Are dietary interventions with a behaviour change theoretical framework effective in changing dietary patterns? A systematic review

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Abstract

Background: The term 'whole dietary pattern' can be defined as the quantity, frequency, variety and combination of different foods and drinks typically consumed and a growing body of research supports the role of whole dietary patterns in influencing the risk of non-communicable diseases. For example, the 'Mediterranean diet', which compared to the typical Western diet is rich in fruits and vegetables, whole grains, and oily fish, is associated with reduced risk of cardiovascular disease and cancer. Social Cognition Models provide a basis for understanding the determinants of behaviour and are made up of behavioural constructs that interventions target to change dietary behaviour. The aim of this systematic review was to provide a comprehensive assessment of the effectiveness and use of psychological theory in dietary interventions that promote a whole dietary pattern.

Methods: We undertook a systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis to synthesize quantitative research studies found in Embase, Medline, PsycInfo, CINAHL and Web of Science. The studies included were randomised and non-randomised trials published in English, involving the implementation of a whole dietary pattern using a Social Cognition Model to facilitate this. Two independent reviewers searched the articles and extracted data from the articles. The quality of the articles was evaluated using Black and Down quality checklist and Theory Coding Scheme.

Results: Nine intervention studies met the criteria for inclusion. Data from studies reporting on individual food group scores indicated that dietary scores improved for at least one food group. Overall, studies reported a moderate application of the theory coding scheme, with poor reporting on fidelity.

Conclusion: To our knowledge, this is the first review to investigate psychological theory driven interventions to promote whole dietary patterns. This review found mixed results for the

effectiveness of using psychological theory to promote whole dietary pattern consumption. However, the studies in this review scored mostly moderate on the theory coding scheme suggesting studies are not rigorously applying theory to intervention design. Few studies reported high on treatment fidelity, therefore, translation of research interventions into practice may further impact on effectiveness of intervention.. Further research is needed to identify which behaviour change theory and techniques are most salient in dietary interventions.

Key words**:** *Psychological theory, whole dietary patterns, theory coding scheme*

Background

Major non communicable diseases (NCD) include, heart disease, stroke, cancer, diabetes, and chronic respiratory disease, and are estimated to represent 41 million deaths per annum globally [1]. According to the World Health Organisation (WHO, 2016) [1], a number of preventable risk factors underlie many NCD's and are the leading cause of death and disability globally regardless of economic status with one of the main risk factors considered to be poor diet attributable to 11 million deaths globally in 2017 [2]. Previously, the focus of research has been on single nutrients or single food groups, as the main disease states were due to nutritional deficiencies. However, the burden of disease has switched [2] to cancer, diabetes, and cardiovascular disease, due to demographic and epidemiological transitions, which are now the leading causes of death globally. This was partly due to a shift in the food environment, with people consuming more high-carbohydrate, low fat diets, which in turn lead people to consume more refined carbohydrates and refined sugar, which increases the risk of cardiometabolic diseases [3]. The dietary determinants of diseases such as cancer and diabetes are different from those of undernutrition and nutrient deficiency states [4]. Non-communicable diseases have multiple interacting dietary determinants consisting of either excess or insufficient intake, which cumulatively affect disease over time [5]. Therefore, research has gone beyond the single nutrient approach and focused on whole dietary patterns, which may be more beneficial to health due to the synergism between nutrients and food groups [6].

Improving dietary quality is not easily achieved. Healthy eating patterns revolve around regular consumption of a variety of foods from key food groups including cereal and cereal products, fruits and vegetables, meat and non-meat alternatives and dairy/non-dairy alternatives with the aim of optimizing nutrient intakes conducive to reducing the risk of chronic illness [7]. Globally between 1990-2010, consumption of healthy foods has increased,

however, the consumption of unhealthy foods had increased to a greater extent [8]. As opposed to a "healthy" dietary pattern , which can be nutrient based or only focus on certain aspects of a diet, for the purpose of this review, a whole dietary pattern is defined as the quantities, proportions, variety or combination of different foods in relation to the 5 foods groups of the Eatwell Guide, UK [9] and the MyPlate, USA [10] (fruit & vegetables, carbohydrates/grains, protein, fats & sugar, dairy products), or an established healthy eating pattern such as the Mediterranean diet [11].

It is clear, that interventions to promote adherence to a healthy dietary pattern are warranted. There is an array of research examining and evaluating the effectiveness of dietary interventions on chronic illnesses. There is some evidence in the literature to suggest, that the reporting of psychological theory use in behaviour change intervention development is associated with larger intervention effects [12]. Using psychological theory to design behaviour change interventions, provides a framework to accumulate evidence, test hypothesis, identify specific constructs that may influence behaviour and suggest which behaviour change techniques should be used in behavioural interventions [13].

Social Cognition Models (SCMs) (e.g. Theory of Planned Behaviour (TPB)) [14] are the most commonly used theories within the field of health psychology and behaviour change [15]. SCMs are useful for explaining, predicting, and understanding dietary behaviours, and in the design of dietary interventions to promote dietary change [16]. However, while SCMs has been used to predict dietary patterns [17,18], there is less evidence in the literature examining the effectiveness of interventions that use SCMs to promote whole dietary patterns, such as the Mediterranean [11], MIND [19], and DASH [20] diets. However, reviews in the literature show mixed results for the effectiveness of theory based dietary interventions. One meta-analysis found no association between dietary intervention effectiveness and theory use [21], while another meta-analysis on theory-based fruit and vegetable intervention among children, found

that after considering quality of studies, theory was associated with vegetable consumption only[22]. Furthermore, a previous review indicated that theory-based interventions were less effective than non-theory-based interventions [23].However, such research is held back by limitations in the extent to which interventions report on theory use, and insufficient descriptions of intervention content [24].

Some studies have been shown not to extensively use psychological theory in developing interventions [25]. One way to examine how theory has been applied to interventions is by applying the 19-item theory coding scheme (TCS) [26]. This scheme specifies whether theory is mentioned, whether theoretical constructs are targeted or measured, if theory was used to select recipients or to tailor the intervention and if theory was tested or refined. The TCS is a reliable tool to describe theory-based interventions; to inform evidence synthesis within reviews and has been used widely in systematic reviews to assess the effectiveness of theory and intervention effectiveness.

To advance behavioural research, improvement in methodologies are needed, with treatment fidelity proposed as a key area for improvement. Treatment fidelity refers to the processes used to ensure intervention components are delivered as intended [28]. To make valid interpretations regarding the efficacy of a behavioural intervention, it is important to provide details of treatment fidelity, which provides insights into the gap between theory and practice. To provide this information, specification of the intervention program is required. According to Bellg et al. [29], five domains to assess, monitor or enhance treatment fidelity have been identified by, as part of The National Institute of Health (NIH) and Behaviour Change Consortium (BCC), which are: (1) design of study, (2) training providers (3) delivery of treatment (4) receipt of treatment (5) enactment of treatment skills.

Previous systematic reviews have assessed the effectiveness of behavioural interventions on fruit and vegetable consumption [30], reduce sugar intake [31], or only reporting on dietary behaviours using one SCM, such as the Social Cognitive Theory [32]. One systematic review [32] aimed to identify effective dietary interventions for older people. However, this review examined both whole dietary patterns and single food groups such as fruit and vegetables. Furthermore, while this review reported the delivery of educational sessions, no theory was mentioned, or theoretical constructs reported. To our knowledge, the current review is the first to assess the effectiveness of SCMs in dietary interventions that use a "whole dietary pattern". Therefore, the aim of this systematic review was to provide a comprehensive and systematic assessment of the effectiveness and use of SCMs in dietary interventions that promote "whole dietary patterns" in adults.

Objectives:

- To describe the extent of psychological theory in the design and implementation of dietary interventions to promote whole dietary patterns
- To evaluate the implementation of psychological theory in the design of dietary interventions to promote whole dietary patterns
- To determine the effectiveness of psychological theory based dietary interventions
- To explore the extent to which the fidelity of the intervention is monitored in these studies.
- To provide recommendations for future research to promote whole dietary patterns

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (see supplementary data file 1) [33] was used to inform the design, conduct and reporting of this systematic review. No ethical approval was sought as only secondary analysis of existing

145 datasets were involved in the study. The study protocol was registered with PROSPERO, the
146 International Prospective Register of Systematic Reviews
147 (crd.york.ac.uk/prospero/index.aspIdentifier; CRD42017057366).

148 **Selection Criteria**

149 In accordance with PRISMA, the PICOs (population, intervention, comparison, outcome, and
150 study design) approach were used to formulate the selection criteria. (see Table 1).

151 Inclusion criteria: 1) study population: all adults aged 18 years or over; 2) study intervention:
152 an intervention involving a "whole dietary pattern" such as the Mediterranean diet [11] Dash
153 diet [18] and MIND diet [17] or foods analysed from at least 4 out of 5 of the food groups
154 identified by the Eatwell Guide, UK (protein, grains/carbohydrates, oil and fats, dairy,
155 fruit/vegetable; 3) psychological theory: studies were included that used a social cognition
156 model to design their intervention (e.g. TPB); 4) study design: randomised controlled trials and
157 , including single arm studies, and pilot studies published in English.

158 Exclusion criteria: 1) study population; studies targeting a population under 18 years old were
159 excluded; 2) study intervention: studies were not included where the dietary behaviour was a
160 de facto medical treatment e.g. gluten free diet. Also, studies analysing data from only single
161 food group and nutrients, such as, fruit and vegetable, or omega 3 were excluded, as these do
162 not constitute a "whole dietary pattern"; 3) psychological theory: studies that do not mention
163 or report on a social cognition model were excluded; 4) study design: studies that were not
164 interventions, such as qualitative or cross-sectional studies were excluded from this review.
165 (see Table 1).

166 **Search Strategy and Study Identification**

167 Literature searches were conducted by (DT) between April 2019 and January 2020 using the
168 following databases: EMBASE (1974-2020), Medline (1974-2020), PsycInfo (1974-2020),

CINAHL (1937-1-2020) and Web of Science (1950-2020). ProQuest Dissertations & Thesis was reviewed to locate unpublished studies and, reference lists of the selected studies for inclusion were searched manually. The following search terms were used in different combinations. Theoretical framework, behaviour change theory, Theory of Planned Behaviour, Theory of Reasoned Action, Health Belief Model, Self-determination Theory, Stages of Change Model, Health Action Process Approach, COM-B model, Social Cognitive Theory, Control Theory, Self-Efficacy Theory, Social Ecological Model, healthy eating, dietary intervention, dietary patterns, healthy eating, whole diets, Mediterranean, DASH and MIND diet were also chosen as search terms as these are "whole dietary patterns", they do not eliminate any food group and promote a healthy lifestyle [7]. The studies were screened by the titles and abstracts. Studies that did not meet the inclusion criteria were excluded. Two researchers (DT&ES) reviewed the abstracts independently that were ambiguous for inclusion. Any disagreements were resolved through discussion with a third researcher (JM).

Data Extraction.

The following information was extracted from each study: author, design, country, quality score, participants characteristics, intervention, control, dietary pattern, theoretical model, outcome measures, main findings (Table 2).

Methodological Quality

The modified version of Downs and Blacks [34] quality checklist was used as some of the included studies were non-randomised studies. Question 27 was modified to "Did the study have sufficient power?" with one point awarded if a sample size calculation was completed [35]. Two researchers (DT&ES) independently assessed the quality of the studies. The Downs and Blacks quality checklist is considered a reliable and valid tool suitable for the use in random and non-random studies [36]. Studies were assessed on quality of reporting (10 questions;

193 partially = 1, no = 0 or yes = 2, or yes =1, no=0), external validity (3 questions; yes = 1, no =
194 0,unable to determine = 0), internal validity – measurement bias (7questions; yes = 1, no = 0,
195 unable to determine = 0), internal validity – selection bias (6 questions; yes = 1, no = 0, unable
196 to determine = 0) and power (1 question ; yes = 1, no = 0, unable to determine = 0), equating
197 to a total achievable score of 28 (see Table 3). Studies that scored less than 14 were considered
198 poor, those that scored between 14-18 were considered fair, those that scored between 19-23
199 were considered good and those scoring between 24-28 were considered excellent [37].

200 In addition to study quality being formally assessed, the Theory Coding Scheme (TCS)
201 [26] was used to assess the extent to which theory was used to design behaviour change
202 interventions within each study. The TCS consists of 19 items across 6 categories relating to;
203 whether a theory was mentioned, if the relevant theoretical constructs are targeted, if theory
204 was used to select participants and/or tailor interventions and if the relevant constructs were
205 measured, if theory was tested and if theory was refined. Responses to all items with the
206 exception of item 7 and 10 with a "yes" were given 1 point and those responded with a "no"
207 and "don't know" were given 0 points. Items 7 (All intervention techniques are explicitly linked
208 to at least 1 theory-relevant construct) and 10 (All theory-relevant constructs are explicitly
209 linked to at least 1 intervention technique) were given 2 points if the criteria were met (see
210 Table 4). Similar scoring has previously been applied [38]. Similar to previous research using
211 the TCS [39], this review scored each study as having a weak (0-7), moderate (8-15), or strong
212 (16-23) use of theory. There was an initial 95% agreement of codes, which demonstrates an
213 acceptable level of agreement. Discussion between researchers resolved any differences within
214 the coding process.

215 Treatment fidelity

Treatment fidelity was assessed using a 29-item checklist [40] which mapped onto 5 domains identified by Bellg.[29] 1) treatment design (6 items); 2) treatment providers (7 items); 3) delivery of treatment (9 items); 4) receipt of treatment (5 items); enactment of treatment skills (2 items). The ability to draw solid conclusions from a study may be decreased, if any one of the domains lack consideration [40] (see Table 5).

Results

Study Characteristic

The basic characteristics of included studies are shown in Table 2.

Type of Studies.

Nine studies met the inclusion criteria (see Figure 1). Seven of the included studies were RCT's [41-47] and 2 non-RCT's [48-49].

Type of Participants

In all studies, participants had a mean age ranging from 34 to 72 years. Females represented between 45-100% of the overall sample. One study [43] did not state the number of males and females who participated. Six of the included studies had apparent healthy participants [41,42,45,47-49]. Three of the included studies had participants with a clinical diagnosis [43,44,46]. Of the nine studies, one was carried out in Australia [44], four in the USA [41,45,46,47], one in Canada [48], and three in the Mediterranean (Greece, Italy and Spain)[42,43,49].

Type of Dietary Pattern

All studies included a whole dietary pattern that took into consideration the main food groups: protein, grains/carbohydrates, oil and fats, dairy, fruit/vegetable (n=9). Two of the nine studies specifically examined the Mediterranean diet [48,49], and one examined the DASH diet [46].

Type of Primary Outcome.

Outcome measures varied across studies. Two studies used the HEI-2005 to assess overall diet quality and adherence to the recommended diet [42,43], with higher scores representing better diet quality. One study assessed adherence to the Mediterranean diet with the Mediterranean Diet Adherence Screener (MEDAS) [49], with higher scores representing higher adherence to the Mediterranean diet. One study used the Diet Guidelines Index (DGI) to measure adherence to healthy recommendations over the previous month. A diet score is obtained with a range of 0-150, with higher scores representing higher levels of healthy eating [44]. One study assessed dietary behaviour with a food frequency questionnaire [50] and compliance to USDA Food Pyramid [41,51]. One study used the AHEI-2010 to assess diet quality [45] with a total score between 0-110, with the higher score representing better diet quality. One study [48] assessed the level of adherence to the Mediterranean diet with a Medscore, which was calculated based on the food frequency questionnaire used in the study. Scores ranged from 0-44, with higher scores representing higher adherence to the Mediterranean diet. One study captured recommended foods by a 24-hour recall questionnaire and compliance with USDA Food Pyramid [47,51]. Finally, one study [46] used the Willett Food frequency Questionnaire [52] to derive a DASH adherence score, with a potential DASH score of 1-40 over 8 food components. Each component score between 1-5, with a higher score representing higher adherence.

Quality of Studies.

Out of a total score of 28, all 9 included studies scored between 15 and 25 on the Black and Downs quality assessment checklist (see Table 3), with one study scoring 25 which is considered excellent quality [45]. Four studies scored between 19-23 which is considered good quality [41,44,47,48], and the remaining four studies scoring between 14-18 which is considered fair quality [42,43,46,49]. Overall, the 9 included studies scored high on the first

subscale of the checklist (reporting). None of the included studies met the criteria for "external validity" subscale, with two studies scoring zero [42,43]. The following section is internal validity-bias which studies scored relatively high on this subsection with scores between 4-6 out of a possible 7. The following subsection is internal validity-confounding (selection bias), which yielded the most variety of scores, which may be due to having different experimental designs. Only one of the RCTs [44] reported sufficiently on randomised intervention assignment concealment. Lastly, power to detect a significant effect was reported by 4 studies [41,45,47,48].

Impact of intervention on dietary behaviour

Two studies [48,49] examined the impact of a theory-based intervention on adherence to the Mediterranean diet. Both studies calculated an overall Medscore pre-post intervention, calculated from the Mediterranean Diet Adherence Screener (MEDAS) [49], or a food frequency questionnaire [48]. Both studies reported a significant increase in Medscore post intervention. One study [46] examined the impact of a tailored behavioural intervention (TBI) on adherence to the DASH diet, compared to a non-tailored intervention (NTI) and usual care (UC) group. At 6 months follow-up, TBI had a higher DASH score than UC and NTI. However, for individual components of the DASH diet such as fruit and vegetables, and wholegrains, there was no significant difference between groups on scores at 6-month follow-up. The remaining 6 studies examined individual components of dietary behaviours based on AHEI [45], HEI [42,43] DGI [44], FFQ [41] and 24hr recall/MyPyramid [47]. From theses 6 studies, one study reported no improvement in dietary behaviour [44]. Only one study reported a significant improvement in fruit [45], vegetable intake [43], carbohydrates/grains [42] and dairy [42]. Two studies reported improvements in protein (fish, poultry, beans, meat, or eggs) [45,47] and total fats [41,42].

Extent of theory use

The extent to which theory was used within the selected studies was assessed using the TCS (Table 4) [26]. From the 9 included studies, the mean total TCS score across studies was 11, which is a moderate application of theory. One study [42] showed a weak application of theory, seven studies [41,43-45,47-49] were moderate, and one study showed a strong application of theory [46]. These scores suggest that theory had not been extensively applied to the design, implementation, and evaluation of behaviour change interventions, and/or theory use was reported with insufficient detail. These scores suggest that most studies are not explicitly reporting theory use in sufficient detail and/or fail to rigorously apply theory to intervention design and implementation. The following section describes the use of theory within the selected studies in terms of the 6 categories of coded items of the TCS [26]: (1) mention of theory; (2) targeting of theoretical constructs;(3) using theory to select recipients or tailor interventions; (4),measurement of constructs; (5) testing of mediation effects; (6) and refining theory.

Category 1: Mention of theory (Items 1-3)

All studies (N=9) mentioned a theory (item 1, Table 4), with only 6 studies referring to theory as a predictor of behaviour and provided evidence of the association of the theory or theoretical construct and target behaviour. For example, one study using the Health Belief Model [41] stated that the best predictor of nutrition related behaviour change is the benefit-cost ratio, and for a change in nutrition behaviour to occur, the perceived benefits must outweigh the barriers. Out of the 9 studies, 7 were reported to be a single theory (item 3, Table 4) such as HAPA, SDT and TTM, while 2 studies combined theories (HBM and SCT).

Category 2: Are relevant constructs targeted (Item 5, 7-11)

Eight of the studies used theory or predictors to select/develop intervention techniques (Item 5, Table 4). Regarding linking intervention techniques to theoretical constructs, only 4 studies explicitly linked all intervention techniques to at least one theoretical construct (Item 7, Table 4), with a further 5 studies linking at least one, but not all, intervention techniques to at least one theoretical construct (Item 8, Table 4). Three studies linked a group of techniques to a group of constructs (Item 9, Table 4). Only 4 studies explicitly linked all relevant theoretical constructs to at least one intervention technique (Item 10, Table 4), with a further 4 studies linking at least one, but not all, constructs with at least one technique (Item 11, Table 4). For example, one study [41] used the HBM to develop an educational intervention to improve dietary practices for CVD prevention. However, the intervention focused on perceived benefits and barriers and neglected other key concepts such as susceptibility and severity of illness, health motivation and perceived control. Another study [47] used the SCT model to develop a dietary intervention and focused their intervention techniques on self-regulation techniques, such as self-monitoring and goal setting, neglecting concepts such as outcome expectancy. Therefore, more than half (N=5) of these studies did not utilise the full predictive power of their chosen theory.

Category 3: Is theory to select participants or tailor interventions.

None of the included studies used theory to select participants (Item 4, Table 4), and only 1 study tailored intervention techniques to the participants. Therefore, the intervention differed for subgroups of participants that varied for a particular construct at baseline (Item 6, Table 4). This study was based on the TTM, and the intervention delivered to each participant varied depending on their stage of change at baseline.

Category 4: Are relevant constructs measured

Seven of the studies reported measuring theoretical constructs pre-post intervention (Item 12, Table 4), and reporting on the validity and reliability of the scales used to measure constructs/predictors (Item 13, Table 4).

Category 5: Testing theory

Seven of the studies reported randomisation, two studies were non-RCTs (Item 14, Table 4). Four of the studies interventions changed the target theoretical constructs. For example, one study [41] using the HBM significantly increased perceived benefits of adoption of positive dietary behaviours and increased nutrition knowledge of CVD and cancer. Also, another study [45] reported that HAPA outcomes in the intervention group reported significantly greater frequency of action planning, and action and coping self-efficacy at follow-up (Item 15, Table 4). Seven of the studies discussed the results in relation to theory (Item 16, Table 4) and three provided support for theory (Item 17, Table 4). That is, studies reported that constructs within the theory, significantly mediated the relationship between the intervention and outcomes. For example, one study [48] that used self-determination theory found that eating related self-determined motivation was associated with an increased adherence to the Mediterranean diet.

Category 6: Refining theory

Refining of theory, or suggestions for future refinement was not reported by any of the included studies (Item 18, Table 4).

Fidelity of interventions

Of the 9 included studies, two studies included an assessment on all 5 domains [45,48]. One study included an assessment on only one domain [49]. Two studies included an assessment on two domains [41,42]. Three studies included an assessment on three domains [43,44,46]. One study included an assessment on four domains [47] (see Table 5).

Study design

All studies made an assessment on study design [41-49], with information about treatment dose provided in the intervention condition, and two providing information on treatment dose in the comparison group [45,47]. All studies reported underpinning theory [41-49]. No further trained providers were employed to allow for setbacks.

Training providers

Two studies provided information on training providers [45,48]. These studies provided information on how trainers were trained and standardisation of provider training. Strategies to enhance training providers included, using the same provider throughout the intervention [48], use of certified trainers [48], and train all providers together [45].

Delivery of treatment

Eight of the studies made at least one assessment on the delivery of treatment [41-48], which was assessed through direct observation of the intervention. Making sure that the interventions were delivered, and the appropriate dose given, being the most reported item in this domain.

Various criteria were used to evaluate the treatment delivery. For example, one study [47] used a checklist after each session to measure degree of adherence, and class attendance [42,47]. In another study, participants reported on the acceptability of the intervention [44], and how the participants rated the overall delivery of the intervention [48]. Other strategies used to assess delivery of treatment were the use of manuals to aid delivery [41,44-46].

Receipt of treatment

Six studies made at least one assessment on the receipt of treatment. Various strategies were used to assess receipt between authors and included ensuring that participants understood the intervention [43-48] and providing resources to enable participants to perform the behaviour

379 [47,48]. Other strategies to assess receipt of treatment included reviewing self-monitoring data
380 [43,45], and assessing confidence in behavioural skills [44-47].

381 *Enactment of treatment skills*

382 Observation and practice of skills required within interventions were included in three of the
383 studies. Observation of these skills in daily life were carried out in two of the studies [47,49].
384 Other strategies to assess whether treatment was being enacted were daily self-monitoring and
385 tracking devices [45].

386

387 **Discussion**

388 To our knowledge, this is the first systematic review to assess the effectiveness of
389 dietary interventions promoting a whole dietary pattern using a social cognition model. This
390 systematic review has investigated the extent of SCM use in designing interventions to increase
391 adherence to whole dietary patterns and explored the associations between theory use and
392 intervention effectiveness. This review also explored the extent to which the 5 domains of
393 treatment fidelity are reported in the selected studies. We found that the overall scores, across
394 the 9 included studies, measured by the TCS averaged 10 out of a possible 21 points. This
395 suggests that the studies were not explicitly theoretically informed or used to their full extent,
396 even though theory was explicitly mentioned. This review also found that only two studies
397 made at least one assessment on all five fidelity domains. As all five components of fidelity
398 are mutually exclusive. The validity of a study is potentially compromised with inattention to
399 any one of the 5 fidelity domains [40].

400 Five behaviour change theories were used in the studies of the current review (HAPA,
401 HBM, SCT, SDT, TTM), with HAPA used by 3 of the 9 included studies. Out of the 9 studies,

one study [44] showed no improvements in diet following the intervention based on the Diet Guidelines Index (DGI) to create an overall single score of diet quality. Previous research has stated that the way in which dietary scales score individual food groups to create a single score can be problematic [53], as observed associations could be due to single components rather than the overall dietary pattern [7]. Small-scale scores are less informative, as the extremes and the inherent characteristics of a pattern or a behaviour may not be fully captured [7]. Furthermore, research has shown that participants had better control of their diet and ate more healthily compared to the general population and therefore, changes in diet quality could not be detected [44]. Also, those in the intervention group perceived less risk awareness to those in the control group, which could have affected their engagement in the intervention [44]. Awareness of the importance of balanced nutrition is shown to be an important factor that may influence dietary choices [54,55].

Five of the studies used a dietary scale that reported individual food group scores. All five studies improved dietary scores for at least one food group. One study found a significant improvement in fruit intake [45], vegetable intake [43], carbohydrates/grains [42], and dairy [42]. Two studies reported improvements in protein (fish, poultry, beans, meat, or eggs) [45,47], and total fats [41,42]. These findings are consistent with a previous review which found that out of half the studies examined, at least one aspect of diet had not improved, with a further 5 studies showing no improvement in diet quality. However, in the same review, one quarter of the studies were found to be explicitly theoretically informed (based on the Theory Coding Scheme), and significantly improved diet quality. Of these 10 studies, 8 reported improvements in fruit and vegetables [25] suggesting that interventions that use behaviour change theory rigorously, lead to better outcomes in trials.

The current review found limited association between the use of psychological theory and improved intervention outcomes, with only three of the studies in this review reporting an

association between theory and intervention effectiveness (assessed through individual TCS items). One possible explanation for the relatively limited effectiveness of the interventions reviewed in the present review is that they apply theory insufficiently. The current review showed that the included studies revealed theoretical implementation weaknesses. Most notably, linking all BCTs to theoretical constructs were met by only 4 out of the 9 studies. Compared to previous findings [56,57], this review observed a closer link between intervention and theory, measured by a higher percentage of studies reporting on linkage between theoretical constructs and intervention techniques (TCS items 7-11). However, in the current review, only studies that explicitly mentioned theory were included. Previous research targeted interventions whether theory was mentioned or not for the target behaviour, with only half the studies reported to be explicitly based on theory, and of those, few targeted all theoretical constructs or linked all BCTs to theoretical constructs [57].

Theory based interventions can help us understand processes and effectiveness of interventions [26] by identifying key constructs that are shown to be related to behaviour and behaviour change techniques related to the relevant constructs, that can be used as a target for intervention design. Research has found that interventions tailored on theoretical concepts were more effective than those tailored on behaviour alone [58]. However, as more than half of the included studies in the current review did not report on this concept fully, the findings limit the extent of evidence of behaviour change factors [59]. Overall, these finding highlight the need for clearer selection, application, and reporting of theory use in the design, implementation, and evaluation of dietary intervention.

Linking BCT's to theory provides an opportunity to refine theory [26] and while the current review found that most of the studies linked at least one BCT to theoretical constructs, none of the studies used the results to refine theory. It is important to address this, as not only is theory important in the developmental stages of intervention design and future interventions,

452 but to the advancement of our understanding of how interventions affect behaviour. This lack
453 of refining theory from interventions is common, with similar results found in recent research
454 [59-61].

455 A second explanation to the relatively limited effectiveness of the interventions
456 reviewed in the present review is that the interventions may not have been delivered as the
457 designers intended. This cannot be ruled out, as treatment fidelity was poorly reported in the
458 current review studies. According to Borrelli. [40] there are five domains of treatment fidelity:
459 study design, training, delivery, receipt, and enactment, all of which are mutually exclusive.
460 The validity of a study is potentially compromised with inattention to any one of the 5 fidelity
461 domains. The overall reporting of treatment fidelity in the current review is poor, with only 3
462 studies reporting on more than three of the five domains. This finding is similar to other reviews
463 considering fidelity [40,62]. Overall, we found that regardless of the theory coding scheme
464 score, those studies that reported high on fidelity, reported improvements in more food groups
465 than those with lower fidelity. For example, one study [46] that scored the highest in the theory
466 coding scheme but low on fidelity, reported a significant improvement in overall DASH score,
467 but not in any of the individual food groups. Furthermore, two of the included studies that
468 scored relatively low on the theory coding scheme and high on fidelity, reported better
469 adherence to the Mediterranean diet [48], and improvement to several of the food groups
470 including fruit, red meat, processed meat and total AHEI scores [45]. Moreover, two studies
471 scoring the lowest on fidelity [41,42], reported improvements on less food groups, which did
472 not include fruit or vegetables. However, these two studies also scored relatively low on the
473 TCS. This finding demonstrates that, while the TCS addresses fidelity of treatment such as,
474 explicitly identifying and use of theory as a basis for intervention design, there are other factors
475 that are not addressed. For example, if insignificant results were found in an intervention and
476 only one or two of the domains were of high fidelity, it is possible that the insignificant results

were due to a lack of attention in the other domains [28], such as the training providers may not have been adequately trained. Therefore, in order to enhance the transition from theory to practice, we recommend that intervention designers include a plan to assess and monitor treatment fidelity based on the 5 domains proposed by Borrelli [40].

Using theory to design behaviour change interventions have been criticised, as they specify what theoretical constructs (i.e. intentions) should be changed to change behaviour, but do not specify how constructs can be changed. However, systematic reviews have recently started to identify links between theoretical constructs and BCTs, enhancing the effectiveness of behaviour change interventions [63]. It has been suggested, those that target change mechanisms at population, community and individual levels are the most effective [64], suggesting that behaviour change interventions may benefit from drawing on a wider range of theories than Social Cognition Models [20]. Recently, new approaches to behaviour change, and the implementation and evaluation of interventions has been developed, in particular, the Behaviour Change Wheel, COM-B model and the BCT taxonomy which helps build the bridge between predicting behaviour and actual behaviour, by specifying the "active ingredients" of the intervention, and this classification will facilitate replication of interventions [65]. The Behaviour Change Wheel seeks to provide a framework, that other theories can be considered. Social Cognition Models constructs mainly fall into the reflective motivation component of the COM-B model and either minimally or not at all into the other 5 components [20]. The COM-B model is a holistic approach for changing behaviour, based on a model of an individual, rather than a mechanistic process of identifying determinants of behaviour based on factors accounting for variation in current behaviour between individuals [20]. The BCW incorporates the COM-B model, TDF and BCT's in a systematic approach in designing an intervention. The BCW is gaining popularity in developing interventions in a range of health behaviours including dietary behaviour [66,67]. Therefore, more research is needed, using new approaches

to understand dietary behaviour, and in the development and evaluation of complex interventions [68].

Strengths and Limitations

A major strength of the current review is the use of the TCS, which allowed for a deeper exploration of the extent of psychological theory driven interventions, and also our understanding of shortcomings in the reporting and implementation on the use of psychological theory. This review did not conduct a meta-analysis, however, the differences found in the included studies populations, interventions and behavioural theories would make the average effect across studies difficult to interpret [69]. Relevant studies may have been excluded due to selection criteria and search terms. For example, studies that are not in English but used theory and relevant to this review would be missed and studies that failed to report they used a behaviour change theory. However, full articles were obtained for possible inclusion for potentially relevant articles, even if theory was not explicitly mentioned in the abstract, further minimising potential bias. Coding of the TCS may be subject to misclassification bias, however, two researchers (DT&LS) interpreted and coded the TCS items to reduce any bias

Conclusion

To our knowledge this is the first review to examine psychological theory driven interventions that use a whole dietary pattern. We have found that, while all the included studies mentioned theory, total scores were mostly moderate, suggesting that theory had not been extensively applied to the design, implementation and evaluation of behaviour change interventions, and/or theory use was reported with insufficient detail. We recommend that future interventions explicitly link theory and outcome, to allow identification of the most

salient intervention techniques and behaviour change theory, to advance our understanding of behaviour change. To enhance the transition from theory to practice, we recommend researchers use a fidelity framework to guide the reporting of treatment fidelity in future research. Mixed results were observed for the effectiveness of theory-based interventions. With the small number of included studies, only one of which was high quality, findings should be interpreted with caution. Future reviews should include both theory and non-theory interventions, to provide evidence of the effectiveness of psychological based interventions compared to no theory use.

Abbreviations

BCC: Behaviour change consortium; BCT: Behaviour change techniques; COM-B: Capability opportunity, motivation and behaviour; CG: Control group; DASH: Dietary Approaches to Stop Hypertension; DGI: Dietary guidelines index; EPOC: Cochrane effective practice and organisation of care; HAPA: Health action process approach; HBM: Health belief model; HEI: Healthy eating index; IG: Intervention group; MEDAS: Mediterranean diet adherence screener; MIND: Mediterranean intervention for neurodegenerative delay; NCD: Non-communicable disease; PICOS: Population, intervention, comparison, outcome, study design; PRISMA: Preferred reporting items for systematic reviews and meta-analysis; PROSPERO: International prospective register of systematic reviews; RCT: Randomised controlled trial; SCT: Social cognitive theory; SDT: Social determination theory; TPB: Theory planned behaviour; TCS: Theory coding scheme; TTM: Transtheoretical model; USA: United states of America; USDA: Dietary guidelines for Americans; WHO: World health organisation.

Declarations

Ethics Approval and Consent to participate

Not applicable

Consent for Publication

Not applicable

Availability of Data and Material

All relevant data is included within the manuscript file

Competing Interests.

The authors declare they have no competing interests.

Funding

The Department for the Economy (DfE) sponsored the research for this paper.

Authors Contributions

DT/ LS designed the review and searched the databases for studies. DT/LS screened, quality assessed, and theory coded included studies. DT drafted the manuscript. LS, JMcC, MK, LK revised the manuscript critically for intellectual content. All authors read and approved the final manuscript

Acknowledgment. The authors would like to thank Dr Lynn Dunwoody and Joan Atkins for providing support and necessary information for the systematic review. No funding was provided for this systematic review.

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780 Figure 1: PRISMA flow chart identifying and screening studies, eligibility of studies and
781 included studies n=9

782

783 **Supplementary information:**

784 Supplementary file 1: PRISMA 2009 checklist

785 The PRISMA 2009 checklist is a 27 item checklist for the reporting of a systematic review
786 and/or meta-analysis, which include the title, abstract, methods, results, discussion, and
787 funding.

788