling the plate – reasons and rationales for early weaning. *Health Education Research, 16,* 471- 479.

Anderson, S.E. & Keim, S.A. (2016). Parent-child interaction, self-regulation, and obesity prevention in early childhood. *Current Obesity Reports, 5*(2), 192-200.

Anzman-Frasca, S., Stifter, C. A., Paul, I. M., & Birch, L. L. (2013). Infant temperament and maternal parenting self-efficacy predict child weight outcomes. *Infant Behavior & Development*, *36*, 494–497.

Apple, R. (1987). *Mothers and medicine: A social history of infant feeding. 1890-1950.* Madison: University of Wisconsin Press.

Appleton, J., Russell, C.G., Laws, R., Fowler, C., Campbell, K. & Denney-Wilson, E. (2018a). Infant formula feeding practices associated with rapid weight gain: A systematic review. *Maternal & Child Nutrition, 14,* 1-14.

Appleton, K.M., Hemmingway, A., Rajska, J. & Hartwell, H. (2018b). Repeated exposure and conditioning strategies for increasing vegetable liking and intake: systematic review and meta-analysis of the published literature. *American Journal of Clinical Nutrition, 108*(4), 842-856.

Arden, M.A. (2010). Conflicting influences on UK mothers' decisions to introduce solid foods to their infants. *Maternal and Child Nutrition, 6*(2)159-73

Arden, M.A. & Abbott, R.L. (2015). Experiences of baby led weaning: trust, control and renegotiation. *Maternal and Child Nutrition*, *11*(4), 829-44.

Armstrong, J. & Reilly, J. J. (2002). Breastfeeding and lowering the risk of childhood obesity, *The Lancet, 359,* 2003-2004.

Azad, M.B., Bridgman, S.L., Becker, A.B. & Kozyrskyj, A.L. (2014). Infant antibiotic exposure and the development of childhood overweight and central adiposity. *International Journal of Obesity (London), 38*(10),1290-1298.

Azad, M.B., Vehling, L., Chan, D., Klopp, A., Nickel, N.C., McGavock, J.M., …CHILD study investigators. (2018). Infant feeding and weight gain: separating breast milk from breastfeeding and formula from food. *Pediatrics, 142,* 1-14.

Babendure, J.B., Reifsnider, E., Mendias, E., Moramarco, M.W. & Davila, Y.R. (2015). Reduced breastfeeding rates among obese mothers: a review of contributing factors, clinical considerations and future directions. *International Breastfeeding Journal, 10,* 1-11.

Bailey, L.C., Forrest, C.B., Zhang, P., Richards, T.M., Livshits, A. & DeRusso, P.A. (2014). Association of antibiotics in infancy with early childhood obesity, *JAMA Pediatrics,* 168 (11), 1063-9.

Baird, J., Fisher, D., Lucas, P., Kleijnen, J., Roberts, H. & Law, C. (2005). Being big or growing too fast: systematic review of size and growth in infancy and later obesity. *BMJ,* 331(7522), 1-6.

Baker, R.D., Greer, F.R. & The Committee on Nutrition. (2010). Clinical report – Diagnosis and prevention of iron deficiency and iron-deficiency anemia in infants and young children (0-3 years of age). *Pediatrics, 126*(5), 1040 – 1050.

Ballard, O. & Morrow, A.L. (2013). Human milk composition: Nutrients and bioactive factors. *Pediatric Clinics of North America, 60*(1), 49-74.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.

Barrera, C. M., Perrine, C. G., Li, R. & Scanlon, K.S. (2016). Age at introduction to solid foods and child obesity at 6 years. *Childhood Obesity, 12*(3), 188-192.

Bartle, N. C. & Harvey, K. (2017). Explaining infant feeding: The role of previous personal and vicarious experience on attitudes, subjective norms, self-efficacy, and breastfeeding outcomes. *British Journal of Health Psychology, 22,* 763-785.

Bartick, M. C., Schwartz, E. B., Green, B. D., Jegier, B. J., Reinhold, A. G., Colaizy, T. T., …Stuebe, A. M. (2017). Suboptimal breastfeeding in the United States: Maternal and pediatric health outcomes and costs. *Maternal & Child Nutrition, 13,* 1-13.

Bartok, C.J. & Ventura, A.K. (2009). Mechanisms underlying the association between breastfeeding and obesity. *International Journal of Pediatric Obesity, 4,* 196-204.

Baughcum, A.E., Burklow, K.A., Deeks, C.M., Powers, S.W. & Whitaker, R.C. (1998). Maternal child feeding practices and childhood obesity. A focus group study of low-income mothers. *Nutrition, 152*, 1010-1014.

Baughcum, A.E., Chamberlin, L.A., Deeks, C.M., Powers, S.W. & Whitaker, R.C. (2000). Maternal perceptions of overweight preschool children. *Pediatrics, 106,* 1380-6.

Belfort, M.B., Gillman, M.W., Buka, S.L., Casey, P.H. & McCormick, M.C. (2013). Preterm infant linear growth and adiposity gain: trade-offs for later weight status and intelligence quotient. *Journal of Pediatrics, 163,* 1564-1569.

Begley, A., Ringrose, K., Giglia, R. & Scott, J. (2019). Mothers' understanding of infant feeding guidelines and their associated practices: A qualitative analysis. *International Journal of Environmental Research and Public Health, 16*(7), 1-16.

Bergmeier, H., Paxton, S. J., Milgrom, J., Anderson, S. E., Baur, L., Hill, B., …Skouteris, H. (2019). Early mother-child dyadic pathways to childhood obesity risk: a conceptual model. *Appetite,* Advanced online publication. https://doi.org/10.1016/j.appet.2019.104459

Birch, L. L. & Anzman, S. L. (2010). Learning to eat in an obesogenic environment: A development systems perspective on childhood obesity. *Child Development Perspectives, 4,* 2, 138-143. DOI: 10.1111/j.1750-8606.2010.00132.x

Biro, G., Hulshof, K. F., Oveson, L., Amorim Cruz, J. A. (2002). Selection of methodology to assess food intake. *European Journal of Clinical Nutrition, 56* (Suppl 2), S25-S32.

Birmingham, P. & Wilkinson, D. (2003). *Using research instruments.* London: Routledge

Bentley, A. (2014). *Inventing Baby Food. Taste, health and the industrialization of the American diet.* Oakland, California: University of California Press.

Bentley, F., Swift, J. A., Cook, R. & Redsell, S. A. (2017). "I would rather be told than not know' – A qualitative study exploring parental views on identifying the future risk of childhood overweight and obesity during infancy. *BMC Public Health, 17,* 1-10.

Berger, R. (2015). Now I see it, now I don't: researcher's position and reflexivity in qualitative research. *Qualitative Research, 15*(2), 219-234.

Berkowitz, R.I., Moore, R.H., Faith, M.S., Stallings, V.A., Kral, T.V., Stunkard, A.J. (2010). Identification of an obese eating style in 4-year-old children born at high and low risk for obesity. *Obesity (Silver Spring)*, *18,* 505-512.

Black, M. M. & Aboud, F. E. (2011). Responsive feeding is embedded in a theoretical framework of responsive parenting. *The Journal of Nutrition, 141,* 490-494.

Black, M.M. & Hurley, K.M. (2017). Responsive feeding: strategies to promote healthy mealtime interactions. *Nestle Nutrition Institute Workshop Series, 87,* 153-165.

Blissett, J., Haycraft, E. & Farrow, C. (2010). Inducing preschool children's emotional eating: relations with parental feeding practices. *American Journal of Clinical Nutrition, 92,* 359-65.

Blissett, J. & Farrow, C.V. (2007). Predictors of maternal control of feeding at 1 and 2 years of age. *Journal of Obesity, 31,* 1520-6.

Boden, J. M., Fergusson, D. M & Horwood, L. J. (2008). Early motherhood and subsequent life outcomes. *Journal of Child Psychology and Psychiatry, 49*, 151-60.

Bolhuis, D.P. & Forde, C.G., Cheung, Y., Xu, H., Martin, N. & de Graaf, C. (2014). Slow food: sustained impact of harder foods on the reduction in energy intake over the course of the day. *PLoS One, 9* (4), 1-7.

Bonevski, B., Randell, M., Paul, C., Chapman, K., Twyman, L., Bryant, J., Brozek, I. & Hughes, C. (2014). Reaching the hard-to-reach: a systematic review of strategies for improving health and medical research with socially disadvantaged groups. *BMC Medical Research Methodology, 14*(42), 1-29.

Bouchard, C., Tremblay, A., Despres, J-P., Theriault, G., Nadeauf, A., Lupien, P.J., …Fournier, G. (1994). The response to exercise with constant energy intake in identical twins. *Obesity Research, 2,* 400-410.

Bray, G. (2004). The epidemic of obesity and changes in food intake: the Fluoride Hypothesis. *Physiology and Behaviour, 82,* 115-12.

Breij, L. M., Mulder, M. T., van Vark-van der Zee, L. C., & Hokken-Koelega, A. (2017). Appetite-regulating hormones in early life and relationships with type of feeding and body composition in healthy term infants. *European journal of nutrition*, *56*(4), 1725–1732.

British Thyroid Foundation (2019). *Hashimoto's Thyroiditis – Introduction.* Retrieved August 1, 2019, from, http://www.btf-thyroid.org/information/parent-carer-guide/32-hypothyroidism/hashimoto-s-thyroiditis/52-hashimoto-s-thyroiditis-introduction

Brown, A. (2014). Maternal trait personality and breastfeeding duration: the importance of confidence and social support. *Journal of Advanced Nursing, 70,* 587-598.

Brown, A. (2016a). *Breastfeeding Uncovered.* London: Pinter & Martin.

Brown, A. (2016b). Differences in eating behaviour, well-being and personality between mothers following baby-led vs. traditional weaning styles. *Maternal and Child Nutrition,* 12, 826-837.

Brown, A. (2017a). *Why Starting Solids Matters.* London: Pinter & Martin.

Brown, A. (2017b). No difference in self-reported frequency of choking between infants introduced to solid foods using a baby-led weaning or traditional spoon feeding approach. *Human Nutrition and Dietetics, 31*(4), 496-504.

Brown, A. & Arnott, B. (2014). Breastfeeding duration and early parenting behavior: The importance of an infant-led, responsive style. *PLOS One, 9,* 1-7.

Brown, A. & Harries, V. (2015). Infant sleep and night feeding patterns during later infancy: association with breastfeeding frequency, daytime complementary food intake, and infant weight. *Breastfeeding Medicine, 10,* 246-52.

Brown, A., Jones, S.W. & Rowan, H. (2017). Baby-led weaning: The evidence to date. *Current Nutrition Reports,* 6, 148-156.

Brown, A. & Jordan, S. (2013). Impact of birth complications on breastfeeding duration: an internet survey. *Journal of Advanced Nursing, 69,* 828-839.

Brown, A. & Lee, M. (2011a). A descriptive study investigating the use and nature of baby-led weaning in a UK sample of mothers. *Maternal and Child Nutrition, 7*(1), 34-47

Brown, A. & Lee, M. (2011b). Maternal control of child feeding during the weaning period: Differences between mothers following a baby-led or standard weaning approach. *Maternal and Child Health Journal, 15,* 8, 1265-1271.

Brown, A. & Lee, M. (2011c). Maternal child-feeding style during the weaning period: association with infant weight and maternal eating style. *Eating behaviours, 12,* 108-111.

Brown, A. & Lee, M. (2012). Breastfeeding during the first year promotes satiety responsiveness in children aged 18-24 months. *Pediatric Obesity,* 7(5), 382-390.

Brown, A. & Lee, M. (2013a). Breastfeeding is associated with a maternal feeding style low in control from birth. *PLoS One,* 8(1), 1-7.

Brown, A. & Lee, M. (2013b). An exploration of experiences of mothers following a baby-led weaning style: developmental readiness for complementary foods. *Maternal and Child Nutritition. 9*(2), 233-243.

Brown, A., & Lee, M. (2015). Early influences on child satiety-responsiveness: the role of weaning style. *Pediatric Obesity, 10,* 57-66.

Brown, A., Rance, J., & Warren, L. (2015). Body image concerns during pregnancy are associated with a shorter breastfeeding duration. *Midwifery, 13*(1), 80-9.

Brown, A. & Rowan, H. (2016). Maternal and infant factors associated with reasons for introducing solids. *Maternal and Child Nutrition, 12,* 500-15.

Brown, A., Raynor, P. & Lee, M. (2011a). Maternal control of child feeding during breast and formula feeding in the first 6-months post-partum. *Journal of Human Nutrition and Dietetics, 24*(2), 117-86.

Brown, A., Raynor, P. & Lee, M. (2011b). Healthcare professionals' and mothers' perceptions of factors that influence decisions to breastfeed or formula feed infants. *Journal of Advanced Nursing, 67,* 1993-2003.

Brown, G.W., Tuholski, J.M., Sauer, L.W., Minsk, L.D. & Rosenstern, I. (1960). Evaluation of prepared milks for infant nutrition: use of the Latin square technique. *Journal of Pediatrics, 56,* 391-399.

Brown, T., Moore, T.H.M, Hooper, L., Gao, Y., Zayegh, A., Ijaz, S., … Summerbell, C.D. (2019). Do diet and physical exercise strategies help prevent obesity in children (aged 0-18 years)? *Cochrane Database of Systematic Reviews* (7).

Butland, B., Jebb, S., Kopelman, P., McPherson, K., Thomas, S., Mardell, J. & Parry, V. (2007). *Foresight. Tackling Obesities: Future Choices – Project Report. 2nd Edition.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf

Butte, N., Fox, M.K., Briefel, R.R., Siega-Riz, A.M., Dwyer, J.T., Deming, D.M. & Reidy, K.C. (2010). Nutrient intakes of US infants, toddlers and pre-schoolers meet or exceed dietary reference intakes. *Journal of the American Dietetic Association,* 110(suppl.12), S27-37.

Butte, N.F. Lopez-Alcaron, M.G. & Garza, C. (2002). *Nutrient adequacy of exclusive breastfeeding for the term infant during the first six months of life.* Retrieved from http://apps.who.int/iris/bitstream/10665/42519/1/9241562110.pdf

Byrne, R., Jansen, E. & Daniels, L. (2017). Perceived fussy eating in Australian children at 14 months of age and subsequent use of maternal feeding practices at 2 years. *International Journal of Behavioural Nutrition and Physical Activity, 14*(123), 1-9.

Carey, W.B. (1985). Temperament and increased weight gain in infants. *Journal of Developmental and Behavioral Pediatrics, 6,* 128-131.

Cameron, S. Taylor, R.W. & Heath, A.L. (2013). Parent-led or baby-led? Associations between complementary feeding practices and health related behaviours in a survey of New Zealand families. *BMJ Open,* 3, 1-9.

Cameron, S.L., Taylor, R.W. & Heath, A-L. (2015). Development and pilot testing of a Baby-Led Introduction to Solids – a version of Baby-Led Weaning modified to address concerns about iron deficiency, growth faltering and choking. *BMC Pediatrics, 15,* 99, 1-11.

Cameron, S., Heath, A.L. & Taylor, R.W. (2012a). How feasible is baby-led weaning as an approach to infant feeding? A review of the evidence. *Nutrients, 4*(11), 1575-609.

Cameron, S., Heath, A.L. & Taylor, R.W. (2012b). Healthcare professionals' and mothers' knowledge of, attitudes to and experiences with baby-led weaning: a content analysis study. *BMJ Open,* 2, 1-9.

Cantarutti, A., Franchi, M., Monzio Compagnoni, M., Merlino, L., & Corrao, G. (2017). Mother's education and the risk of several neonatal outcomes: an evidence from an Italian population-based study. *BMC pregnancy and childbirth*, *17*(1), 1-10.

Carnell, S. & Wardle, J. (2007). Measuring behavioural susceptibility to obesity: Validation of the child eating behavior questionnaire. *Appetite, 48,* 1, 104-113.

Carnell, S. & Wardle, J. (2008). Appetite and adiposity in children: evidence for a behavioual susceptibility theory of obesity. *American Journal of Clinical Nutrition, 88,* 22-9.

Carrol, M., Gallagher, L., Clarke, M., Millar, S. & Begley, C. (2015). Artificial milk-feeding women's views of their feeding choice in Ireland. *Midwifery, 31,* 640-646.

Carstairs, S.A., Craig, L.C.A., Marais, D., Bora, O.E., Kiezebrink, K. (2016). A comparison of prepared commercial infant feeding meals with home cooked recipes. *Archives of Disease in Childhood, 101*(11), 1037-1042.

Chambers, L. (2016). Complementary feeding: Vegetables first, frequently and in variety. *British Nutrition Foundation: Nutrition Bulletin, 41,* 142-146.

Chambers, L., Hetherington, M., Cooke, L., Coulthard, H., Fewtrell, M., Emmett, P., Lowdon, J.,…Stanner, S. (2016). Reaching a consensus on a 'vegetables first' approach to complementary feeding. *Nutrition Bulletin, 41,* 270-276.

Chan, D., Goruk, S., Becker, A.B., Subbaro, P., Mandhane, P.J., Turvey, S.E., …Azad, M.B. (2017). Adiponectin, leptin and insulin in breastmilk: associations with maternal characteristics and infant body composition in the first year of life. *International Journal of Obesity, 42,* 36-43.

Chantry, C.J., Dewey, K.G., Peerson, J.M., Wagner, E.A. & Nommsen-Rivers, L.A. (2014). In-hospital formula use increases early breastfeeding cessation among first-time mothers intending to exclusively breastfeed. *Journal of Pediatrics. 164,* 1339-45.

Chatoor, I & Ganiban, J. (2003). Food refusal by infants and young children. *Cognitive and Behavioural Practice, 10,* 138-146.

Chesi, A. & Grant, S.F.A. (2015). The genetics of pediatric obesity. *Trends in Endocrinology & Metabolism,* 26(12), 711-721.

Chevalier, A. & O'Sullivan, V. (2007). Mother's education and birth weight. *IZA, Discussion paper 2640,* 1-39.

Chiavaroli, V., Derraik, J.G.B., Hofman, P.L. & Cutfield, W.S. (2016). Born large for gestational age: Bigger is not always better. *The Journal of Pediatrics, 170,* 307-311.

Cichero, J.A.Y. (2016). Introducing solid foods using baby-led weaning vs. spoon-feeding: A focus on oral development, nutrient intake and quality research to bring balance back to the debate. *British Nutrition Foundation: Nutrition Bulletin, 41,* 72-77

Clausson, B., Lichtenstein, P. & Cnattinguis, S. (2000). Genetic influence on birthweight and gestational length determined by studies in offspring twins. *BJOG, 107*(3), 375-81.

Clayton, H.B., Li, R., Perrine, C.G. & Scanlon, K.S. (2013). Prevalence and reasons for introducing infants early to solid foods: variations by milk feeding type. *Pediatrics, 131,* e1108-14.

Cluss, P.A., Ewing, L, King, W.C., Cohen Reis, E., Dodd, J.L. & Penner, B. (2013). Nutrition knowledge of low income parents of obese children. *Translational Behavioural Medicine, 3*(2), 218-225.

Cole, T.J., Freeman, J.V. & Preece, M.A. (1998). British growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. *Statistics in Medicine*, *17,* 407-429.

Colley, R.C., Garriguet, D., Adamo, K.B., Carson, V., Janssen, I., Timmons, B.W. & Tremblay, M.S. (2013). Physical activity and sedentary behaviour during the early years in Canada: a cross sectional study, *International Journal of Behavioural Nutrition and Physical Activity, 10,* 1-9.

Cong, X., Judge, M., Xu, W., Diallo, A., Janton, S., Brownell, E.A., Maas, K. Graf, J. (2017). Influence of feeding type on gut microbiome development in hospitalized preterm infants. *Nursing Research, 66*(2),123-133.

Coulthard, H., Harris, G. & Emmett, P. (2010). Long-term consequences of early fruit and vegetable feeding practices in the United Kingdom. *Public Health Nutrition, 13,* 2044-51.

Coulthard, H.& Sealey, A. (2017). Play with your food! Sensory play is associated with tasting of fruits and vegetables in preschool children. *Appetite, 113,* 84-90.

Cow & Gate (2018). *Creamy porridge.* Retrieved May 13, 2019, from https://www.cgbabyclub.co.uk/shop/foods/4-6-months-breakfast/creamy-porridge.html

Crawley, H. & Westland, S. (2019). *First Steps Nutrition Trust. Infant formula – An overview.* Retrieved from https://www.firststepsnutrition.org/composition-claims-and-costs

Crawley, H. & Westland, S. (2017b). *Baby Foods in the UK. A review of commercially produced jars and pouches of baby foods marketed in the UK.* Retrieved from https://static1.squarespace.com/static/59f75004f09ca48694070f3b/t/5a93f885085229b264ff6086/1519646858256/Baby_Food_in_the_UK+_2017.pdf

Crossley, M.L. (2009). Breastfeeding as a moral imperative: An autoethnograpic study. *Feminism and Psychology, 19*(1), 71-87.

Cummins, S., Smith, D.M., Aitken, Z., Marshall, D., Sparks, L. & Anderson A.S. (2010). Neighbourhood deprivation and the price and availability of fruit and vegetables in Scotland. *Journal of Human Nutrition and Dietetics, 23*(5), 494-501.

Cunningham, S.A., Kramer, M.R. & Venkat Narayan, K.M. (2014). Incidence of childhood obesity in the United States. *The New England Journal of Medicine, 370,* 403-411.

D'Andrea, E., Jenkins, K., Mathews, M. & Roebothan, B. (2016). Baby-led weaning: A preliminary investigation. *Canadian Journal of Dietetic Practice and Research, 77,* 2, 72-7.

Daley, S.J. & Hartmann, P.E. (1995). Infant demand and milk supply. Part 1 Infant demand and milk production in lactating women. *Journal of Human Lactation, 11*, 1, 21-6.

Daniels, L.A., Magarey, A., Battistutta, D., Nicholson, J.M., Farrell, A., Davidson, G. & Cleghorn, G. (2009). The NOURISH randomised control trial: Positive feeding practices and food preferences in early childhood – a primary prevention program for childhood obesity. *BMC Public Health, 9,* 1-10.

Daniels, L. (2017). Impact of a baby-led approach to complementary feeding on iron and zinc intake and status: A randomized control trial. (Doctoral Thesis, University of Otago). Retrieved from https://ourarchive.otago.ac.nz/handle/10523/7709

Daniels, L.A., Mallan, M., Nicholson, J.M., Battistutta, D. & Magarey, A. (2013). Outcomes of an early feeding practices intervention to prevent childhood obesity. *Pediatrics, 132*(1), e109-e118

Daniels, L., Heath, A.L., Williams, S.M., Cameron, S.L. Fleming, E.A., Taylor, B.J.,…Taylor, R.W. (2015a). Baby-Led Introduction to SolidS (BLISS) study: a randomized controlled trial of a baby-led approach to complementary feeding. *BMC Pediatrics, 15*(179), 1-15

Daniels, L., Mallan, K.M., Fildes, A., & Wilson, J. (2015b). The timing of solid introduction in an 'obesogenic' environment: a narrative review of the evidence and methodological issues. *Australian and New Zealand Journal of Public Health, 39*, 366-73.

Darlington, A.S. & Wright, C.M. (2006). The influence of temperament on weight gain in early infancy. *Journal of Developmental Behavioral Pediatrics, 27,* 329-35.

Davy, A. (2016). *Provision for learning outdoors for under 5's. State of the Nation survey.* Retrieved from http://www.earlychildhoodforum.org/uploads/EYFS_Outdoors_Final_Report.pdf

Davey-Smith, G. D., & Ebrahim, S. (2002). Data dredging, bias, or confounding. *BMJ (Clinical research ed.)*, *325*(7378), 1437–1438.

Dazeley, P. & Houston-Price, C. (2015). Exposure to foods' non-taste sensory properties. A nursery intervention to increase children's willingness to try fruit and vegetables. *Appetite, 84,* 1-6

de Beer, M., Vrijotte, T.G.M., Fall, C.H.D., van Eijsden, M., Osmond, C. & Gemke, R.J.B.J. (2015). Associations of infant feeding and timing of linear growth and relative weight gain during early life with childhood body composition. *International Journal of Obesity, 39,* 586-592.

de Onis, M. & Blossner, M. (2000). Prevalence and trends of overweight among preschool children in developing countries. *American Journal of Clinical Nutrition, 72,* 1032-9.

de Onis, M. & Lobstein, T. (2010). Defining obesity risk status in the general childhood population: which cut offs should we use? *International Journal of Pediatric Obesity, 5,* 458-60.

Dennison, B.A., Edmunds, L.S., Stratton, H.H. & Pruzek, R.M. (2006). Rapid infant weight gain predicts childhood overweight. *Obesity, 14*(3), 491-9.

Department of Health (2018) *Choosing first foods.* Retrieved February 6, 2018, from https://www.nhs.uk/start4life/choosing-first-foods

Dewey, K.G., Heinig, M.J., Nommsen, L.A., Peerson, J.M., Lonnerdal, B. (1992). Growth of breastfed and formula fed infants from 0-18 months: The DARLING study. *Pediatrics, 89*(6), 1035-1041.

Dewey, K.G., Nommsen-Rivers, L.A., Heinig, M.J. & Cohen, R.J. (2003). Risk factors for suboptimal infant breastfeeding behavior, delayed onset of lactation, and excess neonatal weight loss. *Pediatrics*, *112,* 607-619.

Diana, A., Mallard, S.R., Haszard, J.J., Purnamasari, D.M., Nurulazmi, I., Herlani, P.D., ….Houghton, L. (2017). Consumption of fortified infant foods reduces dietary diversity but has a positive effect on subsequent growth in infants from Sumedang district, Indonesia. *PLoS One, 12,* 1-17.

Dietz, W.H. & Gortmaker, S.L. (1985). Do we fatten our children at the television set? Obesity and television viewing in children and adolescents, *Pediatrics, 75,* 807-812.

DiSantis, K.I. Hodges, E.A. Johnson, S.L. & Fisher, J.O. (2011a). The role of responsive feeding in overweight during infancy and toddlerhood: a systematic review. *International Journal of Obesity. 35,* 480-490.

DiSantis, K.I., Collins, B,N., Fisher, J.O. & Davey, A. (2011b). Do infants fed directly from the breast have improved appetite regulation and slower growth during early childhood compared with infants fed from a bottle? *International Journal of Behavioral Nutrition and Physical Activity, 17,* 1-11.

DiSantis, K.I., Hodges, E.A. & Fisher, J.O. (2013). The association of breastfeeding duration with later maternal feeding styles in infancy and toddlerhood: a cross sectional analysis. *International Journal of Behavioral Nutrition and Physical Activity, 10,* 1-12.

Dogan, E., Yilmaz, G., Caylan, N., Turgut, M., Gokcay, G. & Oguz, M.M. (2018). Baby-led complementary feeding: randomized control study. *Pediatrics International, 60,* 1073-1080

Dollberg, S., Lahav, S. & Mimouni, F.B. (2001). A comparison of intakes of breast-fed and bottle-fed infants during the first two days of life. *Journal of the American College of Nutrition, 20,* 209-11.

Driscoll, D.L., Appiah-Yeboah, A., Salib, P. & Rupert, D.J. (2007). Merging qualitative and quantitative data in mixed methods research: how to and why not. *Ecological and Environmental Anthropology, 3*, 18-28.

Druet, C., Stettler, N., Sharp, S., Simmons, R.K., Cooper, C., Smith, G.D., …Ong, K.K. (2011). Prediction of childhood obesity by infancy weight gain: an individual level meta-analysis. *Pediatric Perinatal Epidemiology, 26*(1), 19-26.

Dubois, L. & Girard, M. (2006). Early determinants of overweight at 4.5 years in a population based longitudinal study. *International Journal of Obesity, 30*(4)610-7.

Duch, H., Fisher, E.M., Ensari, I. & Harrington, A. (2013). Screen time use in children under 3 years old: a systematic review of the correlates, *International Journal of Behavioral Nutrition and Physical Activity, 10,* 1-10.

Dupont, C. (2003). Protein requirements during the first year of life. *The American Journal of Clinical Nutrition, 77,* 1544S-1549S.

Earle, S. (2000). Why some women do not breast feed: Bottle feeding and father's role. *Midwifery, 16*(4), 323-30.

European Food Safety Authority (EFSA). (2009). Scientific Opinion on the appropriate age for introduction of complementary feeding of infants. *EFSA Journal 7*(12), 3-38.

European Food Safety Authority (EFSA). (2014). Scientific Opinion on the essential composition of infant and follow on formulae. *EFSA Journal, 12,* 3760, 1-106.

European Food Safety Authority (EFSA) (2017). Scientific Opinion on the safety and suitability for use by infants of follow-on formulae with a protein content of at least 1.6g/100 kcal. *EFSA Journal, 15*(4781), 1-29.

European Food Safety Authority (EFSA) (2019). *Draft scientific opinion on the appropriate age for introduction of complementary feeding into an infant's diet.* Retrieved August 3, 2019 from https://www.efsa.europa.eu/en/consultations/call/190417

Elias, M.F., Nicolson, N.A., Bora, C. & Johnston, J. (1986). Sleep/wake patterns of breast-fed infants in the first 2 years of life. *Pediatrics, 77,* 322-9.

Elks, C.E., Loos, R.F., Sharp, S.J., Langenberg, C., Ring, S., Timpson, N.J., …Ong, K.K. (2010). Genetic markers of adult obesity risk are associated with greater early infancy weight gain and growth. *PLOS Medicine, 7,* 1-8.

Ekstein, S., Laniado, D. Glick, B. (2010). Does picky eating affect weight-for-length measurements in young children? *Clinical Pediatrics, 49*(3), 217-20.

Emmanouil, A. & Raoult, D. (2018). Gut microbiota modifications and weight gain in early life. *Human Microbiome Journal, 7-8,* 10-14.

Emmett, P.M., Hays, N.P. & Taylor, C.M. (2018). Antecedents of picky eating behavior in young children. *Appetite, 130,* 163-173.

Emmett, P.M. & Jones, L.R. (2015). Diet, growth and obesity development throughout childhood in the Avon Longitudinal Study of Parents and Children. *Nutrition Reviews, 73,* Supplement 3, 175-206.

Eneli, I.U., Crum, P.A. & Tylka, T.L. (2008). The Trust Model: A different paradigm for managing childhood obesity. *Obesity, 16*(10), 2197-2204.

Engel, S.M., Joubert, B.R., Wu, M.C., Olshan, A.F., Haberg, S.E., Magne Ueland, P., ...London, S.J. (2014). Neonatal genome- wide methylation patterns in relation to birthweight in the Norwegian mother and child cohort, *American Journal of Epidemiology, 179,* 834-842.

Engle, P.L., Bentley, M. & Pelto, G.H. (2000). The role of care in nutrition programmes: current research and a research agenda, *Proceedings of the Nutrition Society, 59,* 25-35.

Entwistle, F., Kendall, S. & Mead, M. (2010). Breastfeeding support – the importance of self-efficacy for low income women. *Maternal and Child Nutrition, 6,* 228-42.

Erickson, L.W. (2015). A baby-led approach to complementary feeding: adherence and infant food and nutrient intakes at seven months of age. (Masters' Dissertation, University of Otago). Retrieved from https://ourarchive.otago.ac.nz/handle/10523/6041

Faith, M.S. & Kerns, J. (2005). Infant and child feeding practices and childhood overweight: the role of restriction. *Maternal and Child Nutrition, 1,* 164-168.

Faith, M.S., Berkowitz, R.I., Stallings, V.A., Kerns, J., Storey, M. & Stunkard, A.J. (2004). Parental feeding attitudes and styles and child body mass index: prospective analysis of a gene-environment interaction. *Pediatrics, 114,* e429-36.

Fallani, M., Amarri, S., Uusijarvi, A., Adam, R., Khanna, S., Aguilera, M., … the INFABIO team (2011). Determinants of the human infant intestinal microbiota after the introduction of first complementary foods in infant samples from five European centres. *Microbiology, 157,* 1385-1392.

Fangupo, L.J., Heath, A-L. M., Williams, S., Erickson, L.W., Morison, B.J., Fleming, E.A., Taylor, B.J.,…Taylor, R.W. (2016). A baby-led approach to eating solids and risk of choking. *Pediatrics, 138,* 4, 1-8.

Farrow, C.V. (2005). *Caregivers cognitions and psychopathology and infancy feeding problems: from pregnancy through the first postnatal year.* (Doctoral thesis) Retrieved from EThOS (uk.bl.ethos.422728).

Farrow, C.V. & Blissett, J.M. (2005a). Is maternal psychopathology related to obesogenic feeding practices at 1 year? *Obesity Research,* 13, 1999-2005.

Farrow, C. & Blissett, J. (2005b). Maternal cognitions, psychopathological symptoms, and infant temperament as predictors of early infant feeding problems: A longitudinal study. *International Journal of Eating Disorders, 39* (2), 128-134.

Farrow, C.V. & Blissett, J.M. (2006). Does maternal control during feeding moderate early infant weight gain? *Pediatrics, 118,* e293-e298.

Farrow, C.V. & Blissett, J.M. (2008). Controlling feeding practices: cause or consequence of early child weight? *Pediatrics, 121,* 164-9.

Farrow, C.V. & Blissett, J.M. (2012). Stability and continuity of parentally reported child eating behaviours and feeding practices from 2 to 5 years of age. *Appetite, 58,* 151-6.

Farrow, C.V. & Blissett, J.M. (2014). Maternal mind-mindedness during infancy, general parenting sensitivity and observed child feeding behavior: a longitudinal study. *Attachment & Human Development, 16,* 230-41.

Farrow, C., Blissett, J. & Haycraft, E. (2011). Does child weight influence how mothers report their feeding practices? *International Journal of Pediatric Obesity, 6*(3-4), 306-313.

Farrow, C.V., Haycraft, E. & Blissett, J.M. (2015). Teaching our children when to eat: how parental feeding practices inform the development of emotional eating – a longitudinal experimental design. *American Journal of Clinical Nutrition, 101,* 908-13.

Fields, D.A. & Demerath, E.W. (2012). Relationship of insulin, glucose, leptin, IL-6 and TNF- α in human breast milk with infant body composition. *Pediatric Obesity, 7,* 304-312.

Field, C.J. (2005). The immunological components of the human milk and their effect on immune development in infants. *The Journal of Nutrition, 135*(1), 1-4.

Fisher, R.J. (1993). Social desirability bias and the validity of indirect questioning. *Journal of Consumer Research, 20*(2), 303-315.

Fisher, J.O. & Birch L. L. (1999). Restricting access to palatable foods affects children's behavioral response, food selection and intake. *American Journal of Clinical Nutrition, 69,* 1264–1272.

Fisher, J.O., Birch, L.L., Smiciklas-Wright, H. & Picciano, M.F. (2000). Breastfeeding through the first year predicts maternal control in feeding and subsequent toddler energy intakes. *Journal of the American Dietetics Association, 100*(6), 641-6.

Fisher, J.O., Butte, N.F., Mendoza, P.M., Wilson, T.A., Hodges, E.A., Reidy, K.C. & Deming, D. (2008). Overestimation of infant and toddler energy intake by 24-h recall compared with weighed food records. *American Journal of Clinical Nutrition, 88,* 407-415.

Fildes, V. (1986). *Breasts, bottle and babies – a history of infant feeding.* Edinburgh: Edinburgh University Press.

Fildes, A., van Jaarsveld, C.H., Llewellyn, C., Wardle, J. & Fisher, A. (2015). Parental control over feeding in infancy. Influence of infant weight, appetite and feeding method. *Appetite, 91,* 101-6.

Finistrella, V., Manco, M., Ferrara, A., Rustico, C., Presaghi, F. & Morino, G. (2012). Cross-sectional exploration of maternal reports of food neophobia and pickiness in preschooler-mother dyads. *Journal of the American College of Nutrition, 31*(3), 152-159.

First Steps Nutrition Trust (2017). *Eating well: the first year. A guide to introducing solids and eating well up to baby's first birthday.* Retrieved from http://www.firststepsnutrition.org/pdfs/Eating_well_the_first_year_Nov17_for_web.pdf

Fishbein, M. & Cappella, J.N. (2006). The role of theory in developing effective health communications. *Journal of Communication, 56*(s1), S1-S17.

Felix, J.F., Bradfield, J.P., Monnereau, C., Van der Valk, R.J.P., Stergiakouli, E., Chesi, A. … & Jaddoe, V. W.V. (2015). Genome-wide association analysis identifies three new susceptibility loci for childhood body mass index, *Human Molecular Genetics, 25,* 389-403.

Fetissov, S.O. (2017) Role of the gut microbiota in host appetite control: bacterial growth to animal feeding behaviour. *Nature Reviews Endocrinology, 13,* 11-25.

Fewtrell, M. S., Lucas, A., Morgan, J.B. (2003). Factors associated with weaning in full term and preterm infants, *Archives of Disease in Childhood –Fetal and Neonatal Edition, 88,* F296-F301.

Fogel, A., Goh, A.T., Fries, L., Sandanathan, S., Velan, S.S., Michael, N., …Forde, C.G. (2017). Faster eating rates are associated with higher energy intakes during an ad libitum meal, higher BMI and greater adiposity among 4.5-year-old children: results from the Growing Up in Singapore Towards Healthy Outcomes (GUSTO) cohort. *British Journal of Nutrition, 117,* 1042-1051.

Fomon, S.J. (1974). *Infant Nutrition.* London: Saunders

Fomon, S.J., Owen, G.M. & Thomas, L.N. (1964). Milk or formula volume ingested by infants fed ad libitum. *American Journal of the Disorders of the Child, 108,* 601-612.

Food Standards Agency. (2016). *Our food future.* Retrieved from https://www.food.gov.uk/sites/default/files/our-food-future-full-report.pdf

Frayling, T.M., Timpson, N.J., Weedon, M.N., Zeggini, E., Freathy, R.M., Lindgren, C.M.,…McCarthy, M.I. (2007). A common variant in the FTO gene is associated with body mass index and predisposes to childhood and adult obesity. *Science, 316,* 889-894.
Friel, J.K., Hanning, R.M., Isaak, C.A., Prowse, D. & Miller, A.C. (2010). Canadian infants' nutrient intakes from complementary foods during the first year of life. *BMC Pediatric, 10,* 1-11.

French, S.A., Story, M. & Jeffrey, R.W. (2001). Environmental influences on eating and physical activity. *Annual Review of Public Health, 22,* 309-335.

French, S.A., Epstein, L.H., Jeffrey, R.W., Blundell, J.E. & Wardle, J. (2012). Eating behaviour dimensions: Associations with energy intake and body weight: A review. *Appetite, 59,* 541-549.

Gale, C., Logan, K.M., Santhakumaran, S., Parkinson, J.R.C., Hyde, M.J., Modi, N. (2012). Effect of breastfeeding compared with formula feeding on infant body composition: a systematic review and meta-analysis. *American Journal of Clinical Nutrition,* 95(3), 656-669.

Gale, L. & Davies, N. (2013). Young people's attitudes towards breastfeeding: A survey of 13-15-year old pupils in a south London school. *BJM, 21*(3), 195-201.

Galindo, L., Power, T.G., Beck, A.D., Fisher, J.O., O'Conner, T.M. & Hughes, S.O. (2018). Predicting preschool children's eating in the absence of hunger from maternal pressure to eat: a longitudinal study of low-income, Latina mothers. *Appetite, 120,* 281-286.

Galloway, A. T., Fiorito, L., Lee, Y., & Birch, L. L. (2005). Parental pressure, dietary patterns, and weight status among girls who are "picky eaters". *Journal of the American Dietetic Association*, *105*(4), 541–548.

Garcia, A.L., McLean, K. & Wright, C.M. (2016). Types of fruit and vegetables used in commercial baby foods and their contribution to sugar content. *Maternal and Child Nutrition, 12,* 4, 838-847.

Garcia, A.L., Raza, S., Parrett, A. & Wright, C.M. (2013). Nutritional content of infant commercial weaning foods in the UK. *Archives of Disease in Childhood, 98,* 793-797.

Gerber, J.S., Bryan, M., Ross, R.K., Daymont, C., Parks, E.P., Localio, A.R., Grundmeier, R.W., Stallings, V.A. & Zaoutis, T.E. (2016). Antibiotic exposure during the first 6 months of life and weight gain during childhood, *JAMA,* 315(12)1258-1265.

Gibbs, B.G. & Forste, R. (2014). Socioeconomic status, infant feeding practices and early childhood obesity, *Pediatric Obesity, 9,* 135-46.

Gisel, E.G. (1991). Effect of food texture on the development of chewing of children between six months and two years of age. *Developmental Medicine & Child Neurology, 33,* 69-79.

Gordon, N.P. & Mellor, R.G. (2015). Accuracy of parent-reported information for estimating prevalence of overweight and obesity in a race-ethnically diverse pediatric clinic population aged 3 to 12. *BMC Pediatrics, 15*(5), 1-11

Goyal, N.K., Fiks, A.G. & Lorch, S.A. (2012). Persistence of underweight status among late preterm infants. *Archives of Pediatric Adolescent Medicine, 166,* 424-30.

Gregory, J.E., Paxton, S.J. & Brozovic, A.M. (2010). Pressure to eat and restriction are associated with child eating behaviours and maternal concern about child weight, but not body mass index, in 2 to 4-year-old children. *Appetite, 54,* 550-6.

Grenov, B., Michaelsen, K.F. (2018). Growth components of cow's milk: emphasis on effects in undernourished children. *Food Nutrition Bulletin, 39,* S45-S53.

Grote, Z., Theurich, M & Koletzko, B. (2012). Do complementary feeding practices predict the later risk of obesity? *Current Opinion in Clinical Nutrition and Metabolic Care,* 15(3), 293-297.

Grummer-Strawn L M, & Mei Z. (2004). Does breastfeeding protect against pediatric overweight? Analysis of longitudinal data from the Centers for Disease Control and Prevention Pediatric Nutrition Surveillance System. *Pediatrics, 113,* e81-e86.

Grummer-Strawn, L.M. & Rollins, N. (2015). Summarising the health effects of breastfeeding. *Acta Paediatrica, 104* (S467), 1-2.

Gross, R.S., Fierman, A.H., Mendelsohn, A.L., Chiasson, M.A., Rosenberg, T.J., Scheinmann, R., Messito, M.J., (2010). Maternal perceptions of infant hunger, satiety, and pressuring feeding styles in an urban Latina WIC population. *Academic Pediatrics, 10,* 29-35.

Gross, R.S., Mendelsohn, A.L., Fierman, A.H. & Messito, M.J. (2011). Maternal controlling feeding styles during early infancy. *Clinical Pediatrics, 50,* 1125-1133.

Gross, R.S., Mendelsohn, A.L., Fierman, A.H., Hauser, N.R. & Messito, M.J. (2014). Maternal infant feeding behaviours and disparities in early child obesity. *Childhood Obesity, 10,* 145-52.

Gubbels, J.S., Kremers, S.P., Stafleu, A., Dagnelie, P.C., Goldbohm, R.A., de Vries, N.K. & Thijs, C. (2009). Diet-related restrictive parenting practices. Impact on dietary ontake of 2-year-old children and interactions with child characteristics. *Appetite, 52*(2), 423-9.

Gunnarsdottir, I. & Thorsdottir, I. (2003). Relationship between growth and feeding in infancy and body mass index at the age of 6 years. *International Journal of Obesity Related Metabolic Disorders, 27,* 1523-1527.

Gunther, A.L., Remer, T., Kroke, A. & Buyken, A.E. (2007). Early protein intake and later obesity risk: which protein sources at which time points throughout infancy and childhood are important for body mass index and body fat percentage at 7 y of age? *American Journal of Clinical Nutrition, 86*(6), 1765-72

Hainer, V., Stunkard, A.J., Kunesova, M., Parizkova, J., Stich, V. & Allison, D.B. (2000). Intrapair resemblance in very low calorie diet-induced weight loss in female obese identical twins. *International Journal of Obesity, 24,* 1051-1057.

Hales, C.N. & Barker, D.J.P. (2013). Type 2 (non-insulin dependent) diabetes mellitus: the thrifty phenotype hypothesis, *International Journal of Epidemiology, 42,* 1215-1222.

Halpern, L.F., Garcia Coll, C.T. (2000). Temperament of small-for-gestational-age and appropriate-for-gestational-age infants across the first year of life. *Merrill-Palmer Quarterly, 46,* 738-765.

Hambreaus, L. (1977). Proprietary milk versus human breast milk in infant feeding. A critical appraisal from the nutritional point of view. *Pediatric Clinics of North America, 24,* 17-36.

Harries, V. & Brown, A. (2019). The association between baby-care books that promote strict care routines and infant feeding, night-time care and maternal-infant interactions. *Maternal and Child Nutrition.* Advanced online publication. https://doi.org/10.1111/mcn.12858

Harrison, M., Brodribb, W., & Hepworth, J. (2016). A qualitative systematic review of maternal infant feeding practices in transitioning from milk feeds to family foods. *Maternal and Child Nutrition, 13,* 1-12.

Harrison, M., Brodribb, W., Davies, P.S.W. & Hepworth, J. (2018). Impact of maternal infant weight perception on infant feeding and dietary intake. *Maternal and Child Health Journal, 22,* 1135-1145.

Haschke, F., Grathwohl, D., Detzel, P., Steenhout, P., Wagemans, N. & Erdmann, P. (2016). Postnatal high protein intake can contribute to accelerated weight gain of infants and increased obesity risk. *Nestle Nutrition Institute Workshop Series, 85,* 101-9.

Hathcock, A., Krause, K., Viera, A.J., Fuemmeler, B.F., Lovelady, C. & Ostbye, T. (2014). Satiety responsiveness and the relationship between breastfeeding and weight status of toddlers of overweight and obese women. *Maternal and Child Health Journal, 18,* 1023-30.

Harder, T., Bergmann, R., Kallischnigg, G. & Plagemann, A. (2005). Duration of breastfeeding and risk of overweight: a meta-analysis. *American Journal of Epidemiology*, *162,* 397-403.

Harris, G. & Coulthard, H. (2016). Early eating behaviors and food acceptance revisited: breastfeeding and introduction of complementary foods as predictive of food acceptance. *Current Obesity Reports,* 5, 113-120.

Harshaw, C. (2008). Alimentary epigenetics: A developmental psychobiological systems view of the perception of hunger, thirst and satiety. *Developmental Review, 28*(4)541-569.

Havermans, R.C. & Jansen, A. (2007). Increasing children's liking of vegetables through flavor-flavour learning. *Appetite, 48*(2), 259-62.

Hayes, J.F., Altman, M., Kolko, R.P., Balantekin, K.N., Holland, J.C., Stein, R.I.,… Wilfrey, D.E. (2017). Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment, *Obesity (Silver Spring),* 24(10) 2158-2163.

Head, M.L., Holman, L., Lanfear, R., Kahn, A.T. & Jennions, M.D. (2015). The extent and consequences of p-hacking in science. *PLOS Biology, 13*(3), e1002106.

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. *Evidence Based Nursing, 18*(3), 66-67.

Hetherington, M.M., Madrelle, J., Nekitsing, C., Barends, C., de Graaf, C., Morgan, S., Parrott, H. & Weenen, H. (2016). Developing a novel tool to assess liking and wanting in infants at the time of complementary feeding – The Feeding Infants: Behaviour and Facial Expression Coding System. *Food Quality and Preference, 48*(A), 238-250.

Hebert, J.R., Clemow, L., Pbert, L., Ockene, I.S. & Ockene, J.K. (1995). Social desirability bias in dietary self-report may compromise the validity of dietary intake measures. *International Journal of Epidemiology,* 24(2), 389-398

Hediger, M.L., Overpeck, M.D., Kuczmarski, R.J., Ruan, M.A. (2001). Association between infant breastfeeding and overweight in young children. *JAMA, 285,* 2453-2460.

Hediger, M.L., Overpeck, M.D., Maurer, K.R., Kuczmarski, R.J., McGlynn, A. & Davis, W.W. (1998). Growth of infants and young children born small or large for gestational age. Findings from the third National Health and Nutrition Examination Survey. *Archives of Pediatric and Adolescent Medicine, 152,* 1225-1231.

Heinig, M.J., Nommsen, L.A., Peerson, J.M., Lonnerdal, B., & Dewey, K.G. (1993). Energy and Protein intakes of breast-fed and formula-fed infants during the first year of life and their association with growth velocity: the DARLING study. *American Journal of Clinical Nutrition,* 58(2), 152-161.

Heinz. (2019). *Summer fruit porridge.* Retrieved August 29, 2019 from https://www.heinzbaby.co.uk/product/7600772800/summer-fruit-porridge

Helle, C., Hillesund, E. R. & Overby, N.C. (2018). Timing of complementary feeding and associations with maternal and infant characteristics: A Norwegian cross-sectional study. *PLoS One, 13,* 1-20.

Henderson, L., McMillan, B., Green, J., & Renfrew, M. (2011). Men and Infant Feeding: Perceptions of Embarrassment, Sexuality, and Social Conduct in White Low-Income British Men. *Birth, 38*, 61-71.

Hester, S. N., Hustead, D. S., Mackey, A. D., Singhal, A., & Marriage, B. J. (2012). Is the macronutrient intake of formula-fed infants greater than breast-fed infants in early infancy? *Journal of Nutrition and Metabolism*, *2012,* 1-13.

Higgs, S. & Jones, A. (2013). Prolonged chewing at lunch decreases later snack intake. *Appetite, 62,* 91-5.

Hill, C., Saxton, J., Webber, L., Blundell, J. & Wardle, J. (2009). The relative reinforcing value of food predicts weight gain in a longitudinal study of 7-10-y-old children. *The American Journal of Clinical Nutrition, 90,* 276-281.

Hill, J.O. (2006). Understanding and addressing the epidemic of obesity: An energy balance perspective. *Endocrine reviews, 27,* 750-761.

Hill, J.O., Wyatt, H.R. & Peters, J.C. (2012). Energy balance and Obesity. *Circulation, 126*(1), 126-132

Hinckley, T., Salmon. J., Okely, A.D., Crawford, D. & Hesketh, K. (2012). Preschoolers' physical activity, screen time and compliance with recommendations, *Medicine & Science in Sports and Exercise, 44,* 458-465.

Hiscock, H. & Wake, M. (2001). Infant sleep problems and postnatal depression: a community based study. *Pediatrics, 107,* 1317-22.

Hobbs, A.J., Mannion, C.A., McDonald, S.W., Brockway, M. & Tough, S.C. (2016). The impact of caesarean section on breastfeeding initiation, duration and difficulties in the first four months postpartum. *BMC Pregnancy and Childbirth, 16,* 1-9.

Hoddinott, G.P. & Pill, R. (2001). A qualitative study of women's views about how health professionals communicate about infant feeding. *Health Expectations, 3*(4), 224-233.

Hoddinott, P., Craig, L.C.A., Britten, J. & McInnes, R.J. (2012). A serial qualitative interview study of infant feeding experiences: idealism meets realism. *BMJ Open, 2,* 1-14.

Hodges, E.A., Johnson, S.L., Hughes, S.O., Hopkinson, J.M., Butte, N.F. & Fisher, J.O. (2013). Development of the responsiveness to child feeding cues scale. *Appetite, 65,* 210-219.

Hoppe, C., Molgaard, C., Thomsen, B.L., Juul, A. & Michaelsen, K.F. (2004). Protein intake at 9 mo of age is associated with body size but not with body fat in 10-y-old Danish children. *American Journal of Clinical Nutrition, 79,* 494-501.

Holley, C.E., Farrow, C. & Haycraft, E. (2017). A systematic review of methods for increasing vegetable consumption in early childhood. *Current Nutrition Reports, 6*(2), 157-170.

Holley, C.E., Haycraft, E. & Farrow, C. (2018). Predicting children's fussiness with vegetables: the role of feeding practices. *Maternal Child Nutrition, 14,* 1-9.

Holmes, A.V., Auinger, P. & Howard, C.R. (2011). Combination feeding of breast milk and formula: evidence for shorter breastfeeding duration from the national health and nutrition examination survey. *The Journal of Pediatrics, 159,* 186-181.

Horta, L.B., Loret de Mola, C. & Victora, C.G. (2015). Long term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure and type 2 diabetes: a systematic review and meta-analysis. *Acta Paediatrica, 104,* 30-37.

Hornell, A., Hofvander, Y. & Kylberg, E. (2001). Solids and formula: association with pattern and duration of breastfeeding. *Pediatrics, 107,* 1-7.

Hsieh, H-F. & Shannon, S.E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*, 1277-1288.

Huang, T. & Hu, F.B. (2015). Gene-environment interactions and obesity: recent developments and future directions. *BMC Medical Genomics, 8*(Suppl 1), 1-17.

Huang, J., Zhang, Z., Wu, Y., Wang, J., Zhou, L., Ni, Z.,…Yang, X. (2018) Early feeding of larger volumes of formula milk is associated with greater body weight or overweight in later infancy. *Nutrition Journal, 1,* 1-9.

Hughes, S.O. & Frazier-Wood, A.C. (2016). Satiety and the self-regulation of food intake in children: a potential role for gene-environment interplay. *Current Obesity Reports, 5,* 81-7.

Huh, S.Y., Rifas-Shiman, S.L., Taveras, E.M., Oken., E., Gillman, M.W. (2011) Timing of solid food introduction and risk of obesity in preschool-aged children. *Pediatrics, 127,* 3, e544-e551

Huh, S.Y., Rifas-Shiman, S.L., Zera, C.A., Rich Edwards, J. W., Oken, E., Weiss, S.T. & Gillman. M.W. (2012). Delivery by caesarean section and risk of obesity in preschool age children: a prospective cohort study. *Archives of Disease in Childhood, 97*(7), 610-6.

Hurley, K.M., Cross, M.B., Hughes, S.O. (2011). A systematic review of responsive feeding and child obesity. *Journal of Nutrition, 141*(3), 495-501.

Hurrell, R.F., Reddy, M.B., Juillerat, M-A. & Cook, J.D. (2003). Degradation of phytic acid in cereal porridges improves iron absorption by human subjects. *American Journal of Clinical Nutrition, 7*(5), 1213-1219

Huybrechts, I., Himes, J.H., Ottevaere, C., De Vriendt, T., De Keyzer, W., Cox, B.,… De Henauew, S. (2011). Validity of parent-reported weight and height of preschool children measured at home or estimated without home measurement: a validation study. *BMC Pediatrics, 11*(63), 1-8

Jain, V. & Singhal, A. (2012). Catch up growth in low birth weight infants: striking a healthy balance. *Reviews in Endocrine and Metabolic Disorders, 13,* 141-147.

Jansen, A., Theunissen, N., Slechten, K., Nederkoorn, C., Boon, B., Mulkens, A. & Roefs, A. (2003). Overweight children overeat after exposure to food cues. *Eating Behaviours, 4,* 197-209.

Johannsen, D.L., Johannsen, N.M., & Specker, B.L. (2006). Influence of parents' eating behaviours and child feeding practices on children's weight status. *Obesity (Silver Spring), 14*(3), 431-9.

Johns, H.M., Forster, D.A., Amir, L.H. & McLachlan, H.L. (2013). Prevalence and outcomes of breast milk expressing in women with healthy term infants. *BMC Pregnancy Childbirth, 13,* 1-20.

Jonas, W., Johansson, L.M., Nissen, E., Ejdeback, M., Ransjo-Arvidson, A.B., Uvnas-Moberg, K. (2009). Effects of intrapartum oxytocin administration and epidural analgesia on the concentration of plasma oxytocin and prolactin, in response to suckling during the second day postpartum. *Breastfeeding Medicine, 4,* 71-82.

Johnson, S.L. (2000). Improving pre-schoolers self-regulation of energy intake. *Pediatrics, 106*(6), 1429-1435.

Jones. S. (2016). A history of baby-led-weaning: The evolution of complementary feeding trends, *Journal of Health Visiting, 4*(10), 524-30.

Joseph, K.S., Liston, R.M., Dodds, L., Dahlgren, L. & Allen, A.C. (2007). Socioeconomic status and perinatal outcomes in a setting with universal access to essential health care services. *CMAJ, 177,* 583-590.

Kaisari, P., Yannakoulia, M. & Panagiotakos, D.B. (2013). Eating frequency and overweight and obesity in children and adolsecents: A meta-analysis. *Pediatrics, 131,* 958-967.

Kalliomaki, M., Collado, M.C., Salminen, S. & Isolauri, E. (2008). Early differences in fecal microbiota composition in children may predict overweight. *American Journal of Clinical Nutrition, 87,* 534-8.

Karlberg, J. & Albertsson-Wikland, K. (1995). Growth in full-term small-for-gestational-age infants: from birth to final height. *Pediatric Research,* 38, 733-9.

Karvetti, R.L. & Knuts, L.R. (1985). Validity of the 24-hour dietary recall. *Journal of the American Dietetic Association, 85*(11), 1437-1442.

Kelly, M.P. & Barker, M. (2016). Why is changing health related behaviour so difficult? *Public Helath, 136,* 109-116.

Kerr, N.L. (1998). HARKing: hypothesising after results are known. *Personality and Social Psychology Review, 2*(3), 196-217.

Klesges, R. C., Coates, T. J., Brown, G., Sturgeon-Tillisch, J., Moldenhauer-Klesges, L. M., Holzer, B., … Vollmer, J. (1983). Parental influences on children's eating behavior and relative weight. *Journal of applied behavior analysis*, *16*(4), 371–378.

Klesges, R.C., Mallot, Boschee, P. & Weber, J. (1986). The effects of parental influences on child food intake, physical activity, and relative weight. *International journal of Eating Disorders, 5,* 335-345.

Klok, M.D., Jakobsdottir, S. & Drent, M.L. (2007). The role of leptin and ghrelin in the regulation of food intake and body weight in humans: a review. *Obesity Reviews. 8*(1), 21-34

Kohler, L., Meeuwisse, G. & Mortensson, W. (1984). Food intake and growth of infants between six-and twenty-six weeks of age on breast milk, cow's milk formula, or soy formula. *Acta Paediatrica, 73,* 40-8.

Koletzko, B., von Kries, R., Closa, R., Escribano, J., Scaglioni, S., Giovanni, M., …Grote, V. (2009a). Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial. *American Journal of Clinical Nutrition, 89,* 1836-45.

Koletzko, B., von Kries, R., Closa, R., Escribano, J., Scaglioni, S., Giovanni, M., …Grote, V. (2009b). Can infant feeding choices modulate later obesity risk? *American Journal of Clinical Nutrition, 89,* 1502S-1508S.

Koleva, P.T., Bridgman, S. & Kozyrskyj, A.L. (2015). The infant gut microbiome: evidence for obesity risk and dietary intervention. *Nutrients, 7*, 2237-2260.

Komninou, S., Halford, J.C.G. & Harrold, J.A. (2019). Differences in parental feeding styles and practices and toddler eating behaviour across complementary feeding methods: Managing expectations through consideration of effect size. *Appetite, 137,* 198-206.

Korpela, K., Salonen, A., Virta, L.J., Kekkonen, R.A., de Vos, W.M. (2016). Association of early-life antibiotic use and the protective effects of breastfeeding: Role of the Intestinal Microbiota. *JAMA Pediatrics, 170*(8), 750-7.

Korpela, K., Zijlmans, M.A.C., Kuitunen, M., Kukkonen, K., Savilahti, E., Salonen, A., deWeerth, C. & de Vos, W.M. (2017). Childhood BMI in relation to microbiota in infancy and lifetime antibiotic use. *Microbiome, 5*(26), 1-9.

Kramer, M.S. (2010). Breastfeeding, complementary (solid) foods, and long term obesity risk. *American Journal of Clinical Nutrition, 91*(3), 500-1.

Kramer, M.S., Guo, T., Platt, R.W., Shapiro, S., Collet, J.P., Chalmers, B., …PROBIT Study Group. (2002). Breastfeeding and infant growth: Biology or Bias? Pediatrics, *110*(2), 343-7.

Kramer, M.S., Moodie, E.E.M., Dahhou, M. & Platt, R.W. (2011). Breastfeeding and infant size: Evidence of reverse causality. *American Journal of Epidemiology. 173,* 978-983.

Kramer, M.S. & Kakuma, R. (2002). Optimal duration of exclusive breastfeeding. *Cochrane Database of Systematic Reviews, 2002* (1).

Kramer, M.S. & Kakuma, R. (2012). Optimal duration of exclusive breastfeeding. *Cochrane Database of Systematic Reviews, 2012* (8).

Kronborg, H., Foverskov, E. & Vaeth, M. (2014). Predictors for early introduction of solid food among Danish mothers and infants: an observational study. *BMC Pediatrics, 14,* 1-10.

Kronborg, H., Harder, I. & Hall, E.O.C. (2015). First time mothers' experiences of breastfeeding their newborn. *Sexual and Reproductive Healthcare, 6,* 2, 82-87.

Krumpal, I. (2013). Determinants of social desirability bias in sensitive surveys: literature review. *Quality and Quantity, 47,* 2025-2047.

Kuhle, S., Tong, O.S. & Woolcott, C.G. (2015). Association between caesarean section and childhood obesity: a systematic review and meta-analysis. *Obesity Reviews, 16*(4)295-303.

Lake, A. & Townshend, T. (2006). Obesogenic environments. Exploring the built and food environments. *Journal of the Royal Society for the Promotion of Health, 126*(6), 262-267.

Lakshman, R., Zhang, J., Zhang, J., Koch, F.S., Marus, C., Ludvigsson, J., Ong, K.K. & Sobko, T. (2013). Higher maternal education is associated with favourable growth of young children in different countries. *Journal of Epidemiology and Community Health, 67,* 595-602.

Lakshman, R., Clifton, E.A. & Ong, K.K. (2017). Baby-led weaning – safe and effective but not preventative of obesity. *JAMA Pediatrics, 171,* 832-833.

Larsen, J.S., Hall, E.O.C. & Aagaard, H. (2008). Shattered expectations: when mothers' confidence in breastfeeding is undermined – a metasynthesis. *Scandanavian Journal of Caring Sciences, 22,* 653-661.

Lam, M.C.L. & Adams, J. (2017). Association between home food preparation skills and behaviour, and consumption of ultra-processed foods: Cross-sectional analysis of the UK National Diet and nutrition survey (2008–2009). *International Journal of Behavioral Nutrition and Physical Activity, 14*(68), 1-7.

Lange, C., Visalli, M., Jacob, S., Chabanet, C., Schlich, P., Nicklaus, S. (2013). Maternal feeding practices during the first year and their impact on infants' acceptance of complementary food. *Food quality and preference, 29,* 88-98.

Lansigan, R. K., Emond, J. A., & Gilbert-Diamond, D. (2015). Understanding eating in the absence of hunger among young children: a systematic review of existing studies. *Appetite*, *85*, 36–47.

Laraway, K.A., Birch, L.L., Shaffer, M.L. & Paul, I.M. (2010). Parent perception of healthy infant and toddler growth. *Clinical Pediatrics, 49*(4), 343-349.

Layte, R., Bennett, A., McCrory, C. & Kearney, J. (2014). Social class variation in the predictors of rapid growth in infancy and obesity at age 3 years. *International Journal of Obesity, 38,* 82-90.

Lee, E. (2007). Health, morality, and infant feeding: British mothers' experiences of formula milk use in the early weeks. *Sociology of Health and Illness, 29*(7), 1075-90.

Legarraga, H. (2006). Growth in infancy and childhood: a pediatric approach. In N. Cameron (Ed.), *Human Growth and Development* (pp.21-24). Amsterdam: Academic Press.

Lewis, M. & Worobey, J. (2011). Mothers and toddlers lunch together. The relation between observed and reported behaviour. *Appetite, 56,* 732-736.

Lewis, Z. T., & Mills, D. A. (2017). Differential Establishment of Bifidobacteria in the Breastfed Infant Gut. *Nestle Nutrition Institute workshop series*, *88*, 149–159.

Li, D.K., Chen, H., Ferber, J., & Odouli, R. (2017). Infection and antibiotic use in infancy and risk of childhood obesity: a longitudinal birth cohort study. *The Lancet Diabetes & Endocrinology, 5*(1)18-25.

Li, H-T., Zhou, Y-B. & Liu, J-M. (2013). The impact of cesarean section on offspring overweight and obesity: a systematic review and meta-analysis, *International Journal of Obesity, 37,* 893-899.

Li, L., Parsons, T.J. & Power, C. (2003). Breastfeeding and obesity in childhood: cross sectional study. *BMJ, 327,* 904-905.

Li, R., Fein, S.B. & Grummer-Strawn L.M. (2010). Do infants fed from bottles lack self-regulation of milk intake compared with directly breastfed infants? *Pediatrics, 125*(6), e1386-e1393

Li, R., Magadia, J., Fein, S.B., & Grummer-Strawn L.M. (2012). Risk of bottle-feeding for rapid weight gain during the first year of life. *Archives of Pediatric & Adolescent Medicine, 166*(5), 431-436.

Li, R., Scanlon, K.S., May, A., Rose, C. & Birch, L. (2014). Bottle-feeding practices during early infancy and eating behaviors at 6 years of age. *Pediatrics, 134,* (Suppl 1), S70-S77.

Li, R., Scanlon, K.S. & Serdula, M.K. (2005). The validity and reliability of maternal recall of breastfeeding practice. *Nutrition Reviews, 63,* 103-10.

Lillycrop, K.A. & Burdge, G.C. (2011). Epigenetic changes in early life and future risk of obesity. *International Journal of Obesity. 35*(1), 72-83.

Llewellyn, C.H. & Fildes, A. (2017). Behavioural susceptibility theory: Professor Jane Wardle and the role of appetite in genetic risk of obesity. *Current Obesity Reports, 6*(1), 38-45.

Llewellyn, C.H., van Jaarsveld, C.H.M., Johnson, L., Carnell, S. & Wardle, J. (2011). Development and factor structure of the Baby Eating Behaviour Questionnaire in the GEMINI birth cohort. *Appetite, 57,* 388-396.

Locke, A. (2015). Agency, 'good motherhood' and 'a load of mush': Constructions of baby-led weaning in the press. *Women's Studies International Forum, 53,* 139-146.

Lonnerdal, B. (2017). Excess iron intake as a factor in growth, infections and development of infants and young children. *American Journal of Clinical Nutrition, 106,* 1681S-1687S.

Loos, R.J.F. (2009). Recent progress in the genetics of common obesity. *British Journal of Clinical Pharmacology, 68,* 811-829.

Lovelace, S. & Rabiee-Khan, F. (2015). Food choices made by low income households when feeding their pre-school children: a qualitative study. *Maternal and Child Nutrition, 11,* 870-881.

Lucas, C. T., Messito, M. J., Gross, R. S., Tomopoulos, S., Fierman, A. H., Cates, C. B., … Mendelsohn, A. L. (2017). Characteristics associated with adding cereal into the bottle among immigrant mother-infant dyads of low socioeconomic status and Hispanic ethnicity. *Journal of Nutrition Education and Behavior*, *49*, 27–34

Lucas, P., Arai, L., Baird, J., Kleijnen, J., Law, C. & Roberts, H. (2007). A systematic review of lay views about infant size and growth. *Archives of Disease in Childhood, 92,* 120-127.

Lumeng, J.C., Rahnama, S., Appugliese, D., Kaciroti, N., & Bradley, R.H. (2006). Television exposure and overweight risk in preschoolers, *Archives of Paediatric and Adolescent Medicine, 160*, 417-422.

Lumeng, J.C., Miller, A.L., Appugliese, D., Rosenblem, K. & Kaciroti, N. (2018). Picky eating, pressuring feeding, and growth in toddlers. *Appetite, 123,* 299-305.

Lumeng, J.C., Ozbeki, T.N., Appugliese, D.P., Kaciroti, N., Corwyn, R.F. & Bradley, R.H. (2012). Observed assertive and intrusive maternal feeding behaviours increase child adiposity. *American Journal of Clinical Nutrition, 95,* 640-649.

Luoto, R., Kalliomaki, M., Laitinen, K., Delzenne, N.M., Cani, P.D., Salminen, S. & Isolauri, E. (2011). Initial dietary and microbiological environments deviate in normal weight compared to overweight children at 10 years of age. *Journal of Pediatric and Gastroenterolgy and Nutrition, 52,* 90-5.

Luque, V., Closa-Monasterolo, R., Escribano, J. & Ferre, N. (2015). Early programming by protein intake: The effect of protein on adiposity development and the growth and functionality of vital organs. *Nutrition and Metabolic Insights, 8*(Suppl 1), 49-56.

MacGregor, E., & Hughes, M. (2010). Breastfeeding experiences of mothers from disadvantaged groups: a review. *Community Practitioner, 83*, 30-33.

Magee, B.D., Hattis, D., Kivel, N.M. (2004). Role of smoking in low birth weight. *Journal of Reproductive Medicine, 49,* 23-27.

Maier, A., Chabanet, C., Schall, B., Issanchou, S. & Leathwood, P. (2007). Effects of repeated exposure on acceptance of initially disliked vegetables in 7-month old infants. *Food Quality and Preference, 18*(8), 1023-1032.

Martin, A., Connelly, A., Bland, R.M., & Reilly, J.J. (2017). Health impact of catch-up growth in low-birth weight infants: systematic review, evidence appraisal, and meta-analysis. *Maternal and Child Nutrition, 13,* 1-13.

Martinez, J.A., Corbalan, M.S., Sanchez-Villegas, A., Forga, L., Marti, A. & Martinez-Gonzalez, M.A. (2003). Obesity risk is associated with carbohydrate intake in women carrying the Gln27Glu beta2-adrenoceptor polymorphism. *Journal of Nutrition, 133,* 2549-54.

Mascola, A. J., Bryson, S. W., & Agras, W. S. (2010). Picky eating during childhood: a longitudinal study to age 11 years. *Eating behaviors*, *11*(4), 253–257.

Maslin, K. & Venter, C. (2017). Nutritional aspects of commercially prepared infant foods in developed countries: a narrative review. *Nutrition Research Reviews, 30,* 138-148.

Massachusetts Citizens for Children (2010). *The enough abuse campaign.* Retrieved September 25, 2019 from https://www.enoughabuse.org/the-campaign/stragegies-and-results.html

May, A.L., Donohue, M., Scanlon, K.S., Sherry, B., Dalenius, K., Faulkner, P. & Birch, L. (2007). Child-feeding strategies are associated with maternal concern about children becoming overweight but not children's weight status. *Journal of the American Dietetic Association, 107*(7), 1167-1174.

McAndrew, F., Thompson, J., Fellows, L., Large, A., Speed, M., & Renfrew, M. J. (2012).*Infant Feeding Survey 2010.* . Retrieved from The Information Centre for Health and Social Care: http://www.esds.ac.uk/doc/7281/mrdoc/pdf/7281_ifs-uk-2010_report.pdf

McConahy, K.L., Smiciklas-Wright, H., Birch, L., Mitchell, D.C. & Picciano, M.F. (2002). Food portions are positively related to energy intake and body weight in childhood. *The Journal of Pediatrics, 140*(3), 340-347.

McCrickerd, K. & Forde, C.G. (2016a). Parents, portions and potential distortions: Unpicking children's meal size. *Nutrition Bulletin, 41,* 67-71.

McCrickerd, K. & Forde, C.G. (2016b). Sensory influences on food intake control: moving beyond palatability. *Obesity Reviews, 17,* 18-29.

McFadden, A., & Toole, G. (2006). Exploring women's views of breastfeeding: a focus group study within an area with high levels of socio-economic deprivation. *Maternal and Child Nutriton, 2*, 156-168.

McGowan, L., Caraher, M., Raats, M., Lavelle, F., Hollywood, L., McDonnell, D., ...Dean, M. (2017). Domestic cooking and food skills: A review. *Critical Reviews in Food Science and Nutrition, 57,* 2412-2431.

McInnes, R.J. & Chambers, J.A. (2008). Supporting breastfeeding mothers: a qualitative synthesis. *Journal of Advanced Nursing, 62*(4), 407-427.

McMeekin, S., Jansen, E., Mallan, K., Nicholson, J., Magarey, A. & Daniels, L. (2013). Associations between infant temperament and early feeding practices. A cross-sectional study of Australian mother-infant dyads from the NOURISH trial. *Appetite, 60,* 239-245

Meedya, S., Fahy, K. & Kable, A. (2010). Factors that positively influence breastfeeding duration to 6 months: a literature review. *Women and Birth, 23,* 135-45.

Mennella, J.A., Trabulsi, J.C. (2012). Complementary food and flavor experiences: Setting the foundation. *Annals of Nutrition and Metabolism, 60*(Suppl. 2), 40-50.

Metcalfe, N. & Monaghan, P. (2001). Compensation for a bad start: grow now, pay later? *Trends in Ecology & Evolution, 16,* 254-260.

Michaelsen, K.F. & Greer, F.R. (2014). Protein needs in early life and long-term health. *American Journal of Clinical Nutrition, 99,* 718S-22S.

Michaelsen, K.F., Larnkjaer, A. & Molgaard, C. (2012). Amount and quality of dietary proteins during the first two years of life in relation to NCD risk in adulthood. *Nutrition, Metabolism & Cardiovascular Diseases, 22,* 781-786.

Michaelsen, K.F., Weaver, L., Branca, F. & Robertson, A. (2000). *Feeding and nutrition of infants and young children. Guidelines for the WHO European Region with emphasis on the former Soviet countries.* Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0004/98302/WS_115_2000FE.pdf?ua=1

Michels, K.B., Willett, W.C., Graubard, B.I., Vaidya, R.L., Cantwell, M.M., Sansbury, L.B. & Formon, M.R. (2007). A longitudinal study of infant feeding and obesity throughout life course. *International Journal of Obesity, 31,* 1078-1085.

Mihrshahi, S., Battistutta, D., Magarey, A. & Daniels, L.A. (2011). Determinants of rapid weight gain during infancy: baseline results from the NOURISH randomised control trial. *BMC Pediatrics, 11*(99), 1-8.

Miller, S.A., Wu, R.K.S. & Oremus, M. (2018). The association between antibiotic use in infancy and childhood overweight or obesity: a systematic review and meta-analysis. *Obesity Review, 19,* 1463-1475.

Ministry of Health New Zealand (2018). *Baby led weaning.* Retrieved July 30, 2019 from https://www.health.govt.nz/your-health/pregnancy-and-kids/first-year/6-12-months/feeding-your-baby/baby-led-weaning

Monteiro, P.O. & Victora, C.G. (2005). Rapid growth in infancy and childhood obesity in later life – a systematic review. *Obesity Reviews, 6*(2), 143-54.

Monteiro, P. O. A., Victora, C. G., Barros, F. C. D., & Monteiro, L. M. A. (2003). Birth size, early childhood growth, and adolescent obesity in a Brazilian birth cohort. *International Journal of Obesity, 27,* 1274-84.

Moore, A., Akhter, S., & Aboud, F.E. (2006). Responsive complementary feeding in rural Bangladesh. *Social Science & Medicine, 62*(8), *1917-1930.*

Moore, A.P., Milligan, P. & Goff, L.M. (2014). An online survey of knowledge of the weaning guidelines, advice from health visitors and other factors that influence weaning timing in UK mothers. *Maternal and Child Nutrition, 10*(3), 410-21

Moorcroft, K.E., Marshall, J.L. & McCormick, F.M. (2011). Association between timing of introducing solid foods and obesity in infancy and childhood: A systematic review. *Maternal & Child Nutrition, 7,* 3-26.

Moosavi, S., Sepheri, S., Robertson, B., Bode, L., Goruk, S., Field, C.J., …Azad, M.B. (2019). Composition and variation of the human milk microbiota are influences by maternal and early life factors. *Cell Host & Microbe, 25,* 324-335.

Moral, A., Bolibar, I., Seguranyes, G., Ustrell, J.M., Sebastia, G., Martinez-Barba, C. & Rios, J. (2010). Mechanics of suckin: comparison between bottle feeding and breastfeeding. *BMC Pediatrics, 10*(6), 1-8.

Morison, B.J., Taylor, R.W., Haszard, J.J., Schramm, C.J., Erickson, L.W., Fangupo, L.J., …Heath, A.L. (2016). How different are baby-led weaning and conventional feeding? A cross-sectional study of infants aged 6-8 months. *BMJ Open*, 6, e010665

Morison, B.J., Heath, A.M., Haszard, J.J., Hein, K., Fleming, E.A., Daniels, L., …Taylor, R.W. (2018). Impact of a modified version of baby-led weaning on dietary variety and food preferences in infants. *Nutrients, 10,* 1-13.

Moss, B.G. & Yeaton, W.H. (2014). Early childhood healthy and obese weight status: potentially protective benefits of breastfeeding and delaying solid foods. *Maternal and Child Health Journal, 18,* 1224-32.

Mueller, N.T., Whyatt, R., Hoepner, L., Oberfield, S., Dominguez-Bello, M.G., Widen, E.M., Hassoun, A., Perera, F. & Rundle, A. (2015). Prenatal exposure to antibiotics, caesarean section and risk of childhood obesity, *International Journal of Obesity (London), 39*(4), 665-60.

Murphy, E., Dingwall, R., Greatbatch, D., Parker,S. & Watson, P. (1998). Qualitative research methods in health technology assessment: a review of the literature. *Health Technology Assessment, 2*, 1-294

Murphy, E. (2000). Risk responsibility & rhetoric in infant feeding. *Journal of Contemporary ethnography, 29* (3), 291-325.

Mwatsama, M. & Stewart, L. (2005). *Food Poverty and Health. Briefing Statement. Faculty of Public Health of the Royal Colleges of Physicians of the United Kingdom.* Retrieved from http://www.fph.org.uk/uploads/bs_food_poverty.pdf

Myers, A. & Rosen, J.C. (1999). Obesity stigmatization and coping: Relation to mental health symptoms, body image, and self-esteem, *International Journal of Obesity, 23,* 221-230.

Nader, P.R., Huang, T.K., Gahagan, S., Kumanyika, S., Hammond, R.A., Christoffel, K.K. (2012). Next steps in obesity prevention: altering early life systems to support healthy parents, infants, and toddlers. *Childhood Obesity, 8,* 195-204.

Natamba, B.K., Sanchez, S.E., Gelaye, B. & Williams, M.A. (2016). Concordance between self-reported pre-pregnancy body mass index (BMI) and BMI measured at the first prenatal study contact. *BMC Pregnancy and Childbirth, 16,* 1-8.

National Institutes of Health. (2018). *Iron. Fact Sheet for Health Professionals.* Retrieved March 2, 2018, from https://ods.od.nih.gov/factsheets/Iron-HealthProfessional/#h3

Naylor, A.J. & Morrow, A.L. (2001). *Development of readiness of normal full term infants to progress from exclusive breastfeeding to the introduction of complementary foods.* Retrieved from http://pdf.usaid.gov/pdf_docs/Pnacs461.pdf

Nelson, A.M. (2010). A meta-synthesis of qualitative breastfeeding studies. *Journal of Midwifery & Women's Health, 51,* e13-e20.

Northstone, K., Emmett, P., Nethersole, F. & the ALSPAC Study Team. (2008). The effect of age of introduction to lumpy solids on foods eaten and reported feeding difficulties at 6 and 15 months. *Journal of Human Nutrition and Dietetics, 14* (1), 43-54.

NHS Choices (2018). *Vitamins for children.* Retrieved March 1, 2018, from https://www.nhs.uk/conditions/pregnancy-and-baby/vitamins-for-children/

NHS Choices (2019). *What to feed young children.* Retrieved July 30, 2019, from https://www.nhs.uk/conditions/pregnancy-and-baby/understanding-food-groups/

NHS Digital. (2017). *Statistics on obesity physical activity and diet.* Retrieved from http://digital.nhs.uk/catalogue/PUB23742

NHS Digital. (2018). *Health Survey for England 2017.* Retrieved from https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2017

Nilsen, R.M., Vollset, S.E., Gjessing, H.K., Skjaerven, R., Melve, K.K., Schreuder, P., …Magnus, P. (2009). Self-selection and bias in a large prospective pregnancy cohort in Norway. *Paediatric and Perinatal Epidemiology, 23,* 597-608.

Noble, S., & Emmett, P. (2006). Differences in weaning practice, food and nutrient intake between breast-and formula-fed 4-month-old infants in England. *Journal of Human Nutrition and Dietetics*, *19*, 303-313.

Oakley, L.L., Renfrew, M.J., Kurinczuk, J.J. & Quigley, M.A. (2013). Factors associated with breastfeeding in England: an analysis by primary care trust. *BMJ Open, 3,* 1-11.

O'Cathain, A.O. & Thomas, K.J. (2004). "Any other comments?" Open questions on questionnaires – a bane or bonus to research? *BMC Medical Research Methodology, 4*, 1-7.

Oddy, W.H., Mori, T.A., Huang, T.A., Marsh, J.A. Pennell, C.E., Chivers, P.T….Beilin, L.J. (2014). Early infant feeding and adiposity risk: From infancy to adulthood. *Annals of Nutrition and Metabolism, 64,* 262-270.

Odom, E.C., Li, R., Scanlon, K.S. & Perrine, C.G. & Grumer-Strawn, L. (2013) Reasons for earlier than desired cessation of breastfeeding. *Pediatrics, 131,* e726-e732.

OECD (2017). *Obesity Update.* Retrieved from https://www.oecd.org/els/health-systems/Obesity-Update-2017.pdf

Office for National Statistics. (2015). *Family Spending: 2015. A report on the Living Costs and Food Survey 2014*. Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/compendium/familyspending/2015

Oken, E., Taveras, E.M., Kleinman, K.P., Rich-Edwards, J.W., Gillman, M.W. (2007). Gestational weight gain and child adiposity at age 3 years. *American Journal of Obstetrics and Gynaecology,* 196(4), e1-322.

Okubo, H., Crozier, S.R., Harvey, N.C., Godfrey, K.M., Inskip, H.M., Cooper, C. & Robinson, S.M. (2015). Diet quality across early childhood and adiposity at 6 years: the Southampton Women's Survey. *International Journal of Obesity,* 39(10),1456-1462.

Ong, K.K. (2006). Size at birth, postnatal growth and risk of obesity. *Hormone research in Paediatrics. 65,* 65-69.

Ong, K.K. & Dunger, D.B. (2004). Birth weight, infant growth and insulin resistance. *European Journal of Endocrinology, 151* (Suppl 3), 131-138.

Ong, K.K. & Loos, R.J. (2006). Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. *Acta Paediatrica, 95*(8)904-8.

Ong, K., Emmett, P.M., Noble, S., Ness, A., Dunger, M.D. & the ALSPAC Study Team (2006). Dietary energy intake at the age of 4 months predicts postnatal weight gain and childhood body mass index. *Pediatrics*, *117*, e503-e508.

Ong, K.L. Ahmed, M.A, Emmett, P.M., Preece, M.A. & Dunger, D.B. (2000). Association between post-natal catch up growth and obesity in childhood: prospective cohort study. *BMJ, 320,* 967-71.

Oropeza-Ceja, L.G., Rosado, J.L., Ronquillo, D., Garcia, O.P., Caamano, M.D.C., Garcia-Ugalde, C., …Duarte-Vazquez, M.A. (2018). Lower protein intake supports normal growth of full-term infants fed formula: A randomized control trial. *Nutrients, 10,* 1-14.

O'Sullivan, J., Pearce, M. & Parker, L. (2000). Parental recall of birthweight: How accurate is it? *Archives of disease in childhood, 82*, 202-203.

Owen, C.G, Martin, R.M., Whincup, P.H., Davey-Smith, G., Gillman, M.W. & Cook, D.G. (2005). The effect of breastfeeding on mean body mass index throughout life: a quantitative review of published and unpublished observational evidence. *American Journal of Clincial Nutrition, 82,* 1298-307.

Oxford English Dictionary. (2017). baby-led weaning. *Oxford English Dictionary.* Oxford: Oxford University Press. Retrieved from http://www.oed.com/view/Entry/14250?redirectedFrom=baby-led+weaning#eid1223069760

Pain, R., Bailey, C. & Mowl, G. (2002). Infant feeding in North East England: contested spaces of reproduction. *Area, 33,* 261-272

Palfreyman, Z., Haycraft, E. & Meyer, C. (2015). Parental modelling of eating behaviours: Observational validation of the Parental Modelling of Eating Behaviours scale (PARM). *Appetite, 86* (1), 31-37.

Palmer, G. (1988). *The Politics of Breastfeeding.* London: Pandora.

Palmer, G. (2011). *Complementary Feeding: Nutrition, Culture and Politics.* London: Pinter & Martin

Pannaraj, P.S., Li, F., Cerini, C., Bender, J.M., Yang, S., Rollie, A., …Aldrovandi, G.M. (2017). Association between breast milk bacterial communities and establishment and development of the infant gut microbiome. *JAMA Pediatrics, 171,* 647-654.

Papoutsou, S., Savva, S.C., Hunsberger, M., Jilani, H., Michels, N., Ahrens, W., …Hadjigeorgiou, C. (2018). Timing of solid food introduction and association with later childhood overweight and obesity: The IDEFICS study. *Maternal and Child Nutrition, 14*, 1-8.

Pasricha, S.R., Hayes, E., Kalumba, K., Biggs, B.A. (2013). Effect of daily iron supplementation on health in children aged 4-23 months: a systematic review and meta-analysis of randomized controlled trials. *Lancet Global Health, 1,* e77-e86.

Pezella, A.E., Pettigrew, J. & Miller-Day, M. (2012). Researching the researcher-as-instrument: an exercise in interviewer self-reflexivity. *Qualitative Research, 12* (2), 165-185.

Pietrobelli, A., Agosti, M., & MeNu Group (2017). Nutrition in the First 1000 Days: Ten Practices to Minimize Obesity Emerging from Published Science. *International Journal of Environmental Research and Public Health*, *14*(12), 1491.

Pilgrim, H., Hernandez Alava, M., Blank, L., Payne, N., Guillaume, L., Baxter, S. (2010). *Systematic review of the long term outcomes associated with teenage pregnancy within the UK Draft report.* Retrieved from https://www.nice.org.uk/guidance/ph51/documents/contraceptive-services-for-socially-disadvantaged-young-people-additional-consultation-on-the-evidence-review-of-teenage-pregnancy-outcomes2

Puhl, R. M., & Heuer, C. A. (2010). Obesity stigma: important considerations for public health. *American Journal of Public Health*, *100*, 1019–1028.

Paolella, G. & Vajro, P. (2016). Childhood obesity, breastfeeding, intestinal microbiota, and early exposure to antibiotics. What is the link? *JAMA Pediatrics, 17*(8), 735-737.

Peacock-Chambers, E., Dicks, K., Sarathy, L., Brown, A.A., Boynton-Jarrett, R. (2017). Perceived maternal behavioral control, infant behaviour, and milk supply: A qualitative study. *Journal of Development & Behavioural Pediatrics, 38,* 401-408.

Pearce, J., Taylor, M.A. & Langley-Evans, S.C. (2013). Timing of introduction of complementary feeding and risk of childhood obesity: a systematic review. *International Journal of Obesity, 37*(4)*,* 1295-1306.

Pearce, J. & Langley-Evans, S.C. (2013). The types of food introduced during complementary feeding and risk of childhood obesity: a systematic review. *International Journal of Obesity, 37,* 477-485.

Pearson-Stuttard, J., Zhou, B., Kontis, V., Bentham, J., Gunter, M.J. & Ezzati, M. (2018). Worldwide burden of cancer attributable to diabetes and high body-mass index: a comparative risk assessment. *The Lancet, 6*(6), PE6-E15.

Penny, M.E., Jiminez, M.M. & Marin, R.M. (2016). Early rapid weight gain and subsequent overweight and obesity in middle childhood in Peru. *BMC Obesity, 3*(55), 1-8.

Perez-Escamilla, R. & Kac, G. (2013). Childhood obesity prevention: a life-course framework. *International Journal of Obesity Supplements, 3*(Suppl1), S3-S5

Perry, C. & Thurston, B.N. (2016). Exploring overweight and obesity in pre-school children using routinely collected data: a case study of Halton, Northwest England. *Journal of Public Health, 38,* e240-e246.

Perry, R.A., Mallan, K.M., Koo, J., Mauch, C.E., Daniels, L.A. & Magarey, A.M. (2015). Food neophobia and its associated with diet quality and weight in children aged 24 months: a cross sectional study. *International Journal of Behavioral Nutrition and Physical Activity, 12,* 1-8.

Pluymen, L.P., Smit, H.A., Wijga, A.H., Gehring, U., De Jongste, J.C. & Van Rossem, L. (2016). Cesarean delivery, overweight throughout childhood and blood pressure in adolescence. *Journal of Pediatrics,* 1-7.e3.

Popping, R. (2015). Analyzing open-ended questions by means of text analysis procedures. *Bulletin of sociological methodology, 128,* 23-39.

Powell, F.C., Farrow, C.V. & Meyer, C. (2011). Food avoidance in children, The influence of maternal feeding practices and behaviours. *Appetite, 57,* 683-692.

Prior, E., Santhakumaran, S., Gale, C., Philipps, L.H., Modi, N. & Hyde, M.J. (2012). Breastfeeding after caesarean delivery: a systematic review and meta-analysis of world literature. *American Journal of Clinical Nutrition,* 1-23.

Prader-Willi Syndrome Association UK (2018). *About PWS*. Retrieved August 1, 2019, from https://www.pwsa.co.uk/assets/files/About%20PWS/About%20PWS.pdf

Prendergast, A.J. & Humphrey, J.H. (2014). The stunting syndrome in developing countries. *Paediatric International Child Health, 34,* 250-65.

Prentice, A. (2005). The emerging epidemic of obesity in developing countries. *International Journal of Epidemiology, 35,* 93-99.

Public Health England. (2014). *Adult obesity and type 2 diabetes.* Retrieved June, 2016, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338934/Adult_obesity_and_type_2_diabetes_.pdf

Public Health Wales. (2018). *Every Child. Child Measurement Programme 2017/18*. Retrieved from http://www.wales.nhs.uk/sitesplus/documents/888/CMP%20report%20%28Eng%29.pdf

Qureshi, K. & Rahman, E. (2017). Infant feeding: Medicalization, the state and techniques of the body. *Women's Studies International Forum, 60,* 81-88.

Rapley, G. & Murkett, T. (2008). Baby led weaning: Helping your baby to love good food. London: Vermilion

Rapley, G. (2011). Baby-led weaning: transitioning to solids at the baby's own pace. *Community Practitioner, 84*(6), 20-3

Rapley, G. (2015a). Baby-led weaning: The theory and evidence behind the approach. *Journal of Health Visiting, 3,* 144-51.

Rapley, G. (2015b) *Spoon-feeding or self-feeding? The infant's first experience of solid food.* (Doctoral thesis). Retrieved from CREATE. (https://create.canterbury.ac.uk/id/eprint/14177)

Rapley, G., Forste, R., Cameron, S., Brown, A. & Wright, C. (2015). Baby-led weaning. A new frontier? *ICAN: Infant, Child, & Adolescent Nutrition, 7*(2)1-9.

Rasmussen, F. & Johansson, M. (1998). The relation of weight, length and ponderal index at birth to body mass index and overweight among 18-year-old males in Sweden. *European Journal of Epidemiology, 14,* 373-380.

Reddon, H., Gueant, J.L. & Meyre, D. (2016). The importance of gene-environment interactions in human obesity. *Clinical Science, 1,* 1571-97.

Redsell, S.A. Atkinson, P., Nathan, D., Siriwardena, A.N., Swift, J.A. & Glazebrook, C. (2010). Parents' beliefs about appropriate infant size, growth and feeding behavior: implications for the prevention of childhood obesity. *BMC Public Health, 10,* 1-10.

Reilly, J.J., Jackson, D.M., Montgomery, C., Kelly, L.A., Slater, C., Grant, S. & Paton, J.Y. (2004). Total energy expenditure and physical activity in young Scottish children: Mixed longitudinal study. *The Lancet, 363,* 211-212.

Reinhardt, C., Reigstad, C.S. & Backhed, F. (2009). Intestinal microbiota during infancy and its implications for obesity. *Journal of Pediatric Gastroenterology and Nutrition, 48,* 249-256.

Restrepo-Mendez, M.C., Lawlor, D.A., Horta, B.L., Matijasevich, A., Santos, I.S., Menezes, A.M.B., Barros, F.C. & Victora, C.G. (2015). The association of maternal age with birthweight and gestational age: A cross-cohort comparison. *Paediatric Perinatal Epidemiology, 29,* 31-40.

Reyes, M., Hoyos, V., Martinez, S.M., Lozoff, B., Castillo, M., Burrows, R., … Gahagan, S. (2014). Satiety responsiveness and eating behaviour among Chilean adolescents and the role of breastfeeding. *International Journal of Obesity, 38,* 552-557.

Rietmeijer-Mentink, M., Paulis, W.D., van Middelkoop, M., Bindels, P.J.E., van der Wouden, J.C. (2012). Difference between parental perception and actual weight status of children: a systematic review. *Maternal and Child Nutrition, 9*(1), 3-22.

Rito, A.I., Buoncristiano, M., Spinelli, A., Salanave, B., Kunesova, M., Hejgaard, T., …Breda, J. (2019). Association between characteristics at Birth, Breastfeeding and obesity in 22 countries: The WHO European Childhood Obesity Surveillance Initiative – COSI 2015/2017. *Obesity Facts, 12,* 226-243.

Robinson, S., Marriott, L., Poole, J., Crozier, S., Borland, S., Lawrence, W. … The Southampton Women's Survey Study Group. (2007). Dietary patterns in infancy: the importance of maternal and family influences on feeding practice. *British Journal of Nutrition,* 98, 1029-1037.

Robinson, E., Almiron-Roig, E., Rutters, F., de Graaf, C., Forde, C.G., Tudur Smith, C., …Jebb, S.A. (2014). A systematic review and meta-analysis examining the effect of eating rate on energy intake and hunger. *American Journal of Clinical Nutrition, 100,* 123-151.

Robinson, S.M., Crozier, S.R., Harvey, N.C., Barton, B.D., Law, C.M., Godfrey, K.M., …Inskip. H.M. (2015). Modifiable early-life risk factors for childhood adiposity and overweight: an analysis of their combined impact and potential for prevention. *American Journal of Clinical Nutrition. 101*(2), 368-375.

Robinson, S.M. (2017). Preventing childhood obesity: Early life messages from epidemiology. *Nutrition Bulletin, 42,* 219-225.

Rode, L., Hegaard, H.K., Kjærgaard, H., Møller, L.F., Tabor. A. & Ottesen, B. (2007). Association between maternal weight gain and birth weight. *Obstetrics and Gynaecology, 109,* 1309-1315.

Rodgers, R.F., Paxton, S.J., Massey, R., Campbell, K.J., Wertheim, E.H., Skouteris, H., Gibbons, K. (2013a). Maternal feeding practices predict weight gain and obesogenic eating behaviours in young children: a prospective study. *International Journal of Behavioral Nutrition and Physical Activity, 10,* 1-10.

Rodgers, R.F., Paxton, S.J., McLean, S.A., Campbell, K.J., Wertheim, E.H., Skouteris, H. & Gibbons. (2013). Do maternal body dissatisfaction and dietary restraint predict weight gain in young pre-school children? A 1-year follow-up study. *Appetite, 67,* 30-36.

Roess, A.A., Jacquier, E.F., Catellier, D.J., Carvalho, R., Lutes, A.C., Anater, A. S. & Dietz, W.H. (2018). Food consumption patterns of infants and toddlers: Findings from the Feeding Infants and Toddlers Study (FITS) 2016. *The Journal of Nutrition, 148,* 1525S-1535S.

Rogers, I. (2003). The influence of birthweight and intrauterine environment on adiposity and fat distribution in later life. *International Journal of Obesity, 27,* 755-777.

Rogers, I.S., Ness, A.R., Steer, C.S., Wells, J.C.K., Emmett, P.M., Reilly, J.R., …Smith, G.D. (2006). Associations of size and birth and dual-energy x-ray absorptiometry measures of lean and fat mass at 9 to 10 y of age. *The American Journal of Clinical Nutrition, 84,* 739-747

Rogers, S. (2014). *A longitudinal study investigating the role of breastfeeding, positive maternal interactions and cortisol metabolism in eating behaviours and weight gain in infancy.* (Doctoral thesis). Retrieved from UBIRA. (http://etheses.bham.ac.uk/id/eprint/5017)

Rogers, S.L. & Blissett, J. (2017) Breastfeeding duration and its relation to weight gain, eating behaviours and positive maternal feeding practices in infancy. *Appetite, 108,* 399-406.

Rollins, N., Bhandari, N., Hajeebhoy, N., Horton, S., Lutter, C., Martines, J., . . . Victora, C. (2016). Why invest, and what it will take to improve breastfeeding practices? *The Lancet, 387*, 491-504.

Ross, M.G. & Desai, M. (2014). Developmental programming of appetite/satiety. *Annals of Nutrition and Metabolism, 64,* Suppl 1, 36-44.

Rouhani, M.H., Haghighatdoost, F., Surkan, P.J., & Azadbakht, L. (2016). Associations between dietary energy density and obesity: A systematic review and meta-analysis of observational studies. *Nutrition, 32,* 1037-1047. DOI: http://dx.doi.org/10.1016/j.nut.2016.03.017

Rowan, H. & Harris, C. (2012). Baby-led weaning and the family diet. A pilot study. *Appetite, 58,* 3, 1046-1049.

Rowan, H., Lee, M., & Brown, A. (2019). Differences in dietary composition between infants introduced to complementary foods using baby-led weaning and traditional spoon-feeding. *Journal of Human Nutrition & Dietetics, 32,* 11-20.

Roy, S.M., Spivack, J.G., Faith, M.S., Chesi, A., Mitchell, J.A., Kelly, A., …Zemel, B.S. (2016). Infant BMI or weight-for-length and obesity risk in early childhood. *Pediatrics, 137,* 1-9.

Royal College of Paediatrics and Child Health. (2016). *500 children suffering from type 2 diabetes is a 'wake up call for the nation',* Retrieved June, 2016, from http://www.rcpch.ac.uk/news/500-children-suffering-type-2-diabetes-wake-call-nation.

Royal Society for Public Health (2015). *Tackling the UK's childhood obesity epidemic,* Retrieved May, 2018, from //www.rsph.org.uk/uploads/assets/uploaded/3f492c7e-855d-4930-95198bc1b4dc6f07.pdf

Rudzik, A.E.F. & Ball, H.L. (2016). Exploring maternal perceptions of infant sleep and feeding method amongst mothers in the United Kingdom: A qualitative focus group. *Maternal and Child Health Journal, 20*(1), 33-40.

Russell-Mayhew, S., McVey, G., Bardick, A. & Ireland, A. (2012). Mental health, wellness and childhood overweight/obesity. *Journal of Obesity,* 1-9.

Saari, A., Virta, L.J., Sankilampi, U., Dunkel, L. & Saxen, H. (2015). Antibiotic exposure in infancy and risk of being overweight in the first 24 months of life, *Pediatrics, 135*(4),617-26.

Sacco, M. R., De Castro, N. P., Euclydes, V. L. V., Souza, J. M., & Rondó, P. H. D. C. (2013). Birth weight, rapid weight gain in infancy and markers of overweight and obesity in childhood. *European journal of Clinical Nutrition*, *67*, 1147-53.

Sachs, M. (2011). Baby-led weaning and current UK recommendations – are they compatible? *Maternal Child Nutrition, 7,* 1-2.

SACN. (2018). *Feeding in the first year of life.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725530/SACN_report_on_Feeding_in_the_First_Year_of_Life.pdf

Samuel, T.M., Musa-Veloso, K., Ho, M., Venditti, C & Shahkhalili-Dulloo, Y. (2018). A narrative review of childhood picky eating and its relationship to food intakes, nutritional status, and growth. *Nutrients, 10* (12), 1-30.

Santangeli, L., Sattar, N., Huda, S.S. (2015). Impact of maternal obesity on perinatal and childhood outcomes. *Best Practice & Research Clinical Obstetrics and Gynaecology, 29,* 438-448.

Satter, E.M. (1996). Internal regulation and the evolution of normal growth as the basis for prevention of obesity in children. *Journal of the American Dietetic Association, 96*(9), 860-864.

Savage, J.S., Birch, L.L., Marini, M., Anzman-Frasca, S. & Paul, I.M. (2016). Effect of the INSIGHT responsive parenting intervention on rapid infant weight gain and overweight status at age 1 year. *JAMA Pediatrics, 170*(8), 742-749

Savino, F., Liguori, S.A., Fissore, M.F., & Oggero, R. (2009). Breastmilk hormones and their protective effect on obesity. *International Journal of Pediatric Endocrinology, 2009,* 1-8.

Scaglioni, S., Salvioni, M. & Galimberti, C. (2008). Influence of parental attitudes in the development of children eating behavior. *British Journal of Nutrition. 99,* S22-S25.

Scheiss, S., Grote, V., Scaglioni, S., Luque, V., Martin, F., Stolarczyk, A., … European Childhood Obesity Project (2010). Introduction of complementary feeding in 5 European countries. *Journal of Pediatric Gastroenterology and Nutrition, 50,* 92-98.

Schmeid, V., Beake, S., Sheehan, A., McCourt, C. & Dykes, F. (2010). Women's perceptions and experiences of breastfeeding support: A metasynthesis. *Birth, 38*(1), 49-60.

Schramm, C.J. (2014). *Measuring baby-led weaning: Method development and pilot testing.* (Masters' Dissertation). Retrieved from OUR Archive. (http://hdl.handle.net/10523/4634)

Schwartz, B.S., Pollak, J., Bailey-Davis, L., Hirsch, A.G., Cosgrove, S.E., Nau, C., Kress. A.M., Glass, T.A. & Bandeen-Roche, K. (2016). Antibiotic use and childhood body mass index trajectory. *International Journal of Obesity (London), 40*(4)615-621.

Schwartz, M.B. & Puhl, R. (2003). Childhood obesity: a societal problem to solve. *Obesity reviews,* 4, 57-71.

Scott, J.A., Binns, C.W. & Aroni, R.A. (1997). The influence of reported parental attitudes on the decision to breastfeed. *Journal of Pediatrics and Child Health, 33*(4), 305-307.

Scott, K. M., Bruffaerts, R., Simon, G. E., Alonso, J., Angermeyer, M., de Girolamo, G., … Von Korff, M. (2008). Obesity and mental disorders in the general population: results from the world mental health surveys. *International Journal of Obesity*, *32*, 192–200.

Scott, F.I., Horton, D.B., Mamtani. K., Haynes, K., Goldberg, D.S., Lee, D.Y. & Lewis, J.D. (2016). Administration of antibiotics to children before age 2 years increases risk of childhood obesity, *Gastroenterology, 151*(1), 120-129.e5.

Scott-Pillai, R., Spence, D., Cardwell, C.R., Hunter, A. & Holmes, V.A. (2013). The impact of body-mass index on maternal and neonatal outcomes: a retrospective study in a UK obstetric population, 2004-2011. *BJOG,* 120, 932-939

Shah, M. Copeland, J., Dart, L., Adams-Huet, B. James, A. & Rhea, D. (2014). Slower eating speed lowers energy intake in normal weight but not overweight/obese subjects. *Journal of the Academy of Nutrition and Dietetics, 114,* 393-402.

Shavers, V.L. (2007). Measurements of socioeconomic status in health disparities research. *Journal of the National Medical Association, 99,* 1013-1023.

Shloim, N., Edelson, L.R., Martin, N. & Hetherington, M.M. (2015). Parenting Styles, feeding styles, feeding practices, and weight status in 4-12 year-old children: A systematic review of the literature. *Frontiers in Psychology, 6,* 1-20.

Shloim, N., Vereijken, C.M.J.L., Blundell., P., Hetherington, M.M. (2017). Looking for cues – infant communication of hunger and satiation during milk feeding. *Appetite, 108,* 74-82.

Shortt, E., McGorrian, C., & Kelleher, C. (2013). A qualitative study of infant feeding decisions among low-income women in the Republic of Ireland. *Midwifery, 29*, 453-460.

Silventoinen, K., Rokholm, B., Kaprio, J. & Sorenson, T.I.A. (2010). The genetic and environmental influences on childhood obesity: a systematic review of twin and adoption studies. *International Journal of Obesity, 34,* 29-40.

Simmonds, M., Llewellyn, A., Owen, C.G. & Woolacott, N. (2015). Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. *Obesity Reviews, 17,* 95-107.

Singhal, A. (2017). Long-term adverse effects of early growth acceleration or catch-up growth. *Annals of Nutrition & Metabolism, 70,* 236-240.

Singletary, N., Chetwynd, E., Goddell, L.S. & Fogelman, A. (2017). Stakeholder views of breastfeeding education in schools: a systematic mixed studies review of the literature. *International Breastfeeding Journal, 12*(14), 1-13.

Sirkka, O., Vrijkotte, T., Halberstadt, J., Abrahamse-Berkeveld, M., Hoekstra, T., Seidell, J., & Olthof, M. (2018). Prospective associations of age at complementary feeding and exclusive breastfeeding duration with body mass index at 5-6 years within different risk groups. *Pediatric obesity*, *13*, 522–529.

Skelton, J.A., Irby, M.B., Grzywacz, J. & Miller, G. (2011). Etiologies of obesity in children: Nature and nurture. *Pediatric Clinics of North America, 58*(6), 1333-1354.

Sloan, S., Gildea, A., Stewart, M., Sneddon, H., & Iwaniec, D. (2008). Early weaning is related to weight and rate of weight gain in infancy. *Child Care Health and Development, 34,* 59-64.

Smit, H.J., Kemsley, E.K., Tapp, H.S. & Henry, C.J. (2011). Does prolonged chewing reduce food intake? Fletcherism revisited. *Appetite, 57,* 295-8.

Smith, H.A. & Becker, G.E. (2016). Early additional food and fluids for healthy breastfed full-term infants. *Cochrane Database of Systematic Reviews* (8).

Snethen, J. A., Hewitt, J. B., & Goretzke, M. (2007). Childhood obesity: the infancy connection. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, *36*, 501-510.

Sparks, R., Crawley, H. (2018). Processed dried fruit snacks for young children. Retrieved from, https://www.firststepsnutrition.org/babyfood-composition

Spence, J.C., Carson, V., Casey, L. & Boule, N. (2011). Examining behavioural susceptibility to obesity among Canadian pre-school children: the role of eating behaviours. *International Journal of Pediatric Obesity, 6*(2-2), e501-7.

Spence, L.A., Cifelli, C.J. & Miller, G.D. (2011). The role of dairy products in healthy weight and body composition in children and adolescents. *Current Nutritional Food Science, 7*(1), 40-49.

Spence, A.C., Hesketh, K.D., Crawford, D.A. & Campbell, K.J. (2016). Mothers' perception of the influences on the influences on their child feeding practices – A qualitative study. *Appetite, 105,* 596-603.

Spencer, N., Bambang, S., Logan, S. & Gill, L. (1999). Socioeconomic status and birth weight: comparison of an area-based measure with the Registrar General's social class. *Journal of Epidemiology and Community Health, 53,* 495-498.

Spillman, L. (2012). Factors associated with the age infants are weaned. *The Plymouth Student Journal of Health & Social Work, 4,* 28-45.

Spyreli, E., McKinley, M.C., Allen-Walker, V., Tully, L., Woodside, J.V., Kelly, C. & Dean, M. (2019). "The one time you have control over what they eat": a qualitative exploration of mothers' practices to establish healthy eating behaviours during weaning. *Nutrients, 11*(3), 1-17.

Stettler, N., Kumanyika, S.K., Katz, S.H., Zemel, B.S. & Stallings, V.A. (2003). Rapid weight gain during infancy and obesity in young adulthood in a cohort of African Americans. *American Journal of Clinical Nutrition, 77*(6), 1374-8.

Stettler, N., Zemel, B.S., Kumanyika, S.K., & Stallings, V.A. (2002). Infant weight gain and childhood overweight status in a multicenter cohort study. *Pediatrics, 109,* (2), 194-9.

Stettler, N. (2007). Nature and strength of epidemiological evidence for origins of childhood and adulthood obesity in the first year of life. *International Journal of Obesity, 31* 1035-1043

Stifter, C.A., Anzman-Frasca, S., Birch, L.L. & Voegtline, K. (2011). Parent use of food to soothe infant/toddler distress and child weight status. An exploratory study. *Appetite, 57,* 693-9.

Stunkard, A.J., Berkowitz, R.I, Schoeller, D., Maislin, G. & Stallings, V.A. (2004). Predictors of body size in the first 2y of life: a high risk study of human obesity. *International Journal of Obesity, 28,* 503-513.

Stunkard, A.J., Berkowitz, R.I, Stallings, V.A. & Schoeller, D. (1999). Energy intake, not energy output, is a determinant of body size in infants. *The American Journal of Clinical Nutrition, 69*(3), 524-430.

Swinburn, B., Egger, G. & Raza, F. (1999). Dissecting obesogenic environments: The development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Preventative Medicine, 29,* 563-570.

Tabachnick, B.G. & Fidell, L. (2013). *Using Multivariate Statistics* (6th ed.). Boston: Pearson.

Tarrant, R.C., Younger, K.M., Sheridan-Pereira, M., White, M.J. & Kearney, J.M. (2010) Factors associated with weaning practices in term infants: a prospective observational study in Ireland. *The British Journal of Nutrition, 104*, 544-1554.

Taveras, E.M., Scanlon, K.S., Birch, L., Rifas-Shiman, S.L. Rich Edwards, J.W., Gillman, M.W. (2004). Association of breastfeeding with maternal control of milk feeding at age 1. *Pediatrics, 114*(5), e557-e583.

Taylor, C.M., Wernimont, S.M., Northstone, K. & Emmett, P.M. (2015). Picky/fussy eating in children: Review of definitions, assessment, prevalence and dietary intakes. *Appetite,* 95, 349-359.

Taylor, R.W., Williams, S.M., Fangupo, L.J., Wheeler, B.J., Taylor, B.J., Daniels, L., Fleming, E.A.,…Heath, A-L, M. (2017). Effect of a baby-led approach to complementary feeding on infant growth and overweight. *JAMA Pediatrics, 171*(9), 838-846

Thompson, A.L. & Bentley. M.E. (2013). The critical period of infant feeding for the development of early disparities in obesity. *Social Science & Medicine, 97,* 288-96.

Thompson, A.L. Adair, L.S. & Bentley, M.E. (2013). Pressuring and restrictive feeding styles influence infant feeding and size among a low income African-American sample. *Obesity, 21*(3), 562-71.

Thorisdottir, B., Gunnarsdottir, I., Palsson, G.I., Halldorsson, T.I. & Thorsdottir, I. (2014). Animal protein intake at 12 months is associated with growth factors at the age of six. *Acta Paediatrica, 103,* 512-517.

Timmons, B.W., LeBlanc, A.G., Carson, V., Connor Gorber, S., Dillman, C., Janssen, I., … Tremblay, M. S. (2012). Systematic review of physical activity and health in the early years (aged 0-4 years). *Applied Physiology, Nutrition and Metabolism, 37*(4), 773-792.

Totzauer, M., Luque, V., Escribano, J., Closa-Monasterolo, R., Verduci, E., ReDionigi, A., …Grote, V. (2018). Effect of lower versus higher protein content in infant formula through the first year on body composition from 1-6 years: Follow-up of a randomized control trial. *Obesity, 26,* 1203-1210.

Townsend, E. & Pitchford, N.J. (2012). Baby knows best? The impact of weaning style on food preferences and body mass index in early childhood in a case-controlled study. *BMJ Open,* 2, 1-6.

Trasande, L., Blustein, J., Liu, M., Corwin, E., Cox, L.M. & Blaser, M.J. (2013). Infant antibiotic exposures and early-life body mass, *International Journal of Obesity (London), 37* (1), 16-23.

Trickey, H., Fox, R., Brown, A., Jones, S., Turley, R. & Murphy, S. (2019). *Improving intention to breastfeed in low-breastfeeding-rate Welsh communities. Summary of findings towards intervention development.* Public Health Wales. Publication in progress.

Tschann, J.M., Gregorich, S.E., Penilla, C., Pasch, L.A., de Groat, C.L., Flores, E., … Butte, N.F. (2013). Parental feeding prectices in Mexican American families: initial test of an expanded measure. *Internationl Journal of Behavioural Nutrition and Physical Activity, 10,* 1-11.

Tyrell, J., Huikari, V., Christie, J.T, Cavadino, A., Bakker, R., Brion, M-J. A, ... Freathy, R.M. (2012). Genetic variation in the 15q25 nicotine acetylcholine receptor gene cluster (CHRNA5-CHRNA3-CHRNB4) interacts with maternal self-reported smoking status during pregnancy to influence birth weight. *Human Molecular Genetics, 21,* 5344-5358.

Ulrich, D.A. & Hauck, J.L. (2013). Programming physical activity in young infants at risk for early onset of obesity. *Kinesiology Review, 2,* 221-232.

UNICEF. (2018). *Breastfeeding. A mother's gift, for every child.* https://www.unicef.org/publications/files/UNICEF_Breastfeeding_A_Mothers_Gift_for_Every_Child.pdf

UNICEF UK (2015). *Introducing Solid Foods.* Retrieved from https://www.unicef.org.uk/babyfriendly/wp-content/uploads/sites/2/2008/02/Start4Life-Introducing-Solid-Foods-2015.pdf

UNICEF UK (2019). *Responsive bottle feeding.* Retrieved from https://www.unicef.org.uk/babyfriendly/wp-content/uploads/sites/2/2019/04/Infant-formula-and-responsive-bottle-feeding.pdf

Vail, B., Prentice, P., Dunger, D.B., Hughes, I.A., Acerini, C.L., & Ong, K.K. (2015). Age at weaning and infant growth: Primary analysis and systematic review. *Journal of Pediatrics, 167,* 317-324.

Van Geel, M., Vedder, P. & Tanilon, J. (2014). Are overweight and obese youths more often bullied by their peers? A meta-analysis on the relation between weight status and bullying. *International Journal of Obesity, 38,* 1263-1267

van Jaarsveld, C.H., Llewellyn, CH., Johnson, L., Wardle, J. (2011). Prospective associations between appetitive traits and weight gain in infancy. *American Journal of Clinical Nutrition, 94,* 1562-7.

van der Klaauw, A.A. & Farooqi, S. (2015). The hunger genes: Pathways to obesity. *Cell, 1*(26)199- 132.

van der Willik, E.M., Vrijkotte, T.G.M, Altenburg, T.M., Gademan, M.G.J. & Kist-van Holthe, J. (2015). Exclusively breastfed overweight infants are at the same risk of childhood overweight as formula fed overweight infants. *Archives of Disease in Childhood, 100,* 932-937

van Rossem, L., Taveras, E. M., Gillman, M. W., Kleinman, K. P., Rifas-Shiman, S. L., Raat, H., & Oken, E. (2011). Is the association of breastfeeding with child obesity explained by infant weight change? *International Journal of Pediatric Obesity, 6*, e415–e422.

van Rossem, L., Kiefte-de Jong, J.C., Looman, C.W.N., Jaddoe, V.W.V., Hofman, A., Hokken-Koelega, A.C.S., …Raat, H. (2013). Weight change before and after the introduction of solids: results from a longitudinal birth cohort. *British Journal of Nutrition, 109,* 370-375.

Velders, F.P., De Wit, J.E., Jansen, P.W., Jaddoe, V.W.V., Hofman, A. Verlhurst, F.C. & Tiemeier, H. (2012). FTO at rs9939609, food responsiveness, emotional control, and symptoms of ADHD in preschool children. *PLoS One, 7*(11), 1-7.

Ventura, A.K. (2017a). Does breastfeeding shape food preferences links to obesity? *Annals of Nutrition & Metabolism, 70 (suppl3),* 8-15.

Ventura, A.K., (2017b). Associations between breastfeeding and maternal responsiveness: A systematic review of the literature. *Advances in Nutrition, 8*(3), 495-510.

Ventura, A.K., Inamdar, L.B. & Mennella, J.A. (2015). Consistency in infants' behavioural signaling of satiation during bottle-feeding. *Pediatric Obesity, 10,* 180-7.

Ventura, A.K. & Birch, L.L. (2008). Does parenting affect children's eating and weight status? *International Journal of Behavioural Nutrition and Physical Activity, 5*(15), 1-12.

Ventura, A.K. & Hernandez, A. (2019). Effects of opaque, weighted bottles on maternal sensitivity and infant intake. *Maternal and child Nutrition, 15,* 1-9.

Ventura, A.K. & Pollack Golen, R. (2015). A pilot study comparing opaque, weighted bottles with conventional clear bottles for infant feeding. *Appetite, 85,* 178-84

Victora, C.G., Bahl, R., Barros, A.J.D., Franca, G.V.A., Horton, S., Krasevec, J., …Rollins, N.C. (2016). Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *The Lancet, 387,* 475-490.

Victora, C.G., Barros, F.C., Horta, B.L. & Martorell, R. (2001). Short-term benefits of catch-up growth for small-for-gestational-age infants *International Journal of Epidemiology, 30,* 1325-1330

Vidgen, H.A. & Gallegos, D. (2014). Defining food literacy and its components. *Appetite, 76,* 50-9.

Ville, A., Levine, E., Zhi, D., Lararia, B. & Wojcicki, J.M. (2018). Alterations in the gut microbiome at 6 months of age in obese Latino infants. *Journal of the American Journal of Nutrition,* Advanced Online Publication. https://doi.org/10.1080/07315724.2019.1606744

Wakefield, J. (2015, March 27). Children spend six hours or more a day on screens. *BBC News.* Retrieved from http://www.bbc.co.uk/news/technology-32067158

Walker, R.W. & Goran, M.I. (2015). Laboratory determined sugar content and composition of commercial infant formulas, baby foods and common grocery items targeted to children. *Nutrients, 7*(7), 5850-5867.

Walliman, N. (2006). *Social research methods.* London: Sage.

Walsh, A., Kearney, L., & Dennis, N. (2015). Factors influencing first-time mothers' introduction of complementary foods: a qualitative exploration. *BMC public health*, *15*, 939.

Walton, K.A., Murray, L.J., Gallagher, A.M., Cran, G.W., Savage, M.J., Boreham, C. (2000). Parental recall of birthweight: A good proxy for recorded birthweight? *European Journal of Epidemiology, 16*, 793-796.

Wang, A., Harrison, K., Musaad, S., Donovan, S.M., Teran-Garcia, M., & the STRONG Kids Research Team (2019). Genetic risk scores demonstrate the cumulative association of single nucleotide polymorphisms in gut microbiome-related genes with obesity phenotypes in preschool age children. *Pediatric Obesity, 14*(9), 1-12

Wang, G., Johnson, S., Gong, Y., Polk, S., Divall, S., Radovick, S., …Wang, X. (2016). Weight gain in infancy and overweight or obesity in childhood across the gestational spectrum: a prospective cohort study. *Scientific Reports, 6,* 1-10.

Wang,Y. & Chen, H.J. (2012). Use of Percentiles and Z-scores in Anthropometry. In V. Preedy (Ed.) *Handbook of Anthropometry.* (pp.29-48). New York: Springer.

Wardle, J., Sanderson, S., Gibson, E.L. & Rapoport, L. (2001). Factor-analytic structure of food preferences in four-year-old children in the UK. *Appetite, 37* (3), 217-223.

Wardle, J. (2007). Eating behaviour and obesity. *Obesity Reviews, 8,* s1, 73-75

Wardle, J., Carnell, S., Haworth, C.M., Farooqi, S., O'Rahilly, S. & Plomin, R. (2008a). Obesity associated with genetic variation in FTO is associated with diminished satiety, *Journal of Clinical Endocrinology and Metabolism, 93,* 3640-3643.

Wardle, J., Carnell, S., Haworth, C.M. & Plomin, R. (2008b). Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *American Journal of Clinicial Nutrition, 87,* 398-404.

Wardle J, Llewellyn C, Sanderson S, Plomin R. (2009) The FTO gene and measured food intake in children. *International Journal of Obesity, 33*(1),42–5.

Wardle, J., Sanderson, S., Guthrie, C.A., Rapoport, L. & Plomin, R. (2002). Parental feeding style and the intergenerational transmission of obesity risk. *Obesity Research, 10,* 453-62

Wasser, H., Bentley, M., Borja, J., Davis Goldman, B., Thompson, A., Slining, M…. Adair, L. (2011). Infants perceived as "fussy" are more likely to receive complementary foods before 4 months. *Pediatrics, 127*(2),229-37.

Webber, L., Hill, C., Saxton, J., van Jaarsveld, C.H.M. & Wardle, J. (2009). Eating behaviour and weight in children. *International Journal of Obesity, 33,* 21-28.

Webber, L., Hill, C., Cooke, L., Carnell, S. & Wardle, J. (2010). Associations between child weight and maternal feeding styles are mediated by maternal perceptions and concerns. *European Journal of Clinical Nutrition, 64,* 259-65.

Weber, M., Grote, V., Closa- Monasterolo, R., Escribano, J., Langhendries, J-P., Dain, E.,…Koletzko, B. (2014). Lower protein content in infant formula reduces BMI and obesity risk at school age: follow up of a randomized trial. *American Journal of Clinical Nutrition, 99*(5), 1041-51.

Wells, J.C. & Ritz, P. (2001). Physical activity a 9-12 months and fatness at 2 years of age. *American Journal of Human Biology, 13* (3), 384-9.

Welsh Assembly Government. (2010). *Assessing the costs to the NHS associated with alcohol and obesity in Wales.* Retrieved from http://gov.wales/statistics-and-research/assessing-costs-nhs-associated-alcohol-obesity/?lang=en

Welsh Government. (2015a). *Turning the curve on childhood obesity in Wales. Preventing childhood obesity steering group. Final report.* Retrieved from http://gov.wales/docs/dpsp/publications/140828-turning-curve-childhood-obesity-report.pdf

Welsh Government. (2015b). *Welsh Health Survey. 2014 Results.* Retrieved from http://gov.wales/statistics-and-research/welsh-health-survey/?lang=en

Welsh Government (2019). Healthy Weight: Healthy Wales. Retrieved from https://gov.wales/sites/default/files/consultations/2019-01/consultaton-document_0.pdf

Weng, S.F., Redsell, S.A., Swift, J.A., Yang, M. & Glazebrook, C.P. (2012). Systematic review and meta-analyses of risk factors for childhood overweight identifiable during infancy, *Archives of Disease in Childhood, 97,* 1019-1026.

Werthmann, J., Jansen, A., Havermans, R., Nederkoorn, C., Kremers, S. & Roefs, A. (2015). Bit's and pieces. Food texture influences food acceptance in young children. *Appetite, 84,* 181-187.

Westland, S. & Crawley, H. (2018) *Fruit and vegetable based purees in pouches for infants and young children.* Retrieved from https://www.firststepsnutrition.org/babyfood-composition

Wijlaars, L. P. M. M., Johnson, L., van Jaarsveld, C. H. M. & Wardle, J. (2011). Socioeconomic status and weight gain in early infancy, *International Journal of Obesity, 35,* 7, 963-970.

Williams, C.B., Mackenzie, K.C. & Gahagan, S. (2014). The effect of maternal obesity on the offspring. *Clinical Obstetrics and Gynecology, 57*(3), 508-515.

Wilson, H.V. (2002). Power and partnership: a critical analysis of the surveillance discourses of child health nurses. *Journal of Advanced Nursing, 36* (2), 294-301.

Withrow, D. & Alter, D.A. (2011). The economic burden of obesity worldwide: a systematic review of the direct costs of obesity. *Obesity Reviews, 12,* 131-141.

Witt, W.P., Mandell, K.C., Wisk, L.E., Cheng, E.R., Chatterjee, D., Wakeel, F., Park, H. & Zarak, D. (2016). Infant birthweight in the US: the role of preconception stressful life events and substance use. *Archives of Women's Mental Health, 19*(3), 529-42.

Wojcicki, J.M. (2011). Maternal pre-pregnancy body mass index and initiation and duration of breastfeeding: a review of the literature. *Journal of Women's Health, 20,* 341-7.

Woo, J.G., Guerrero, M.L., Altaye, M., Ruiz-Palacios, G.M., Martin, L., Dubert-Ferrandon, A., Newburg, D.S. & Morrow, A.L. (2009). Human milk adiponectin is associated with infant growth in two independent cohorts. *Breastfeeding Medicine, 4*(2), 101-109.

Wood, C.T., Skinner, A. C., Yin, S.H., Rothman, R.L., Sanders, L.M., Delamater, A., …Perrin, E.M. (2016). Association between bottle size and formula intake in 2-month-old infants. *Academic Pediatrics, 16* (3), 254-259.

World Health Organization. (2001). *Complementary feeding. Report of the global consultation. Summary of guiding principles.* Retrieved from http://www..int/nutrition/publications/Complementary_Feeding.pdf

World Health Organization (2002). *Report of the expert consultation on the optimal duration of exclusive breastfeeding.* Retrieved from https://apps.who.int/iris/bitstream/handle/10665/67219/WHO_NHD_01.09.pdf?ua=1

World Health Organization (2003a). *Obesity and Overweight.* Retrieved from http://www.who.int/dietphysicalactivity/media/en/gsfs_obesity.pdf

World Health Organization. (2003b). *Global Strategy for Infant and Young Child Feeding.* Retrieved from http://www.who.int/nutrition/publications/infantfeeding/9241562218/en/

World Health Organization. (2006). *WHO Child Growth Standards.* Retrieved from https://www.who.int/childgrowth/standards/Technical_report.pdf?ua=1

World Health Organization. (2008). *Training Course on Child Growth Assessment: Interpreting Growth Indicators.* Retrieved from https://www.who.int/childgrowth/training/module_c_interpreting_indicators.pdf?ua=1

World Health Organization. (2016a). *Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity. Report of the ad hoc working group on science and evidence for ending childhood obesity.* Retrieved June, 2016, from http://apps.who.int/iris/bitstream/10665/206549/1/9789241565332_eng.pdf?ua=1

World Health Organization. (2016b). *Exclusive breastfeeding to reduce the risk of childhood overweight and obesity.* Retrieved January, 2016, from http://www.who.int/elena/titles/breastfeeding_childhood_obesity/en/

World Health Organization (2016c). *Daily Iron Supplementation in infants and children.* Retrieved from http://apps.who.int/iris/bitstream/10665/204712/1/9789241549523_eng.pdf?ua=1&ua=1

World Health Organization (2017a). *Obesity and Overweight.* Retrieved April, 2018, from http://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight

World Health Organization (2017b). *Cardiovascular diseases.* Retrieved July 30, 2019, from https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

World Health Organization (2017c). *Report of the Commission on Ending Childhood Obesity.* Retrieved from https://apps.who.int/iris/bitstream/handle/10665/259349/WHO-NMH-PND-ECHO-17.1-eng.pdf?sequence=1

World Medical Association. (2018). WMA Declaration of Helskini – Ethical Principles for Medical Research Involving Human Subjects. Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/

Worobey, J., Lopez, M. I., & Hoffman, D. J. (2009). Maternal behavior and infant weight gain in the first year. *Journal of Nutrition Education and Behavior*, *41*, 169–175.

Wrieden, W., Peace, H., Armstrong, J. & Barton, K. (2003). *A short review of dietary assessment methods used in national and Scottish research studies.* Retrieved from https://www.food.gov.uk/sites/default/files/multimedia/pdfs/scotdietassessmethods.pdf

Wright, C.M., Cameron, K., Tsiaka, M. & Parkinson, K.N. (2011). Is baby-led weaning feasible? When do babies first reach out for and eat finger foods? *Maternal and Child Nutrition, 7*(1), 27-33

Wright, D.R., Glanz, K., Colburn, T., Robson, S.M. & Saelens, B.E. (2018). The accuracy of parent-reported height and weight for 6-12 year old U.S. children. *BMC Pediatrics, 1*(52), 1-8

Wright, C.M., Parkinson, K.N. & Drewett, R.F. (2004). Why are babies weaned early? Data from a prospective population based cohort study, *89*(9), 813-6.

Wu, Y.Y., Lye, S. & Brollais, L. (2017). The role of early life growth development, the FTO gene and exclusive breastfeeding on child BMI trajectories. *International Journal of Epidemiology, 46,* 1512-1522.

Wyman W (2015). Access-Excel.tips, Retrieved September 20, 2018 from http://access-excel.tips/probability-range-z-score.

Wyse, R., Campbell, E., Nathan, N. & Wolfenden, L. (2011). Associations between characteristics of the home food environment and fruit and vegetable intake in preschool children: a cross sectional study. *BMC Public Health,* 11(938), 1-10.

Yan, J., Liu, L., Zhu, Y., Huang, G. & Wang, P.P. (2014). The association between breastfeeding and childhood obesity: a meta-analysis. *BMC Public Health, 14,* 1-11.

Yanovski, J.A. (2015). Pediatric Obesity. An introduction. *Appetite, 93,* 3-12.

Yassour, M., Vatanen, T., Sijander, H., Hamalainen, A-M., Harkonen, T., Ryhanen, S.J., …Xavier, R.J. (2016). Natural history of infant gut microbiome and the impact of antibiotics on strain-level diversity and stability. *Science Translational Medicine, 8*(353) 1-22.

Yu, Z.B., Han, S.P., Zhu, C., Wang, X.J., Cao, X.G. & Guo, X.R. (2011). Birth weight and subsequent risk of obesity: a systematic review and meta-analysis. *Obesity Reviews, 12,* 525-542.

Yuan, C., Gaskins, A. J., Blaine, A.I., Zhang, C., Gillman, M.W., Missmer, S.A., Field, A.E. & Chavarro, J.E. (2016). Association between cesarean birth and risk of obesity in offspring in childhood, adolescence and early adulthood. *JAMA Pediatrics, 170,* 11:e162385.

Zhou, X. & Zhang, L. (2014). Letter to the Editor: The influence of dietary energy density on childhood obesity, Iranian Journal of Public Health, 43, 11, 1587-1588

Zeve, D., Regelmann, M.O., Holzman, I.R. & Rapaport, R. (2016). Small at birth, but how small? The definition of SGA revisited. *Hormone Research in Paediatrics, 86,* 357-360.

Ziegler, E.E. (2006). Growth of breast-fed and formula-fed infants. *Nestle Nutrition Workshop,* 58, 51-9.

Appendix 1 – Questionnaire

About you and your baby

A little bit about you:

1. How many children do you have? [ ]
2. How old are you? [ ]
3. a) Are you currently employed (if you are on Maternity Leave please tick Yes)? **Y** □ **N** □

   b) **If Yes** what is your job title or **if No** what was your last job title before you stopped

   [ ]

4. What is the highest level of education you completed? **Please tick one option**.

□	□	□	□	□
Up to GCSE	A level	Diploma	Degree	Post- grad

A bit more about your baby:

5. Was your baby born on or after 37 weeks gestation? **Y** □ **N** □
6. What was his/her birth weight? [ ] (Lbs and oz)**or** [ ] (g)
7. Does your baby have any health problems? **Y** □ **N** □

   <u>If Yes: Please discuss this with the researcher to make sure it is still suitable for your baby to take part in the study.</u>

8. Is your baby a Boy □ **or** Girl□
9. How old is your baby in weeks? [ ]
10. a) How did you feed your baby **at birth**? **Please tick one option**.

□	□	□
Breast-fed	Expressed breast milk	Formula milk

b) How are you **currently** feeding your baby? **Please tick all that apply.**

☐	☐	☐
Breast-feeding	Expressed breast milk	Formula/other milk

c) If your baby has had formula milk how old was your baby in weeks when he/she first had formula/other

d) If you breastfed your baby at birth but have now stopped. How old was your baby in weeks when you stopped breastfeeding?

11. a) IN THE PAST WEEK: Has your baby been eating any solid food? **Y** ☐ **N** ☐

If YES - Please skip questions 11 b, c, d & e and go straight to questions 12-16

IF NO:

b) What age (in weeks) do you plan on starting weaning your baby?

c) Please give your reason/reasons for this answer.

d) Which of the following matches most closely with your plans/thoughts about weaning?

☐	☐	☐	☐	☐
I am going to be giving pureed food with a spoon.	I am going to follow a Baby-led weaning approach, giving my baby finger foods only.	I am going to do a mix of giving some pureed food and finger foods.	I don't know. I've thought about the different ways of weaning but I haven't decided which I prefer to use yet.	I don't know. I haven't thought much about weaning yet. I don't know about the different ways of weaning.

e) Please give your reason/reasons for this answer.

<u>Thank you and please stop here and complete your Contact Details on Page 8</u>

A bit about weaning: (Only complete this section if your baby has started eating solid food).

12. What age was your baby in weeks when he/she started eating solids?
13. When your baby **FIRST STARTED SOLIDS** ….

(IMPORTANT: This is not what your baby does now but what happened when you first started weaning/ introducing solids. **Please tick one option from part a) *and* one option from part b)**

a) Did your baby feed him/herself unaided? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
Every piece of food that went into his/her mouth was put there by baby.	Most of the time baby fed self but needed occasional help e.g. to eat a yoghurt.	About half the time baby fed self.	Most of the time an adult fed baby with a spoon. Baby occasionally fed self e.g. a rusk or toast.	An adult always fed baby by putting the food into baby's mouth with a spoon.

b) Did your baby eat pureed or mashed food (rather than finger foods)? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
All food was of a pureed or mashed texture, this includes baby cereal/ rice.	Most food was of a pureed or mashed texture but occasionally baby ate finger-foods e.g. rusk or toast.	About half the time food was pureed or mashed, half the time baby ate finger foods.	Most of the time baby ate finger foods but occasionally baby ate something like yoghurt or baby cereal/rice.	Baby always ate finger foods in their whole form. E.g. sticks of carrot, toast, chunks of banana. No purees.

c) What were your reasons for choosing to wean/ introduce solids this way?

14. How does your baby eat **NOW**?

a) Does your baby feed him/herself unaided? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
Every piece of food that went into his/her mouth was put there by baby.	Most of the time baby fed self but needed occasional help e.g. to eat a yoghurt.	About half the time baby fed self.	Most of the time an adult fed baby with a spoon. Baby occasionally fed self e.g. a rusk or toast.	An adult always fed baby by putting the food into baby's mouth with a spoon.

b) Does your baby eat pureed or mashed food (rather than finger foods)? **Please tick one option**.

☐	☐	☐	☐	☐
Always	Often	Sometimes	Rarely	Never
All food was of a pureed or mashed texture, this includes baby cereal/ rice.	Most food was of a pureed or mashed texture but occasionally baby ate finger-foods e.g. rusk or toast.	About half the time food was pureed or mashed, half the time baby ate finger foods.	Most of the time baby ate finger foods but occasionally baby ate something like yoghurt or baby cereal/rice.	Baby always ate finger foods in their whole form. E.g. sticks of carrot, toast, chunks of banana. No purees.

A bit more about how your baby eats now:

15. IN THE PAST WEEK: Please describe a **typical day's** feeding:

a) How many milk feeds does your baby have in 24 hours?

b) How many times does your baby eat solids per day (meal or snack)?

c) How much of your baby's food intake comes from milk **or** solids? **Please tick one option**.

☐	☐	☐	☐	☐
All from milk. No solids.	Mostly from milk. Small amounts of solids.	About half from milk/half from solids.	Not much from milk. Mostly from solids	All from solids. No milk.

16. What did your baby eat and drink **YESTERDAY**? (Please try to be as specific as you can and include milk feeds)

E.g. Breakfast: 20 minute breastfeed. ½ slice of brown toast with butter. ¼ of a banana.

Lunchtime: 7oz formula milk (SMA), ½ jar of Heinz Sweet potatoes. (include brand name if possible)

Evening meal: Home-made spaghetti Bolognese. 4 tablespoons.

Thank you for your time. There are no more questions - Please complete your Contact Details on Page 8.

FOR COMPLETION BY RESEARCHER

CODE NAME

Boy □ **or** Girl□

Date:

Weight (g)

Session number:

Length (cm)

Head Circumference (cm)

Contact Details

CODE NAME [ ]

Parent's name:__________________________________

Baby's Name: ____

Baby's Date of Birth: _____________________________

Home Address

(for home visit) : _______________________________

____

____

Post Code: _______________________________

OR

Baby Group Address: _______________________________

(for group visit) ____________________________

Contact Number: ___________________________

Email (optional): ___________________________

Appendix 2- Poster

Are you a parent of a baby about to start or just started weaning?

Would you like to be part of a research study looking at the effects of different ways of weaning?

The study involves weighing and measuring your baby at 2-6 monthly intervals until your child is 2 (maximum 7 measurements in total over around 18 months). Each session will take about 30 minutes each time in a place of your choice. Even if you are only able to take part in one weighing/measuring session – I'd still love to hear from you!

Who is doing the research?

Hi my name is Sara Jones, I am a Health Visitor doing PhD research at Swansea University. I am interested in finding out if different ways of weaning affect babies' weight as they grow.

For more information please call/text the researcher Sara Jones on 0XXXXXXXXX or email [redacted].uk If you want to take part and I will send you an info pack.

Appendix 3 – Information pack and consent form

The SHIFT study participant information pack

My name is Sara Jones - I am a qualified nurse and health visitor and I am interested in finding out more about the different ways of weaning or starting solids. I have been supported by Swansea University to do this research as part of my PhD studies.

You may be aware that there are different ways of weaning.

- Some Parents give their babies pureed foods on a spoon to begin with and then start lumpier foods and finger foods later.
- Some Parents follow an approach called 'baby-led weaning', which means that the baby starts on finger foods (like pieces of cooked carrot, whole pieces of banana, toast etc.) straight away from the start of weaning and don't give purees at all.
- Some Parents use a mix of the two, some purees and some finger foods.

Researchers have started looking into these different ways of weaning, but at the moment it is still not clear whether any of these different ways of weaning make a difference to babies' eating or growth. One area researchers are interested in is whether weaning might affect how much weight babies gain. The aim of my research is to explore how babies grow and see if there is any relationship with how they are weaned.

For my study I would like to weigh and measure the length and head circumference of lots of babies, who were weaned in all three different ways as follows:

4 months	6 months	8 months	10 months	12 months	18 months	24 months
Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby
N.b. If we start late or miss one or two appointments that will not be a problem. If you wish to only take part as a one-off weigh/measure that will also be fine. You may also decide to withdraw from the study at any time.						

The weighing/measuring session can take place in a place of your choice, perhaps your baby group or your home and should only take around half an hour. You will also be asked to complete a short questionnaire to help to know a little bit more about how you feed your baby which will help me analyse the results. A detailed information sheet and examples of the questionnaires can be found on the website www.blwresearch.com which should answer any questions you may have about the study, or I can send you a paper copy if you like. If, however, you would like to ask me any questions about the study or about your invitation, please do not hesitate to phone or text me on [redacted], or e.mail me if you prefer: [redacted]

If you would like to take part, please call/text or email me on the details given above. If I am out of the office, please leave a message with your contact details and I will call you back.

IMPORTANT: I'm afraid that your baby will not be able to take part if he/she was born early (before 37 weeks gestation). Your baby may or may not be able to take part if they have a medical condition (depending on what it is) if you are interested in taking part but not sure if your baby can be included due to a medical condition please contact me and I can let you know.

Thank you for considering this invitation.

1) What does the researcher want to know?

I am interested in finding out if there is a difference in the weight and the pattern of weight gain in babies who were weaned using different ways of weaning. This will involve weighing and measuring lots of babies who were weaned in different ways. I will also need some basic background information (see example questionnaires) about you and your baby, in particular around how you feed your baby – this is important to help me to analyse the data properly (see the 'About you and your baby' questionnaire at the end of this information sheet).

2) What is the point of the research?

There are lots of different ways to start solid foods, but there is not much research on the topic. For many years the advice was that babies should start off weaning on spoon-fed purees and then progress to lumpier textures and finger foods later on. However, baby-led weaning, which means that babies are given finger foods only from the very start of weaning, is gaining popularity here in the UK and in other countries.

We don't yet know whether the traditional approach of spoon-feeding or whether baby-led weaning makes any difference to babies' weight. Some researchers have already started looking into this but no-one yet has actually weighed babies to check and compare whether the way babies were weaned affects their weight and their pattern of weight gain over time.

The aim of my research is increase the knowledge about weaning, to inform future parents and health care professionals.

3) Who will the researcher be?

I have been a qualified nurse since 2009 and a health visitor since 2014. I used to work for Flying Start and ABMU Health Board in Swansea but I no longer work for Flying Start or the Health Board as I have decided to go to Swansea University to do research full-time as part of a PhD. I decided to make the move from working as a health visitor to becoming a researcher because I am very interested in finding out more about child nutrition. My supervisors are Dr. Amy Brown and Dr. Michelle Lee, from Swansea University, who are both experts in the field of infant feeding research. Their contact details can be found on the consent form as well as on our website www.blwresearch.com.

4) Will I have to sign a consent form?

Yes. Please see a copy of the consent form at the end of this information sheet, I will ask you to return this to me if you decide to take part. You may, however, withdraw your consent ***at any time.***

When we arrange a date and time for me to weigh and measure your baby I will be able to answer any questions that you may have and I will collect one copy of the consent form at that time. You can keep a copy of the form, if you wish.

5) How long will the appointment take and what will it entail?

It will usually only take half an hour. When I arrive I will ask you to first return the consent form to me I will then ask you to fill in a very short questionnaire with some basic information about you and your baby (please see the questionnaires at the end of this information sheet –there are 3 questionnaires attached. Which one you complete will depend on the age of your baby and whether it is your first or subsequent session, but you will only be asked to complete one each time).

I will be able to answer any questions you may have about filling in this questionnaire on the day. I will also need to keep a record of your contact details so that I can make an arrangement to see you again in 2-6 months, if you agree (please see question 9 regarding how these details are kept). ***Please note you can decide to withdraw from the study at any time and if so you will not be contacted by me again.***

Once you have completed the questionnaire I will then ask you to undress your baby to be weighed. I will use the same type of scales and measuring mat as your health visitor usually uses and these will be cleaned with anti-bacterial wipes between each use. I will weigh and measure your baby exactly as s/he is usually weighed and measured by the Health Visitor. The whole process of weighing and measuring usually only takes around 5-10 minutes.

6) If I agree to take part, where/when will the appointment take place?

I would be happy to meet you at your own home or if you prefer, I can come to the baby group that you normally attend and meet you there. If I meet you at your home, I will arrange a mutually convenient time with you beforehand. It might be a good idea to let me know a time when your baby is not usually having a feed or sleeping. However I know that this is difficult to predict so please do not worry if your baby is asleep or feeding at the appointment time, I will be happy to wait or return a little later. Or you may, of course, postpone it or cancel it at any time, with no problem. My contact details can be found on the consent form attached as well as on the website blwresearch.com.

7) Who should be present at the appointment?

I will be the only researcher attending, and there will never be someone else coming in my place. I have a full, enhanced DBS clearance to work with children and I will wear my photo ID badge from the university and also bring my nursing registration card (NMC PIN number) should you wish to see it.

If I meet you at your home, it is completely up to you who will be present (if anyone). If you wish your partner, a family member or a friend to be there that will be fine.

8) Will the appointment be recorded in any way?

No, I will not be recording using any visual or audio equipment. I will need to write down the weights and measurements but as described in Question 9 below this information will be kept securely.

9) What will happen to the information I give?

As soon as I meet you and your baby for the first time I will assign you and your baby a code name. From then on I will only use the code name on any information that I hold relating to you and your baby. I will need to keep a list of code names and contact details so that I can identify you and contact you for the next session of weighing/measuring but this list will be kept securely and separately from all of the information I hold about you. Both the information and the list of contact details will be kept very securely in a locked filing cabinet at the University and will only be accessible by me.

The information from the forms and the weights and measurements of the babies will be uploaded on to my computer into a system called SPSS (Statistical Package for the Social Sciences) with secure access, known only to me. SPSS is used to analyse the data and produce statistics. I will also need to discuss the anonymised data with my supervisor at the university, Dr Amy Brown (her contact details are on the consent form).

Any data from the study will be used for the stated purposes only and will be destroyed after 5 years, following completion of the study and to comply with the research practices of the College of Human and Health Sciences, Swansea University. At the end of my research I will produce a thesis, which aims to make sense of all the information I have found and draw some conclusions about how weaning may affect babies' weight. Some of the work that makes up the thesis may be published in health care research journals or may be presented in conferences attended by health care professionals and other people interested in child nutrition. All the babies who took part will only be referred to by their code names.

THEREFORE - NO INFORMATION WHICH MAY IDENTIFY YOU WILL BE ATTACHED TO ANY OF THE INFORMATION GATHERED, ANY OF THE INFORMATION ON THE COMPUTER SYSTEM, THE FINAL THESIS OR IN THE PUBLISHED FINDINGS.

10) Who will know that I have taken part in the study?

You are free to tell anyone about taking part, but I will protect your anonymity from my perspective. I offer confidentiality of information within the boundaries of my professional responsibilities as a registered nurse and health visitor, which includes highlighting issues of harmful practices. This means that the only time that I will share anything about you or your baby with anyone else will be if I am very worried about your child's safety. This is because as a health visitor I have a duty to pass on any information to the relevant people if I believe a child is ill, suffering or at risk of significant harm.

In the very rare case that I feel I need to pass on any concerns of this nature I will tell you that I am going to pass on the information, and also to who (GP, health visitor or social worker). If I am very worried about your child's health, I will seek permission from you to speak to your health visitor or GP, or advise you to do so.

I will not otherwise inform your GP or Health Visitor about your participation in the study.

11) Will you be able to give me any health visiting support/advice when I take part in the study?

As our meeting is purely in order for me to carry out my research study, I would not be able to offer you any health visiting services at the same time. The care provided for you by your own health visitor and/or doctors will not be affected in any way, whether you decide to take part in the research, or not.

Also, if you decide to withdraw your consent or the information you have given from the study at any time, this may be done easily, with no consequences to you or your family

12) What if I am worried about my baby's weight or measurements following our appointment?

If you are worried about your baby's weight or measurements in any way the best course of action would be to speak to your health visitor or GP.

13) Will I be able to see the results of the study?

Yes, on completion of the research I plan to send all participants details of how to access the study findings. I will also provide links to my final thesis and study findings on the website www.blwresearch.com. You may also contact me if you are interested to know more information about the study results.

14) Is there any reward for me, if I take part in this study?

I'm afraid that there are no payments, expenses or other rewards available for taking part. However, I hope that you will enjoy taking part and that you will consider your information to be useful in informing future parents and health care professionals' understanding of the effects of different ways of weaning.

N.B. All research done by university students is looked at by an independent group of people, called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity.

My study has been reviewed by the College of Human and Health Sciences Psychology Research Ethics Committee and I have been given permission to go ahead with it.

PARTICIPANT'S CONSENT FORM

Please read and tick the boxes before signing this form

I have read and fully understand all the points made in the information sheet (Frequently Asked Questions) about **The SHIFT study**	
I agree to allow the researcher to keep an anonymised form containing details about me and my baby.	
I agree to allow the researcher to weigh and measure my baby for the purpose of the research.	
I agree to my **fully anonymised** information I give being used in the way described in the information sheet (Frequently Asked Questions)	

Participant's Signature ....

Name (Printed)
……………………………………………………………………………………

Researcher's Signature ....

Name (Printed)
……………………………………………………………………………………

Date...

Full details of the study are available on the website
www.blwresearch.com

You may email our dedicated email address
e.mail: [redacted]

Or contact me, the researcher Sara Jones for information:
Email: [redacted]
Phone/Text: [redacted]

You may also contact my supervisors if you wish,
Dr Amy Brown e.mail [redacted]
Dr Michelle Lee email [redacted]

Appendix 4- Ethics application

DEPARTMENT OF PSYCHOLOGY

APPLICATION FOR RISK ASSESSMENT AND ETHICAL APPROVAL

PLEASE COMPLETE THE FORM USING TYPESCRIPT

(handwritten applications will not be considered)

Name	Sara Jones Student Number: [redacted]
Address	College of Human and Health Sciences
University E-mail address	[redacted]
Title of Proposed Research	Weaning and Weight Study (WAWS) (name was subsequently changed to the SHIFTstudy)
Type of Researcher (please tick)	☐ Undergraduate student ☐ MSc student - Abnormal and Clinical Psychology ☐ MSc student - Research Methods in Psychology ☐ MSc student - Cognitive Neuroscience ☑ PhD student ☐ Member of staff **<u>For MSc students only</u>**: This ethics application is for: (please tick) ☐ Empirical Project 1 ☐ Empirical Project 2 ☐ Empirical Project 3 ☐ 60 credit project
Name of supervisor	Dr Amy Brown (1st supervisor), Dr Michelle Lee (2nd Supervisor)

1. Briefly describe the main aims of the research you wish to undertake. Please use non-technical language wherever possible.
This study aims to identify whether there are any differences in weight/BMI/percentile position in infancy based on method of introducing solid foods.

The term weaning is a common term used to describe the process of introducing solid food into a baby's diet. There are a number of different approaches to weaning,

- the traditional approach of spoon-feeding pureed food,
- 'baby-led weaning' where the baby self-feeds food in their whole form,
- or a mix of the two.

Advocates of 'baby-led weaning' claim that babies weaned using this approach are better at knowing when they are full and so self-regulate their appetite, implying a decreased likelihood of overweight and obesity. An initial self-report study supported this, suggesting baby-led babies had a reduced incidence of overweight as toddlers. However further work is needed using clinical measures e.g. weighing and measuring infant weight and growth and to track at what age any potential differences in weight may emerge.

The aim of this research is therefore to weigh and measure infants over a series of time points from aged 6 – 24 months, and compare the three methods of introducing solid food.

2. Briefly describe the overall design of the project

The study will involve sessions of weighing and measuring babies' length and head circumference at set intervals from the age of 4 months up to 24 months. (Please see below).

Feb 2016	April 2016	June 2016	Aug 2016	Oct 2016	April 2017	Oct 2017
Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7
4 months	6 months	8 months	10 months	12 months	18 months	24 months
Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure baby	Weigh & measure child	Weigh & measure child

To maximize participation and data, participants can take two routes into the study: a one-off weight and measurement (e.g. if baby is 8 months old and weighted as a one-off – this would add cross sectional data to the 8 months data alone), or secondly they may participate on a longitudinal basis with follow up at each age time point.

Brief questionnaires will be given at each session to determine feeding style and infant feeding variables. The participants will be assigned to 1 of 3 comparison groups as follows.

1) Traditional Weaning
2) Baby led Weaning
3) Mixture between Traditional and Baby led Weaning.

(Please see Q3 for more information about the questionnaires. The questionnaires are also attached to this application).

Data analysis will compare the weight gain trajectories of each of the 3 comparison groups.

3. Briefly describe the methods of data collection and analysis. Please describe all measures

to be employed (e.g., questionnaire responses, reaction times, accuracy, skin conductance responses, etc.). If questionnaire or interviews are to be used, please provide the questionnaire / interview questions and schedule.

4. Location of the proposed research (i.e., Departmental labs, schools, etc)

The sessions will take place either at the parent's home or at a baby group (at the preference of the parent).

5. Describe the participants: give the age range, gender, inclusion and exclusion criteria, and

any particular characteristics pertinent to the research project.

Participants will be healthy full-term babies and children aged 4-24 months and one of their parents (ideally the parent who is most involved in the baby/child's feeding).

Exclusion criteria are babies born before 37 weeks gestation, low birth weight (i.e. babies born weighing less than 2500g), babies with significant health concerns, or problems with weight gain/feeding issues such as failure to thrive, colic, reflux and gastrointestinal problems (as reported by the parent).

Mothers will be aged 18+, able to complete the English language questionnaire and able to give consent.

Inclusion and exclusion criteria will be checked at the initial point of contact with me and at subsequent sessions, as health problems may arise throughout the course of the study.

6. How will the participants be selected and recruited?

☐ Subject pool.

☑ General public

☐ Other. Please give details:

Participants will be recruited from local mum and baby groups and also online forums/groups such as Facebook, Twitter, Mumsnet and Bounty who have ‘local’ boards.

The study will be advertised in baby groups and public places using a poster (see attached). Online, the study will be advertised on social media via the researcher's and the supervisor's contacts with online mum and baby forums. 'Sharing' will be encouraged and thus it is hoped that sampling will snowball online in this way. Details of how to contact the researcher to take place will be on the advert.

Permission will also be sought from group leaders to attend mother and baby groups to give information about the study. Members of the group will be given information about the study, and then time to consider participation, before being invited to have their baby weighed and measured. The researcher will not put pressure on participation and will set up in a quieter area of the room.

The poster and online adverts will contain a link to the study website. Participants will be able to follow the link to the study where they can get in contact for more information.

www.blwresearch.com

This domain is owned by me and I am the only person with administrative access to the site. It will be used to post information about the study, participant information sheets, FAQs and contact details for myself and my supervisors. Participants will be invited to phone/text/email me directly if they want to take part. There is also a contact form on the home page of the website that links directly to my email account with password protected access.

The website is a place to find all the information/study documents, contact details and a blog about my experiences of being a PhD student (anonymity and confidentiality of all others will be assured and no study or identifiable data will be included in the blog). However, anonymised study results may be published on the website at the end of the study.

7. Will the study be advertised outside the Department's Electronic Subject Pool system (e.g. via a poster or email notice)?	Yes	☑
	No	☐

If yes, please provide the wording of the advertisement here (or attach a copy of the intended advertisement to this Ethics Form):

Please see Poster attached for use in Baby Groups.

On Facebook, Twitter and Online forums advert will read:

Are you a parent of a baby about to start or just started weaning? Would you like to take part in research? Researchers at Swansea University are looking for parents with babies aged from 4-12 months to take part in a study looking at how babies are weaned differently and if this affects babies' weight over time. For more information please visit www.blwresearch.com

The Poster may also be posted online as a 'picture' post, to accompany the succinct advert.

8. What procedures (e.g., interviews, computer-based learning tasks, etc.) will be carried out

on the participants?

Babies will be measured and weighed by me, a qualified health visitor. This would preferably take place in a public place such as a baby group (especially for the initial session) however, there will be some occasions where I will be able to accommodate a home visit if preferable to the parent.

The process of weighing and measuring will be done in the usual way (as the health visitors routinely do) and will be therefore be familiar to all parents and babies. Parents will assured that all equipment and the researcher's hands are cleaned between each baby. They will be advised to bring a blanket to wrap baby up in after weighing/measuring.

Procedure of weighing/measuring (Under 24 months):

Baby will be weighed naked (no nappy). Parent will therefore first be asked to undress baby then place the baby (lying or sitting) on the weighing scales (SECA scales used by health visitors: http://www.seca.com/en_bz/products/all-products/product-details/seca354.html). This procedure takes less than 10 seconds, after this the parent may pick up the baby and replace the nappy.

Baby's length will then be measured in a nappy only, using a measuring mat on a flat surface. (SECA measuring mat used by health visitors: http://www.seca.com/en_bz/products/all-products/product-details/seca210.html)

Baby's head will be supported by the parent so that it is touching the board at the top of the mat. One leg will be physically guided down by me into a straight position to obtain length measurement. This procedure only takes around 30 seconds.

Baby's head circumference will be measurement will be done using one use only head tapes designed for this purpose. http://www.seca.com/en_bz/products/all-products/product-details/seca212.html The parent will be asked to hold the baby in a normal comfortable position during head measurement. There is usually no need for the head to be held still. This procedure takes less than 10 seconds.

Procedure for weighing/measuring (Over 24 months)

Child may stand on weighing scales with minimal clothing as tolerated. The SECA scales convert from lying scales to standing scales by removing the top 'boat' shaped part. Most children of this age become distressed or shy if asked to remove all clothing and nappy. Usually health visitors weigh children over 2 in light clothing (no shoes, coats), to minimise this potential distress, therefore this will also be the method used for this study.

Child's height measured using a Leicester height measure as standardly used by health visitors: http://www.healthforallchildren.com/shop-base/shop/heightlength-measuring-equipment/leicester-height-measure-mk-ii/. The child stands on the plastic base, looking forward and the top panel is gently lowered (by me) to touch the top of the child's head. This procedure takes less than 1 minute.

Head circumference as above using SECA head tape.

9.	What potential risks to the participants do you foresee and how do you propose to ameliorate/deal with potential risks? For instance, provide contact details of Student Counseling services and relevant community support organizations, etc.

Parents are often concerned about their baby's weight, weight gain and weaning is a topic on which parents routinely seek advice. The nature of this study involves weights and measurements that are extra to the routine health checks, and in doing so there is a small risk that this could heighten parents anxieties, especially if a problem is identified (e.g. a drop or rise in 2 percentile lines in either weight, length or head circumference is a concern that requires a health visitor referral to a GP).

As a health visitor I am used to dealing with these issues as they arise and reassuring parent but I will be clear that the purpose of my visit is <u>not to provide health visiting advice or services</u>, and I will reiterate this to the parent. However, if a baby appears to be unwell or shows a change in 2 or more percentile lines as described above I will seek consent from the participant to refer them to their health visitor or GP.

In particular, if any child safeguarding concerns arise, I will have a duty to report this to the local children's services in line with the All Wales Child Protection Procedures (see below). If this becomes necessary I will inform the parent that I am doing so, whom I am informing, and why.

http://www.childreninwales.org.uk/wp-content/uploads/2015/09/All-Wales-Child-Protection-Procedures-2008.pdf

10.	What potential risks to the interests of the researchers do you foresee and how will you ameliorate/deal with potential risks?

As I will be occasionally visiting people in their homes, on my own, there are potential risks to my safety as with all lone workers. However, I will work within the University's lone worker policy, and carry a mobile phone with me at all times. As a health visitor working in the community previously, I am used to lone home visits, and the risks involved in this research will be no greater than in health visiting work.

11.	How will you brief and debrief participants? *(Please attach copy of debrief information to be given to participants)*

Please see attached participant information sheets and FAQs. These will be available on the study website but a paper copy can be made available for any participant on request. Participants will also be able to contact me via my e.mail or the website for more information on the overall anonymous results of the study once it is complete and has been analysed. A debrief letter will be sent to all participants on completion of their involvement (see attachment).

12. Will informed consent be sought from participants?	Yes *(Please attach a copy of the consent form)*	☑
	No	☐
If no, please explain below:		

13. If there are doubts about participants' abilities to give informed consent, what steps have you taken to ensure that they are willing to participate?
The participant information sheets and FAQs are thorough and detailed which provides extensive information for informed consent. Participants may also contact me or my supervisors if they have any questions. As a registered nurse and health visitor I will be able to use my professional judgment to assess capacity. Please see table below outlining the recruitment, consent assurance process.

Recruited from Baby Group/ in person	**Advert Poster or Online**
1. Parent speaks to me in person and expresses interest in taking part.	1. Parent sees Poster or advert on Facebook, Twitter, Mumsnet, Bounty forum.

	The Parent expresses interest by phone/text/email to me.
2. I will immediately • First check inclusion/ exclusion criteria. • Explain what the study involves and that consent can be withdrawn at any time. • Give the parent paper copies of the information pack comprising Letter, FAQs, Questionnaires, Consent form. After time to read the information & ask questions. I will • Ask parent to sign one copy of the consent form so that Session 1 may take place immediately in baby group. • Assign a code-name and obtain contact details for follow up.	2. I will immediately • First check inclusion/ exclusion criteria. • Explain what the study involves and that consent can be withdrawn at any time. • Direct the parent to www.blwresearch.com where they can find the online information pack comprising Letter, FAQs, Questionnaires, Consent form. OR Send out paper copies in the post if preferred. • Invite parent to make a provisional appointment with me for Session 1 at their regular baby group. Remind them that they may cancel this at any time (by texting me) if once they have read all the information, they change their mind. At Session 1 I will • Ask parent to sign one copy of the consent form. • Assign a code-name and obtain contact details for follow up.
3. At the end of session 1 I will make an appointment to return in 2 **months' time** (either to the baby group or at home) and at the same time give the participant an appointment card with my contact details on it. I will remind the participant that they can change their mind, cancel the appointment and withdraw from the study at any time, without prejudice. I will inform the participant that I will get in touch (by text message) 1 week before the second appointment as a reminder and to check they still want to take part.	
4. At session 2 and subsequent sessions, future appointments will be made at the end of the session, appointment cards given and participants will be contacted 1 week in advance of the next appointment to ensure ongoing consent.	

14. If participants are under 18 years of age, please describe how you will seek informed

	consent. If the proposed research is to be conducted in a school, please describe how you will seek general consent from the relevant authorities and attach a copy of any written consent.
A person with parental responsibility for the baby/child may consent to take part. Parents must be over 18 years of age to take part in the study.	

15.	How will consent be recorded?
Please see attached consent form.	

16.	Will participants be informed of the right to withdraw without penalty?	Yes	☑
		No	☐
If no, please detail the reasons for this: This is made explicit on the participant FAQs and will be verbally reiterated by me at the sessions. Participants will be informed that once data has been through the analysis stage it will be difficult to remove it from the study. Prior to this stage, I will be able to withdraw data pertaining specifically to their baby if they wish, because I will have access to the file of participants' codenames and personal details (see Q17 of this application).			

17.	How do you propose to ensure participants' confidentiality and anonymity?
Please see the 'About you and your baby/Child' Questionnaires. These will also contain all the data and the weight and measurement recordings. There will be no participant identifiable data on these sheets. Code names will be assigned by the researcher. A separate sheet with name and contact details will be necessary for follow up visits / longitudinal data analysis. There will be no personal identifiable information in the final thesis or published papers. Participants are made aware of the efforts made to ensure confidentiality and anonymity in the participant information sheets/FAQs. The only exception to this would be in the case of child safeguarding as mentioned in Q9 of this application.	

18. Please describe which of the following will be involved in your arrangements for storing data:

- ☑ Manual files (e.g. paper documents or X-rays)
- ☐ Home or other personal computer
- ☑ University computer
- ☐ Private company or work-based computer
- ☐ Laptop computer
- ☐ Other (please define)

Please explain, for each of the above, the arrangements you will make for the security of the data (please note that any data stored on computer must have password protection as a minimum requirement):

Locked filing cabinets in the university PGR students' room (Haldane 117).

Paper records of the data (no identifiable details on these sheets – codename only) and the file of codenames and contact details will be kept separately from each other in different cabinets with different keys.

Password Protection on student researchers' university computer in PGR students' room (Haldane 117)

19. Will payments or subject pool credits be made to participants?	Yes	☐
	No	☑

If yes, please specify quantities involved (e.g., £5 or 1 hour credits):

Applicant's signature: ______________________________ Date: __________________

Supervisor's signature: ______________________________ Date: _________________