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Identifying weight management clusters and examining differences in eating behaviour and psychological traits: An exploratory study

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ABSTRACT

Previous research has suggested differences in psychological traits and eating behaviours between groups of individuals with varying weight management profiles, for example, differences between individuals who have maintained weight loss compared to those who have not. However, no study has looked at differences in traits across a sample with a broad range of characteristics including variations in bodyweight and its management. Across two studies, we identified and validated weight management profiles using a clustering approach and examined trait differences across groups. Data were collected using online questionnaires (Study 1: secondary data analysis; Study 2: primary data analysis allowing for cluster validation). Cluster analysis was implemented with BMI, diet history, weight suppression (difference between highest and current weight) as primary grouping variables, and age and gender as covariates. Differences in psychological and eating behaviour traits (e.g., restraint) were explored across clusters. In study 1, 423 participants (27.21 ± 9.90 years) were grouped into 5 clusters: 'lean men', 'lean young women', 'lean middle-aged women', 'successful' and 'unsuccessful dieters'. The cluster structure was broadly replicated with two additional groups identified ('lean women without dieting' and 'very successful dieters') in study 2 with 368 participants (34.41 ± 13.63 years). In both studies, unsuccessful dieters had higher restrained and emotional eating scores than lean individuals, and in study 1, they also had higher food addiction scores than successful dieters. Individuals could be grouped in terms of their weight management profiles and differences in psychological and eating behaviour traits were evident across these groups. Considering the differences in traits between the clusters may further improve the effectiveness and adherence of weight management advice.

Despite the overall upward trend in overweight and obesity that is prevalent within many countries globally (NCD Risk Factor Collaboration, 2016), there remain individuals who seem to 'buck the trend'. For example, they may have remained lean across their lifetime (Yacamán-Méndez et al., 2021) or they may have successfully lost weight (Bray & Ryan, 2021) and maintained it over a significant time period (Paixão et al., 2020). One possibility is that those individuals who have had relative success managing their bodyweight, possess advantageous psychological and eating style traits.

A number of studies have examined such traits across participant groups characterised by particular weight trajectories. For example, Gold, et al. (2020) found that weight loss maintainers had higher levels of the personality trait of conscientiousness compared to weight re-gainers. While Neumann et al. (2018) found that weight loss maintainers with an unstable weight trajectory across 2 years were characterised by higher emotional and external eating scores compared to those with a stable weight trajectory, and both of these groups had higher restrained eating scores compared to a general population sample.

These previous studies have tended to compare such traits across particular target groups (e.g., weight loss maintainers compared to weight re-gainers), which has been a valuable approach to identifying strategies for long term weight loss. However, there has yet to be a study that has examined psychological and eating style traits across a sample with a wide range of characteristics including varying bodyweight and its management (i.e., recruitment does not target a particular bodyweight or weight trajectory). Cluster analysis is an exploratory analytical approach which allows for participants within a broad sample to be grouped based on their similarity on a particular set of factors. This approach, therefore, allows us to identify profiles of individuals

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characterised in terms of bodyweight and its management, and to make comparisons between them in terms of psychological and eating behaviour traits. Notably, a recent study used exploratory cluster analysis to explore patterns of eating behaviour amongst participants with severe obesity (Romain et al., 2022). This resulted in the identification of three profiles ('struggling with food', 'low loss of eating control' and 'pleasure from eating') that could be used to improve the personalisation of patient care. In our context, the identification of profiles across a sample with a broad range of characteristics including variation in bodyweight and its management (i.e., not purposively sampling for a particular bodyweight such as severe obesity) could contribute to research knowledge that helps to improve the personalisation of dietary and bodyweight management advice.

Moreover, the benefit of identifying profiles of individuals characterised by bodyweight and its management is firstly, to allow for the comparison of these profiles in terms of psychological and eating behaviour traits within a single model. This removes comparability issues when examining such traits across groups from different studies or datasets. Secondly, participants can be included who may just fall outside inclusion and exclusion criteria for studies that purposively sample particular bodyweights or weight trajectories. Indeed, in so doing, we can also compare the profiles yielded using a clustering approach with a broad sample to the groupings that are characterised within the broader literature. Finally, profiles identified may offer insight into how different traits may co-occur and indicate interrelationships to be explored in future research. For example, Romain, et al. (2022) found that low emotional and uncontrolled eating scores co-occurred within a single profile with higher psychosocial quality of life.

Therefore, across two studies, we sought to find groupings of individuals based on bodyweight and its management using cluster analysis, and to compare these groupings on a range of relevant psychological and eating style traits. In order to operationalise ideas around bodyweight management, we drew on Lowe's (1993) seminal and still pertinent 'Three Factor Model of Dieting'. This is a framework that identifies three facets of dieting behaviour; (1) frequency of dieting and overeating which speaks to historical cycles of dieting and subsequent overeating, (2) current dieting, and (3) weight suppression which speaks to weight loss. Therefore, in addition to body mass index (BMI: reflecting body weight adjusted for height), dieting history, current dieting status and weight suppression were considered within our approach.

For study 1, a secondary analysis of an existing dataset (Price, Higgs, & Lee, 2015) was conducted, this included widely used psychological and eating style trait measures that are relevant to bodyweight/BMI. Questionnaires such as the Power of Foods Scale (Lowe et al., 2009), the Dutch Eating Behaviour questionnaire (Van Strien, Frijters, Bergers, & Defares, 1986), and the Yale Food Addiction Scale (Gearhardt, Corbin, & Brownell, 2009) were included (a comprehensive list of all measures is included in the methods section). To identify groupings of BMI and weight management (these groups are hereafter called 'weight management profiles'), cluster analysis was used, which also allows for the consideration of other factors which might influence weight and weight loss such as age and gender (e.g., Li, et al., 2021; Lifestyles Team & NHS Digital., 2019; Svetkey et al., 2014). The benefit of taking a secondary data analysis approach is that it can provide a first insight on a new research question before refining an approach for a future original study (Smith et al., 2011). Indeed, here, study 2 was original research that sought to refine and validate the findings of the first study.

1. Study 1

The aims and methodology for Study 1 were pre-registered at the Open Science Framework (OSF; https://osf.io/g4stb/). A tentative hypothesis was pre-registered which predicted that amongst clusters, a grouping characterised by a lean bodyweight and low weight suppression would emerge and contrast with a grouping characterised by a lean bodyweight and high weight suppression as well as one characterised by a high bodyweight and low weight suppression. Otherwise, an exploratory approach was taken with respect to the comparison of psychological and eating behaviour traits across clusters, therefore no specific hypotheses were pre-registered. Nevertheless, based on previous literature, we broadly predicted that 'obesogenic' traits (e.g., disinhibited or emotional eating) would be higher amongst clusters characterised by a higher BMI combined with a lower weight suppression.

1.1. Methods of study 1

1.1.1. Participants

Participants were recruited by Price et al. (2015) from the student population at both Swansea University and the University of Birmingham, as well as from the wider community ($N = 496$). Of those, 423 participants' data were available for secondary data analysis (40 individuals had missing demographic data and 33 individuals were either missing weight or weight suppression values, or they were 'improbable', e.g., a BMI <14 kg/m^2). Sample size calculation was not undertaken due to a lack of a rule-of-thumb or standardised approach for cluster analyses (see also Siddiqui, 2013).

Participants were mostly female (77.54%), had an average age of 27.21 years, a BMI in the healthy range and were non-dieters, while most of the individuals who dieted in order to lose weight, had done so 1–3 times in the last three years (for all demographics see Table 1).

The original study was granted departmental ethical approval by the Swansea University, Department of Psychology Research Ethics committee.

1.1.2. Materials of study 1

Participants were presented with the Dutch Eating Behaviour Questionnaire (Van Strien et al., 1986), the short Three Factor Eating Questionnaire (Karlsson, Persson, Sjostrom, & Sullivan, 2000), Power of Food Scale (Lowe et al., 2009), Emotional Eating Scale (Arnow, Kenardy, & Agras, 1995), Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995), and Yale Food Addiction Scale (Gearhardt et al., 2009). Descriptions of these validated questionnaires can be found in supplemental data 1 A) and Cronbach's alpha levels of all questionnaires in Table 2.

1.1.3. Procedure for Price et al. (2015)

All questions were presented using Survey Monkey (Palo Alto, California, USA).

Students attended the lab to fill in the questionnaires, while community volunteers accessed them remotely. After the participant information and the written consent form, subjects were asked about their demographics such as gender, age, height, and weight. Next psychological and eating behaviour traits were assessed, followed by a debrief.

Table 1
Baseline demographic characteristics of sample.

	Value
Total N	423
Gender [female] [a]	328 (77.54)
Dieting status [are currently dieting] [a]	86 (20.33)
Dieting score (possible range: 0–4) [b]	1.09 (1.18)
Age [years] [b]	27.21 (9.90)
BMI [kg/m^2] [b]	24.23 (4.88)
Underweight [a]	22 (5.20)
"Healthy" weight [a]	264 (62.41)
Overweight [a]	98 (23.17)
Obesity [a]	39 (9.22)

[a] Results are presented as N (%).
[b] Results are presented as M(SD).

Table 2
Cronbach's alpha values for all questionnaires used according to Price et al. (2015).

Measure	Cronbach's alpha
DEBQ Dietary Restraint	.93
DEBQ External Eating	.85
DEBQ Emotional Eating	.92
TFEQ Cognitive Restraint	.81
TFEQ Uncontrolled Eating	.85
TFEQ Emotional Eating	.75
PFS Available	.89
PFS Present	.84
PFS Tasted	.79
EES Anger/frustration	.87
EES Anxiety	.78
EES Depression	.74
YFAS Symptom count	.62
BIS Motor	.70
BIS Attention	.68
BIS Nonplanning	.74
BIS Total	.84

DEBQ: Dutch Eating Behaviour Questionnaire, TFEQ: Three Factor Eating Questionnaire, PFS: Power of Food Scale, EES: Emotional Eating Scale, YFAS: Yale Food Addiction Scale, BIS: Barratt Impulsiveness Scale.

1.1.4. Secondary analyses of existing data

The dataset is openly accessible at the OSF (https://osf.io/g4stb/).

Weight and height were self-reported (37.6%) for some participants and for others measured (62.4%) in the lab. BMI based on self-reported and measured weight and height were combined for further analysis (details about the calculation and reasoning for the combination can be found in the supplemental data 1 B)).

A dieting score was created by combining scores for two questions (if the participant had ever dieted and if so, how often they dieted on separate occasions in the last 3 years), with '0' indicating that an individual had never dieted to lose weight, if they had dieted 1–3 times in the last three years it was scored '1', for 4–6 times '2', for 7–10 times '3' and for 11 times or more '4'.

Weight suppression was calculated as the difference between the current and highest weight excluding pregnancy. Additionally, a percentage change score was calculated for ease of comparability with current weight as denominator. Some differences between highest and current weight were negative, meaning that the current weight was higher than the highest reported weight. When participants with negative weight suppression were excluded, the same clusters were identified. Therefore, in order to retain participants who might have confused question about their highest and current weight ($n = 44$), the absolute weight difference (only the value without the sign) was utilized for further calculations.

In line with other cluster analyses (Romain et al., 2022; Walthouwer, Oenema, Soetens, Lechner, & de Vries, 2014) an alpha level of 0.05 was used. However, some exploratory analyses use a more conservative threshold of $p < 0.01$. Therefore, exact p-values are provided in the supplemental data 2 to facilitate readers' evaluation of our findings. The analyses were conducted using IBM SPSS Statistics (Version 22.0.0.1).

A hierarchical cluster analysis (CA) was performed with current BMI, dieting score, and weight suppression (in percentage and kg) as standardised z-scores, as well as gender and age as covariates. Squared Euclidean distance and Ward's method were used. Combining information from the dendrogram and the agglomeration schedule, five clusters seemed to be the optimal number. ANOVA/chi-square and post-hoc analyses, i.e., Games-Howell, were applied to assess differences between the clusters regarding current dieting and the variables which were used for the CA (for categorical variables Bonferroni corrections were applied).

Next, differences in psychological traits between the clusters were identified using MANOVA and post-hoc analyses (with Games-Howell for between-clusters and False Discovery Rate according to Benjamini-Hochberg (Genovese, Lazar, & Nichols, 2002) for between-variable differences) entering all traits at once.[1] Where responses to validated questionnaire measures were not normally distributed, logarithmic transformation was conducted. However, no difference in results before and after transformation could be found and therefore the original results (without transformation) are presented.

1.2. Results of study 1

1.2.1. Participant characteristics and cohort-level means

Cohort-level means for key measures can be found in Table 3.

1.2.2. Weight management clusters

In total, five clusters were identified. Values for key characteristics can be found in supplemental data 1 C) and a graphical representation in Fig. 1.

Two clusters emerged that represented 'lean men' (cluster 1) and 'lean young women' (cluster 2). They combined low diet score – therefore low diet frequency – and low weight suppression with a low percentage of participants who currently diet (men: 6.8% and women: 12.1%) and a BMI in a 'healthy' range. This indicates that individuals within these clusters manage to stay lean with little or no need for dieting. There were differences in dieting score and BMI which might be due to gender and age (men: 28 years versus women: 21 years). Cluster 3

Table 3
Participants' characteristics.

	Value
Current weight [kg]	67.84 (15.57)
Highest weight [kg]	72.21 (17.08)
Absolute weight suppression [kg] [a]	4.88 (5.89)
Absolute weight suppression [%] [a]	7.28 (8.36)
EES	
Anger/Frustration (possible: 11–55)	21.14 (7.83)
Anxiety (possible: 8–40)	17.77 (6.09)
Depression (possible: 6–30)	14.86 (4.52)
Total (possible: 25–125)	53.77 (16.33)
PFS (possible: 1–5)	
Food available	2.48 (1.10)
Food present	3.12 (1.05)
Food tasted	2.88 (0.88)
Total	2.80 (0.89)
TFEQ (possible: 1–4)	
Restrained eating	2.57 (0.77)
Uncontrolled eating	2.31 (0.59)
Emotional eating	2.32 (0.74)
DEBQ (possible: 1–5)	
Cognitive restraint	2.84 (0.98)
Emotional eating	2.52 (0.84)
External eating	3.11 (0.69)
BIS11	
Motor impulsiveness (possible: 11–44)	23.49 (4.83)
Attentional impulsiveness (possible: 8–32)	17.59 (3.74)
Nonplanning impulsiveness (possible: 11–44)	24.84 (5.22)
Total (possible: 30–120)	65.92 (11.10)
YFAS (possible: 0–7)	1.95 (1.46)

All results are presented as M(SD); EES: Emotional Eating Scale, PFS: Power of Food Scale; TFEQ: Three Factor Eating Questionnaire; DEBQ: Dutch Eating Behaviour Questionnaire; BIS11: Barratt Impulsiveness Scale; YFAS: Yale Food Addiction Scale.

[a] Absolute weight suppression is the absolute value of weight suppression (meaning the values themselves without the signs).

[1] A deviation between the pre-registered analysis plan is noted, a MANOVA rather than ANOVA was used to examine the difference in psychological and eating behaviour traits across clusters.

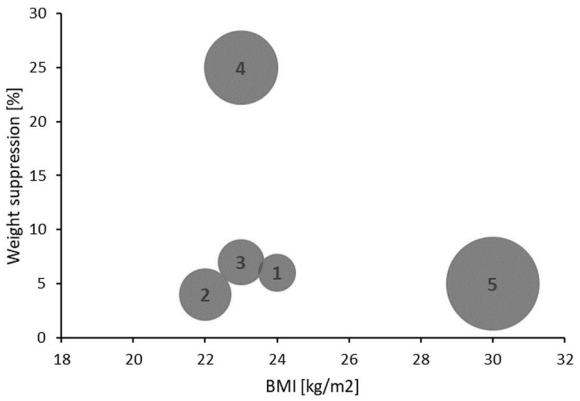

Fig. 1. Graphical representation of the main characteristics of the clusters. The size of the circles represents the diet score of each cluster. The number represents the number of the cluster: 1. 'lean men' (n = 73), 2. 'lean young women' (n = 165), 3. 'lean middle-aged women' (n = 58), 4. 'successful dieters' (n = 47), and 5. 'unsuccessful dieters' (n = 80).

was labelled 'lean middle-aged women' with similar dieting scores and BMI as lean men and young women.

'Successful dieters' were the fourth cluster and comprised of men and women. This cluster was characterised by a high dieting frequency and a higher percentage of individuals who currently diet (34.0%) compared to the lean groups (Clusters 1, 2 and 3) along with higher weight suppression. This group of participants seem to be dieters who are successful in their efforts to lose weight. The final cluster can be described as 'unsuccessful dieters' (dieting is often attempted but efforts are not successful), as they had a high dieting frequency (diet score) and a high BMI but low weight suppression. Of all the clusters, the 'unsuccessful dieters' had the highest percentage of individuals who were currently dieting (46.3%).

1.2.3. Comparison of psychological and eating behaviour traits between clusters

The main differences in traits between the clusters are presented graphically in Fig. 2 and a table of all traits can be found in supplemental data 1 D).

Across clusters, 'unsuccessful dieters' had the highest scores for all psychological and eating behaviour traits except for cognitive restraint (DEBQ and TFEQ), external eating and non-planning impulsiveness. Notably, 'unsuccessful dieters' differed significantly from 'successful dieters' in the present subscale of the PFS and food addiction only. In addition, the 'unsuccessful dieters' cluster differed from the 'lean men' and 'lean middle-aged women's' clusters across a number of different measures; there were significant differences between 'unsuccessful dieters' and 'lean middle-aged women' on most traits (except for PFS tasted, TFEQ-restrained eating and BIS-11 nonplanning impulsiveness). For the 'lean male' cluster compared to the 'unsuccessful dieters', there were significant differences for motor and total impulsiveness, restraint, emotional eating due to anger/frustration and depression (and the subscales of the TFEQ and DEBQ), PFS and food addiction.

'Successful dieters' had the highest score in both restraint scales (TFEQ and DEBQ); for the restraint scale from the TFEQ, this was significantly higher for 'successful dieters' than for all three of the lean clusters. For the restraint scale from the DEBQ this was significantly higher for 'successful dieters' than for 'lean men' and 'lean young women'.

Amongst the lean clusters, some differences were found, in particular between 'lean young women' and 'lean middle-aged women'. 'Lean young women' were more likely than 'lean middle-aged women' to eat due to anxiety or general negative emotions (TFEQ and DEBQ), due to hedonic or external cues, and had higher scores in uncontrolled eating, attentional and overall impulsiveness, and food addiction. In addition,

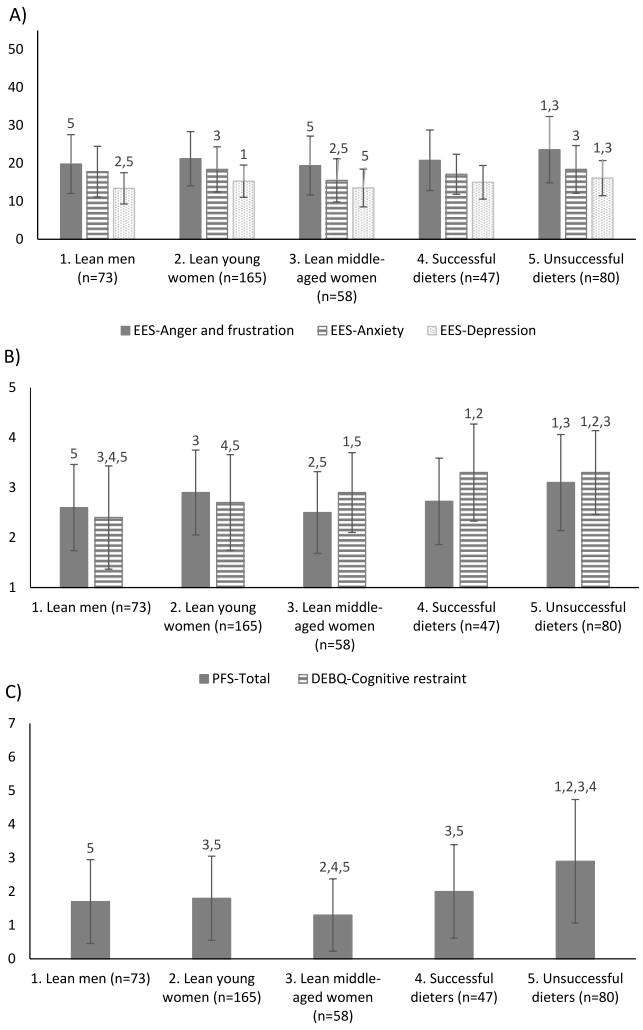

Fig. 2. Comparison of psychological and eating behaviour traits between the five clusters: A) emotional eating (EES), B) total hedonic hunger (PFS) and cognitive restraint (DEBQ), and C) food addiction (YFAS). The error bars represent the standard deviation. The numbers above the bars indicate a significant difference in the same trait (same coloured bar) to the clusters with this number, e.g., the anger and frustration score of 'lean men' is significantly different to cluster 5 ('unsuccessful dieters').

compared to 'lean men', 'lean young women' ate more due to depressive mood, the presence of hedonistic cues and had higher nonplanning and total impulsiveness. With respect to 'lean men', they had significantly higher scores in uncontrolled eating and lower scores in cognitive restraint (TFEQ and DEBQ) than 'lean middle-aged women'.

2. Interim discussion of study 1

Participants were clustered to identify groupings of individuals based on bodyweight and its management, and these clusters were then compared across a range of psychological traits including eating behaviours. In total five clusters were identified: 1) 'lean men', 2) 'lean young women', 3) 'lean middle-aged women', 4) 'successful dieters', and 5) 'unsuccessful dieters'.

Consistent with our hypothesis, clusters of individuals who are lean with little need for dieting were identified; these were 'lean men', 'lean young women', and 'lean middle-aged women' (BMI <25 kg/m^2) who had low weight suppression (<7%) and a low dieting score (<1). We also identified two clusters of dieters, successful who had a lean bodyweight and high weight suppression (>7%) and unsuccessful who were

overweight with low weight suppression and a high dieting frequency (>1). As expected, 'unsuccessful dieters' showed the highest values in 'obesogenic' traits such as emotional eating and food addiction, with the greatest cluster differences emerging between this group, and the 'lean men' and 'lean middle-aged women'.

When considering results obtained via cluster analysis, it is important to consider their validity, i.e., that the clustering identified is not peculiar to the particular sample. Researchers might consider internal cross-validation, whereby a sample is initially split into two and a clustering solution is tested in one of the sub-samples and validated with the other (e.g. Fu & Perry, 2020). Here, we were concerned not to reduce our sample size by taking this approach and instead sought to validate via replication (e.g. Rovniak et al., 2010). This involves collecting an independent second sample in a subsequent study that can be used to validate and confirm the initial cluster analysis. The aim of such an exercise is the consistent replication of the initial cluster structure within the second sample. Therefore, a second study was conducted. In addition, since study 1 was a secondary data analysis using a sample collected to primarily address another research question, a second study allowed for the modest addition of measures pertinent to the current research question.

3. Study 2

The overarching aim of study 2 was to validate and confirm the primary cluster structure identified in study 1 via replication. In so doing we aimed to address our broader research question of identifying groupings of individuals based on their bodyweight and its management. The pre-registered hypotheses states that similar clusters to those in study 1 would be identified. Our secondary aim was to optimise and confirm findings assessing differences in psychological and eating behaviour traits across clusters. Similar to study 1, no specific hypotheses were pre-registered regarding the differences in traits. Nevertheless, based on study 1 and previous research, we broadly predicted that 'obesogenic' traits (e.g., emotional eating) would be higher for a cluster characterised as 'unsuccessful dieters' (as named in study 1).

Three additional measures were added, time perspective (ZTPI), food craving (FCQ) as well as a questionnaire differentiating between flexible and rigid restraint, whilst other measures were removed, the TFEQ, PFS, YFAS and EES. These additions and removals are discussed in turn below. Study 2 was conducted as part of a larger study but for the sake of brevity only relevant results are presented here. The aims and methodology of the overall study were pre-registered at the OSF (https://osf.io/4b2ex/).

The first additional measure was time perspective which describes a person's view of their future, past and present. This was added because there is an increasing interest in the relationship between BMI and time perspective. Previous research found that future thinking was negatively associated with BMI, while past negative and present time perspective positively associated with BMI (Adams & Nettle, 2009; Griva, Tseferidi, & Anagnostopoulos, 2015; Guthrie, Butler, Lessl, Ochi, & Ward, 2014). However, little research has been conducted in relation to weight loss and maintenance. Secondly, the Food Craving Questionnaire (FCQ) was added as it was shown to distinguish between groups that are analogous to the clusters identified in Study 1 (individuals with little need to diet, successful and unsuccessful dieters), offering an opportunity to further validate our approach (Meule, Lutz, Vögele, & Kübler, 2012). Thirdly, measures of flexible and rigid restraint were added as this two-factor structure (Westenhoefer, Stunkard, & Pudel, 1999) may offer better understanding of the relationship between cognitive restraint, and BMI and weight management, which has at times been contested (Hawks, Madanat, & Christley, 2008; Westenhoefer, 1991; Westenhoefer et al., 1999). Indeed, rigid restraint is positively, and flexible restraint negatively related to intake (Hawks et al., 2008).

Lastly, in order to avoid repetition where possible, the TFEQ was removed because of the inclusion of flexible and rigid restraint which is a measure based on the TFEQ. Therefore, overall restraint was measured using the DEBQ only. The DEBQ also assesses emotional eating and external eating and therefore facilitated the removal of the EES and the PFS. Finally, considering overall questionnaire length and the relative controversy regarding its conceptual origins in food addiction (e.g., Fletcher & Kenny, 2018), we also removed the YFAS.

3.1. Methods of study 2

3.1.1. Participants

Recruitment of participants was UK-wide, utilising social media, websites aimed at participant recruitment (e.g., www.callforparticipants.com), as well as Swansea University online staff community boards and distribution channels via other universities. Prospective participants were excluded if they met the following criteria: under 18 years old, pregnant or breastfeeding, taking medication or being diagnosed with a condition influencing appetite, having a history of or current diagnosis of an eating disorder, and low proficiency in English.

According to Siddiqui (2013) there is no rule-of-thumb or standardised sample size calculation for cluster analysis, which is the primary analysis used. Therefore, the aim was to recruit a similar number of participants as in study 1 (N = 423). Due to the poor quality in responding, the current data fell slightly short of this goal. In total, 675 people clicked on the link to the survey. 128 individuals did not give consent and hence could not proceed to the main survey, 161 individuals did not complete the survey, 9 individuals skipped eligibility questions, and 9 individuals reported a BMI <18 kg/m^2 (to minimise the risk of including individuals with possible eating disorders). Therefore, data for 368 participants was available for analyses.

The majority of participants were female (76.9%), white (78.3%), and non-smokers (92.4%), with an average age of 34.41 years (SD = 13.63 years) (for demographics see Table 4).

Participants were entered into a prize raffle for Amazon e-vouchers of 2 x £25 if they completed the study. The study was approved by the Research Ethics Committee of the Department for Psychology, Swansea University.

3.1.2. Materials

External, emotional and restrained eating were measured using the Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien et al., 1986) and impulsiveness was assessed using the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995). Additionally, time perspective (ZTPI), food craving (FCQ-T-r), flexible and rigid restraint were assessed. Descriptions of the questionnaires can be found in the supplemental data 1 E) and Cronbach's alpha values for all questionnaires are presented in Table 5.

Table 4
Baseline demographic characteristics of sample.

	Value
Total N	368
Gender [a]	
Male	83 (22.6)
Female	283 (76.9)
Other	2 (0.5)
Gender identity [a]	
The same as at birth	367 (99.7)
Different to birth	1 (0.3)
Dieting status [are currently dieting] [a]	85 (23.1)
Age [years] [b]	34.41 (13.63)
BMI [m/kg^2] [b]	25.06 (5.03)
'Healthy' weight [a]	220 (59.8)
Overweight [a]	140 (38.0)
Missing [a]	8 (2.2)
Dieting score (possible range: 0–4) [b]	0.58 (0.58)

[a] Results are presented as N (%).
[b] Results are presented as M(SD).

Table 5
Cronbach's alpha values for all questionnaires used in study 2.

	Cronbach's alpha
DEBQ	
Cognitive restraint	.88
Emotional eating	.94
External eating	.83
Flexible restraint	.79
Rigid restraint	.75
BIS-11	
Attentional impulsiveness	.70
Motor impulsiveness	.63
Nonplanning impulsiveness	.74
Total	.83
ZTPI	
Past negative	.86
Present hedonistic	.83
Future	.78
Past positive	.80
Present fatalistic	.80
DBTP	
FCQ-T	.95

3.1.3. Procedure

All questionnaires were designed and presented using the online survey platform Qualtrics, www.qualtrics.com (Provo, Utah, USA).

After confirming written consent, participants completed demographic questions and provided further background information such as smoking and dieting status. Participants responded to a battery of measures of psychological and eating behaviour traits which were kept in the same order for each participant: DEBQ, flexible and rigid restraint, BIS-11, ZTPI and FCQ-T-r. Participants were asked to provide their email address which was used to inform the participant if they had had been successful in the prize draw. Participants were either debriefed immediately or at a later time and thanked for their participation at the end of the main questionnaire.

3.1.4. Analyses

All analyses were performed in IBM SPSS statistics 23. The data are deposited at OSF (https://osf.io/p3q2w/).

To assess the influence of time perspective, the Deviation from the Balanced Time Perspective (DBTP) was calculated (Stolarski, Bitner, & Zimbardo, 2011; Zhang, Howell, & Stolarski, 2013). An explanation of the calculation is presented in supplemental data 1 F).

Otherwise, the procedures as described in study 1 were followed.

3.2. Results of study 2

3.2.1. Participant characteristics and cohort-level means

An overview of the participant characteristics can be found in Table 6 and Table 7. Notably, about half of the sample (45.7%) had never dieted while most of the dieters (49.2%) had done so about one to three times in the last three years.

3.2.2. Weight management clusters

In total seven clusters were identified (basic characteristics of each cluster in Fig. 3 and supplemental data 1 G)).

Clusters 1 to 4 represented all lean participants with a 'healthy' BMI combined with a low diet score. Clusters 1 and 3 had the lowest dieting scores, with cluster 1 comprised of 'lean men' with a very low dieting score and cluster 3 comprised of 'lean women without dieting' who reported never dieting. Amongst clusters comprised of women (2, 3 and 4), differentiation was based firstly on dieting score with the 'lean young women' (cluster 2) dieting the most, followed by the 'lean middle-aged women' (cluster 4) and then the 'lean women without dieting'. Secondly, BMI was similar for the 'lean young women' and 'lean middle-aged women' but was significantly lower for the 'lean women without dieting'. Thirdly, weight suppression for the 'lean women without dieting' and the 'lean young women' was lower than for the 'lean middle-aged women'. Finally, 'lean middle-aged women' were older (56.2 ± 7.7 years) than the other two lean clusters comprised of women ('lean young women' = 25.4 ± 4.7 years and 'lean women without dieting' = 26.7 ± 6.5 years).

Clusters 5 ('young successful dieters') and 6 ('very successful dieters') comprised participants with a 'healthy' or slightly overweight BMI with high weight suppression. Cluster 7 ('unsuccessful dieters') was characterised by obesity and low weight suppression. The diet scores and number of individuals who currently diet was not significantly different between the groups of dieters.

Table 6
Categorical participants' characteristics.

	N (%)
Ethnicity	
White	288 (78.3)
Mixed, multiple ethnic groups	8 (2.2)
Asian, Asian British	62 (16.8)
Black, African, Caribbean, black British	3 (0.8)
Other ethnic groups	6 (1.6)
Prefer not to say	1 (0.3)
Occupation	
Student	155 (42.1)
Full-time employment	123 (33.4)
Part-time employment	42 (11.4)
Self-employment	20 (5.4)
Parent, carer, unemployed	27 (7.3)
Missing	1 (0.3)
Living situation	
Alone	48 (13.0)
Shared flat	102 (27.7)
With partner	99 (26.9)
With family	118 (32.1)
Missing	1 (0.3)
If ever on diet	
No	168 (45.7)
Yes	200 (54.3)
Bariatric surgery	
No	338 (99.7)
Yes	1 (0.3)
Dieting Score	
Never dieted	168 (45.7)
Dieted 1–3 times in last 3 years	181 (49.2)
Dieted 4–6 times in last 3 years	16 (4.3)
Missing	3 (0.8)

3.2.3. Comparison of psychological and eating behaviour traits between clusters

The main differences in traits between the clusters are presented graphically in Fig. 4 and a table of all traits can be found in supplemental data 1 H).

'Unsuccessful dieters' did not differ in any of the psychological traits from the two successful dieters' clusters. However, the restrained and emotional eating scores for the 'unsuccessful dieters' were significantly higher than the scores for the lean men and women who do not need to diet. 'Unsuccessful dieters' also scored higher in food craving and emotional eating compared to the lean middle-aged women's cluster. For time perspective, there was only a significant difference in the present fatalistic time perspective between 'unsuccessful dieters' and 'lean young women', but not for any other sub-scale. No difference between 'unsuccessful dieters' and any of the other clusters in time perspective was found.

The 'young successful dieters' had the highest scores in restraint (DEBQ, rigid and flexible restraint), as well as in food craving. The restrained eating (DEBQ, rigid and flexible) and food craving scores were significantly different to the 'lean men' and 'lean women without dieting' clusters. Additionally, emotional eating was higher for 'young successful dieters' than for 'lean men' and food craving higher than 'lean middle-aged women'. The 'very successful dieters' cluster did not show

Table 7
Continuous participants' characteristics.

	M (SD)
Weight [kg]	70.38 (16.78)
Highest weight [kg] [a]	76.24 (19.34)
Height [cm]	167.04 (8.99)
Weight suppression [kg]	6.10 (7.81)
Weight suppression [%]	8.76 (11.63)
Exercise [min per week]	
Light activities	204.57 (192.41)
Moderate activities	31.24 (73.72)
Vigorous activities	53.22 (101.42)
Strength workout	57.54 (97.18)
Exercise score	542.44 (515.81)
Mean exercise score	67.80 (64.48)
DEBQ (possible: 1–5)	
Cognitive restraint	2.77 (0.81)
Emotional eating	2.70 (0.93)
External eating	3.16 (0.63)
Flexible restraint (possible: 1–12)	5.76 (3.13)
Rigid restraint (possible: 1–16)	6.34 (3.47)
BIS-11	
Attentional impulsiveness (possible: 8–32)	16.38 (3.74)
Motor impulsiveness (possible: 11–44)	21.89 (4.05)
Nonplanning impulsiveness (possible: 11–44)	23.73 (4.99)
Total (possible: 30–120)	61.99 (10.32)
ZTPI (possible: 1–5)	
Past negative	3.02 (0.79)
Present hedonistic	3.18 (0.56)
Future	3.54 (0.56)
Past positive	3.49 (0.69)
Present fatalistic	2.58 (0.68)
DBTP	2.20 (0.61)
FCQ-T (possible: 15–90)	44.29 (15.48)

BMI: Body Mass Index, WIMD: Wales Index of Multiple Deprivation, DEBQ: Dutch Eating Behaviour Questionnaire, BIS-11: Barratt Impulsiveness Scale, ZTPI: Zimbardo Time Perspective Inventory, DBTP: Deviation from the Balanced Time Perspective, FCQ-T: Food Craving Questionnaire – Trait.

[a] This is the highest weight an individual has had since their current height excluding pregnancy.

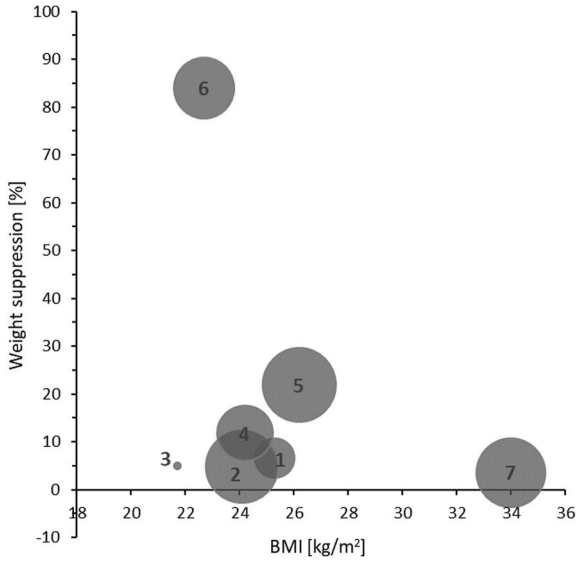

Fig. 3. Graphical representation of the main characteristics of the clusters. The size of the circles represents the diet score of each cluster. The number represents the number of the cluster: 1. 'lean men' (n = 68), 2. 'lean young women' (n = 65), 3. 'lean young women without dieting' (n = 81), 4. 'lean middle-aged women' (n = 43), 5. 'young successful dieters' (n = 40), 6. 'very successful dieters' (n = 4), and 7. 'unsuccessful dieters' (n = 38).

significant differences to any of the other clusters.

Across the lean clusters, the greatest number of differences were found by comparison to the lean men's cluster. 'Lean men' had lower scores than 'lean young women' in restrained (DEBQ, flexible and rigid) and emotional eating, future time perspective and food craving, but higher scores in present fatalistic time perspective. Restraint and future time perspective were also lower for 'lean men' than 'lean middle-aged women'. In contrast, attentional and total impulsiveness as well as past negative time perspective were higher in the lean men's cluster compared to the lean middle-aged women's cluster. Compared to the 'lean women without dieting', 'lean men' had lower future time perspective. 'Lean young women' and 'lean women without dieting' differed in restrained eating (DEBQ, rigid and flexible) and food craving. However, 'lean women without dieting' and 'lean middle-aged women' contrast only in restraint (DEBQ, rigid and flexible), but not in food craving. Differences between 'lean middle-aged women' and 'lean young women' can be found in emotional eating and food craving.

4. Overall discussion

The overarching aim of these studies was to identify groupings across a broad sample based on bodyweight and its management. In line with our hypothesis and in support of Lowe's three factor model of dieting, three types of clusters emerged across the two studies similarly to the groupings used in previous literature: lean individuals with little or no need to diet historically or currently, successful dieters who were currently lean but had a history of dieting and had previously had a higher body weight, and unsuccessful dieters who had overweight and little difference to their highest weight despite current and history of dieting. Individual clusters within these categories were also characterised further by age and gender, which was considered less in previous research. Notably, whilst these broad categories were replicated across Studies 1 and 2, there were some differences in the structure of individual clusters within these categories that are discussed further below.

The secondary and exploratory aim was to compare the weight management clusters regarding their psychological and eating behaviour traits. In line with our overarching prediction, we found that traits that are often regarded as obesogenic were associated with our clusters characterised by higher BMI combined with a lower weight suppression, labelled 'unsuccessful dieters'. Indeed, most differences in traits were observed between the 'unsuccessful dieters' and clusters with lean individuals, supporting previous literature. In study 1, 'unsuccessful dieters' had higher scores in restraint, emotional and hedonic eating, and food addiction than lean men and women. 'Unsuccessful dieters' also had higher scores on external and uncontrolled eating compared to middle-aged women. This is in line with the weight management literature in which participants with unstable weight showed higher scores in restrained compared to general population and additionally higher external and emotional eating scores than individuals with stable weight (Neumann et al., 2018). Also, higher emotional eating was related to weight regain (Grief & Miranda, 2010), indicating influences of these psychological factors on weight loss and maintenance. The results of study 1 were partially supported by study 2, which showed higher (rigid) restrained and emotional eating compared to the 'lean men' and 'lean young women'.

In study 1, 'Unsuccessful dieters' not only had significantly higher food addiction scores than participants in the lean groups, but also compared to the successful dieters group. Additionally, hedonic hunger of present foods was higher than 'successful dieters'. Notably, these two traits are the variables with the highest compulsiveness on the uncontrolled eating continuum proposed by Vainik, García-García, and Dagher (2019), and might indicate an important factor responsible for the success of weight loss maintenance. The theory proposes placing psychological traits which assess either the reason for overeating or loss of control over eating on a continuum based on an increase of severity and compulsiveness of uncontrolled eating. The continuum ranges from

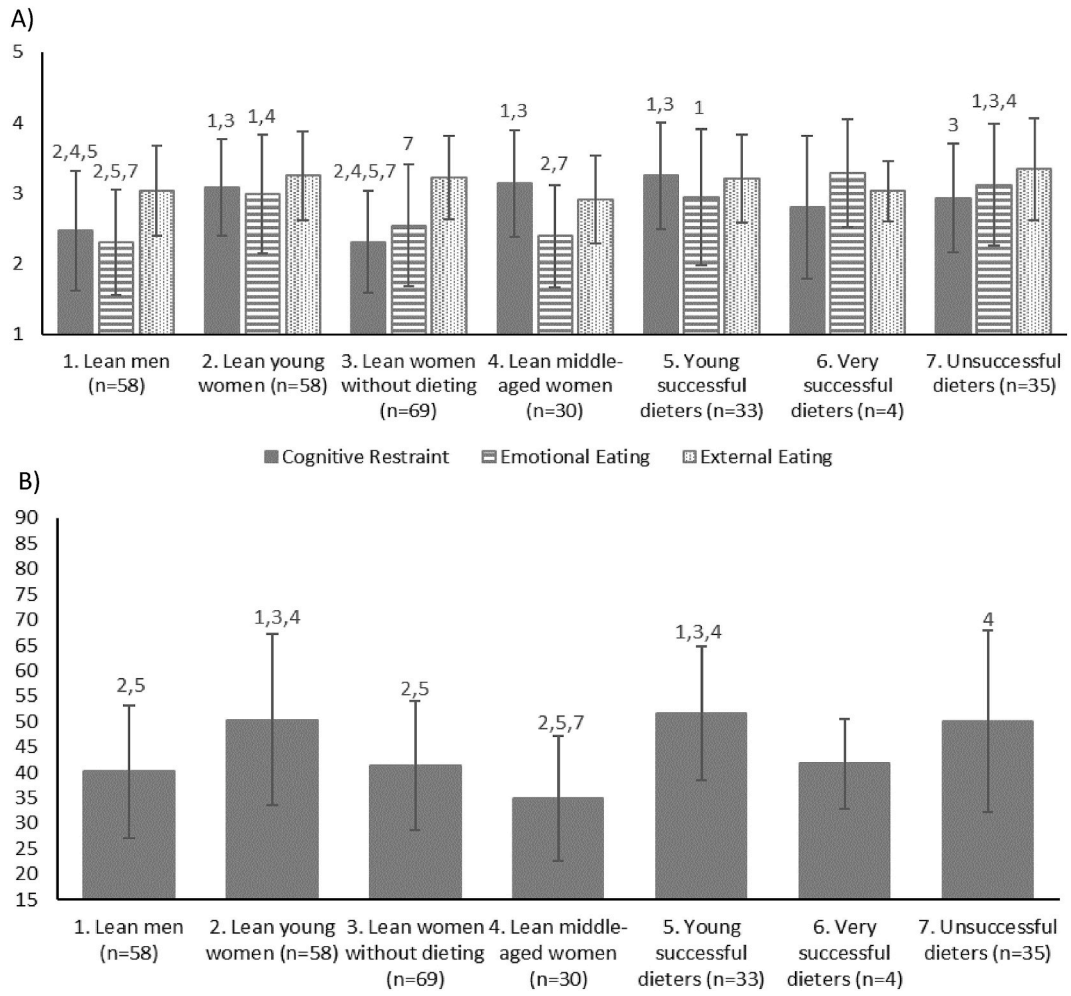

Fig. 4. Comparison of psychological and eating behaviour traits between the seven clusters: A) restrained, emotional, and external eating (DEBQ), B) Food craving (FCQ-T). The error bars represent the standard deviation. The numbers above the bars indicate a significant difference in the same trait (same coloured bar) to the clusters with this number, e.g., the food craving score of lean men is significantly different to clusters 2 ('lean young women') and 5 ('young successful dieters').

"passive overeating" (occasional impulsive overeating), over emotional and disinhibited eating to binge eating and can lead to food addiction (assessed by the YFAS). Factors of this uncontrolled eating phenotype were related to BMI and some of the constructs, such as disinhibition, also to intake (Price et al., 2015; Vainik et al., 2019; Vainik, Neseliler, Konstabel, Fellows, & Dagher, 2015). Since hedonic hunger and food addiction have the highest severity of uncontrolled eating, it is harder for individuals with higher scores in these traits to manage their intake leading to a higher BMI and a higher probability to struggle losing weight or to regain weight after weight loss.

Our results also provide further support for the non-linear relationship between BMI categories and food addiction suggested by Meule (2012), which might explain the inconsistent results in previous literature which had assumed a linear relationship. In Fig. 5, the BMI categories of the clusters as well as of the whole sample were mapped on the curve reported by Meule (2012) and show a similar line. It also provides a visual representation of a higher food addiction score of the 'unsuccessful dieters' (cluster 5 in study 1) compared to the other clusters with a lower BMI (also discussed in the paragraph above).

Notably, in both studies, there was one cluster with only men, while there were two or three clusters with only women. This may be because the overall sample included more women than men (study 1: $n = 77.5\%$ women; study 2: $n = 76.9\%$ women) and therefore the men were limited in diversity on our clustering measures. Another possibility is that it may indicate that it is only at the leaner end of the spectrum that gender is a

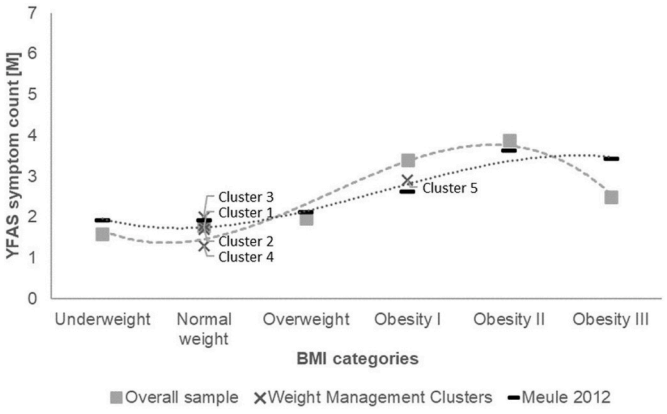

Fig. 5. Relationship between the mean YFAS symptom count and BMI category of overall sample (grey squares) and the clusters (grey x) in presented study as well as of the sample presented by Meule (2012) (black). Curved lines represent third order polynomial trend lines (overall sample of presented study = dashed line ($R^2 = 0.940$) and sample by Meule (2012) = dotted line ($R^2 = 0.095$)). Cluster 1 = Lean men, Cluster 2 = Lean young women, Cluster 3 = Lean middle-aged women, Cluster 4 = Successful dieters, Cluster 5 = Unsuccessful dieters.

meaningful differentiator. The all-male clusters were lean and had the lowest scores in restrained eating, emotional eating, food addiction, future time perspective and craving. This supports the current literature about gender differences in such traits (Cepeda-Benito, Fernandez, & Moreno, 2003; Provencher, Drapeau, Tremblay, Després, & Lemieux, 2003). Another possibility is that the gender differences were only evident for the leaner participant groups because a greater number of lean participants afforded power to detect these effects. By contrast, limited sample size amongst successful and unsuccessful dieter groups may have limited power to detect gender differences. Therefore, future research may consider the recruitment of similar numbers of individuals with 'healthy' and overweight/obesity.

Lean clusters were also differentiated by age, and these young and middle-aged clusters varied in psychological traits. In study 1, middle-aged lean women had lower values than the young lean women in most psychological and eating behaviour traits, such as in emotional, uncontrolled, and external eating, power of food and total impulsiveness. Since lower scores in these traits are related to lower BMI (Meule & Blechert, 2017; Price et al., 2015), these traits may have helped participants to maintain their healthy weight into their forties. However, in study 2, reversed relationships were observed, with middle-aged women showing higher scores in restrained eating (assessed by DEBQ, flexible and rigid restraint) compared to the younger women. This may be explained by differential weight suppression across studies with the 'lean middle-aged women' having a weight suppression of about 4 kg (7% of their highest weight) in study 1 compared to about 8 kg (12% of their highest weight) in study 2. In the weight loss maintenance literature, weight loss and maintenance were related to higher restraint (Grief & Miranda, 2010; Neumann et al., 2018). This might explain why the higher weight suppression was related to higher restraint scores in study 2, while the lower weight suppression in study 1 was associated with a lower restraint score.

Considering dieting history in addition to weight suppression gave a better picture of dieting behaviour and weight fluctuations, in particular for lean participants. The lowest weight suppressions were around 5%, which is considered clinically relevant weight loss (Ryan & Yockey, 2017), yet these individuals did not report dieting. This suggests that they do not use diets to keep a 'healthy' weight and that a moderate weight suppression of 5% might be a 'normal' state for many individuals. One possible explanation why these lean groups might not need to diet is that they use strategies to maintain their weight but do not label these as dieting to lose weight. This is consistent with a study by Gatzemeier, Price, Wilkinson, and Lee (2019). They found a wide range of strategies which were used to manage intake of tempting foods in the day-to-day life amongst participants who did not identify themselves as dieting and were lean. Future research might investigate if these strategies are not only effective in sustaining lifetime weight, but also in weight loss maintenance. Another possible explanation for why some participants did not need diets to maintain their 'healthy' weight might be the differences in psychological and eating behaviour traits as discussed above. Having lower scores in obesogenic traits such as emotional eating and food addiction might protect lean people from weight gain. Therefore, they do not need to lose weight and to use diets. For example, individuals with higher emotional eating scores use eating to deal with their emotions which can lead to overeating and weight gain. However, people with low emotional eating might have other coping strategies such as physical activity and therefore do not engage in the disinhibited eating behaviours which are associated with weight gain.

Another aspect to consider is the size of the differences in traits between the clusters using effect sizes (see supplemental data 2 for detailed comparisons and values). In study 1, most differences were of a small-to-medium effect[2] which can often be seen in eating behaviour research (e.g., Evers, Dingemans, Junghans, & Boevé, 2018; Price, Higgs, & Lee, 2016). However, for some group comparisons, restrained eating (TFEQ and DEBQ), uncontrolled eating and food addiction showed medium-to-large effect sizes. However, in study 2, most effect sizes were medium-to-large. For restrained eating and food craving, the differences were of small-to-medium or large effect size depending which groups were compared. While most differences were of small-to-medium and medium-to-large effect sizes across the two studies, also large effects were seen in study 2 for restraint and food craving. These results indicate that the differences might be large enough to have an impact on eating behaviour, intake, and weight. Therefore, psychological and eating behaviour traits should be considered when researching and giving advice for weight management.

A future study utilising our approach might consider recording length of dieting episodes and periods of time at a particular weight (e.g., current weight and highest weight) and/or the inclusions of a measure such as the 'Dieting and Weight History Questionnaire' (Witt, Katterman, & Lowe, 2013). This would be helpful in identifying whether our 'successful dieters' in both studies could be considered weight loss maintainers due to a maintained reduced bodyweight over particular time periods (e.g., one year). These additional measures would also be helpful in further characterising the 'very successful dieters cluster' which emerged in study 2. These individuals lost on average 84% of their highest bodyweight but did not indicate that they underwent bariatric surgery, had a low dieting frequency (<1) and a 'healthy' BMI ($M = 22.7 \pm 2.2$ kg/m^2). There might be a range of explanations for this strong weight loss. These participants may have attended a commercial diet program for many years and lost weight over the time. Further information would also help to eliminate the possibility that this cluster is due to methodological issue, for example, these participants were outliers and mistyped their highest weight.

4.1. Implications

These results have a range of implication for future research and contribute to the evidence base underpinning the personalisation and improvement of weight management advice.

Firstly, the cluster analysis supported the weight management groupings which have been used in previous research (McGuire, Wing, Klem, & Hill, 1999). Therefore, the reliability of the results of these previous studies is strengthened. However, our results also provided evidence that factors such as age, gender and dieting history should be considered together with weight and weight loss to characterise individuals more precisely (further discussed in the paragraphs above).

Secondly, this more precise characterisation may help to personalise weight management advice based on the needs and dieting history of the individual, and therefore potentially making it more effective. Additionally, the results showed differences in psychological and eating behaviour traits between the weight management clusters, such as higher scores in emotional eating and food addiction for unsuccessful dieters. Adequately incorporating advice that considers these traits in weight management approaches for particular groups may support success.

Thirdly, the identified clusters can be used as a basis for future research. A next step for improving weight management advice could be to identify the strategies utilized by people in particular clusters to manage food intake. Capitalising on strategies that are already engaged in to one degree or another (which may indicate a degree of acceptability and feasibility) and incorporating them into weight management advice, might be an opportunity to promote adherence to weight management approaches (Makris & Foster, 2011; Pagoto & Appelhans, 2013). Moreover, identifying acceptable strategies for each cluster may help to tailor advice according to weight management goal, for example weight loss, weight loss maintenance or lifetime weight maintenance.

[2] Classification based on Cohen (1992).

4.2. Strengths and limitations

Firstly, cluster analysis is an exploratory tool to group a sample based on researcher-chosen variables. To identify the number of clusters, the dendrogram and agglomeration schedule were used, which are somewhat subjective. In order to improve validity, the results of study 1 were replicated in study 2 with a separate sample (as suggested by Fu & Perry, 2020; Rovniak et al., 2010) and the methods pre-registered. Secondly, the majority of measurements were 'self-report' in nature. With respect to BMI, though self-reported height and weight can be under- and overreported, respectively, as discussed earlier, there is a strong relationship between self-reported and researcher-measured BMI. As such, self-reported BMI is widely used in the scientific literature (Celis-Morales et al., 2015; Pursey, Burrows, Stanwell, & Collins, 2014). Hence, a strength of the current study was the inclusion of researcher-measured BMI (60%) in Study 1. Thirdly, the studies were cross-sectional and no information was collected which would help to determine the causal relationship between the traits and clusters. Understanding the direction in a longitudinal context might help to design more successful weight loss and maintenance programs either by trying to change the psychological traits first or choosing the program based on the traits of the individual. Lastly, most of the traits between study 1 and 2 differed except restrained, emotional and external eating assessed with the DEBQ, and impulsivity measured by the BIS11. Therefore, comparison between the two studies regarding the traits was difficult. However, the main aim of study 2 was to validate the cluster structure and examining the differences in traits between the groups in an exploratory analysis. The wide range of traits is also one of the strengths of this study. As the data is open access, this allows other researchers to investigate more specific research questions with the help of our dataset.

4.3. Conclusion

In both studies, clusters of individuals who are lean with little or no need for dieting, successful and unsuccessful dieters were identified using the diet history and weight suppression factors in line with the Three-Factor Model of Dieting (Lowe, 1993). This supports the groupings of successful and unsuccessful weight loss used in previous research. However, additionally, lean individuals were differentiated according to gender, age and if they had never or only rarely dieted, which should be considered in future research and weight management advice. These clusters varied in their psychological traits, with 'unsuccessful dieters' showing higher restrained and emotional eating scores compared to lean individuals (in both studies). Study 1 also supported the uncontrolled eating continuum (Vainik et al., 2015) and the non-linear relationship between BMI and food addiction (Meule, 2012), with significant differences between successful and unsuccessful dieters in hedonic hunger and food addiction. More research about the directionality of the relationship between the traits and weight management is needed to personalise weight loss and maintenance programs by changing the psychological traits of the individual or choosing the program depending on the traits.

Author contributions

All authors contributed to conceptualisation, methodology, and writing – review&editing. JG was responsible for data curation, formal analysis, investigation, project administration, visualisation, and original draft preparation. LLW, MP and MDL were supervising. All authors approved the final article.

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Ethical statement

For study 1, the original study was granted departmental ethical approval by the Swansea University, Department of Psychology Research Ethics committee. Also study 2 received departmental ethical approval by the Swansea University, Department of Psychology Research Ethics committee.

For both studies, participants had to give consent in order to proceed the survey.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106039.

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