Forming new health behaviour habits during weight loss maintenance – The PREVIEW Study

Maija Huttunen-Lenz[1], Sylvia Hansen[2], Anne Raben[3,4], Margriet Westerterp-Plantenga[5], Ian Macdonald[6], Gareth Stratton[7], Nils Swindell[7], J. Alfredo Martinez[8], Teodora Handjieva-Darlenska[9], Sally D Poppitt[10], Marta P. Silvestre[10,11], Mikael Fogelholm[12], Elli Jalo[12], Jennie Brand-Miller[13], Roslyn Muirhead[13], Thomas M Larsen[3], Pia Siig Vestentoft[3], Svetoslav Handjiev[9], Wolfgang Schlicht[13]

[1]Institute of Nursing, University of Education Schwäbisch Gmünd, 73525 Schwäbisch Gmünd, Germany

[2]Cologne Center for Ethics, Rights, Economics, and Social Sciences of Health, University of Cologne, Cologne, Germany

[3]Department of Nutrition, Exercise and Sports, University of Copenhagen, 1958 Frederiksberg, Denmark

[4] Steno Diabetes Center Copenhagen, Gentofte, Denmark

[5]Maastricht University, Department of Nutrition and Movement Sciences, 6200 MD Maastricht, NL

[6]MRC/ARUK Centre for Musculoskeletal Ageing Research, National Institute for Health Research (NIHR) Nottingham Biomedical Research Centre, University of Nottingham, School of Life Sciences, Nottingham NG7 2UH, UK and and Scientific Director, Nestle Institute of Health Sciences, Nestle Research, Route du Jorat 57, CH 1000 Lausanne 26,

Switzerland.

[7]Sport and Exercise Sciences, Swansea University, Swansea, West Glamorgan, GB

[8]University of Navarra, Department of Nutrition and Physiology Pamplona, CIBER Fisiopatología Obesidad y Nutrición (CIBERobn), Instituto de Salud Carlos III, IMDEAfood Madrid, 28029 Madrid, Spain; IDISNA Navarra, Pamplona, Spain

[9]Medical University of Sofia, Department of Pharmacology and Toxicology, Sofia 1000, Bulgaria

[10]University of Auckland, Human Nutrition Unit, School of Biological Sciences, Department of Medicine, Auckland 1024, New Zealand

[11]CINTESIS, NOVA Medical School, NMS, Universidade Nova de Lisboa, 1169-056 Lisboa, Portugal

[12]Department of Food and Nutrition, 00014 University of Helsinki, Helsinki, Finland

[13]School of Life and Environmental Sciences and Charles Perkins Centre, University of Sydney, NSW 2006, Australia

[13]Department of Exercise and Health Sciences, University of Stuttgart, 70569 Stuttgart, Germany

Author notes

Maija Huttunen-Lenz* ORCID 0000-0002-1034-1613

Conceptualisation of the idea, investigation, project administration, data analysis, writing – original draft

Sylvia Hansen

Investigation, project administration, writing – review & editing

Anne Raben

PREVIEW Project and PREVIEW intervention study (RCT) concept and design, management,

funding acquisition (main), writing – review & editing

Margriet Westerterp-Plantenga

PREVIEW Project and Study concept and design, investigation, project administration, writing – review & editing

Ian Macdonald ORCID 0000-0002-7540-9850

Investigation, project administration, writing – review & editing

Gareth Stratton ORCID 0000-0001-5618-0803

Investigation, project administration, writing – review & editing

Nils Swindell

Investigation, project administration, writing – review & editing

J. Alfredo Martinez

Investigation, project administration, writing – review & editing

Teodora Handjieva-Darlenska

Investigation, project administration, writing – review & editing

Svetoslav Handjiev

Investigation, project administration, writing – review & editing

Sally D Poppitt ORCID 0000-0002-2214-8378

Investigation, project administration, writing – review & editing

Marta P Silvestre

Investigation, project administration, writing – review & editing

Mikael Fogelholm

PREVIEW Project and intervention study (RCT) concept and design, investigation, project administration, writing – review & editing

Elli Jalo

Investigation, project administration, writing – review & editing

Jennie Brand-Miller

PREVIEW Project and Study concept and design, investigation, project administration, writing – review & editing

Roslyn Muirhead

PREVIEW Project Study investigation, project administration, writing – review & editing

Thomas M Larsen

Design the PREVIEW intervention study (RCT), investigation, project administration, writing – review & editing

Pia Siig Vestentoft

Investigation, study administration, writing – review & editing

Wolfgang Schlicht ORCID-ID 0000-0002-2134-2259

PREVIEW Study and developing the PREMIT behaviour modification intervention concept and design, investigation, project administration, writing – review & editing

Correspondence concerning this article should be addressed to Maija Huttunen-Lenz, Institute of Nursing Science, University of Education, Oberbettringerstraße 200, 73525 Schwäbisch Gmünd, E-Mail: maija.huttunen-lenz@ph-gmuend.de

Disclosure statement

ClinicalTrials.gov Identifier: NCT01777893

Funding

The EU framework programme 7 (FP7/2007–2013) grant agreement # 312057. National Health and Medical Research Council – EU Collaborative Grant, AUS 8, ID 1067711. The Glycemic Index Foundation Australia through royalties to the University of Sydney. The New Zealand Health Research Council (14/191) and University of Auckland Faculty Research Development Fund. The Cambridge Weight Plan, UK donated all products

for the 8-week LED period. The Danish Agriculture & Food Council. The Danish Meat and Research Institute. National Institute for Health Research Biomedical Research Centre (NIHR BRC) (UK). Biotechnology and Biological Sciences Research Council (BBSRC) (UK). Engineering and Physical Sciences Research Council (EPSRC) (UK). Nutritics (Dublin) donated all dietary analyses software used by UNOTT. Juho Vainio Foundation (FIN), Academy of Finland (grant numbers: 272376, 314383, 266286, 314135), Finnish Medical Foundation, Gyllenberg Foundation, Novo Nordisk Foundation, Finnish Diabetes Research Foundation, University of Helsinki, Government Research Funds for Helsinki University Hospital (FIN), Jenny and Antti Wihuri Foundation (FIN), Emil Aaltonen Foundation (FIN). The funders of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report.

Conflict of interest

Anne Raben received honorariums from the International Sweeteners Association and Unilever. Pia Siig Vestentoft received travel grants from the Cambridge Weight Plan, UK. Ian Macdonald was a member of: the UK Government Scientific Advisory Committee on Nutrition; the Mars Scientific Advisory Council, the Mars Europe Nutrition Advisory Board; Scientific Adviser to the Waltham Centre for Pet Nutrition; Nestle Research Scientific Advisory Board; the Novozymes Scientific Advisory Board; and treasurer of the Federation of European Nutrition Societies and of the World Obesity Federation. Jenny Brand-Miller was President and Director of the Glycemic Index Foundation, oversees a glycaemic index testing service at the University of Sydney. Sally Poppitt was the Fonterra Chair in Human Nutrition and Principle Investigator for NZ National Science Challenge High Value Nutrition. Thomas Meinert Larsen is advisor for the ‘Sense’ diet programme. J. Alfredo Martinez is President of IUNS. All other authors have no conflicts of interest to declare.

Additional contribution – Please see Appendix 1

Abstract

Changing lifestyle habits to achieve and maintain weight loss can be effective in prevention of type 2 diabetes. Ability to resist temptations is considered one of the key factors in behaviour change. This study examined how both habit-strength, motivation, and temptations for an energy-dense diet developed during the maintenance stage of a behaviour modification intervention tool. Participants with prediabetes and overweight/obesity were recruited in the two-phase trial PREVIEW with the aim to achieve ≥8% body weight loss over 2 months, and maintain weight loss over a subsequent 34-month period. The four-stage intervention (PREMIT) supported participants in weight-maintenance. Uni- and multivariate analyses were completed from the beginning of the PREMIT maintenance stage (week 26 of the PREVIEW trial) with 962 individuals who completed the trial. Habit-strength and ability to resist temptations increased during the early PREMIT adherence stage (weeks 26 to 52) before plateauing during middle (weeks 52 to 104) and late (weeks 104 to 156) PREMIT adherence stages. Higher habit-strength for energy dense diet was significantly associated with larger weight-regain ($p \leq .007$). No changes in motivation or interaction with PREMIT attendance were observed. Changing diet habits is a complex, multifactorial process with participants struggling at least with some aspects of weight maintenance. Habits against consuming energy dense, sweet and fatty, food appeared effective in protecting against weight re-gain. The observed effect sizes were small reflecting the complexity of breaking old habits and forming new ones to support long term maintenance of weight loss.

Key words: Habits, temptations, motivation, weight-loss maintenance, diabetes type 2

Introduction

Habits such as physical inactivity or eating an energy-dense diet with high saturated fat and added sugar are major risk factors for developing type 2 diabetes (T2D) (Chan & Luk, 2016). Several studies have shown that progression from prediabetes to T2D can be prevented by modifying lifestyle habits such as an energy-dense diet and physical inactivity (Dombrowski et al., 2014; Lindström et al., 2003; Tamayo et al., 2014). However, maintenance of weight loss can be difficult to achieve (Dombrowski et al., 2014; Gardner et al., 2012; Rockette-Wagner et al., 2017).

Motivation, whether externally controlled through pressure and incentives to behave in a certain way or internally controlled through value placed on the behaviours, is an important determinant of successful behaviour change and maintenance (R. Ryan & Deci, 2000). Resisting temptations (i.e. resisting a desire to do something that one should not) is central during formation of new behaviours (Hausenblas et al., 2001). Temptations to consume energy-dense food or high added sugar diets, arise especially when cognitive functions such as planning and problem solving are disrupted by stress, insufficient sleep, and facing tempting stimuli (Appelhans et al., 2016; Burke et al., 2018). Research has suggested that healthy habits like being physically active or avoiding convenience foods, for instance, protect against temptations to consume energy-dense foods (Appelhans et al., 2016). Habits reduce demands on cognitive function necessary to resist temptations when, for example, tired or stressed (Appelhans et al., 2016; Lin et al., 2016).

Habits describe automated behaviours (automaticity), triggered by situational cues (de Vries et al., 2014; Gardner et al., 2015), and formed through repeated performance (Gardner, 2012). Once formed, a habit does not need frequent repetition. Essential for a habit is a cue-dependent automaticity. Habit-strength is a function of the frequency of an action retrieved in a stable context which has acquired a high degree of automaticity (de Vries et al., 2014;

Gardner et al., 2015; Labrecque & Wood, 2015). Habit-strength plateaus when a behaviour becomes automated (Lally et al., 2010) and is a strong predictor for future behaviours (Verhoeven et al., 2012). Furthermore, research has indicated that autonomous motivation, i.e. behaviours done due their own value not because external or internal rewards or threats, is associated with positive changes in health habits and better health outcomes (Ng et al., 2012; Ntoumanis et al., 2021).

Previously, both individual (Diabetes Prevention Program (DPP) Research Group, 2002) and group formats (The Look AHEAD Research Group, 2014) have been successfully used to achieve weight loss and weight loss maintenance. In the AHEAD study, group sessions introduced participants to behavioural weight maintenance techniques, and those who struggled with weight loss, received additional, individual, interventions (The Look AHEAD Research Group, 2006). Similarly, PREMIT (PREVIEW- Behaviour-Modification-Intervention-Toolbox), which formed a part of an international T2D prevention study PREVIEW (Kahlert et al., 2016; Raben et al., 2021) supported the formation of healthy eating habits, using group sessions with same content for all participants to target behavioural determinants such as motivation or self-efficacy associated with habit-formation (Figure 1) (Bandura, 1996; Michie et al., 2008; Richard Ryan et al., 2008).

Behaviour modification is a complex endeavour requiring initiating and maintaining new behaviours (Ryan et al., 2008). In most studies using a theory-based approach the focus is on the effectiveness of the behaviour change techniques in reaching the intervention outcome (e. g. increasing the physical activity volume). In this study a theory-based approach was employed to examine the intervening mechanisms or determinants leading to the outcomes (Bauman et al., 2002; Craig et al., 2008). It was assessed how habit-strength, motivation, and temptations for energy-dense food (e.g. consuming or buying food high in fat or sugar) varied during the maintenance stage of PREMIT (weeks 26 - 156 of the PREVIEW

RCT), which formed a part of an international T2D prevention study PREVIEW (Raben et al., 2021). Previously published results from weeks 8 - 26 showed that frequent PREMIT attendance was associated with lower habit-strength for an energy-dense food and lower weight re-gain (Huttunen-Lenz et al., 2019).

(1) Following hypothesis were formed: (a) in the early maintenance stage (weeks 26 - 52) – when new habits were formed – decreasing habit-strength for energy-dense food was associated with decreasing temptations for energy-dense food and with increasing autonomous and intrinsic motivation as well as with increasing ability to resist temptations; (b) during middle (weeks 52 - 104) and late (weeks 104 -156) maintenance stages habit-strength, autonomous motivation, temptations and resisting temptations would have reached a plateau, while extrinsic and intrinsic motivations decrease; (c) the hypothesised effects are moderated by attendance at the PREMIT group sessions. (2) As habit formation in PREVIEW was not an end in itself, but conducive to prevent weight re-gain, it was hypothesised that higher resistance to temptations, higher autonomous motivation, and lower habit-strength at week 156 were associated with lower weight re-gain. (3) Finally, it was hypothesised that more frequent PREMIT attendance was associated with lower weight re-gain.

Methods

Study design

The PREVIEW randomised controlled trial (RCT) comprised two phases. Phase I was an 8-week weight loss phase using a low-energy diet (Cambridge Weight Plan Ltd., Corby, UK). Phase II was a 34-month weight-maintenance phase for participants who had lost ≥8% of initial body weight during Phase I. Before starting phase II, eligible participants were randomised into different intervention arms with a 2 x 2 diet and physical activity factorial design (higher protein with lower glycemic index (GI) diet, or moderate protein with medium

GI diet; high-intensity physical activity or moderate-intensity physical activity). The full study protocol and the main results have been published elsewhere (Raben et al., 2021).

A transtheoretical approach allowed using different theories or theoretical models and techniques to support participants moving forward in their targeted behaviour change from one stage to another. PREMIT was designed to support diet and physical activity habit changes and was integral to the PREVIEW RCT. The PREMIT was based among others (e. g., Health Action Process Approach Schwarzer et al., 2008) on the transtheoretical stage model by Prochaska & DiClemente (1992). PREMIT used behavioural change techniques to encourage new behaviours to imbed into habits (Michie et al., 2008).

As shown in figure 1, PREMIT followed four stages (stage 1 preliminary, stage 2 preparation, stage 3 action, stage 4 maintenance) (Kahlert et al., 2016). During the PREVIEW study the participants were invited to follow a regimen of 18 group sessions. PREMIT stages followed a time division (starting in week 0 of Preview and ending in week 156). Participants following the PREVIEW study regimen were allocated in general to the different stages as the study progressed, but they were not assessed individually if they had reached a specific consciousness stage. PREMIT maintenance stage was divided additionally into an early (3 sessions), middle (3 sessions), and late (2 session) stage. This was done to reflect the main contents in the group session and the frequency of over the time (Figure 1).

The PREMIT was delivered by counsellors in groups of 10 - 20 participants. The overall approach was consistent across all four PREVIEW arms, irrespective of diet or exercise RCT assignment. As the main results indicated no significant differences between the groups in T2D incidence or weight change (Raben et al., 2021), for the purposes of the analyses here, participants were considered as a one group. Mirroring the common healthcare practice, participants' readiness to progress from one stage to the other was not assessed, but

instead participants were taught techniques that allowed them to move between the stages, for example, in cases of relapse.

During preparation and action stages (weeks 8 - 26) participants were supported in development of new behaviours, while at the maintenance stage (weeks 26 - 156) the emphasis was on forming the newly developed behaviours into habits. Habit formation was supported by enhancing self-regulatory mechanisms such as skills to prevent and manage relapses that could be incorporated into everyday life (for further details see Kahlert et al., 2016).

FIGURE 1 ABOUT HERE

Participant recruitment

Participants were recruited from eight study sites: Copenhagen, Denmark; Helsinki, Finland; Nottingham, United Kingdom; Maastricht, The Netherlands; Navarra, Spain; Sofia, Bulgaria; Auckland, New Zealand; and Sydney, Australia. Men and women with BMI ≥ 25kg/m^2, who were aged 25 to 70 years were eligible for participation. Pre-diabetes was confirmed following the American Diabetes Association criteria with an oral glucose tolerance test (OGTT) (American Diabetes Association, 2011). Participants we recruited by advertising in print and visual media, and by direct contact with primary and occupational health care providers. The relevant Human Ethics Committees approved the study protocol for each study site. Each participant provide a written informed consent (Fogelholm et al., 2017).

Data collection

Anthropometric (e.g. body weight and height), metabolic (e.g. HbA_{1c}), demographic (e.g. sex, age) and social-cognitive variables (e.g. habit-strength) were collected at weeks 26, 52, 104, 156 of the PREVIEW RCT (see Figure 1). Attendance frequency to PREMIT was

assessed from week 8. All measurements of social-cognitive variables were collected using standardised questionnaires, which, for non-English speaking countries, were translated into local languages. Using standard practice, the accuracy of the questionnaire translations was checked by back-translations.

Outcome measurements

Height and body weight. Height was measured at the screening visit in meters. Weight measured in light clothes at week 26, week 52, week 104, week 156.

Demographic characteristics. European Social Survey and International Social Survey (ESS, 2015).

Habit-strength for an energy-dense diet. The questionnaire included 6 items, 3 for eating high-fat or high calorie foods, and 3 for snacking between meals (based on Ji & Wood, 2007; Wood, Tam, & Guerrero Witt, 2005). The questions asked about behavioural frequency and stability of context over the past few weeks with maximum score of 343 reflecting strong habit-strength for high fat/high caloric food. Cronbach's Alphas were calculated separately for each time point ranging from $\alpha = .79$ to $\alpha = .80$, indicating satisfactory scale reliabilities.

Self-regulation of motivation – diet. The Treatment Self-Regulation Questionnaire (Levesque et al., 2007) with 15 items was used to measure four dimensions of motivation: autonomous i.e., inherent satisfaction of a behaviour; introjected i.e., valuing a behaviour as a mean to reach an important goal; extrinsic i.e., a behaviour as a mean to gain e.g. reward or approval from others; amotivation i.e., behaviour perceived as irrelevant (R. Ryan & Deci, 2000). The scale had the maximum score of 7, indicating strong tendency towards the particular self-regulatory style. Amotivation was not included in the analyses. Cronbach's Alphas were calculated separately for each time point and ranged from $\alpha = .82$ to $\alpha = .93$.

Diet temptations. Temptations for energy-dense food were measured with a 7-item scale abutted to the "Temptation to not Exercise Scale - subscale of competing demands"

with maximum score of 5 indicating strong temptations (Hausenblas et al., 2001). Cronbach's Alphas were calculated separately for each time point ranging from α = .88 to α = .90, indicating satisfactory scale reliabilities.

Resisting energy-dense diet temptations. Participants were asked about the ease of following a healthy diet as recommended in PREVIEW in different situations with maximum score of 5 reflecting lower resistance to temptations. The questionnaire was abutted to the "Influences on Physical Activity Instrument" (Donahue et al., 2006) and "Temptations for an Unhealthy Diet" (Hausenblas et al., 2001). Cronbach's Alphas were calculated separately for each time point ranging from α = .84 to α = .87, indicating satisfactory scale reliability.

With data at week 26, a principal components analysis with varimax-rotation was calculated. A two-factor solution emerged. Five of the items (passing a fast-food restaurant / a hard day / other eat fatty or sweet food / looking in the shops at sweet or fatty food / fatty and sweet food is available) loaded on factor "1" (*Eigenvalue* = 2.98) explaining 42.5% of the variance (factor label: "*accessing energy-dense food*"). Two of the items (eating out / celebrating) loaded on factor "2" (*Eigenvalue* = 1.78) explaining 25.4% of the variance (factor label: "*consuming energy-dense food*"). The two-factor solution explained 67.9% of the total variance. A confirmatory factor analysis with the data at week 52 affirmed the two-factor solution.

Statistical methods

Analyses were based on 962 participants who completed the PREVIEW RCT. For the moderation analysis, frequency of PREMIT attendance was calculated from the start of PREMIT action stage (week 8). The last visit, i.e., PREMIT wrap-up session 18 (see figure 1), was not included, leaving 13 sessions. Participants were retrospectively divided into three

groups: (1) *infrequent* (0 - 6 sessions attended, n = 228), (2) *frequent* (7 – 10 sessions attended, n = 449), and (3) *very frequent* (11 – 13 sessions attended, n = 285) attenders.

Weight-change percentage was calculated for the whole PREMIT maintenance stage as (Weight_Week156 – Weight_Week26)/Weight_Week26) *100. BMI was calculated as BMI = kg/m^2. For cognitive variables missing data were imputed. Sensitivity analyses with the original dataset were conducted. No extreme outliers were removed. Significant deviations from normality were found for habit-strength and autonomous motivation. Data transformations improved normal distribution only for autonomous motivation. Due to multiple testing and violations of the normal distribution, all statistical tests were considered significant at the level of $p \leq .008$ (Tabachnick & Fidell, 2014).

Mixed Multivariate Analysis of Variance (MANOVA) examined interactions and main effects between cognitive variables over time as within participants variables, and frequency of PREMIT attendance as between participants variable with Type IV model and Pillai's Trace criterion. Repeated measures ANOVAs with Greenhouse-Geisser corrections examined main effect. Three post hoc between participants comparisons were done at each timepoint as well as within participant pairwise comparisons between weeks 26 and 52 (early maintenance stage), weeks 52 and 104 (middle maintenance stage), and weeks 104 and 152 (late maintenance stage). Linear multiple regression was used to evaluate the association between weight-change percentage from week 26 to 156 (dependent variable) and cognitive variables at week 156 (as predictor variables). ANOVA was used to compare weight change percentage at week 156 between groups (PREMIT attendance frequency).

All analyses were completed using SPSS® v27 statistical program. Apart from ω^2, Cramer's *V*, and η^2_p, effect sizes ($d_{\text{Repeated Measures}}$, d_{Cohen}) were calculated using Lenhard and Lenhard (2016).

Results

Associations between participant characteristics and PREMIT attendance frequency

Older participants were found more likely to attend, while infrequent attenders had higher rate of employment. Participant characteristics and summary of the comparisons for the three groups of PREMIT attenders can be found in Appendix Table A1.

Habit-strength, motivations, and temptations over time in relation to PREMIT attendance frequency

Main effects were found for "time" ($F(12, 942) = 16.0$, $p \leq .008$, $\eta^2_p = .23$, large effect). No interaction effect on "time" (habit strength, motivation, temptations, and avoiding temptations) by "frequency of PREMIT attendance" ($F(36, 1886) = 1.1$, $p > .008$) or main effect for attendance frequency ($F(12, 1910) = 1.9$, $p > .008$) was found. Means and standard deviations before data transformations for habit-strength, motivation, and temptations for all participants and separated by PREMIT attendance frequency are shown in Table 1.

TABLE 1 ABOUT HERE

Main effect "time" – habit strength, temptations and motivation

Univariate repeated measures ANOVAs with Greenhouse-Geisser correction indicated significant changes over time regardless of the PREMIT attendance frequency: habit-strength ($F(2.9) = 41.9$, $p \leq .008$, $\eta^2_p = .04$, small effect); temptations ($F(2.9) = 31.8$, $p \leq .008$, $\eta^2_p = .03$, small effect); resisting temptations ($F_{(3.0)} = 23.3$, $p \leq .008$, $\eta^2_p = .02$, small effect); autonomous motivation ($F_{(3.0)} = 18.4$, $p \leq .008$, $\eta^2_p = .02$, small effect); introjected motivation ($F(3.0) = 4.8$, $p \leq .008$, $\eta^2_p = .01$, small effect); and external motivation ($F_{(3.0)} = 16.4$, $p \leq .008$, $\eta^2_p = .02$, small effect).

Pairwise comparisons "time" – early PREMIT maintenance stage (weeks 26 - 52)

Habit-strength (M_{Diff} = 9.6, $p \leq .008$, $d_{Repeated\ Measures}$ = .2, small effect) and diet temptations (M_{Diff} = .1, $p \leq .001$, $d_{Repeated\ Measures}$ = .2, small effect) increased significantly, while resisting energy-dense food temptations decreased significantly (M_{Diff} = -.1, $p \leq .008$, $d_{Repeated\ Measures}$ = -.2, small effect). Autonomous motivation increased statistically significantly, but effect size indicated no real changes (M_{Diff} = -.02, $p \leq .001$, $d_{Repeated\ Measures}$ = .0, no effect). No significant changes were observed for introjected (M_{Diff} = .1, $p > .008$) or external motivation (M_{Diff} = .1, $p > .008$).

Pairwise comparisons "time" – middle PREMIT maintenance stage (weeks 54 - 104)

Both habit strength (M_{Diff} = 5.8, $p \leq .008$, $d_{Repeated\ Measures}$ = .1, no effect) temptations (M_{Diff} = .1, $p \leq .008$, $d_{Repeated\ Measures}$ = .0, no effect) for unhealthy diet showed statistically significant changes, but effect size indicated no real changes. No significant changes were observed for resisting energy dense food temptations (M_{Diff} = -.0, $p > .008$), or autonomous (M_{Diff} = -.0, $p > .008$), introjected (M_{Diff} = .1, $p > .008$), and external (M_{Diff} = .1, $p > .008$) motivations.

Pairwise comparisons "time" – late PREMIT maintenance stage (weeks 104 - 156)

No significant changes were observed for habit strength (M_{Diff} = 3.5, $p > .008$), and temptations (M_{Diff} = .0, $p \geq .008$) or resisting temptations (M_{Diff} = .0, $p > .008$) for energy dense diet. For motivation no significant changes we found for either autonomous (M_{Diff} = -.0, $p > .008$), introjected (M_{Diff} = .1, $p > .008$), and external (M_{Diff} = .1, $p > .008$) motivations.

Associations of habit-strength, motivation, and temptations with weight-change

Multiple linear regression with weight-change percentage during the PREMIT adherence stage (weeks 26 to 156) as the dependent variable indicated that habit strength, motivation, and temptations at week 156 were significantly associated ($F(3, 953) = 22.3$, $p \leq .008$, $R^2 = .07$ / $R^2_{adj} = .06$, small effect). However, of the independent variables, only habit-

strength was found to be significantly associated with the weight-change (β = .1) with higher habit-strength associated with higher weight-change, i.e. higher weight re-gain (see Table 2).

TABLE 2 ABOUT HERE

PREMIT attendance and weight re-gain

Significant effect was found between PREMIT attendance frequency and weight re-gain (F_{Welch} (2, 524) = 8.7, $p < .008$, $\omega^2 = .02$, small effect). *Post-hoc* comparisons with Games-Howell correction indicated that very frequent attenders re-gained significantly less weight than frequent attenders ($M_{\text{Diff}} = –2.0$, $p \leq .008$, $d_{\text{Cohen}} = .3$, small effect). No significant difference was found either between very frequent and infrequent attenders ($M_{\text{Diff}} = –.5$, $p > .008$) or between frequent and infrequent attenders ($M_{\text{Diff}} = 1.5$, $p > .008$).

Discussion

The main focus in these analyses was to examine theory-driven assumptions of associations between intervention attendance, habit-strength for energy-dense food, motivation to eat healthy diet, and temptations for fatty and sweetened food during the maintenance stage of PREMIT behaviour modification intervention. The results conformed the hypotheses only partially. Against expectations, only main effect for “time” was found, without main effect for “PREMIT group attendance” or interaction between “time” and “attendance frequency”. However, at the end of the PREVIEW trial (week 156), more frequent PREMIT attendance was associated with lower weight re-gain. Results regarding participant characteristics were similar with previous literature (e.g. Diabetes Prevention Program (DPP) Research Group, 2002) with older participants more likely to attend.

Unexpectedly, habit-strength and temptations for energy-dense food increased – not decreased – while ability to resist temptations decreased – not increased - during the early PREMIT maintenance stage (weeks 26 - 52) stage. Furthermore, instead of increasing

autonomous or introjected motivation, no changes were observed. At the middle and the late maintenance stages, no further changes in cognitive variables were observed. Therefore, as expected, after the early maintenance stage the self-reported habit-strength (Lally et al., 2010), temptations, and resisting temptations plateaued (Appelhans et al., 2016; Lin et al., 2016). For motivation, expected decrease in introjected or external motivation was not observed during middle and late adherence stages (R. Ryan & Deci, 2000; Richard Ryan et al., 2008).

As with the behavioural components of the DPP and AHEAD trials (Diabetes Prevention Program (DPP) Research Group, 2002; The Look AHEAD Research Group, 2006), PREMIT supported development of new habits (Kahlert et al., 2016). Despite expectations that frequent participation at group sessions would equip participants to cope better with the challenges of weight loss maintenance, more frequent attendance was not associated with more favourable outcomes in social-cognitive variables, but was associated with lower weight re-gain. Although only compared to frequent attenders. Further, at the at the end of the PREVIEW weight maintenance phase, only higher habit-strength for energy-dense food was individually associated with greater weight re-gain.

Habits have been shown to protect from temptations especially in situations of reduced cognitive control (Appelhans et al., 2016; Lin et al., 2016). As expected (Gardner et al., 2012; Lally et al., 2010), habit-strength plateaued during middle and late PREMIT maintenance stages, when the new diet behaviours were expected to be embedded as habits, but only after habit-strength for an energy-dense diet unexpectedly increased during the early maintenance stage. Unexpected increase in habit-strength after rapid weight-loss (Phase I in PREVIEW RCT) was observed previously (Huttunen-lenz et al., 2019), when participants reported very low habit-strength for energy-dense food, but after starting to adapt to a "healthy" diet habit-strength increased again. However, as in the current study, on average,

habit-strength remained on a low level. Therefore, the observed small increases in habit-strength could reflect initial challenges in adapting to new behaviours before formation of autonomous habits (Gardner et al., 2012).

The ability to resist temptations to an energy-dense diet has been suggested as one of the key factors in maintaining new behaviours and thus weight loss maintenance (Hausenblas et al., 2001). The unexpected increase in temptations and decrease in ability to resist temptations during the early adherence period before plateauing as expected (Appelhans et al., 2016; Hausenblas et al., 2001). As PREMIT deployed techniques to enable participants to resist temptations and reinforce habit formation (Bandura, 1996; Michie et al., 2008; Renner & Schwarzer, 2005; Richard Ryan et al., 2008), current results may reflect cognitive burden to maintain new dietary behaviours in everyday life when surrounded with potential temptations to eat unhealthy foods before habits are imbedded (Gardner et al., 2012).

Increased autonomous motivation for healthy eating should help in weight maintenance as healthy eating behaviours are performed due their intrinsic value (e.g. enjoyment), not because aiming to reach e.g. personally important goal such as weight maintenance (introjected motivation) or external rewards such as approval of others (extrinsic motivation) (R. Ryan & Deci, 2000; Richard Ryan et al., 2008). While acknowledging that participants were likely to be highly motivated, it was unexpected no changes in any of the motivation variables could be observed. Overall, participants reported very high autonomous motivation, which may have led very little room for improvements, i.e. ceiling effect. Values for introjected and external motivation were lower, but showed no changes. While indicating that participants weight maintenance behaviours were predominantly motivated by their intrinsic value, motivational style was nevertheless not associated with weight re-gain. It is possible that participants not only committing but completing a 36-months intervention are very motivated, thus not necessarily reflecting general population.

While results indicated that habit strength is positively associated with weight maintenance (Hausenblas et al., 2001; Verhoeven et al., 2012), it was less clear how PREMIT contributed to weight maintenance, especially as frequent – but not infrequent - attenders had the highest weight re-gain. Similarly, to the AHEAD and DPP studies (Diabetes Prevention Program (DPP) Research Group, 2002; The Look AHEAD Research Group, 2006), PREMIT attendance appeared to be associated with weight loss maintenance. But, it was unclear through which pathways the effects might have been caused, as the results were not in line with the theoretical assumptions. As the purpose in here was not to test the predictions of a specific behaviour modification theory, the results here should not be taken as support or rebuttal of a specific theory. Together with previous results (Huttunen-Lenz et al., 2019), it appears that changes in behavioural determinants (i.e., social-cognitive variables) and their association with weight change does not strictly follow theoretical assumption, at least among highly motivated participants. It might well be possible, that very frequent attenders gained the most benefits from the PREMIT group sessions, while infrequent attenders may have felt less need for support and thus attended less frequently. But this conclusion remains speculative to assume.

There is evidence, that interventions using health behaviour theories are more effective than those lacking a theoretical basis. Nevertheless, a lesson learned here is, that it might be effective to adapt a theory-based behaviour change strategy to a given natural environmental, instead of following a theory-based regimen strictly. In an RCT those adaptations are not welcome, but in real life they might be. The challenge is to translate science into practice without losing sight of the specific circumstances (Tabak et al., 2017).

This study had a number of limitations. The cut-off points, separating the attendance groups, could be criticised as artificial. While a stringent *p*-value was used to protect against type I errors, results should nevertheless be interpreted with caution due to deviations from

data normality. The analyses also concentrated on the maintenance stage of PREMIT intervention and included a limited number of variables associated with behaviour modification and maintenance. However, regardless of the limitations, this study offered insights into behavioural mechanisms and complementary behaviour change techniques of complex healthcare intervention over two- and half-year weight maintenance stage. Although the observed effect-sizes in this study tended to be small, the combined results contributed to testing theoretical assumptions of cognitive processes involved in formation of new diet habits during the behavioural maintenance stage in a real-life setting. Further, small effect sizes were likely a reflection of the multifactorial nature of behaviour change over a long-lasting time period. In conclusion, habit-strength emerged as an important determinant of successful maintenance of weight-loss.

Conclusions

Behaviour change is a complex task or "wicked problem". In this study, many of the hypotheses, especially those postulating specific directions of the changes in social-cognitive variables were not met. When expected to enter the behavioural maintenance stage of PREMIT, participants appeared to struggle with some aspects of the behavioural maintenance before the new behaviours appeared to stabilise. In these analyses, habit strength appeared as the key variable, so that lower habit-strength for energy-dense food (fatty and sweetened) at the end of the weight maintenance stage was associated with lower weight re-gain. This reinforces the notion that developing new habits can be effective in protecting against weight re-gain (Gardner et al., 2012). In addition, the study contributed to understanding mechanisms of complex theory-based interventions (Craig et al., 2008).

References

American Diabetes Association. (2011). Standards of Medical Care in Diabetes—2011. *Diabetes Care*, *34*(Supplement 1), S11–S61. https://doi.org/https://doi.org/10.2337/dc11-S011

Appelhans, B. M., French, S. A., Pagoto, S. L., & Sherwood, N. E. (2016). Model of Intervention Strategies. *Appetite*, *96*, 268–279. https://doi.org/10.1016/j.appet.2015.09.035

Bandura, A. (1996). Social cognitive theory of human development. In T. Husen & T. N. Postlethwaite (Eds.), *International Encyclopedia of Education* (2nd ed., pp. 5513–5518). Pergamon Press.

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: The role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine*, *23*(2), 5–14. https://doi.org/10.1016/S0749-3797(02)00469-5

Burke, L. E., Shiffman, S., Siewiorek, D., Smailagic, A., Kriska, A., Ewing, L. I., Zheng, Y., Mancino, J., & Rathbun, S. L. (2018). Abstract P251 : Triggers of Temptations and Urges Do Not Change During a 12- Month Behavioral Intervention for Weight Loss. *Circulation*, *133*(AP251), 6–7. https://www.ahajournals.org/doi/10.1161/circ.133.suppl_1.p251

Chan, J. C. N., & Luk, A. O. Y. (2016). Diabetes : A Cinderella Subject We Can ' t Afford to Ignore. *PLoS Medicine*, *13*(7 : e1002068.), 4–7. https://doi.org/10.1371/journal.pmed.1002068

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ*, *337*. https://doi.org/10.1136/bmj.a1655

de Vries, H., Eggers, S. M., Lechner, L., Van Osch, L., & Van Stralen, M. M. (2014). Predicting fruit consumption: The role of habits, previous behavior and mediation effects. *BMC Public Health*, *14*(1), 730. https://doi.org/10.1186/1471-2458-14-730

Diabetes Prevention Program (DPP) Research Group. (2002). The Diabetes Prevention Program (DPP): description of lifestyle intervention. *Diabetes Care*, *25*(12), 2165–2171. https://doi.org/10.2337/diacare.25.12.2165

Dombrowski, S. U., Knittle, K., Avenell, A., Araújo-Soares, V., & Sniehotta, F. F. (2014). Long term maintenance of weight loss with non-surgical interventions in obese adults: Systematic review and meta-analyses of randomised controlled trials. *BMJ (Online)*, *348*(May), 1–12. https://doi.org/10.1136/bmj.g2646

Donahue, K., Mielenz, T., Sloane, P., Callahan, L., & Devellis, R. (2006). Identifying supports and barriers to physical activity in patients at risk for diabetes. *Prev Chronic Dis.*, *3*(4), A119. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1779283/

ESS. (2015). *European Social Survey. (2015). ESS Round 7 (2014/2015) Technical Report.*

Fogelholm, M., Larsen, T., Westerterp-Plantenga, M., Macdonald, I., Martinez, J., Boyadjieva, N., Poppitt, S., Schlicht, W., Stratton, G., Sundvall, J., Lam, T., Jalo, E., Christensen, P., Drummen, M., Simpson, E., Navas-Carretero, S., Handjieva-Darlenska, T., Muirhead, R., Silvestre, M., … Raben, A. (2017). PREVIEW: Prevention of Diabetes through Lifestyle Intervention and Population Studies in Europe and around the World. Design, Methods, and Baseline Participant Description of an Adult Cohort Enrolled into a Three-Year Randomised Clinical Trial. *Nutrients*, *9*(6), 632. https://doi.org/10.3390/nu9060632

Gardner, B. (2012). Habit as automaticity , not frequency. *European Health Psychologist*, *14*(2), 32–36. https://www.ehps.net/ehp/index.php/contents/article/view/ehp.v14.i2.p32

Gardner, B., Corbridge, S., & McGowan, L. (2015). Do habits always override intentions? Pitting unhealthy snacking habits against snack-avoidance intentions. *BMC Psychology*, *3*(1), 8. https://doi.org/10.1186/s40359-015-0065-4

Gardner, B., Lally, P., & Wardle, J. (2012). Making health habitual: the psychology of 'habit-formation' and general practice. *British Journal of General Practice*, *62*(605), 664 LP – 666. https://doi.org/10.3399/bjgp12X659466

Hausenblas, H. A., Dannecker, E. A., Downs, D. S., Gardner, R. E., Fallon, E. A., Focht, B. C., Loving, M. G., & Nigg, C. R. (2001). A missing piece of the transtheoretical model applied to exercise: Development and validation of the temptation to not exercise scale. *Psychology and Health*, *16*(4), 381–390. https://doi.org/10.1080/08870440108405514

Huttunen-lenz, M., Hansen, S., Larsen, T. M., Christensen, P., Drummen, M., Adam, T., Taylor, M. A., Simpson, E., Martinez, J. A., Navas-Carretero, S., Handjieva-Darlenska, T., Poppitt, S. D., Silvestre, M. P., Fogelholm, M., Jalo, E., Muirhead, R., Brodie, S.,

Raben, A., & Schlicht, W. (2019). The PREVIEW Study Supporting Behavior Change in an International Intervention Study Among Participants with Pre-Diabetes. *European Journal of Health Psychology*, *26*(1), 10–20. https://doi.org/10.1027/2512-8442/a000026

Ji, M., & Wood, W. (2007). Habitual Purchase and Consumption: Not Necessarily What You Intend. *Journal of Consumer Psychology*, *17*(17), 261–276. https://doi.org/10.1016/S1057-7408(07)70037-2

Kahlert, D., Unyi-Reicherz, A., Stratton, G., Meinert Larsen, T., Fogelholm, M., Raben, A., & Schlicht, W. (2016). PREVIEW Behavior Modification Intervention Toolbox (PREMIT): A Study Protocol for a Psychological Element of a Multicenter Project. In *Frontiers in Psychology* (Vol. 7, p. 1136). https://doi.org/10.3389/fpsyg.2016.01136

Labrecque, J. S., & Wood, W. (2015). What measures of habit strength to use ? Comment on Gardner (2015). *Health Psychology Review*, *April*. https://doi.org/10.1080/17437199.2014.992030

Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, *40*(6), 998–1009. https://doi.org/https://doi.org/10.1002/ejsp.674

Lenhard, W., & Lenhard, A. (2016). *Calculation of Effect Sizes*. Dettelbach (Germany): Psychometrica. https://doi.org/DOI: 10.13140/RG.2.1.3478.4245

Levesque, C. S., Williams, G. C., Elliot, D., Pickering, M. A., Bodenhamer, B., & Finley, P. J. (2007). Validating the theoretical structure of the Treatment Self-Regulation Questionnaire (TSRQ) across three different health behaviors. *Health Education Research*, *22*(5), 691–702. https://doi.org/10.1093/her/cyl148

Lin, P. Y., Wood, W., & Monterosso, J. (2016). Healthy eating habits protect against temptations. *Appetite*, *103*, 432–440. https://doi.org/10.1016/j.appet.2015.11.011

Lindström, J., Louheranta, A., Mannelin, M., Rastas, M., Salminen, V., Eriksson, J., Uusitupa, M., & Tuomilehto, J. (2003). The Finnish Diabetes Prevention Study (DPS): Lifestyle intervention and 3-year results on diet and physical activity. *Diabetes Care*, *26*(12), 3230–3236. https://doi.org/10.2337/diacare.26.12.3230

Michie, S., Johnston, M., Francis, J., Hardeman, W., & Eccles, M. (2008). From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour

Change Techniques. *Applied Psychology*, *57*(4), 660–680. https://doi.org/10.1111/j.1464-0597.2008.00341.x

Ng, J. Y. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L., & Williams, G. C. (2012). Self-Determination Theory Applied to Health Contexts: A Meta-Analysis. *Perspectives on Psychological Science*, *7*(4), 325–340. https://doi.org/10.1177/1745691612447309

Ntoumanis, N., Ng, J. Y. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Lonsdale, C., & Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review*, *15*(2), 214–244. https://doi.org/10.1080/17437199.2020.1718529

Prochaska, J. O., & DiClemente, C. C. (1992). Stages of change in the modification of problem behaviors. In M. Hersen, R. M. Eisler, & P. Miller (Eds.), *Progress on Behavior Modification* (pp. 184–214). Sycamore Press.

Raben, A., Vestentoft, P. S., Brand-Miller, J., Jalo, E., Drummen, M., Simpson, L., Martinez, J. A., Handjieva-Darlenska, T., Stratton, G., Huttunen-Lenz, M., Lam, T., Sundvall, J., Muirhead, R., Poppitt, S., Ritz, C., Pietiläinen, K. H., Westerterp-Plantenga, M., Taylor, M. A., Navas-Carretero, S., … Fogelholm, M. (2021). The PREVIEW intervention study: Results from a 3-year randomized 2 x 2 factorial multinational trial investigating the role of protein, glycaemic index and physical activity for prevention of type 2 diabetes. *Diabetes, Obesity and Metabolism*, *23*(2), 324–337. https://doi.org/https://doi.org/10.1111/dom.14219

Renner, B., & Schwarzer, R. (2005). The motivation to eat a healthy diet : How intenders and nonintenders differ in terms of risk perception, outcome expectancies, self-efficacy, and nutrition behavior. *Polish Psychological Bulletin*, *36*(1), 7–15. http://nbn-resolving.de/urn:nbn:de:bsz:352-opus-72632

Rockette-Wagner, B., Kriska, A. M., Storti, K. L., Dabelea, D., Edelstein, S., Florez, H., Franks, P. W., Montez, M. G., & Pomeroy, J. (2017). Activity and Sedentary Time 10 Years After a Successful Lifestyle Intervention: The Diabetes Prevention Program. *American Journal of Preventive Medicine*, *52*(3), 292–299. https://doi.org/10.1016/j.amepre.2016.10.007

Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic

motivation, social development, and well-being. *The American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, Richard, Patrick, H., Deci, E., & Williams, G. (2008). Facilitating health behaviour change and its maintenance: Interventions based on Self-Determination Theory. *The European Health Psychologist*, *10*, 2–5.

Schwarzer, R., Luszczynska, A., Ziegelmann, J. P., Scholz, U., & Lippke, S. (2008). Social-Cognitive Predictors of Physical Exercise Adherence: Three Longitudinal Studies in Rehabilitation. *Health Psychology*, *27*(1 SUPPL.), 54–63. https://doi.org/10.1037/0278-6133.27.1(Suppl.).S54

Tabachnick, B. G., & Fidell, L. S. (2014). *Using multivariate statistics. International Edition* (6th ed.). Pearson.

Tabak, R. G., Chambers, D. A., Hook, M., & Brownson, R. C. (2017). The Conceptual Basis for Dissemination and Implementation Research: Lessons from Existing Models and Frameworks. In *Dissemination and Implementation Research in Health* (2nd ed.). Oxford University Press. https://doi.org/10.1093/oso/9780190683214.003.0005

Tamayo, T., Rosenbauer, J., Wild, S. H., Spijkerman, A. M. W., Baan, C., Forouhi, N. G., Herder, C., & Rathmann, W. (2014). Diabetes in Europe: An update. *Diabetes Research and Clinical Practice*, *103*(2), 206–217. https://doi.org/10.1016/j.diabres.2013.11.007

The Look AHEAD Research Group. (2006). The Look AHEAD Study: A Description of the Lifestyle Intervention and the Evidence Supporting It. *Obesity*, *14*(5), 737–752. https://doi.org/https://doi.org/10.1038/oby.2006.84

The Look AHEAD Research Group. (2014). Eight-year weight losses with an intensive lifestyle intervention: The look AHEAD study. *Obesity*, *22*(1), 5–13. https://doi.org/https://doi.org/10.1002/oby.20662

Verhoeven, A. A. C., Adriaanse, M. A., Evers, C., & Ridder, D. T. D. De. (2012). The power of habits : Unhealthy snacking behaviour is primarily predicted by habit strength. *British Journal of Health Psychology*, *17*, 758–770. https://doi.org/10.1111/j.2044-8287.2012.02070.x

Wood, W., Tam, L., & Guerrero Witt, M. (2005). Changing Circumstances, Disrupting Habits. *Journal of Personality and Social Psychology*, *88*(6), 918–933. https://doi.org/10.1037/0022-3514.88.6.918

673 **Figure 1**

674 *PREVIEW intervention study and PREMIT Behaviour modification intervention schedules*

PREVIEW RCT	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 16	Week 20	**Week 26**	Week 32	Week 44	**Week 52**	Week 64	Week 78	**Week 104**	Week 130	**Week 156**
PREVIEW phases	**Phase I Weight loss**					**Phase II Weight maintenance**												
PREMIT Stages	**Stage 1 Preliminary stage**				**Stage 2 Preparation stage**			**Stage 3 Action stage**			**Stage 4 Behavioural maintenance stage**							
PREMIT sessions number and timing	1	2	3	4	5	6	7	8	9	**10**	11	12	**13**	14	15	**16**	17	**18**
Data collection points relevant for this study										⇧ End of action stage			⇧ Early maintenance stage			⇧ Middle maintenance stage		⇧ Late maintenance stage
Conceptual framework for the analyses	**Supporting weight loss - Emphasis on successful weight loss and planning the new diet habits after weight loss**					**Preparing and acting on the healthy diet behaviours. Learning new behavioural and thinking patterns regarding healthy diet**					**Imbedding the healthy diet behaviours in to habits**			**Maintaining the new healthy diet habits, dealing with set backs**			**Healthy diet habits maintained**	
Summary of expected changes in cognitive variables											**Resisting temptations - increasing / Habit strength unhealthy diet - decreasing / Temptations - decrease / Autonomous & intrinsic motivation - increase**			**Resisting temptations - no change / Habit strength unhealthy diet - no change / Temptations - no change / Autonomous Motivation - no change / Intrinsic & extrinsic motivation decrease**			**Resisting temptations - no change / Habit strength unhealthy diet - no change / Temptations - no change / Autonomous motivation - no change / Intrinsic & extrinsic motivation decrease**		

Behavioural determinants targeted and sessions included in the evualuation of the PREMIT attendance frequency = **13 (bold)**

Session 1: Instructions low-energy diet
Session 2: Habitual behaviour change, action self-efficacy
Session 3: Action self-efficacy
Session 4: Action self-efficacy and planning, outcome expectancies
Session 5: Action planning
Session 6: Self-regulation, self-efficacy, outcome expectancies
Session 7: Adhering to new behaviours, social support, overcoming barries
Session 8: Self-efficacy, self-regulation, overcoming barriers
Session 9: Self-regulation, motivation, social support
Session 10: Self-regulation, motivation
Session 11: Coping self-regulation
Session 12: Coping self-regulation
Session 13: Coping self-regulation
Session 14: Relapse management
Session 15: Relapse and coping management
Session 16: Relapse management
Session 17: Relapse and coping management
Session 18: Conclusion

675

676 **Table 1**

677 *Means and standard deviations for cognitive variables of unhealthy diet habit-strength and temptations, motivation healthy diet, and resisting fatty*
678 *and sweetened food temptations*

Variable ***means and standard deviations (M ± SD)***	**Grand mean** **(n = 962)**	***PREMIT*** ***infrequent attenders*** ***(n =228)***	***PREMIT*** ***frequent attenders*** ***(n =449)***	***PREMIT*** ***very frequent attenders*** ***(n = 285)***	***Significant changes***
Weight change Percentage % (i.e. weight re-gain)	n = 957	n = 225	n = 447	n = 265	
Weeks 26 to 156	8.2 ± 6.4	7.6 ± 7.1	9.1 ± 6.6	7.1 ± 6.9	
Habit-strength energy-dense food (1 – 343)					
Week 26 (End of action / start of maintenance stage)	44.8 ± 45.6	49.7 ± 45.2	45.6 ± 48.1	39.8 ± 41.3	*All participants significant increase from week 26 to 52*
Week 52 (End of early maintenance stage)	54.0 ± 49.6	62.2 ± 50.9	53.7 ± 48.7	47.9 ± 49.3	
Week 104 (End of middle maintenance stage)	60.6 ± 53.5	63.6 ± 58.0	62.5 ± 52.9	55.1 ± 50.2	
Week 156 (End of late maintenance stage)	64.1 ± 56.4	66.2 ± 57.2	65.4 ± 56.7	60.2 ± 55.3	
Temptations fatty and sweetened food (1 – 5)					
Week 26 (End of action / start of maintenance stage)	2.3 ± .8	2.4 ± .8	2.3 ± .8	2.1 ± .8	*All participants significant increases from week 26 to 52*
Week 52 (End of early maintenance stage)	2.4 ± .8	2.5 ± .8	2.4 ± .8	2.2 ± .8	
Week 104 (End of middle maintenance stage)	2.4 ± .8	2.6 ± .9	2.5 ± .8	2.3 ± .8	
Week 156 (End of late maintenance stage)	2.5 ± .8	2.5 ± .8	2.5 ± .8	2.4 ± .8	

Avoiding fatty and sweetened food (1 – 5)					
Week 26 (End of actions / start of maintenance stage)	3.4 ± .8	3.4 ± .7	3.4 ± .7	3.5 ± .8	*All participants significant decrease week 26 to 52*
Week 52 (End of early maintenance stage)	3.3 ± .8	3.3 ± .8	3.3 ± .7	3.4 ± .8	
Week 104 (End of middle maintenance stage)	3.3 ± .8	3.2 ± .8	3.3 ± .8	3.4 ± .8	
Week 156 (End of late maintenance stage)	3.3 ± .8	3.3 ± .8	3.2 ± .8	3.4 ± .8	
Autonomous motivation healthy diet (1 – 7)					
Week 26 (End of action / start of maintenance stage)	6.3 ± .7	6.4 ± .7	6.5 ± .7	6.4 ± .8	*No significant changes*
Week 52 (End of early maintenance stage)	6.3 ± .8	6.3 ± .8	6.4 ± .8	6.3 ± .9	
Week 104 (End of middle maintenance stage)	6.3 ± .9	6.2 ± .8	6.3 ± .9	6.3 ± .9	
Week 156 (End of late maintenance stage)	6.3 ± .9	6.2 ± .9	6.3 ± .8	6.2 ± .9	
Introjected motivation healthy diet (1 – 7)					
Week 26 (End of action / start of maintenance stage)	4.6 ± 1.7	4.5 ± 1.6	4.5 ± 1.7	4.5 ± 1.7	*No significant changes*
Week 52 (End of early maintenance stage)	4.5 ± 1.7	4.5 ± 1.7	4.5 ± 1.7	4.5 ± 1.7	
Week 104 (End of middle maintenance stage)	4.4 ± 1.7	4.4 ± 1.6	4.4 ± 1.8	4.4 ± 1.6	
Week 156 (End of late maintenance stage)	4.4 ± 1.7	4.2 ± 1.7	4.4 ± 1.8	4.4 ± 1.8	
External motivation healthy diet (1 – 7)					
Week 26 (End of action / start of maintenance stage)	3.1 ± 1.5	3.2 ± 1.5	3.0 ± 1.5	3.0 ± 1.6	*No significant changes*
Week 52 (End of early maintenance stage)	3.0 ± 1.5	3.1 ± 1.5	3.0 ± 1.5	3.0 ± 1.5	
Week 104 (End of middle maintenance stage)	2.9 ± 1.5	3.0 ± 1.5	2.9 ± 1.5	2.9 ± 1.5	
Week 156 (End of late maintenance stage)	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.6	2.9 ± 1.6	

679

Table 2

Correlations and standardized and unstandardized correlation coefficients for habit strength and temptations for unhealthy food and resisting temptations for unhealthy food

Variables	Correlation							Coefficient	
	Weight-change percentage	Energy dense diet / fatty and sweetened food			Motivation diet				
		Habit strength	Temptations	Avoiding temptations	Autonomous	Introjected	External	B	*B* (*t*, *p*-value)
Weight-change percentage	-	.19	.22	-.21	.07	.00	.05	.01	
Habit strength (1 – 343)	.19	-	.40	-.38	.13	-.03	.05	.93	**.11 (*t* = 3.3, *p* ≤ .008)**
Temptations energy dense diet (1 – 5)	.22	.40	-	-.73	.23	-.06	.17	-.76	.11 (*t* = 2.4, *p* > .008)
Avoiding temptations energy dense diet (1 – 5)	-.21	-.38	-.73	-	-.22	.02	-.19	.01	-.09 (*t* = -1.9, *p* > .008)
Autonomous motivation (1 - 7)	.07	.13	.23	-.22	-	-.37	-.07	.57	.02 (*t* = .5, *p* > .008)
Introjected motivation (1 – 7)	.00	-.03	-.06	.02	-.34	-	.39	.08	.02 (*t* = .6, *p* > .008)
External motivation (1 – 7)	.05	.05	.17	-.19	-.07	.39	-	-.00	-.00 (*t* = -.03, *p* > .008)

Significant result highlighted in **bold**