

**Identification of Effective Behaviour Change Techniques in Dietary Interventions for  
Adolescents: A Systematic Review and Meta-Analysis**

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## TABLE OF CONTENTS

<b>List of Figures.....</b>	<b>4</b>
<b>List of Tables .....</b>	<b>4</b>
<b>Abstract.....</b>	<b>5</b>
Declaration.....	6
Contribution Statement .....	7
Acknowledgements.....	8
<b>Methodology .....</b>	<b>13</b>
Eligibility Criteria for studies .....	13
Population .....	14
Intervention.....	14
Comparator .....	15
Outcomes .....	15
Types of studies .....	15
Other .....	15
Information sources and search strategy.....	15
Study Selection .....	16
Quality Appraisal.....	16
Data extraction.....	17
Coding of BCTs.....	18
Measuring effectiveness of BCTs.....	19
Meta-analysis .....	20
<b>Results .....</b>	<b>22</b>
Information search and study selection.....	22
Study and intervention characteristics .....	24

Population characteristics .....	24
Study characteristics .....	25
Dietary behaviours targeted by the studies .....	25
Effective interventions .....	34
BCTs and Categories .....	41
Effective BCTs.....	42
Meta-analysis .....	44
<b>Discussion.....</b>	<b>50</b>
Main findings .....	50
Findings in previous literature .....	52
Strengths and limitations.....	53
Gaps in knowledge for future studies .....	54
Conclusion and Implications.....	56
<b>References.....</b>	<b>57</b>
<b>Appendices.....</b>	<b>66</b>
Appendix A - Inclusion and Exclusion Criteria for Review .....	67
Appendix B - Search Terms for Database Search .....	69
Appendix C - Sample Data Extraction Sheet.....	72
Appendix D - Categories and BCTs as per BCT Taxonomy v1 .....	75

### **List of Figures**

Figure 1 PRISMA Flow Chart Showing Inclusion and Exclusion of Studies .....	23
Figure 2 Quality Component Ratings as a Percentage Across Studies.....	24
Figure 3 Coding Frequency of use of Behaviour Change Technique Categories.....	42
Figure 4 Behaviour Change Techniques Used in More than 5 Interventions.....	43
Figure 5 Meta-Analysis re BCT 1.2 'Problem Solving' .....	45
Figure 6 Meta-Analysis re BCT 4.1 'Instruction on How to Perform a Behaviour' .....	47
Figure 7 Meta-Analysis re BCT 12.5 'Adding Objects to the Environment' .....	48

### **List of Tables**

Table 1 Population Characteristics of Included Studies .....	26
Table 2 Summary of Interventions Included in Review .....	35
Table 3 Association of BCTs with Effective Interventions .....	44
Table 4 Association of BCTs with Reduction in SSB Consumption.....	49

## Abstract

The aim of this study is to identify the most effective behaviour change techniques (BCTs) used in dietary behaviour interventions with early to mid adolescents, with the objective of applying these to reinforce healthy diet behaviours and to intervene when undesirable diet behaviours emerge at this critical time in their development.

Searches were executed in CINAHL, Cochrane, Dental and Oral Sciences Source, EMBASE, Medline, PubMed, PsycINFO, Scopus, and Web of Science. Eligibility included randomised, controlled, quasi-experimental or pre-post testing dietary intervention studies aiming to change dietary outcomes of individual adolescents aged 10-16 years, and using a control group or pre-post testing. BCTs were identified and coded using an internationally acknowledged taxonomy. Quality appraisal was also conducted.

Thirty-two eligible interventions were identified for inclusion and twenty-five of the interventions reported significant improvement in at least one dietary behaviour from baseline and compared to the control group. The most common dietary behaviours examined in the interventions were fruit and vegetable intake and reduction in sugar sweetened beverages (SSBs). The most frequent and effective BCTs identified were Demonstration of the Behaviour, Adding Objects to the Environment, Behavioural Practice/ Rehearsal and Instruction on How to Perform a Behaviour.

The studies varied in complexity, length and description of interventions, and the majority had only short follow up periods. To build a more solid evidence base around effective behaviour change techniques for adolescents, current health behaviour change research could be used to design and describe interventions and also to track maintenance of behaviours after the intervention has ended.

### **Declaration**

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

### **Contribution Statement**

In writing this thesis, I had three supervisors, two subject based supervisors in the Faculty of Health and Medical Sciences and a supervisor from the School of Psychology within the same Faculty. My two subject-based supervisors had already registered the Systematic Review with PROSPERO (the International prospective register of systematic reviews) in the United Kingdom, developed the search terms, undertaken the literature search on the databases and performed the abstract screening of records prior to my starting. One of my subject-based supervisors (CM) and I independently reviewed and screened the full text articles for eligibility and then conferred as necessary where we had different opinions. My supervisor (CM) and I worked in the same way in respect to the quality appraisal of the articles. I undertook identifying potential original studies from Systematic Reviews captured through the literature search, all of the data extraction, online training in coding behaviour change techniques, coding of BCTs used in the interventions, and data analysis from that point, although both subject supervisors provided advice regarding the design of the data extraction form. I wrote up all aspects of the thesis, although the literature search methodology was advised to me by CM and the search terms provided for inclusion in the appendix. Feedback was given by the supervisors on the different sections of the thesis as permitted (except for the Discussion section).

## **Acknowledgements**

I wish to express my deepest gratitude to my supervisors Professor Paula Moynihan, Dr Carly Moores and A/Professor Rachel Roberts for your tireless, patient and encouraging support of me in working on this Review. Your kind guidance and unstinted provision of your highly valuable time has helped support me in every aspect of this study and in the writing of my thesis. .

I also want to acknowledge and thank my wonderful husband and sons for their unflagging and heartfelt personal and practical support of me throughout the entire time spent researching and writing this Honours thesis. Not to forget my very good friends Maeve and Maryam who have greatly boosted my spirits along the way.



## **Identification of Effective Behaviour Change Techniques in Dietary Interventions for Adolescents: A Systematic Review and Meta-Analysis**

Good nutrition and a healthy diet are essential in promoting physical, oral, and mental health and wellbeing, while deficiencies in nutrients and poor dietary patterns are associated with significant health consequences across the lifespan and increase the risk of developing early onset of chronic conditions and non-communicable diseases such as diabetes, heart disease, hypertension, stroke and cancers (Australian Institute of Health and Welfare, 2015; Movassagh, Baxter-Jones, Kontulainen, Whiting, & Vatanparast, 2017; World Health Organization, 2000). These are amongst the top ten causes of death globally, and make up most of the top ten causes of death in upper middle income and high income countries over the last twenty years (World Health Organization, 2020). While adolescence has tended to be seen as a relatively healthy phase of life, the prevalence of overweight and obesity in this age group has been increasing steadily in both developed and developing countries, affecting one in six adolescents globally in 2016 (World Health Organization, 2018). In Australia, 25% of Australian children and adolescents (5-17 years old) were classified as overweight or obese in the year 2017-2018 according to the Australian Institute of Health and Welfare (2020). This has serious long-term implications as it puts adolescents at high risk of sleep apnea, asthma, anxiety, depression, development of dental caries and erosion of teeth enamel, as well as an increased risk of overweight and obesity and consequent co-morbidities in adulthood (Australian Institute of Health and Welfare, 2020; Moynihan & Petersen, 2004; World Health Organization, 2005). Establishing good nutrition and healthy eating patterns in adolescence is therefore of great concern to governments and societies world-wide, especially given that dietary habits and food preferences have been shown to be formed early on in life and track quite stably into adulthood (Mikkila, Rasanen, Raitakari, Pietinen, & Viikari, 2005; Movassagh et al., 2017). Adolescents are defined by the United Nations as those aged

between 10 and 19 and make up 1.2 billion - approximately 16% - of the world's population (UNICEF, 2019).

Adolescence is a period in life which is marked by substantial biological, physiological, psychological, cognitive, behavioural and social changes, a period in which an individual transitions from childhood to adulthood (Gutgesell & Payne, 2004; Hazen, Schlozman, & Beresin, 2008). It is a time of rapid growth, increasing self-awareness, of achieving greater autonomy and turning from parents towards an increasing circle of friends and peers as relevant role models and advisors in respect to behaviours (Gutgesell & Payne, 2004; Miller, Lo, Bauer, & Fredericks, 2020), and a time where social norms and other priorities compete with healthy lifestyle goals (Cunha, de Souza Bda, Pereira, & Sichieri, 2013; Miller et al., 2020; World Health Organization, 2005). Dietary behaviours are included in these changes, with adolescents adopting new habits such as skipping meals, increasing intake of sugar sweetened beverages, eating snacks that are high in fat and sugar or salt but low on nutrients, as well as not eating a sufficient quantity of fruit and vegetables (Akseer, Al-Gashm, Mehta, Mokdad, & Bhutta, 2017; Ghasab Shirazi, Kazemi, Kelishadi, & Mostafavi, 2019). It is also a period however, when good nutrition and a healthy diet is of most importance, and when there is a greater requirement for protein and energy than for any other age group due to their rapid physical and developmental growth (Akseer et al., 2017; Story, Neumark-Sztainer, & French, 2002; World Health Organization, 2005). This makes adolescence a timely period in which to reinforce good dietary behaviours and to intervene when undesirable dietary behaviours start to emerge.

However, changing eating behaviours is not just a matter of providing knowledge about the benefits of nutrition and healthy eating (Kelly & Barker, 2016; Vézina-Im et al., 2017), although this is important, or of applying models that work with adults and young children when adolescent developmental stages and requirements are quite different. On the contrary, an understanding of the complex social, cognitive and emotional factors that influence and

interact with adolescents' eating behaviours (do Amaral e Melo, de Carvalho Silva Vargas, dos Santos Chagas, & Toral, 2017) is necessary, especially in the light of the increasing availability, convenience and advertising of processed, food and beverages that contribute to obesity and makes selecting healthy choices more difficult (Akseer et al., 2017).

Adolescence starts biologically with puberty, the onset of which begins between eight and thirteen years old in girls and from twelve years old in boys, with various factors such as ethnicity, health and nutritional status affecting the timing of onset (Hazen et al., 2008). In recent years, the onset of puberty has started to appear even earlier in girls, but later in boys, possibly due to the rise of obesity (Hazen et al., 2008). The physical changes that come with puberty also have a strong influence on factors such as psychological, social and cognitive shifts in development which adolescents undergo on their journey from child to adulthood. From mid-adolescence onwards, there starts a period of maturation, where adolescents are realising and understanding their personality, values, identity and their relationships with parents and best friends and emerge from the uncertainty and emotions of earlier adolescence ((Meeus, 2016). Given that there is a longitudinal pattern of development towards maturation, which would call on different behaviour change techniques to address, this study has selected to look at early to mid-adolescence between the ages of 10 and 16 as the period where guiding towards healthy dietary behaviours would be most impactful. It is therefore important to determine what interventions and techniques might be used to successfully influence and help adolescents to change their dietary behaviours onto a healthy path..

Many studies with interventions for school students have been undertaken in the last thirty years in a wide range of countries around the world to attempt to improve their nutrition and dietary behaviours. These studies have identified the need to prevent or treat specific problems or diseases, to increase specific nutrients in the diet such as calcium or iron, or to meet the recommended amounts of fruit and vegetables, as the basis for such

interventions and have reported various degrees of success (Michie, Carey, et al., 2018). The interventions vary in their degree of complexity and intensity, potentially involving a large number of different components and activities and often based on one or more psychosocial behaviour change theories, such as Social Cognitive theory (Bandura, 1986), Theory of Planned Behaviour (Ajzen, 1985) and the Transtheoretical Model (Prochaska & Velicer, 1997) to help shape and structure the intervention. However, if what was done in the intervention to help bring about the successful change in interventions is not well described or different terminology or definitions are used by different interventions (Michie et al., 2013), it can be very difficult to determine what the effective elements and mechanisms of behaviour were so they can be replicated in future experimental interventions, or translated into everyday health practices. Taxonomies of behaviour change techniques (BCTs) have been developed over the two decades (Michie et al., 2011; Michie et al., 2015) to enable precise and consistent characterization and reporting of the basic, observable and active content of interventions and also to aid in identifying which specific techniques were present in, and potentially associated with, effective interventions which can be applied across disciplines and across countries (Michie et al., 2013).

Previous reviews have looked at interventions to change dietary behaviours in children and adolescents (Diep, Chen, Davies, Baranowski, & Baranowski, 2014; Van Cauwenberghe et al., 2010), or in adolescents and young adults (Hackman & Knowlden, 2014) to ascertain aspects of the interventions that make them effective, but only a small number of reviews have targeted adolescents only. Some of the adolescent only studies looked at effectiveness in respect to behaviour theory, intensity of the intervention (Racey et al., 2016), or method of delivery such as serious computer games (Dias, Domingues, Tibes, Zem-Mascarenhas, & Fonseca, 2018), including technology (Ajie & Chapman-Novakofski, 2014; do Amaral e Melo et al., 2017). Only a very few studies have looked at determining the behaviour change techniques that were effective in adolescent interventions, and these addressed uses of social

media in interventions only (Hsu, Rouf, & Allman-Farinelli, 2018), or included only studies using a specific dietary behaviour, such as sugar sweetened beverages (Vézina-Im et al., 2017) or dairy product consumption (Marquez, Racey, Preyde, Hendrie, & Newton, 2015).

There is a need therefore to review a broader range of dietary behaviours in a general population of adolescents, given that the health concerns related to adolescent nutrition and dietary habits are world-wide. This study aims to undertake this review in respect to the earlier development period of adolescents, with the objective of contributing towards the evidence necessary to determine behaviour change techniques that are effective in developing successful dietary behaviour interventions in the early to mid-adolescent age group and the consequent translation of this evidence into guiding adolescents towards healthier dietary behaviours.

### **Methodology**

This Systematic review has been reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). This paper is related to a PROSPERO registered Systematic Review [CRD42020164544] being a subsample of the moderate and high quality papers from that review.

### **Eligibility Criteria for studies**

Eligibility criteria for studies included in this Review was determined through a Population, Intervention, Comparator, Outcome, Study Design (PICOS) framework.

### ***Population***

The target population for this study was human adolescents aged 10 – 16 years old; this age group was selected as it aligns with early to mid-adolescence. Where there was a wider age range of participants in a study, the mean/median age needed to be within 10-16 or the data for the 10 - 16 years old participants reported separately. Furthermore, adolescent data had to be reported separately to any other participants that might be included in the intervention, such as care givers. Exclusions were studies that selected participants on the basis of a disease or a specific psychological or physical condition, or who were pregnant or post-partum. The exception to this was participants with dental caries or who were overweight or obese.

### ***Intervention***

Eligible interventions were those that aimed to change dietary outcomes of individual adolescents. Interventions could address obesity if the intervention component were dietary only and could investigate oral health/secondary prevention of caries as long as the intervention included a dietary component. Interventions targeted to adolescents could also involve others, such as parents, family, friends, or peers. There was no limit in terms of time, and interventions could be group-based, one-to-one or a combination, and involve any kind of technology or none. Eligible settings included schools – including as part of the curriculum - family home, community, and dental settings. However, interventions that included supplements, pharmaceuticals, surgery, performance enhancing nutrition such as may be required for high level adolescent athletes, or supplied food or drink to participants were excluded; as were interventions that incorporated additional components to address healthy lifestyle issues such as physical activity, smoking, alcohol use, and other drug use.

### ***Comparator***

Comparator groups eligible were those with a different intervention, a varied intensity of intervention, usual care, no exposure to intervention or, at a minimum, pre and post testing of the intervention group.

### ***Outcomes***

Studies needed to have at least one outcome reported at both pre and post intervention for both intervention and comparator groups, that addressed the effectiveness of the intervention on any of the following: diet and nutritional quality, food and/or drink intakes, nutrient intakes, eating habits, nutrition knowledge, attitudes, beliefs, intentions, self-efficacy or food and nutrition literacy.

### ***Types of studies***

Intervention studies with randomised, controlled, quasi-experimental or pre-post designs were eligible. Qualitative designs, cross-sectional and observational studies were not eligible, nor were Systematic Reviews.

### ***Other***

Limits set were peer-reviewed, published research papers in English language from 1990 to 2020, with a full text available. The year limit of 1990 was chosen so as to identify more contemporary interventions which may be more relevant to apply in future interventions. Grey literature was excluded. A full list of inclusion and exclusion criteria is provided in Appendix A.

### **Information sources and search strategy**

Literature searches were conducted in CINAHL, Cochrane, Dental and Oral Sciences Source, EMBASE, Medline, PubMed, PsycINFO, Scopus, and Web of Science on 13 January 2020 by reviewer CM. Search terms were based on four broad PICO concepts describing the study: Adolescent, Behaviour change intervention study, Comparator group, and Diet and Nutrition outcomes. Keywords searched for included adolescen\* or teen\*; behavio\*r or diet\*

or nutrition\*; beverage, food, eating, drink, sugar, fruit, vegetable; program evaluation, intervention, program, trial, controlled study, intervention study. A research librarian assisted with transforming search terms to data-base specific terms where required. Proximity searching was used where possible to ensure retrieval of articles about behaviour change, where this was not possible, behaviour or behaviour/behavioural change terms were used as another search term. Further potentially eligible articles were identified through a manual search of the reference lists of Systematic Reviews identified through the database search. A full list of search terms for the various data bases accessed is provided in Appendix B.

### **Study Selection**

Records identified from the database searches were screened for duplicate articles, which were then removed. The remaining search records identified from each of the databases were exported to and compiled in EndNote X9 (Clarivate Analytics, 2020) from where they were exported to Covidence (Veritas Health Innovation, 2017) for screening. Title and abstract screening of records for eligibility was performed in Covidence by one reviewer (CM) with a second reviewer (PM) screening a random sample of 5%. Full text screening was independently performed by the author and another reviewer (CM) and was done in accordance with the eligibility criteria noted above. The screening followed an exclusion hierarchy (included in Appendix A with eligibility criteria) with reasons for exclusion being recorded. Articles identified by the manual search of reference lists underwent the same two-step screening process. Disagreements were resolved by discussion between the author and reviewer CM until consensus was reached.

### **Quality Appraisal**

Each study was reviewed using the Effective Public Health Practice Project's (EPHPP) 2009 Quality Assessment Tool for Quantitative Studies and its accompanying Dictionary (2017) so that overall study quality could be assessed. The EPHPP tool (Thomas, Ciliska, Dobbins, & Micucci, 2004) was developed for use in research papers looking into



public health type topics and guides the assessment of study quality based on six different components, including participant selection bias, study design, treatment of confounding variables; blinding; data collection methods and withdrawal and dropout reporting. Each component receives a guided rating of weak, moderate, or strong, and then are scored across components to provide a global quality rating of weak, moderate, or strong. A study is rated globally as strong when there are no weak ratings assigned for any of the components, as moderate when one weak rating is assigned, and rated as weak when two or more components are rated as weak.

Quality appraisals were undertaken independently by the author and another reviewer (CM) and scoring compared. Different papers related to the same intervention study were appraised together as one study. Where necessary for any particular study, additional or clarifying information was obtained from the related published protocol and online supplementary materials if available. Differences in component scoring were compared and discussed by the reviewers until agreement was reached; notes were recorded. Studies rated as globally weak were excluded, and only studies with an agreed global rating of strong or moderate were included in the Review, thus reducing overall risk of bias, and also providing a more manageable number of articles overall.

### **Data extraction**

A detailed form was developed, based on the TIDieR checklist (Hoffmann et al., 2014) and the PICO structure to extract relevant data. Data included Metadata (citation, year and country of intervention), study details (design, description, setting, length, data collection points, follow ups and appraised quality rating), Population information (inclusion/exclusion criteria, sample size, ages, gender, SES information, etc.), Intervention information (number of sessions and frequency, involvement of parent/peers in intervention, etc.), Behaviour change (theory underpinning intervention if any, BCTs identified by author/s, BCTs identified by reviewer), Comparator group details (sample size, treatment), Results details

(measurement methods, diet outcomes measured, sample size analysed, statistically significant results, other interesting results). Additional intervention information was also gathered from papers identified as linked and relevant results reported in a separate section of the data extraction sheet. A copy of the developed data extraction sheet is included in Appendix C. Data extraction was conducted by the author in two stages; with the identification and coding of Behaviour Change Techniques in each study only starting after all the other data was extracted for all included studies.

### **Coding of BCTs**

The Behaviour Change Taxonomy v1, developed by Michie et al. (2013), was used to assess and identify BCTs used in the interventions. This taxonomy is an extensive hierarchy of 93 separate behaviour change techniques under 16 categories which enables the active constituents of interventions to be identified with precision and reported and can be used across a wide range of behaviours (Michie et al., 2015). The review author undertook the recommended online training ([www.bct-taxonomy.com](http://www.bct-taxonomy.com)) to learn to code BCTs according to the taxonomy prior to coding.

Interventions were read carefully and, in line with the BCT Taxonomy v1 training, a BCT was only coded if there was a clear indication it was present according to the definition in the taxonomy and was directly applied to the behaviour or behaviours targeted by the intervention. Thus, if an intervention did not provide sufficient information to show the use of, for example, BCTs *5.1 Information about health consequences* or *4.1 Instruction on how to perform the behaviour*, then these BCTs were not coded. If a more detailed description of the intervention was available to assist in coding BCTs, published Protocols or supplementary materials available online where the paper was located were used, as has been done in other reviews (Martin, Chater, & Lorencatto, 2013); further clarification was not sought from authors due to time constraints.

As has been done in previous studies using the BCT Taxonomy (Ashton et al., 2019; Samdal, Eide, Barth, Williams, & Meland, 2017), only BCTs that were unique to the intervention condition were coded, such that if a BCT was also included in the control/comparator condition it was not recorded for the intervention group; likewise, where a study had multiple intervention arms, the BCTs were only coded for the arm where they were unique compared to the control arm. Identification and coding of BCTs was undertaken by the author only as shortage of time and resources prevented coding by two independent reviewers, however after coding all the studies, a sample of 10% (4 studies) was selected using an online random number generator and re-assessed for identification of BCTs and coding as a quality checking method. Motivational Interviewing (MI) techniques where specifically described as such in the study, were not coded in terms of the BCT Taxonomy given that while there has been found to be some overlap in some of the content-based techniques, there are also many relationship-based techniques that are unique to Motivational Interviewing (Hardcastle, Fortier, Blake, & Hagger, 2017) and there would not be sufficiently clear evidence to code a specific BCT.

### **Measuring effectiveness of BCTs**

The frequency of specific BCT categories used across studies was explored to discern any patterns in the use of behaviour change techniques amongst the included studies, as well as their association with effective interventions. Individual BCTs within the categories identified were then assessed for their own association with effective interventions. Association with effective interventions was determined by summing the number of times a BCT was used in an effective intervention and dividing that by the number of times the BCT was used in the total number of interventions to obtain a ratio, as has been used in other reviews, with a higher ratio indicating BCTs that are most likely to be effective (Ashton et al., 2019; Martin et al., 2013; Michie, West, Sheals, & Godinho, 2018). The effectiveness of an intervention was determined by whether there was a statistically significant positive

change from baseline in one or more dietary related outcomes in the intervention group compared to the control condition (or weakest active comparator if no control group) (Ashton et al., 2019), and measurement was either by an objective method or based on a validated Food Frequency Questionnaire (FFQ) or 24 hour recall instrument, as used in other reviews (Marquez et al., 2015; Racey et al., 2016). In the instances where an intervention only had one group, effectiveness was determined by a statistically significant positive change from baseline in one or more dietary related outcomes. Association of frequently used BCTs with dietary behaviours only where there were ten or more interventions addressing the behaviour was also assessed. This focus was necessary due to the very large amount of data associated with the wide number of dietary variables identified. Selecting the dietary variables for which there were most data was most likely to yield results amenable to analysis.

### ***Meta-analysis***

Meta-analyses were carried out to assess whether there was an overall effect amongst the randomized control trial interventions in improving dietary behaviour compared to controls, and also to determine the outcome effect where a specific BCT was present in the intervention and also where it was absent or was not unique to the intervention arm. This method of evaluating the effect of BCTs has been used in many studies (Michie, West, et al., 2018). Only the most common dietary behaviour identified was analysed due to lack of time and resources, and only BCTs that had been used in four or more randomized control studies were included in the analysis to reduce the possibility of making Type 1 errors due to unnecessary multiple comparisons. The meta-analysis was carried out using Comprehensive Meta-Analysis (CMA) software, Version 3 (Borenstein, Hedges, Higgins, & Rothstein, 2013) using a Random Effects model, which takes between studies variation in true effect sizes into account. This is likely to be the case where included studies use a variety of intervention designs and outcome measures. CMA software applies weights to studies using inverse

variance, where the variance includes both within study and between study variance (Borenstein, Hedges, Higgins, & Rothstein, 2011).

Where dietary consumption was reported in grams per day, grams were converted into servings per day by dividing by 106; 106g being a standard portion size for fruit and vegetables used in previous meta-analyses (Ashton et al., 2019). Data was entered as Pre and Post means, standard deviations and population for both intervention and control arms. Where the standard error of a mean was given instead, it was converted into a standard deviation by multiplying it by the square root of the sample size:  $SD = SE \times \sqrt{N}$  (Higgins, Li, & Deeks, 2020). Some studies had multiple intervention arms which were entered separately into the meta-analysis, but to avoid double counting of participants in the control group, the shared control arm was split into even parts, with the means and SDs remaining the same (Higgins, Eldridge, & Li, 2020). Furthermore, where studies reported fruit and vegetable intake separately, these were entered separately and combined by selecting the CMA software option to use the mean of the selected outcome, to avoid them being treated as independent outcomes. Only the baseline and immediate post intervention results were selected for the meta-analysis as some of the included studies did not have a further follow up result. The pre-post correlation was entered as .7 as this is considered a conservative value for studies with a repeated measures design (Estrada, Ferrer, & Pardo, 2018).

Pooled results are reported as mean differences with 95% confidence intervals (95% CI) and with two-tailed P-values, while heterogeneity is reported with  $I^2$ , Q value with degrees of freedom (df) and  $p$  value and Tau squared. Investigations into high heterogeneity, such as by conducting sub-group analysis or meta-regressions, was only carried out if there were ten or more studies in the meta-analysis as it has been suggested that the results would be of doubtful value if there were less (Deeks, Higgins, & Altman, 2020). Analysis using Hedges G (weighted) for effect size was also run for each set of data. Publication bias was

assessed in CMA by visually appraising a funnel plot of standard error by difference in means.

## Results

### Information search and study selection

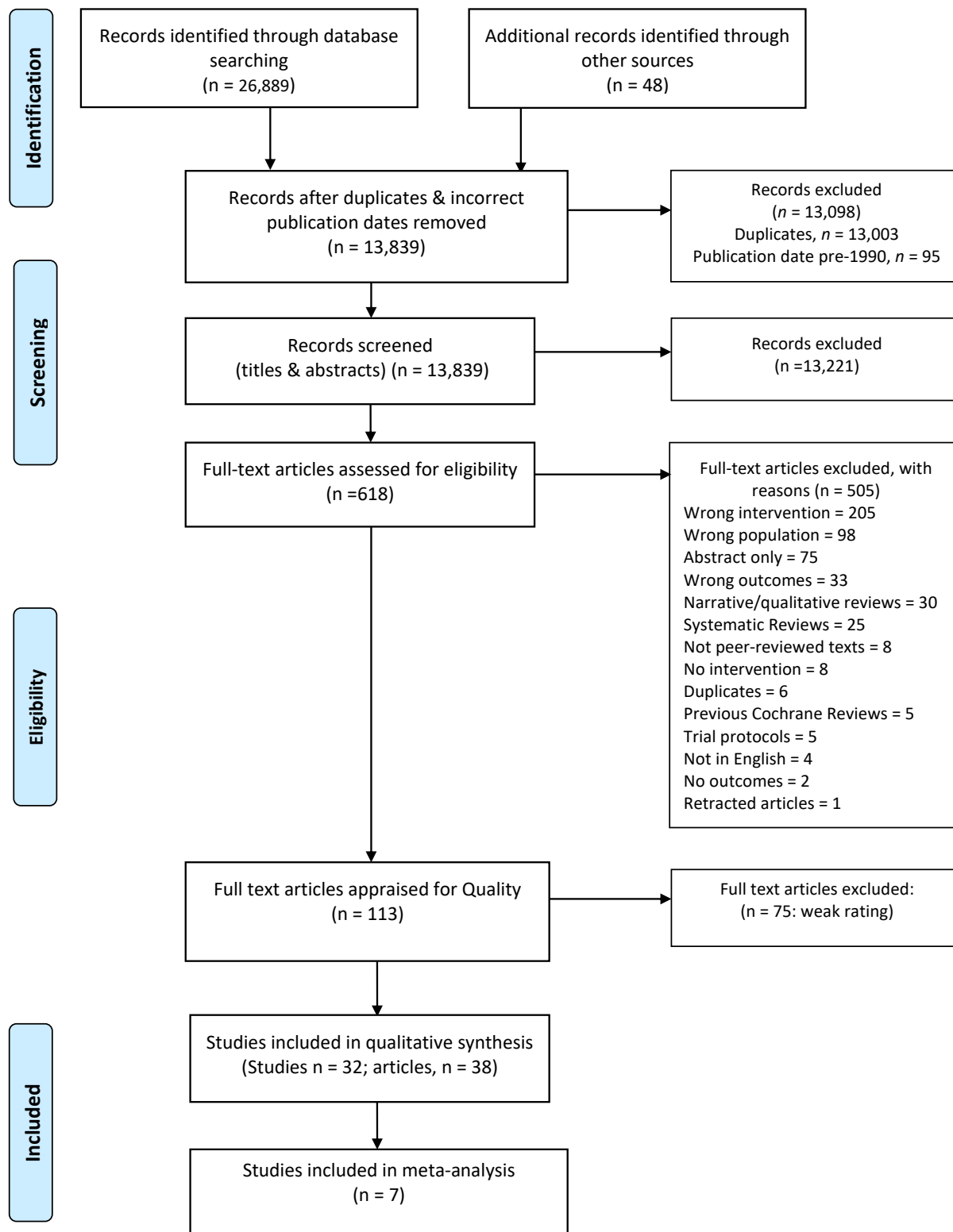
A total of 26,889 articles were identified from the database search, of which 13,003 were removed as duplicates and 95 removed due to having an earlier publication date than specified. An additional 48 articles were identified through a manual search of reference lists of Systematic Reviews identified by the database search. Abstract and title screening excluded a further 13,221 articles. Full text review was thus undertaken on 618 articles of which 113 were identified as eligible according to the criteria. There was a high level of agreement between the reviewers for inclusion of studies (85%); disagreements were resolved by discussion until consensus was reached.

Quality appraisal of these articles resulted in a further 75 articles being excluded due to being rated as weak on two or more components. Out of the 38 articles finally selected for inclusion in the Review, there were 32 original studies (see Figure 1 for Review flowchart).

Differences in scoring on quality was compared and discussed between the reviewers until agreement was reached. The mean agreement rate between the two reviewers for the final quality grade assigned to studies was 82%, and 81% for agreement on the individual domains grade, which is considered an excellent agreement rate (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012). The majority of included studies had strong ratings on study design (n=26), dealing with confounders (n=27), data collection methods (n=27) and withdrawals and dropouts (n=24). However only 16% of these studies received a global rating of strong; with blinding being the main component that accounted for a weak component rating in 62.5% of the studies. Quality assessment component ratings as a percentage of the included studies as a whole are shown in Figure 2. Excluded studies were rated as weak on

**Figure 1**

*PRISMA Flow Diagram Showing the Inclusion and Exclusion of Studies for this Review*



withdrawals and dropouts (73%), blinding (95%), data collection methods (49%) and confounders (47%) in particular.

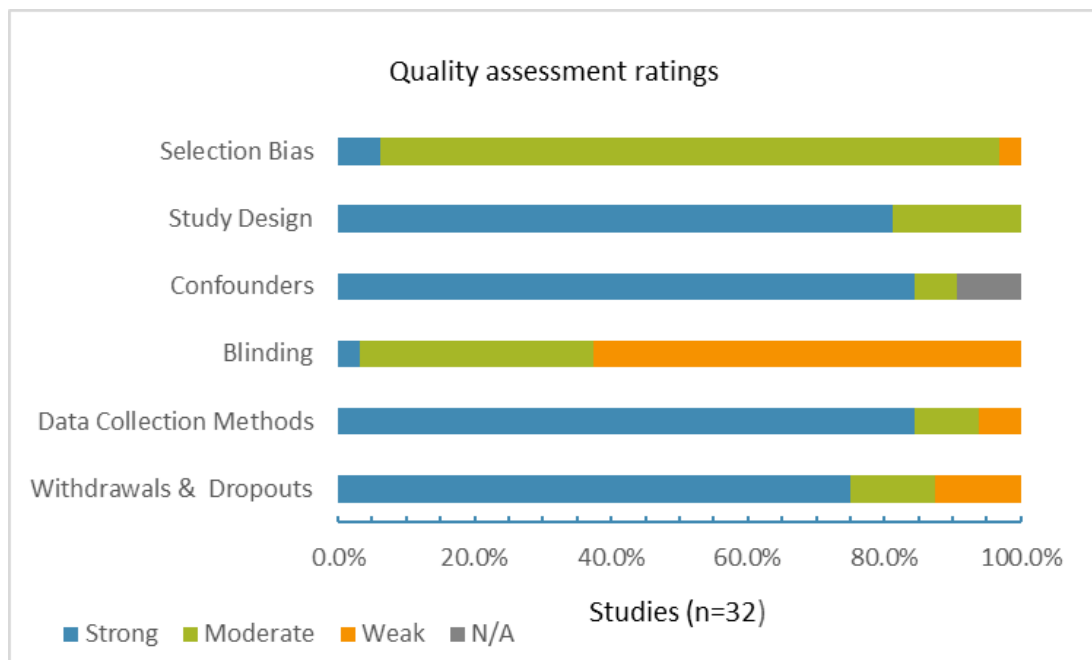
## Study and intervention characteristics

### *Population characteristics*

The pooled population of the thirty-two studies included was approximately 14,200; participants ages varied from early adolescent groups (9-11) through to older groups (13-18 years old), with a mean age of 12.66 years. The majority of studies were in a school setting and most studies included both boys and girls as participants (mean proportion overall 48% males), however six studies targeted girls only, and one study had boys only. Studies were located in eighteen countries across the world, including USA, Iran, Brazil, several European countries, Tanzania, Ethiopia, Turkey, India, Aruba (Caribbean) and Hong Kong, and

## Figure 2

*Quality Component Ratings as a Percentage Across Studies*





participants were from a wide range of socio-economic status (SES) backgrounds and from both urban and rural areas. Population characteristics are summarised in Table 1.

### ***Study characteristics***

Twenty-two studies were described as randomized, cluster randomized, or group randomized, while five were described as quasi-experimental, three as single group with pre-post testing, one as a pilot study (with control and pre-post testing) and one as a pre-test post-test non-equivalent control group design. Eight studies had more than one intervention arm. Interventions varied widely in duration from 50 minutes through to four years, with the most common lengths of time being 2-3 months and 6-9 months; only four studies had interventions lasting a year or more. Data collection points included baseline and immediate end of intervention (EI) (7 studies), Baseline and 1-3 months after EI (13 studies) and baseline and 6 months or more after EI (4); only eleven studies had more than one post intervention test, with eight of these being within six months of the first post test, and three being a year or more afterwards. Nearly half of the studies were published from 2015 to 2019. Table 2 summarises the intervention characteristics of the study.

### ***Dietary behaviours targeted by the studies***

Fourteen studies looked at one dietary behaviour only, and the remaining eighteen studies looked at between two and four dietary behaviours each. The most common dietary behaviour targeted by the interventions was fruit and vegetable consumption, this was included in thirteen studies overall with seven of these studies assessing fruit and vegetable intake only. Eleven studies addressed the intake of sugar sweetened beverages (SSBs), including a range of beverages such as sports drinks, sodas, cordials, powder based drinks

**Table 1***Population Characteristics of Included Studies*

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low	Not reported
Bagherniya 2017	Iran	IG: 13.53 (0.67) CG: 13.35 (0.60)	12 to 16	Female only	BMI ≥ 85th percentile	Urban	Income data not reported 82-85% of parents had education below university level	Not reported
Birnbaum 2002/Lytle 2004	USA	Not reported	Year 7	Both Male/Female % IG1: 46.5 / 53.5 IG2: 50.7 / 49.3 IG3: 50.4 / 49.6 CG: 51.3/ 48.7	Not reported	Urban	Income data Not reported but stated to be low-income	White: 68.7%) African Americans 10.4%, Asians or Pacific Islanders 6.9%, Multiracial 5.6%, Other 8.5%
Bryan 2019	USA	Not reported	Year 8 13-15	Both Male/Female % 49 / 51	Not reported	Rural & Urban	38% economically disadvantaged	White 51% Latino 44% Black/African American or mixed race 5%
Cotter 2013	Portugal	11.4 ± 1.0	Year 5-6	Both Male / Female % 45 / 55	urinary creatinine, namely at least 0.1 mmol/kg per 24 h.	Urban	Not reported	Not reported
Cunha 2013 / Cunha 2015	Brazil	11.2 (SD = 1.3)	Year 5-6	Both - percentages/No . not reported	Not reported	Urban	One of the poorest areas in Brazil. No other SES information provided.	Only skin colour reported (White 25.6%, Brown 45%, Black 29% approx.)

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low	Not reported
Dansa 2019	Ethiopia	15 years	11 to 19	Female only	pregnancy at baseline or during the time of intervention	Rural	93% farming households >70% households at poverty level	Not reported
Dehdari 2014	Iran	13	13 years old	Female only	Ability to read and write Farsi, residency in Qom city and studying in the 7th grade	Urban	Average income areas, 78-92% of parents with Yr 12 education level or less	Not reported
Di Noia 2008 / Di Noia 2010	USA	12.4 ± .98	11 to 14	Both Male/Female % 39 / 61	African-American ethnic/racial heritage and 11-14 y.o.	Urban	87% of participants came from communities in which 20% or more of families had incomes below the federal poverty level	African-American, Hispanic (15%)
Fonseca 2019	Brazil	14.8 ± 1.0 yrs	Year 9	Both Male/ Female % 52.9 / 47.1	Not reported	Urban	Not reported, but authors state: "students attending public schools are more likely to be from lower socioeconomic status families"	Not reported
Franken 2018	Aruba (The Caribbean)	11.4 ± .98	10 to 14	Both Male/Female %: 46 / 54	Not reported	Regional (Island)	Not reported	Not reported
Ghasab-Shirazi 2019	Iran	13.5	13 to 15	Female only	being a resident of Isfahan, not having a history of diseases requiring a special diet.	Urban	65-70% families had moderate economic status; 29-33% families had poor economic	Not reported

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low  status,, approx. 17% good economic status	Not reported
Gur 2019	Turkey	12.02 ( $\pm$ 1.18 yrs)	9 to 15	Both Male/Female %: 45.2 / 54.8	Not reported	Urban	Not reported	Not reported
Gutschall 2013	USA	12.6 $\pm$ 1.9	8 to 15	Both Male/Female %: 75.5 / 24.5	Enrolment in an established community-based after-school program	Rural	Income USD 38, 400 $\pm$ 21,150	15.5% Hispanic, 84.5% white
Haerens 2007	Belgium	13.2 $\pm$ 0.5	Year 7	Both Male/ Female % Total: 29.6/70.4	School needed to have at least 2 x Year 7 classes	Urban	Not reported	Not reported
Hassapidou 1997	Greece	Intervention: M / F 13.4 $\pm$ 0.8 / 13.3 $\pm$ 0.5 Control: M / F 13.2 $\pm$ 0.4 / 13.2 $\pm$ 0.5	2nd year of high school 13-14 y.o.	Both Male /Female % IG: n = 32 / 41 CG: n = 32 / 21	Not reported	Both	SES: % Income < 100k DRS, 100-200k DRS, > 200k DRS IG: M / F 16/12, 59/71, 25/17 CG: M / F 13/10, 56/71, 31/19	Not reported
Holund 1990 (c) /Holund 1990 (a)	Denmark	14	Year 8	Both no information re numbers/ %	Year 8 students	Urban	Not reported	Not reported

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low	Not reported
Karimi-Shahanjarini 2013	Iran	IG1 mean age 14.06; IG2 mean age 14.21; CG mean age 13.83	Years 6 to 8	Female only	Not reported	Urban	IG1 IG2 CG Education:% mothers/fathers < 12 yrs: 40/37, 39/33, 37/37 12 yrs: 39/40, 42/41, 45/39 > 12 yrs: 21/23, 19/26, 18/24	Not reported
Kaveh 2018	Iran	14.1 ± 1.0	12 to 16	Female only	High school student, female, aged 12-16, Tehran resident	Urban	Economic status % IG/CG: Very good 4.2 / 8.0 Good 39.4 / 44.3 Average 45.3 / 42.6 Poor 11.1 / 5.2	Not reported
Keshani 2019	Iran	IG - 13.87 (0.89) CG - 13.94 (0.9)	13 to 15	Both Male/ Female % IG 45.4 / 54.6 CG 54.1 / 45.9	Exclusion: students with chronic diseases, or special diets or identified as refugee	Urban	Father Job: IG / CG % High rank 2.4 / 1.3 Medium rank 28.2 / 24.3 Low rank 59.5 / 68.9 Retired 7.3 / 2.7 Unemployed 2.4 / 2.7	Not reported

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low	Not reported
Lane 2018	USA	IG: 11.7 (0.6) CG: 11.8 (0.7)	Year 6 and 7	Both Female / Male % IG: 60.5 / 39.5 CG: 58.1 / 41.9	Attended regular science class Not part of prior formative study	Rural	Not reported - but notes school located in area that: <ul style="list-style-type: none"> <li>• Is designated medically underserved area</li> <li>• experiences high rates of poverty and chronic diseases, incl highest rates of obesity</li> </ul>	Not reported
Lin 2017	Iran	IG1: 14.62 ± 3.01 IG2: 14.49 ± 3.24 CG: 14.12 ± 2.35	13 to 18	Both (but separate schools) Male / Female % IG1: 53 / 47 IG2: 48 / 52 CG: 51 / 49	Not reported	Urban	Monthly household income in Rials Mean (SD) IG1: 981.63 ± 382.22 IG2: 962.21 ± 321.61 CG: 991.12 ± 304.40	Not reported
Mangunkusomo 2007	The Netherlands	10.3	9 to 12	Both Female / Male % IG 54.4 / 45.6 CG 51.1 / 48.9	Not reported	Urban and Rural	Not reported	Dutch (> 84.5% < 89%)
Prell 2005	Sweden	approx 14	Year 8	Both Male/Female % IG1: 34 / 66 IG2: 55 / 45 CG: 49 / 51	Not reported	Urban	Not reported	Swedish: 86%- 93% (remaining percentage: 'other')
Rani 2013	India	Not reported	Year 8 & 9 12-15	Both Male and	Not reported	Urban	"middle socio-economic status".	Not reported

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3 Female % 64 / 36	Pupils attending their 6th primary public school year	Both	Low	Not reported
Sichieri 2008	Brazil	IG 10.9 (0.81) CG 10.9 (0.75)	Year 4 9-12	Both Male / Female % IG 46.9 / 53.1 CG 47.4 / 52.6	Not reported	Urban	"Most students in the public schools are from families of low socio-economic level."	% IG CG White 41.8 42.3 Black 32.3 26.9 Mulatto 25.9 30.6
Smit 2016	The Netherlands	10.75 ± 0.8	9 to 13	Male 48% Female 52%	School not already engaged in a water drinking stimulation program	Urban	Not reported	> 95% Dutch or west European
Te Velde 2008 / Wind 2008	Norway, The Netherlands, Spain	10.7 (IG), 10.8 (CG)	10 to 13	Both Male / Female % IG: 45.7/54.3 CG: 49.4/50.6	Not reported	Urban	Family educational level: (parent with higher educ level) Yrs IG% CG% <7: 8.3 8.1 7—9: 25.2 17.8 10-12: 26.0 31.4 > 12: 40.5 42.6	Not reported

Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year	Both	Low	Not reported
Thompson 2015	USA	Not reported	9 to 11	Both Male/Female % 47.3/52.7	4th or 5th grade, Fluent in English or Spanish, access to high speed internet, computer, parent willing to participate	Not reported	Highest level of household education was predominately post-graduate study (36.7%), and average household income was > \$61,000 (57.6%) Parents were mostly female (96.3%), White (40.3%), married (77.5%), and 40–59 years old (55.3%)	White-36.8%, Hispanic 27.4%, African American 26.4%
Thompson 2009 / Latif 2011	USA	13 (± 0.1)	10 to 14	Male only	Troop inclusion: scouts had high likelihood of having home computer with internet access. Scout inclusion: troop membership, home computer with internet access	Urban	Highest Education level in household: IG/CG % HS graduate or less 3.1 / 9.0 Some College/Tech 16.9 / 33.7 College graduate 38.5 / 34.8 Post-graduate 41.5 / 22.5	IG / CG % Anglo-American 78.1 / 68.1 African-American 4.7 / 3.3 Hispanic 7.8 / 18.7 Mixed/Other 9.4 / 9.9
Tolvanen 2010	Finland	11.9	2001: 11 to 12 2005: 15 to16	Both Male / Female % IG 51/49 CG 50/50	Inclusion in RCT (RIG & RCG): children 11- to 12 y.o. at beginning of study with at least one active caries Inclusion in CG: all	Urban	RIG /RCG Mother's occupational level = high % 30 / 32 Father's occupational level = high % 28 / 30	Not reported



Lead author	Country	Mean age of participants	Age range or school year level	Gender	Selection criteria	Rural/Urban	SES	Ethnicity/Race
Astrom 2012	Tanzania	13.8 years	10 to 19	Both Male / Female% 49.7 / 50.3	Pupils attending their 6th primary public school year children 11- to 12 years-old at beginning of study (no caries) Exclusion: mentally disabled or handicapped children attending special schools	Both	Low	Not reported
Wu 2017	Hong Kong	Not reported	12 to 13	Both Male / Female %: Total: 51.2/ 48.8 CG: 34.2 / 65.8 IG1: 50.3 / 49.7 IG2: 66.5 / 33.5	Inclusions: not have major chronic disease, have unfavourable oral health behaviour (brushing less than 2 x day or snacking 3 or more times per day), communicate in Cantonese or Mandarin.	Urban	Parental education (mother or father, whichever lower) as indicator for SES): % Total, CG, IG1, IG2 Primary: 21.9, 23, 23.3, 19.7 Secondary: 66.8, 70.8, 65, 54.9 Post Secondary: 11.3, 6.2, 11.7, 15.4	Not reported

Note. IG = Intervention Group, CG = Control Group, RIG = Intervention group within the RCT, RCG = Control group within the RCT

and juice, with the reduction of SSBs, or increase in water intake and consequent reduction of SSBs being the sole focus of four of these studies. Reduction in unhealthy snacking, such as salty, sweet and highly processed snacks or sweets, and/or replacing with healthy snacks was looked at by seven studies, with three of these addressing reduction in snacking behaviours from an oral health perspective. Eight studies looked at increasing dietary/nutrition knowledge, along with dietary and/or oral health behaviours. Intake of dietary fats was covered by four studies. The eating of breakfast was addressed specifically by one study, whilst two others looked at breakfast consumption amongst other dietary behaviours. Four studies looked at various and differing aspects of diet quality, including macro and micronutrients and energy intake from food. Salt intake and fish intake were addressed by one study each. There were four papers that looked at improving dietary behaviours from a purely oral health perspective (reduction of caries).

Thirteen behaviour change theories and models in all were used as the basis for the design or approach of interventions, with Social Cognitive Theory (8) and the Theory of Planned Behaviour (6) being the most common, with five studies using more than one theory. Refer to Table 2 for detail regarding specific studies targeting these theories.

### **Effective interventions**

The results of each study were evaluated to determine the effectiveness of their interventions. Twenty-five studies were assessed as having at least one statistically significant ( $p < .05$ ) dietary intake result from baseline for the intervention group as a whole compared to the control group, or in studies where there was only one study arm, at least one statistically significant and effective dietary intake result in the full population sample after the intervention compared to baseline. Seven studies did not meet this criteria, either by seeing no or little improvement from baseline for the intervention group (Åstrøm & Mashoto, 2012; Mangunkusumo, Brug, de Koning, van der Lei, & Raat, 2007; Sichieri, Paula Trotte, de Souza, & Veiga, 2009), improvement from baseline was not significant in comparison

**Table 2***Summary of Interventions Included in Review*

Lead Author	Study Design / study arms (incl control/ comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Astrom 2012	Multi-group before-after design – non randomised / 2	TPB	Knowledge of Oral Health and Decreased intake of sugared snacks	6 months	1768 / 1306	5.1, 9.1	0	Moderate
Bagherniya 2017	Cluster Randomized Controlled Trial / 2	SCT	Fruit & Veg intake Calorie intake from fats	7 months	172 / 172	3.1, 3.2, 4.1, 5.1, 6.1, 8.1, 9.1, 10.3, 12.5	+	Strong
Birnbaum 2002/ Lytle 2004	Group-randomized trial design / 4	SCT, TPB	Daily servings of fruits, vegetables, F&V and improve usual food choices	1 school year (Fall 98 to Spring 99)	3878 / 3503	1.2, 3.2, 4.1, 5.1, 6.1, 7.1, 8.1, 10.1, 10.3, 12.5	+	Moderate
Bryan 2019	Randomised controlled field experiment / 2	Values alignment	Dietary choices as measured by purchases in the school cafeteria	2 days	362 / 362	6.2, 13.2	+	Moderate
Cotter 2013	Randomised study / 3	Not reported	Salt intake Herbs as substitute for salt intake	6 months	139 / 127	4.1, 5.3, 6.1, 8.1, 12.5	+	Moderate
Cunha 2013 / Cunha 2015	Paired randomized school-based trial / 2	“Pedagogy of the Oppressed” (teaching theory)	Healthy food and drink intake Consumption of SSBs and sugar Replacement of highly processed snacks with fresh fruits or healthy homemade food	9 months	478 / 478	1.1, 5.1, 5.3, 8.1, 8.2, 9.1, 12.5	+	Moderate

Lead Author	Study Design / study arms (incl control/ comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Dansa 2019	Quasi-experimental study design with pre-test post-test measurements / 2	HBM	Knowledge, attitudes, and practices (KAP) re pulse consumption Nutritional status of participants	6 months	132 / 132	2.2, 4.1, 5.1, 6.1, 6.3, 8.1	+	Moderate
Dehdari, 2014	Quasi-experimental study with control group / 2	Pender's HPM	Intake of energy, fibre, protein, carbohydrate and macro and micro-nutrients in breakfast	4 weeks	100 / 100	2.2, 2.3, 3.1, 4.1, 6.1, 6.2, 8.1, 9.1, 12.5	+	Moderate
Di Noia 2008 / Di Noia 2010	Pre-test post-test quasi-experimental study. / 2	TTM	Fruit and vegetable consumption	4 weeks	549 / 507	1.1, 1.4, 2.2, 3.1, 5.1, 5.2, 5.5, 8.2, 10.9, 12.1, 12.3, 13.1, 15.4	+	Moderate
Fonseca 2019	Experimental, randomized, controlled nutritional intervention / 2	Not reported	Dietary knowledge, food intake, dietary behaviours, self-perceived dietary knowledge & diet quality	2 weeks – not clear	676 / 461	5.1, 6.1, 12.5	+	Moderate
Franken 2018	Cluster randomized controlled trial / 2	Social network approach, incorporating self-persuasion theory and SDT	Consumption of water and SSBs in population Water and SSB consumption behavior of <i>Peer Influencers</i>	8 weeks	394 / 377	1.4, 3.1, 5.3, 6.1, 6.2, 12.5, 13.1	+	Strong

Lead Author	Study Design / study arms (incl control/comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Ghasab-Shirazi 2019	Randomized controlled trial / 2	SCT	Breakfast, fruit and vegetable consumption per week, daily serving sizes of fruit and vegetables Unhealthy snacks and fast foods consumption per week	8 weeks	230 / 230	1.1, 1.2, 2.1, 3.1, 4.1, 5.1, 6.1, 8.1	+	Moderate
Gur 2019	Pre-test/post-test single-group quasi experimental design / 1	TTM	F&V intake per day	8 weeks	842 / 802 / 702 at 6m FU	1.8, 2.1, 2.3, 3.1, 5.1, 7.1, 10.4, 12.1, 12.5	+	Moderate
Gutschall 2013	One group with pre and post testing / 1	SCT	Nutrition knowledge Weekly servings of selected food items (healthy & unhealthy) Make own breakfast	10 weeks	68 / 44	1.1, 2.3, 3.1, 4.1, 5.1, 6.1, 6.2, 12.5	+	Moderate
Haerens 2007	Clustered randomized controlled trial / 2	TPB; SCT; Attitude, Social Influence and Self-efficacy Model	Dietary fat intake for those who did not meet dietary guidelines Maintenance of dietary habits for those who meet dietary guidelines	50 minutes	333 / 304	2.2, 3.1, 4.1,	0	Moderate
Hassapidou 1997	Pilot study, with control and pre-post testing / 2	Not reported	Intake of F&V, nutrients and saturated fats	10 weeks	126 / 126	5.1, 9.1	0	Moderate

Lead Author	Study Design / study arms (incl control/ comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Holund 1990 (c)/ Holund 1990 (a)	Pre-test/post-test non-equivalent control group design / 2	Social learning theory; HBM; Theory of Cognitive Dissonance, Michigan Group Dynamics approach	Knowledge re nutrition and sugar relationship to caries; intake of foods with sugar and fat, intake of sugar/fat snacks between meals	3 weeks	127 / 114	5.1, 6.1, 6.2, 13.3	+	Strong
Karimi-Shahanjari 2013	Cluster randomized controlled trial / 3	TPB	Unhealthy snacking behavior and intention to consume unhealthy snacks change in healthy snack consumption	10 days	739 / 601 / FU 590	1.1, 1.2, 1.4, 5.1, 12.5	+	Moderate
Kaveh 2018	Randomised controlled trial / 2	TPB	Nutritional knowledge	Not clear	578 / 578	5.1	+	Moderate
Keshani 2019	Randomised field trial with control /	HBM, Collaborative learning	Diet quality - Dietary intake (Dairy, F, V, Grain), Sugar intake, Fat intake, Omega 3 & Omega 6 fatty acids, Energy intake	4 x 90 minute sessions, not clear over what period.	336 / 311	1.2, 5.1, 8.1	+	Moderate
Lane 2018	Matched-contact randomized crossover study	TPB	Overall SSB consumption (oz) Overall SSB calories	6 weeks	76 / 71	1.1, 1.2, 2.3, 3.1, 4.1, 5.1, 5.3, 8.1, 13.1	0	Moderate
Lin 2017	Randomised controlled trial / 3	Health Action Process Approach (HAPA)	F&V intake	Not reported	1455 / 1413	1.2, 1.4, 2.3, 5.1, 9.3	+	Moderate

Lead Author	Study Design / study arms (incl control/comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Mangunkusomo 2007	Clustered randomised BL-Post test experimental design / 2	Not reported	F&V intake	2 weeks	486 / 469	3.1, 2.2, 9.1	0	Moderate
Prell 2005	Controlled intervention, pre & post testing / 3	TPB	Consumption of fish Increased knowledge about fish	School year	390 / 228	4.1, 6.1, 7.1, 8.1, 12.5	+	Moderate
Rani 2013	One group, pre and post testing / 1	HBM	Dietary intake & frequency of F&V, dairy, carbonated drinks, snacks Frequency of skipped meals, fast-food restaurant visits in 1 week.	10 weeks	196 / 181	2.2, 4.1, 5.1	+	Moderate
Sichieri 2008	Cluster randomised controlled trial	Not reported	Reduction in SSB intake	7 months	1134 927	5.3, 7.1, 12.5	0	Moderate
Smit 2016	Randomized control trial	Social network approach, incorporating self-persuasion theory and self-determination theory	Water consumption volume and frequency in students overall SSB consumption Intention to drink water	8 weeks	243 / 210	3.1, 5.3, 6.1, 6.2, 12.5, 13.1	+	Strong
Te Velde 2008 / Wind 2008	Group-randomised / 2	SCT, Ecological model	Intake of fruit and vegetables in IG compared to CG	2 years – 1 year intensive and 1 year less intensive	1801 /1172 (2nd FU)	3.1, 4.1, 12.5	+	Moderate

Lead Author	Study Design / study arms (incl control/ comparator group)	Theory base	Dietary behaviours targeted	Length of Intervention	Baseline population size (incl Control) / Sample size analysed (incl Control)	BCTs identified (unique to intervention group/s) (see Table 4 & Appendix D for description)	Effectiveness of intervention	Study Quality Global rating
Thompson 2015	Group randomised study / 4	SCT	F&V intake	3 months approx.	400 Child/parent pairs / 387 pairs	1.2, 1.4, 7.1	+	Moderate
Thompson 2009 / Latif 2011	Group randomised trial / 2	SCT, Behavioral Inoculation Theory, Maintenance Theory, Elaboration Likelihood Model	Fruit, fruit juice and low fat vegetable consumption	9 weeks	473 / 432	1.1, 1.2, 1.5, 4.1, 6.1, 8.1, 10.6, 12.5	+	Moderate
Tolvanen 2010	Randomized clinical trial / 4	Not reported	Changes in children's oral health-related behavior, knowledge, and attitudes Reduction in frequency of eating candies, drinking soft drinks, sports drinks	4 years	2001: 1638 of which RCT group = 497 2003 FU 1463, 2005 FU: 1362 of which RCT = 474	1.2, 15.1	0	Strong
Wu 2017	Single-blinded randomized controlled trial (randomised at school level) / 3	Not reported, uses Motivational interviewing	Snacking frequency	Not clear.	512 / 512	3.1 Also Motivational interviewing, and Risk Assessment	+	Moderate

Note. SSB = Sugar Sweetened Beverages, F&V = Fruit and Vegetables. TPB = Theory of Planned Behaviour, SCT = Social Cognitive Theory, TTM = Trans Theoretical Model,

HBM = Health Belief Model, SDT = Self Determination Theory, HPM = Health Promotion Model. Effectiveness: + meets criteria, 0 does not meet criteria.



with the control group (Lane et al., 2018; Tolvanen, Lahti, Poutanen, Sepp, & Hausen, 2010), or the intervention had an effective result in one sub-group (e.g. females) but not shown as effective in the intervention population as a whole (Haerens et al., 2007; Hassapidou, Fotiadou, & Maglara, 1997).

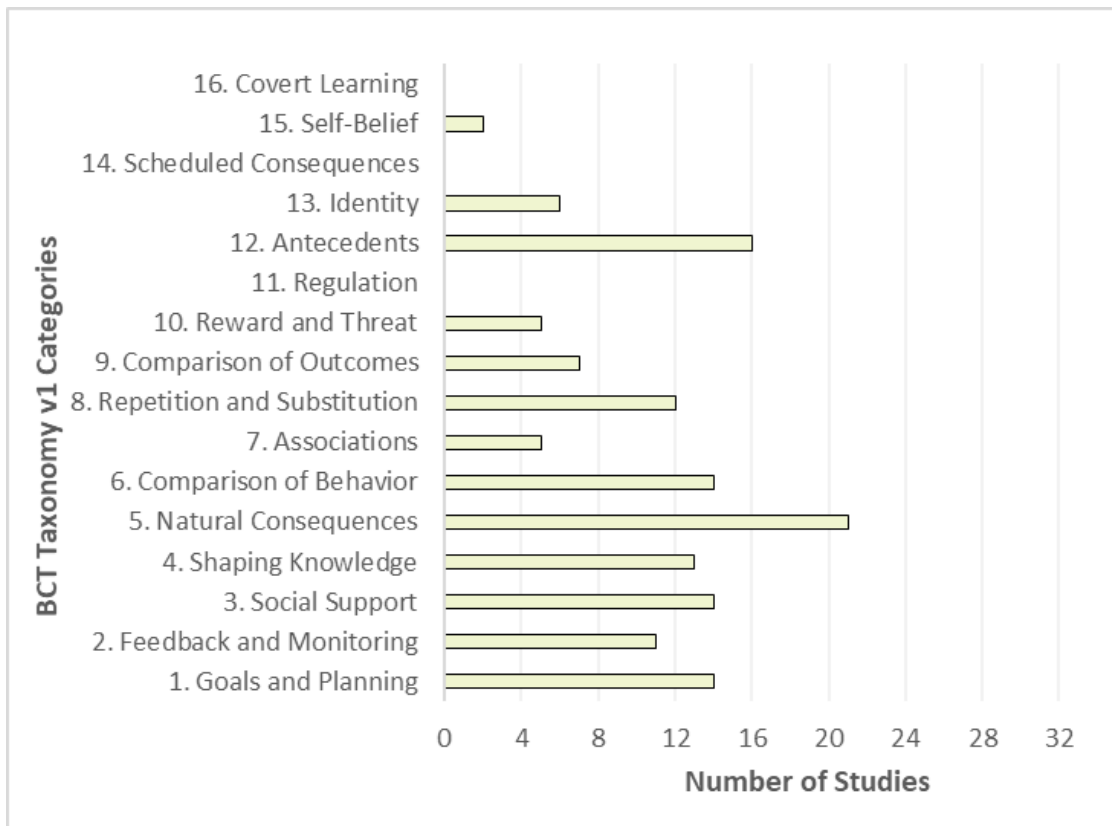
### **BCTs and Categories**

The recoding of BCTs for a random selection of 10% (four studies) as an accuracy check resulted in a 90% agreement with the previous coding. The most common categories of BCTs from the BCT Taxonomy v.1 (Michie et al., 2013) identified in all thirty two studies were Natural Consequences (in 65.6% of studies), Antecedents (50%), Goals and Planning, Social Support, and Comparison of Behaviour (43.8%), Shaping Knowledge (40.6%) and Repetition and Substitution (37.5%). Three categories were not used at all: Regulation, Scheduled Consequences and Covert Learning (Figure 3). In the 25 effective interventions, the two most used categories were the same (Natural Consequences and Antecedents being identified in 76% and 60% of effective studies respectively), as were the other common categories noted, but ranked slightly differently. Comparison of Behaviour was identified in 56% of studies, while Goals and Planning, Social Support, Shaping Knowledge and Repetition and Substitution were each identified in 44% of effective studies.

Specific BCTs identified as being most used in the 32 studies were: 5.1 Information about health consequences (53.1% of studies), 12.5 Adding objects to the environment (46.9%), 3.1 Social support (unspecified), 4.1 Instruction on how to perform a behaviour, 6.1 Demonstration of the behaviour (each in 40.6% of studies) and 8.1 Behavioural practice/rehearsal (34.4%). These are shown in Figure 4. These BCTs are all from within the most common categories identified. Fifteen BCTs were used in five or more studies overall. Most studies included multiple BCTs, ranging from two to thirteen, while two studies had only one BCT clearly identified. The most common combination, used by 14 studies

**Figure 3**

*Coding frequency of each BCT Taxonomy v1 category out of 32 studies*



identified as effective, was between three and six of the following BCTs: 3.1, 4.1, 5.1, 6.1, 8.1 and 12.5, while BCT 1.1 was also included in this combination by 4 studies. Two studies included motivational interviewing. Only one study (Lin, Scheerman, Yaseri, Pakpour, & Webb, 2017), specifically nominated behaviour change techniques being used in their intervention as per the Michie et al. (2013) BCT taxonomy.

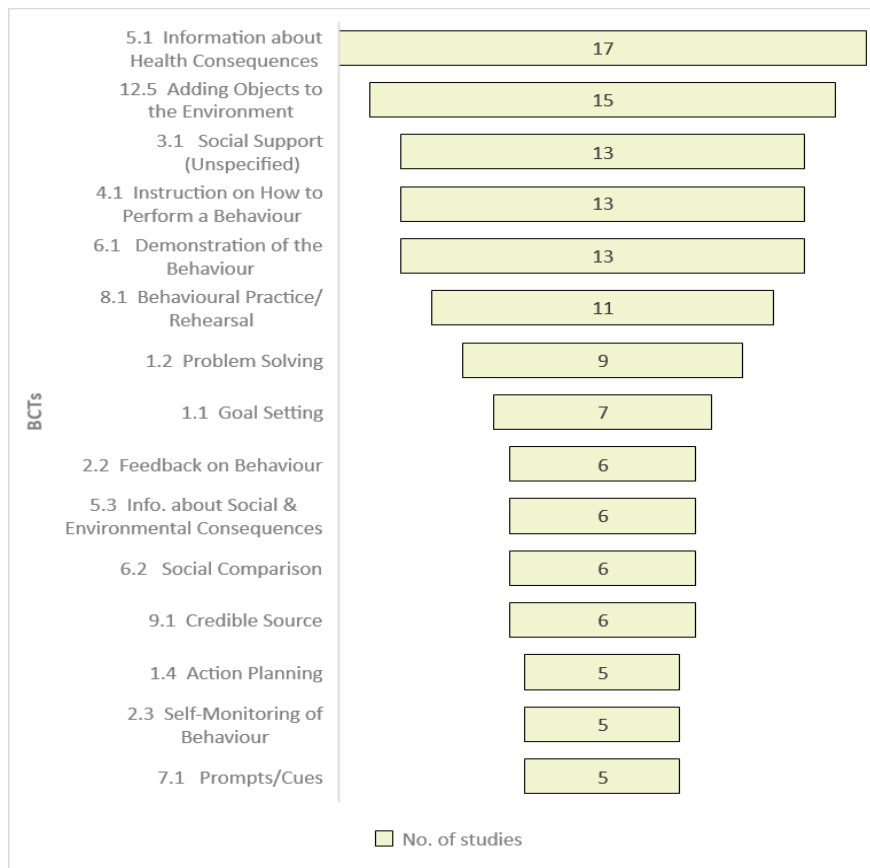
### ***Effective BCTs***

Three behaviour change techniques had a 100% association with effective interventions: 6.1 Demonstration of the Behaviour, 6.2 Social Comparison and 1.4 Action Planning, while two BCTs had an association of greater than 90% with effective interventions, and a further five BCTs had an association of 82% or more (see Table 3).

Twelve BCTs that were used in less than five studies over all were also exclusive to effective studies (not shown).

**Figure 4**

*BCTs used in more than 5 studies*



**Table 3***BCTs association with effective interventions, high to medium*

BCT	No. of effective studies (n = 25)	No. of studies (N = 32)	Ratio: effective/total
6.1 Demonstration of the Behaviour	13	13	1.00
6.2 Social Comparison	6	6	1.00
1.4 Action Planning	5	5	1.00
12.5 Adding Objects to the Environment	14	15	0.93
8.1 Behavioural Practice/Rehearsal	10	11	0.91
1.1 Goal Setting	6	7	0.86
4.1 Instruction on How to Perform a Behaviour	11	13	0.85
5.1 Information about Health Consequences	14	17	0.82
2.3 Self-Monitoring of Behaviour	4	5	0.80
7.1 Prompts/Cues	4	5	0.80
1.2 Problem Solving	7	9	0.78
3.1 Social Support (Unspecified)	10	13	0.77
2.2 Feedback on Behaviour	4	6	0.67
5.3 Info. about Social & Environmental Consequences	4	6	0.67
9.1 Credible Source	3	6	0.50

Note: BCTs shown were identified in more than 5 studies overall and had an effectiveness ratio of more than .5

### Meta-analysis

A meta-analysis was conducted on seven RCT studies, including multiple intervention arms where present, which looked at increasing fruit and vegetable consumption in the intervention arm/s compared to the control arm in terms of serves per day, giving a pooled population of 7,923 participants. A random effects analysis of these (12 intervention arms in total) revealed an overall improvement of 0.6 (95% CI [0.315, 0.888],  $p < .001$ ) serves per day.

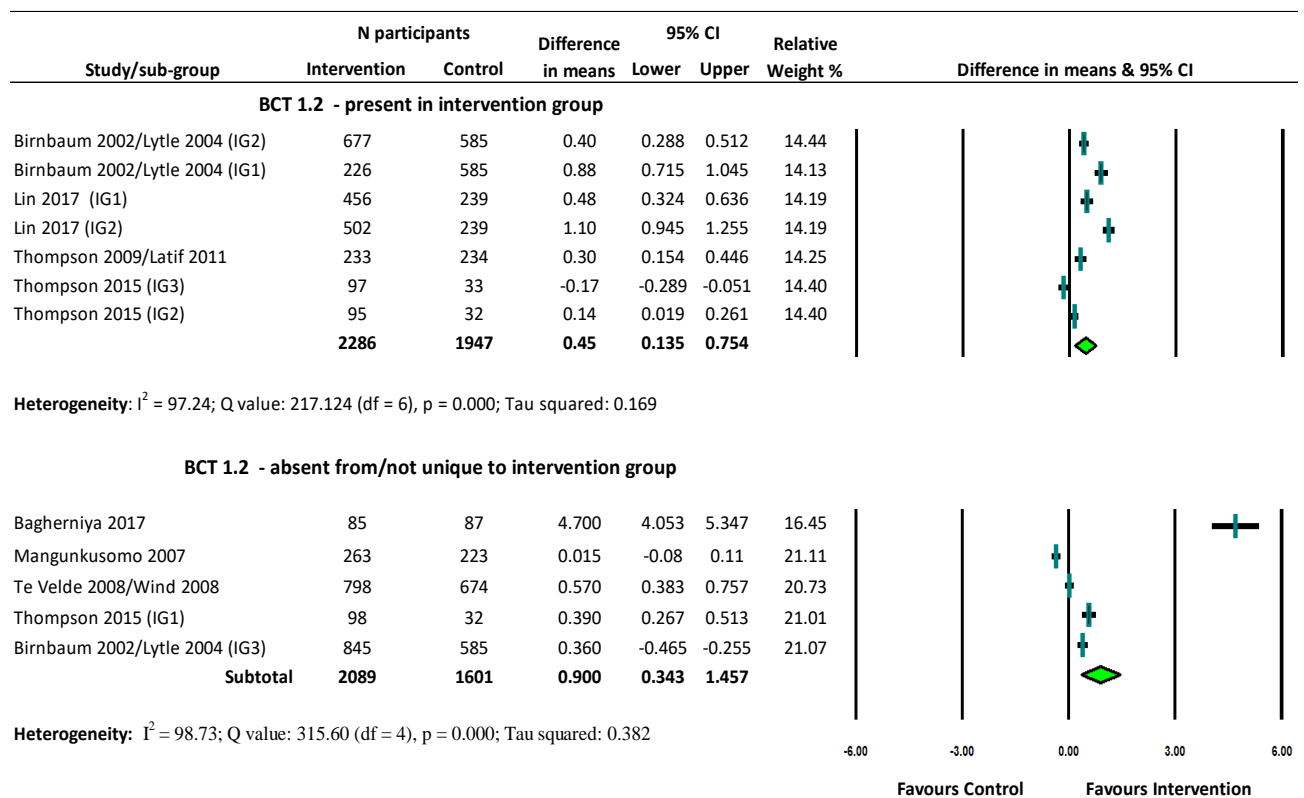
Heterogeneity was very high with  $I^2 = 98.1\%$ . All but one of the studies in the meta-analysis used cluster randomization by school or group but had reported undertaking multi-level analysis to account for this and also reported controlling for potentially confounding variables. Most studies reported intention-to-treat analyses using “baseline observation carried forward” as a method to handle withdrawals and dropouts from the study, although two used complete data only. Behaviour change techniques that were identified in at least

four of these studies as being unique to the intervention group included 1.2 Problem solving, 4.1 Instruction on how to perform a behaviour and 12.5 Adding objects to the environment.

Results showed (figure 5) that interventions incorporating ‘Problem solving’ had a mean difference overall of 0.45 (95% CI = 0.135 - 0.754,  $p = 0.005$ ) serves per day compared to the control group. The results for studies with interventions not using ‘Problem solving’ or not using it uniquely showed a mean difference overall of 0.90 (95% CI [0.343-1.457],  $p = .002$ ) serves per day compared to the control group, however, it was evident that one study was an outlier with a much greater mean difference than the other studies. Heterogeneity was high in both of these groups ( $I^2 = 97.24$  and  $98.73$  respectively). The analysis using Hedges  $g_w$  for the effect size showed a medium overall effect for BCT 1.2 present (Hedges  $g_w = 0.51$ , 95% CI [0.022, 0.958],  $p < .001$ ) and also for BCT 1.2 absent/not unique, but a slightly smaller effect (Hedges  $g_w = 0.49$ , 95% CI [0.261, 0.767],  $p = .04$ ).

## Figure 5

*Meta-analyses in respect to BCT 1.2 ‘Problem Solving’.*

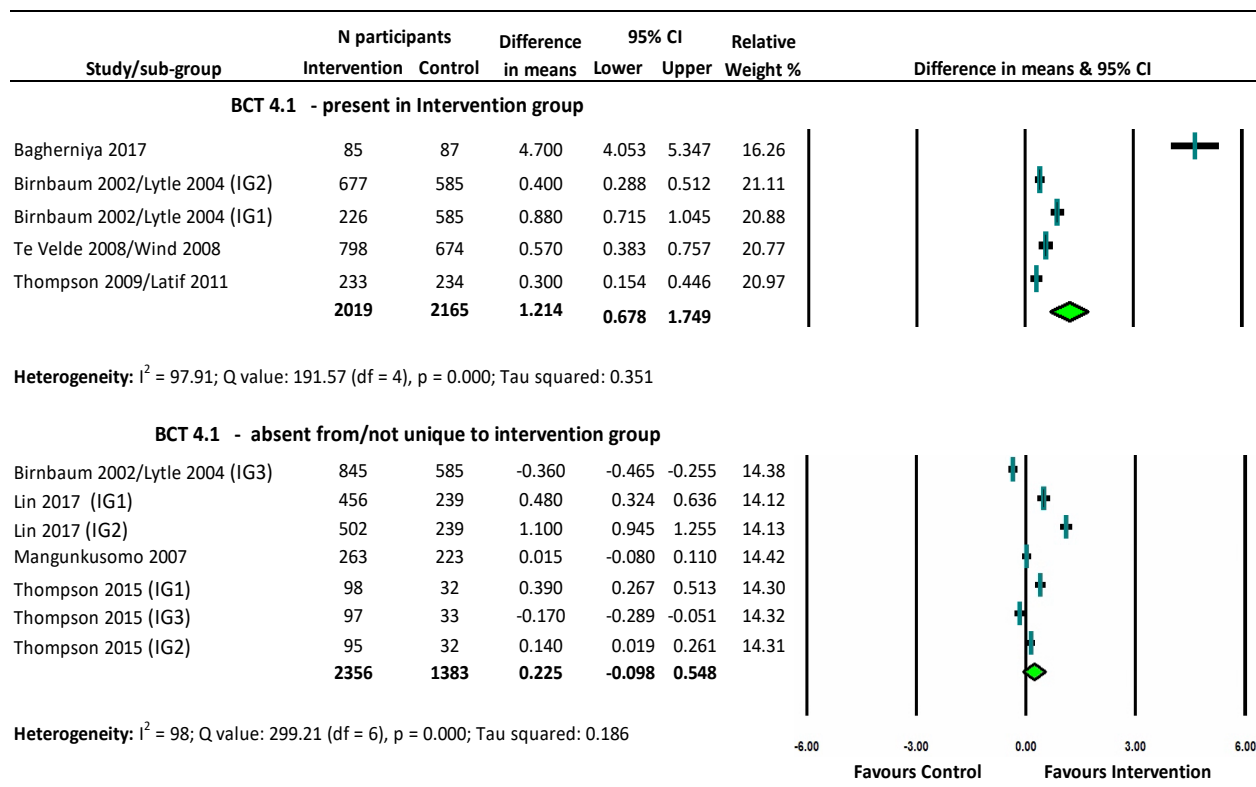


Note: (IG#) = Intervention group number where more than one intervention arm in study; the control group sample (n) was split according to the number of arms in the study.

Interventions identified as including the BCT 4.1 ‘Instruction on how to perform a behaviour’ showed a marked difference after the intervention of 1.214 (95% CI [0.678, 1.749],  $p < 0.001$ ) servings per day compared to control, while interventions that did not uniquely use this BCT had a minor, non-significant increase of 0.225 (95% CI [-0.080, 0.529],  $p = 0.148$ ) servings. Heterogeneity in these analyses was substantial (see figure 6). There was overall a moderate to large effect size for interventions where BCT 4.1 was present (Hedges  $g_w = 0.76$ , 95%CI [0.422, 1.105],  $p < .001$ ) compared to a small non-significant effect for those where it was absent or not unique (Hedges  $g_w = 0.29$ , 95%CI [0.134, 0.707],  $p = .18$ ) however again, this large effect difference was mainly due to a single study.

**Figure 6**

*Meta-analyses in respect to BCT 4.1 'Instruction on how to perform a behaviour'*



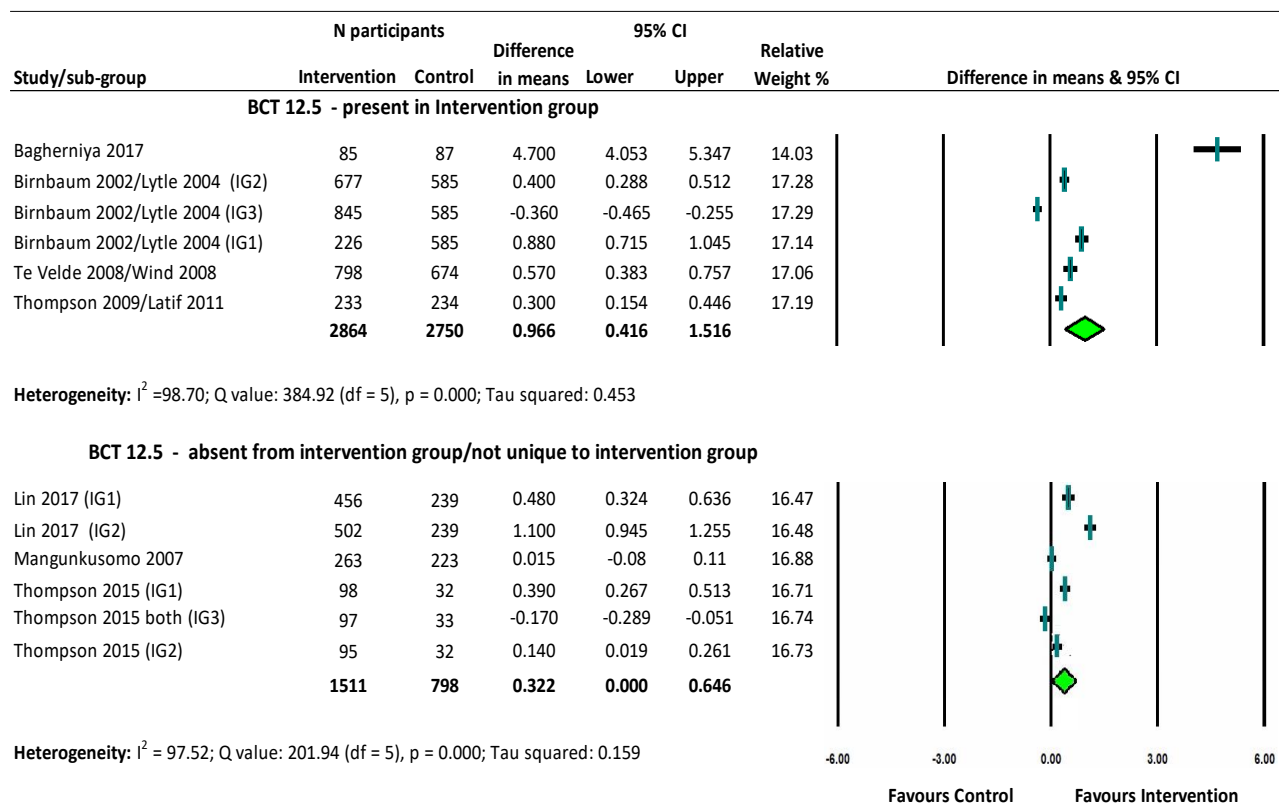
Note: (IG#) = Intervention group number where more than one intervention arm in study, the control group sample (n) was split according to the number of arms in the study.

The analysis of studies with interventions using BCT 12.5 'Adding objects to the environment', indicated a mean difference of 0. 0.97 (95% CI [0.416 - 1.516],  $p = .001$ ) serves per day compared to the control group, while those not using this BCT or where it was not unique to the intervention group, showed an overall improvement of just 0.32 (95%CI [0.000, 0.646],  $p = 0.05$ ) in intake. The large difference between the pair of analyses (BCT included/not included) appeared to be due to the one study with a notably larger mean intake in fruit and vegetables by participants after the intervention. Heterogeneity was reported as  $I^2 = 98.70$  for studies including BCT 12.5 and  $I^2 = 97.52$  for those that did not (figure 7). Overall effect size for the interventions where BCT 12.5 was present was medium (Hedges  $g_w = 0.59$ , 95%

CI [0.184, 1.000],  $p = .004$ ), with a small to medium effect size for interventions not using this BCT or not uniquely so (Hedges  $g_w = 0.39$ , 95% CI [0.003 0.781],  $p = .048$ ).

## Figure 7

*Meta-analyses in respect to BCT 12.5 'Adding objects to the environment'.*



Note: (IG#) Intervention group number where more than one intervention arm in study; the control group sample (n) was split according to the number of arms in the study.

## Other data synthesis

The six studies addressing fruit and vegetable intake that were not included in the meta-analysis were very varied, and used between 2 and 13 BCTs, with only one study incorporating more than two of the main combination of BCTs. Five of these studies were found to have effective interventions however. Reduction in intake of sugar beverages was addressed in eleven studies which were also varied in approach and study type and therefore not suitable for meta-analysis. The association between the most identified BCTs overall with



the studies targeting SSBs was assessed and is reported below in Table 4 in order of strength of association. A positive association denotes a statistically significant decrease was reported in the consumption of SSBs, while a neutral association denotes either some improvement but not significant, or no decrease was noted from baseline. No negative associations (increase in intake) were noted overall.

**Table 4**

*Association of BCTs with reduction in sugar sweetened beverage consumption*

BCT	Negative association (increase)	Neutral association —	Positive association (decrease)
<b>12.5 Adding objects to the environment</b>		■ Sichieri 2008	■ Cunha 2013 ■ Fonseca 2019 ■ Franken 2018 □ Gutschall 2013 ■ Smit 2016
<b>6.1 Demonstration of the behavior</b>			■ Fonseca 2019 ■ Franken 2018 □ Gutschall 2013 ■ Smit 2016
<b>5.1 Information about health consequences</b>		■ Lane 2018* ■ Astrom 2012	■ Cunha 2013 ■ Fonseca 2019 □ Gutschall 2013 □ Rani 2013
<b>5.3 Information about social and environmental consequences</b>		■ Lane 2018* ■ Sichieri 2008	■ Cunha 2013 ■ Franken 2018 ■ Smit 2016
<b>BCT 3.1 Social support (unspecified)</b>		■ Lane 2018*	■ Franken 2018 □ Gutschall 2013 ■ Smit 2016
<b>6.2 Social Comparison</b>			■ Franken 2018 □ Gutschall 2013 ■ Smit 2016

<b>1.1 Goal Setting (Behaviour)</b>	■ Lane 2018*	■ Cunha 2013 □ Gutschall 2013
<b>8.1 Behavioural Practice &amp; Rehearsal</b>	■ Lane 2018*	■ Cunha 2013
<b>4.1 Instruction on How to Perform a Behaviour</b>	■ Lane 2018*	□ Gutschall 2013 □ Rani 2013
<b>9.1 Credible Source</b>	■ Astrom 2012	■ Cunha 2013
<b>2.3 Self-Monitoring of Behaviour</b>	■ Lane 2018*	□ Gutschall 2013
<b>1.4 Action Planning</b>		■ Franken 2018
<b>2.2 Feedback on Behaviour</b>		□ Rani 2013
<b>1.2 Problem Solving</b>	■ Lane 2018* ■ Tolvanen 2010	
<b>7.1 Prompts/Cues</b>	■ Sichert 2008	

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\*Note: Significant difference within intervention group but not compared to control /comparator group.

■ Study has 2+ arms, including control/comparator group    □ Study has only one arm.

Total sample size indicator: <100 □ 100 -599 □ 600-1000 □ >1000 □

## Discussion

### Main findings

Fruit and vegetable intake and reduction of sugar sweetened beverages were the main dietary targets for interventions. Meta-analysis showed that the randomized control trial behaviour change interventions targeting fruit and vegetable intake in adolescents resulted in an overall increase of 0.6 serves per day when compared to the control group. It also showed that behaviour change techniques Instruction on how to perform a behaviour and Adding objects to the environment were associated with the effectiveness of the interventions, with

increases of just under 1 serve (.99) and just over half a serve (.64) daily respectively for interventions using these BCTs compared to those not using the BCT or where it was not unique to the intervention group. There was a negative effect for Problem solving in the meta-analysis, however it is noted that this maybe because one of the studies (Bagherniya et al., 2017), which had a much larger effect for fruit and vegetable intake than all the other studies in the meta-analysis did not include this BCT. Heterogeneity was very high for all meta-analyses, indicating that the studies have different true effects (Borenstein et al., 2011), which was to be expected given the wide range of study and intervention characteristics between the studies, as well as potential variation in the degree of fidelity in implementing the interventions, and therefore the summary estimates noted above should be interpreted cautiously. Results revealed that these interventions also included and often shared a number of other BCTs (between 3 and 9), some of which may well have contributed to the increased intake in fruit and vegetables.

In terms of BCTs associated with effective studies, twelve behaviour change techniques were highly associated with effective interventions, having a ratio greater than .75. Six of these BCTs were shown to be frequently used and often combined to various degrees (between three and six per intervention), covering a comprehensive group of basic techniques. They include instructing how to perform the behaviour, advising of the health consequences of the behaviour, demonstrating (modelling), rehearsing and practicing the behaviour, adding objects to the environment (to facilitate performance of the behavior), and arrange social support or praise (from parents, friends, teachers or peers, etc.) to encourage performance of the behaviour. These techniques are noted as being important and relevant to the cognitive development level of early-mid adolescence. The remaining six BCTs with a strong association to effective interventions were only used in 15-30% of studies overall, but addressed techniques such as setting defined goals for and planning details for performance of the behaviour, establishing a method to self-monitor and record performance of the

behaviour, introducing cues and reminders at relevant places and times to prompt performance of the behaviour, and to attend to the performance of the behaviour by peers so as to compare their own performance. These techniques are addressing self-regulation type behaviours which early-mid adolescents are starting to develop. These BCTs were often used in combination within the same group or used in combinations of both groups of BCTs. There was no pattern noted as to the BCTs used by the various Behaviour Change theories which were reported by studies as influencing the interventions.

Studies identified as less effective tended to use fewer BCTs in their interventions, and used only one or two of the BCTs identified above, except for Lane et al. (2018) which combined five of them. This study did show significant improvement in the intervention group compared to baseline with a moderate effect size, although the change was not significantly different from the control group (which the authors attributed to potential group interaction outside of the intervention).

### **Findings in previous literature**

The increase of just over half a serve (0.6) in daily intake of fruit and vegetables overall is in line with increases found by Ashton et al. (2019) and Lara et al. (2014) which look at dietary behaviours in adults; studies addressing adolescents' diet behaviour change tended not to conduct meta-analyses and therefore did not specify an overall quantitative increase or decrease for a dietary outcome, only reporting whether there were improvements noted in the studies' results (do Amaral e Melo et al., 2017; Hsu et al., 2018) or were assessed as effective (statistically different outcomes in a positive direction) (Racey et al., 2016; Vézina-Im et al., 2017). In terms of behaviour change techniques, Social support, Information about health consequences, Goal setting and Adding objects to the environment and combinations of BCTs were also identified by some reviews into adolescent dietary behaviours (Vézina-Im et al., 2017), while others have found Social support, Instruction on

how to perform a behaviour and Demonstration of behaviour (Modelling) as being used frequently and effectively in interventions for adolescents, using either the current BCT Taxonomy v1 (Hsu et al., 2018) or an earlier taxonomy (Brannon & Cushing, 2014). The finding by this review that the more effective interventions used more BCTs is also supported by other studies (Lara et al., 2014; Samdal et al., 2017). Bohlen et al. (2020) note that the use of multiple BCTs within an intervention doesn't necessarily increase effectiveness per se but using a combination of BCTs along with a pertinent behavior change theory has been associated with greater effectiveness.. This review was not specifically considering how theories referred to in interventions were applied or whether they were linked to the BCTs included in the interventions and therefore directly linked to the degree of effectiveness of the intervention, however the most common theories identified in effective studies match those noted in other reviews ((Vézina-Im et al., 2017).

### **Strengths and limitations**

This review is unique in that it includes studies that use a wide variety of study and intervention types across a range of countries which aim to improve a range of dietary behaviours in adolescents 10 to 15 years old and do not focus on any specific chronic or acute disease. The studies selected looked at dietary behaviours only so they would have sufficient power to find meaningful results and were not restricted to randomized control trials in order to provide a broader view of the interventions being applied in respect to behaviour change to improve diet/nutrition in adolescents. The studies were also conducted in the real world, taking place mostly in schools in a wide range of countries, cultures and social economic status of participants which means the results may be more generalizable to adolescents universally. This review has also used a well-recognized and internationally validated BCT Taxonomy and its associated online training to identify and code the behaviour change techniques used in the interventions, and only BCTs that were unique to the intervention arm/s were coded which enabled a contrast between intervention and control groups.

Among the limitations is that the real world context has the drawback that there are high levels of heterogeneity between studies, which requires that the findings be considered cautiously. Most of the interventions took place in schools and used school students as participants, which is similar to other reviews given that this makes it easier to recruit a wide range of adolescent participants and have ongoing access to them, (do Amaral e Melo et al., 2017; Vézina-Im et al., 2017), however shortages in time, resources and competing demands on teachers can lead to marked inconsistencies in implementation of the interventions. Some of the studies included noted that this had been an issue, especially with complex or longer term interventions (Lane et al., 2018; te Velde et al., 2008). The small number of studies available for the meta-analysis ( $n = 7$ ) reduced the number of BCTs able to be explored for association with effectiveness and was limited to the immediate post intervention results due to the small number of studies with follow up testing. Also, as there were less than ten studies, investigation of heterogeneity through meta-regression or sub-group analysis was not carried out.

Coding of behaviour change techniques was also challenging, as studies varied greatly in respect to the detail of intervention provided and some BCTs may have been coded as absent or coded incorrectly as a result of inadequate description used by the study authors, however this is an issue for many studies coding techniques used in interventions (Michie, West, et al., 2018; Samdal et al., 2017). In addition, the author lacked prior experience in coding and while it is recommended that two coders undertake the task independently and then confer, there were insufficient resources for this to be put into place.

### **Gaps in knowledge for future studies**

This review has examined what behaviour change techniques are associated with effective dietary interventions for adolescents, however the varied approach to and description of interventions and differing quality of studies makes it possible to draw only

general inferences. There needs to be many more high quality studies done to determine the extent to which individual BCTs, combinations of BCTs identified and behaviour change theories have an effect on the outcome of interventions for adolescents, given the negative health outcomes that are consequent on continuing with poor dietary behaviours. Very recent work in the health behaviour change field generally is seeking to look at the designing of interventions and implementation of interventions in different and more methodical ways, not only to increase understanding of how BCTs work in respect to the underlying mechanisms of action in health behaviour change but also how to apply and implement this research in an appropriate way in the community ((Byrne, 2020; Hagger, Moyers, McAnally, & McKinley, 2020; Michie, Carey, et al., 2018). Such approaches could also ideally be applied to interventions for adolescents.

For example, although one of the most common behaviour change techniques included in studies was Information about health consequences, it has been suggested by some studies and reviews that future health consequences in adulthood that might arise from obesity, excessive intake of soft drinks or insufficient intake of fruit and vegetables are not a particular issue for adolescents as they can appear too distal to be of concern (Bagherniya et al., 2017). Approaches to dietary interventions and BCTs applied to change dietary behaviours could perhaps be linked to more immediate personal or social issues to investigate if this would increase effectiveness, such as the values alignment intervention study to try to counteract the reinforcement of strong positive associations for junk food in advertising (Bryan, Yeager, & Hinojosa, 2019). Their study looked at the effect of an intervention which reframed junk food marketing to children and adolescents as being incompatible with adolescent values, on their consequent dietary choices in the school cafeteria; it was reported as being successful with male participants in particular. Although the actual behaviour change techniques used, being the basic active elements of interventions, might not change with an altered approach more suited to adolescent priorities, the effectiveness of any

individual or combination of techniques may become more apparent and thereby incrementally lead to effective interventions for adolescents more broadly.

Another area for future study is to determine an optimum length of time for a school-based intervention, and how to deal with the deterioration of the intervention effect over time – how are positive outcomes to be maintained after the intervention? In this review, only nine studies had more than one follow up test once the intervention had finished, and in most of them the effect had declined to some degree. Future research could investigate whether different BCTs would be required to maintain the initial positive effects. Furthermore if the intervention is very short and the post test conducted very soon afterwards, the effectiveness of the interventions could be overstated, as noted by Racey et al. (2016) .

### **Conclusion and Implications**

A need has been clearly established to enable adolescents to improve their dietary behaviours to reduce the significant chronic health and disease risks arising from poor dietary behaviours in this age group, and when they become adults. The intervention studies addressing improving dietary intake in adolescents are highly heterogenous and of mixed quality however, which makes it difficult to tease out the answers necessary and ongoing research is required to work towards that goal. This review has contributed through identifying a number of behaviour change techniques that are associated with effective interventions in improving adolescent dietary behaviours, with the suggestion that effective combinations of BCTs will be those that are associated with the cognitive and social development stage of the adolescent participants and used in interventions that best meet the interests of this age group.



## References

- Ajie, W. N., & Chapman-Novakofski, K. M. (2014). Impact of computer-mediated, obesity-related nutrition education interventions for adolescents: a systematic review. *Journal of Adolescent Health, 54*(6), 631-645.
- Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In *Action control* (pp. 11-39). Berlin, Heidelberg: Springer.
- Akseer, N., Al-Gashm, S., Mehta, S., Mokdad, A., & Bhutta, Z. A. (2017). Global and regional trends in the nutritional status of young people: a critical and neglected age group. *Annals of the New York Academy of Sciences, 1393*(1), 3-20.  
doi:<https://doi.org/10.1111/nyas.13336>
- Armijo-Olivo, S., Stiles, C. R., Hagen, N. A., Biondo, P. D., & Cummings, G. G. (2012). Assessment of study quality for systematic reviews: a comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. *Journal of evaluation in clinical practice, 18*(1), 12-18.
- Ashton, L. M., Sharkey, T., Whatnall, M. C., Williams, R. L., Bezzina, A., Aguiar, E. J., . . . Hutchesson, M. J. (2019). Effectiveness of Interventions and Behaviour Change Techniques for Improving Dietary Intake in Young Adults: A Systematic Review and Meta-Analysis of RCTs. *Nutrients, 11*(4). doi:10.3390/nu11040825
- Åström, A. N., & Mashoto, K. O. (2012). Changes in oral health related knowledge, attitudes and behaviours following school based oral health education and atraumatic restorative treatment in rural Tanzania. *Norsk Epidemiologi, 22*(1), 21-30.
- Australian Institute of Health and Welfare. (2015). *National Youth Information Framework (NYIF) indicators*. Retrieved from Canberra:  
<https://www.aihw.gov.au/reports/children-youth/nyif-indicators>

Australian Institute of Health and Welfare. (2020). *Overweight and obesity among Australian children and adolescents*. Retrieved from Canberra:

<https://www.aihw.gov.au/reports/overweight-obesity/overweight-obesity-australian-children-adolescents>

Bagherniya, M., Sharma, M., Darani, F. M., Maracy, M. R., Safarian, M., Birgani, R. A., . . .

Keshavarz, S. A. (2017). School-based nutrition education intervention using social cognitive theory for overweight and obese Iranian adolescent girls: A cluster randomized controlled trial. *International Quarterly of Community Health Education*, 38(1), 37-45. doi:<http://dx.doi.org/10.1177/0272684X17749566>

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, 1986(23-28).

Bohlen, L. C., Michie, S., de Bruin, M., Rothman, A. J., Kelly, M. P., Groarke, H. N., . . .

Johnston, M. (2020). Do Combinations of Behavior Change Techniques That Occur Frequently in Interventions Reflect Underlying Theory? *Annals of Behavioral Medicine*, 54(11), 827-842.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2011). *Introduction to meta-analysis*: John Wiley & Sons.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2013). *Comprehensive Meta-Analysis Version 3*. Englewood, NJ: Biostat. Retrieved from <https://www.meta-analysis.com/>

Brannon, E. E., & Cushing, C. C. (2014). Is There an App for That? Translational Science of Pediatric Behavior Change for Physical Activity and Dietary Interventions: A Systematic Review.

Bryan, C. J., Yeager, D. S., & Hinojosa, C. P. (2019). A values-alignment intervention protects adolescents from the effects of food marketing. *Nature Human Behaviour*, 3(6), 596-603. doi:10.1038/s41562-019-0586-6

- Byrne, M. (2020). Gaps and priorities in advancing methods for health behaviour change research. *Health psychology review, 14*(1), 165-175.
- Cunha, D. B., de Souza Bda, S., Pereira, R. A., & Sichieri, R. (2013). Effectiveness of a randomized school-based intervention involving families and teachers to prevent excessive weight gain among adolescents in Brazil. *PLoS ONE, 8*(2), e57498. doi:10.1371/journal.pone.0057498
- Deeks, J. J., Higgins, J. P. T., & Altman, D. G., (eds). (2020). Chapter 10: Analysing data and undertaking meta-analyses. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions version 6.1*.
- Dias, J. D., Domingues, A. N., Tibes, C. M., Zem-Mascarenhas, S. H., & Fonseca, L. M. M. (2018). Serious games as an educational strategy to control childhood obesity: a systematic literature review. *Revista latino-americana de enfermagem, 26*.
- Diep, C. S., Chen, T.-A., Davies, V. F., Baranowski, J. C., & Baranowski, T. (2014). Influence of behavioral theory on fruit and vegetable intervention effectiveness among children: a meta-analysis. *Journal of Nutrition Education and Behavior, 46*(6), 506-546.
- do Amaral e Melo, G. R., de Carvalho Silva Vargas, F., dos Santos Chagas, C. M., & Toral, N. (2017). Nutritional interventions for adolescents using information and communication technologies (ICTs): A systematic review. *PLoS ONE, 12*(9), e0184509.
- Estrada, E., Ferrer, E., & Pardo, A. (2018). Statistics for Evaluating Pre-post Change: Relation Between Change in the Distribution Center and Change in the Individual Scores. *Front Psychol, 9*, 2696. doi:10.3389/fpsyg.2018.02696
- Ghasab Shirazi, M., Kazemi, A., Kelishadi, R., & Mostafavi, F. (2019). The improvement of dietary behaviors among Iranian adolescent girls: a theory-based randomized

- controlled trial. *Health Education Research*, 34(2), 159-172.  
doi:<https://dx.doi.org/10.1093/her/cyz004>
- Gutgesell, M. E., & Payne, N. (2004). Issues of adolescent psychological development in the 21st century. *Pediatrics in Review*, 25(3), 79-85.
- Hackman, C. L., & Knowlden, A. P. (2014). Theory of reasoned action and theory of planned behavior-based dietary interventions in adolescents and young adults: a systematic review. *Adolescent Health, Medicine and Therapeutics*, 5, 101.
- Haerens, L., Deforche, B., Maes, L., Brug, J., Vandelanotte, C., & De Bourdeaudhuij, I. (2007). A computer-tailored dietary fat intake intervention for adolescents: Results of a randomized controlled trial. *Annals of Behavioral Medicine*, 34(3), 253-262.  
doi:10.1007/bf02874550
- Hagger, M. S., Moyers, S., McAnally, K., & McKinley, L. E. (2020). Known knowns and known unknowns on behavior change interventions and mechanisms of action. *Health psychology review*, 14(1), 199-212.
- Hardcastle, S. J., Fortier, M., Blake, N., & Hagger, M. S. (2017). Identifying content-based and relational techniques to change behaviour in motivational interviewing. *Health Psychol Rev*, 11(1), 1-16. doi:10.1080/17437199.2016.1190659
- Hassapidou, M. N., Fotiadou, E., & Maglara, E. (1997). A nutrition intervention programme for lower secondary schools in Greece. *Health Education Journal*, 56(2), 134-144.  
doi:10.1177/001789699705600204
- Hazen, E., Schlozman, S., & Beresin, E. (2008). Adolescent psychological development: A review. *Pediatrics in Review*, 29(5), 161.
- Higgins, J. P. T., Eldridge, S., & Li, T., (eds). (2020). Chapter 23: Including variants on randomized trials. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions version 6.1*. Retrieved from <http://www.training.cochrane.org/handbook>

Higgins, J. P. T., Li, T., & Deeks, J. J., (eds). (2020). Chapter 6: Choosing effect measures and computing estimates of effect. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions version 6.1* Retrieved from [www.training.cochrane.org/handbook](http://www.training.cochrane.org/handbook)

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., . . . Johnston, M. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *Bmj*, *348*.

Hsu, M. S., Rouf, A., & Allman-Farinelli, M. (2018). Effectiveness and behavioral mechanisms of social media interventions for positive nutrition behaviors in adolescents: a systematic review. *Journal of Adolescent Health*, *63*(5), 531-545.

Kelly, M. P., & Barker, M. (2016). Why is changing health-related behaviour so difficult? *Public Health*, *136*, 109-116. doi:10.1016/j.puhe.2016.03.030

Lane, H., Porter, K. J., Hecht, E., Harris, P., Kraak, V., & Zoellner, J. (2018). Kids SIP smartER: a Feasibility Study to Reduce Sugar-Sweetened Beverage Consumption Among Middle School Youth in Central Appalachia. *American Journal of Health Promotion*, *32*(6), 1386-1401. doi:10.1177/0890117117715052

Lara, J., Evans, E. H., O'Brien, N., Moynihan, P. J., Meyer, T. D., Adamson, A. J., . . . Mathers, J. C. (2014). Association of behaviour change techniques with effectiveness of dietary interventions among adults of retirement age: a systematic review and meta-analysis of randomised controlled trials. *BMC Medicine*, *12*(1), 177. doi:10.1186/s12916-014-0177-3

Lin, C. Y., Scheerman, J. F. M., Yaseri, M., Pakpour, A. H., & Webb, T. L. (2017). A cluster randomised controlled trial of an intervention based on the Health Action Process Approach for increasing fruit and vegetable consumption in Iranian adolescents. *Psychology & Health*, *32*(12), 1449-1468. doi:10.1080/08870446.2017.1341516

- Mangunkusumo, R. T., Brug, J., de Koning, H. J., van der Lei, J., & Raat, H. (2007). School-based Internet-tailored fruit and vegetable education combined with brief counselling increases children's awareness of intake levels. *Public Health Nutrition*, *10*(3), 273-279. doi:10.1017/S1368980007246671
- Marquez, O., Racey, M., Preyde, M., Hendrie, G. A., & Newton, G. (2015). Interventions to increase dairy consumption in adolescents: a systematic review. *ICAN: Infant, Child, & Adolescent Nutrition*, *7*(5), 242-254.
- Martin, J., Chater, A., & Lorencatto, F. (2013). Effective behaviour change techniques in the prevention and management of childhood obesity. *Int J Obes (Lond)*, *37*(10), 1287-1294. doi:10.1038/ijo.2013.107
- Meeus, W. (2016). Adolescent psychosocial development: a review of longitudinal models and research. *Developmental Psychology*, *52*(12), 1969.
- Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & Health*, *26*(11), 1479-1498.
- Michie, S., Carey, R. N., Johnston, M., Rothman, A. J., de Bruin, M., Kelly, M. P., & Connell, L. E. (2018). From Theory-Inspired to Theory-Based Interventions: A Protocol for Developing and Testing a Methodology for Linking Behaviour Change Techniques to Theoretical Mechanisms of Action. *Ann Behav Med*, *52*(6), 501-512. doi:10.1007/s12160-016-9816-6
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. E. (2013). The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Annals of Behavioral Medicine*, *46*(1), 81-95. doi:10.1007/s12160-013-9486-6

- Michie, S., West, R., Sheals, K., & Godinho, C. A. (2018). Evaluating the effectiveness of behavior change techniques in health-related behavior: a scoping review of methods used. *Translational Behavioral Medicine*, 8(2), 212-224.
- Michie, S., Wood, C. E., Johnston, M., Abraham, C., Francis, J. J., & Hardeman, W. (2015). Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). *Health Technol Assess*, 19(99). doi:10.3310/hta19990
- Mikkila, V., Rasanen, L., Raitakari, O. T., Pietinen, P., & Viikari, J. (2005). Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. *Br J Nutr*, 93(6), 923-931. doi:10.1079/bjn20051418
- Miller, A. L., Lo, S. L., Bauer, K. W., & Fredericks, E. M. (2020). Developmentally informed behaviour change techniques to enhance self-regulation in a health promotion context: a conceptual review. *Health psychology review*, 14(1), 116-131.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*, 6(7), e1000097. doi:10.1371/journal.pmed.1000097
- Movassagh, E. Z., Baxter-Jones, A. D. G., Kontulainen, S., Whiting, S. J., & Vatanparast, H. (2017). Tracking Dietary Patterns over 20 Years from Childhood through Adolescence into Young Adulthood: The Saskatchewan Pediatric Bone Mineral Accrual Study. *Nutrients*, 9(9). doi:10.3390/nu9090990
- Moynihan, P., & Petersen, P. E. (2004). Diet, nutrition and the prevention of dental diseases. *Public Health Nutrition*, 7(1a), 201-226.
- Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion*, 12(1), 38-48.

- Racey, M., O'Brien, C., Douglas, S., Marquez, O., Hendrie, G., & Newton, G. (2016). Systematic review of school-based interventions to modify dietary behavior: does intervention intensity impact effectiveness? *Journal of School Health, 86*(6), 452-463.
- Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *Int J Behav Nutr Phys Act, 14*(1), 42. doi:10.1186/s12966-017-0494-y
- Sichieri, R., Paula Trotte, A., de Souza, R. A., & Veiga, G. V. (2009). School randomised trial on prevention of excessive weight gain by discouraging students from drinking sodas. *Public Health Nutrition, 12*(2), 197-202. doi:10.1017/S1368980008002644
- Story, M., Neumark-Sztainer, D., & French, S. (2002). Individual and Environmental Influences on Adolescent Eating Behaviors. *Journal of the American Dietetic Association, 102*(3, Supplement), S40-S51. doi:[https://doi.org/10.1016/S0002-8223\(02\)90421-9](https://doi.org/10.1016/S0002-8223(02)90421-9)
- te Velde, S. J., Brug, J., Wind, M., Hildonen, C., Bjelland, M., Pérez-Rodrigo, C., & Klepp, K. I. (2008). Effects of a comprehensive fruit- and vegetable-promoting school-based intervention in three European countries: the Pro Children Study. *British Journal of Nutrition, 99*(4), 893-903. doi:10.1017/S000711450782513X
- Thomas, B., Ciliska, D., Dobbins, M., & Micucci, S. (2004). A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews on Evidence-Based Nursing, 1*(3), 176-184.
- Tolvanen, M., Lahti, S., Poutanen, R., Sepp, L., & Hausen, H. (2010). Children's oral health-related behaviors: individual stability and stage transitions. *Community Dentistry & Oral Epidemiology, 38*(5), 445-452. doi:10.1111/j.1600-0528.2010.00549.x
- UNICEF. (2019, October). Adolescents overview. Retrieved from <https://data.unicef.org/topic/adolescents/overview/>



- Van Cauwenberghe, E., Maes, L., Spittaels, H., Van Lenthe, F. J., Brug, J., Oppert, J.-M., & De Bourdeaudhuij, I. (2010). Effectiveness of school-based interventions in Europe to promote healthy nutrition in children and adolescents: systematic review of published and 'grey' literature. *British Journal of Nutrition*, *103*(6), 781-797.
- Veritas Health Innovation. (2017). Covidence. In: Melbourne, Australia.
- Vézina-Im, L.-A., Beaulieu, D., Bélanger-Gravel, A., Boucher, D., Sirois, C., Dugas, M., & Provencher, V. (2017). Efficacy of school-based interventions aimed at decreasing sugar-sweetened beverage consumption among adolescents: a systematic review. *Public Health Nutrition*, *20*(13), 2416-2431.
- World Health Organization. (2000). *Nutrition for health and development: a global agenda for combating malnutrition*. Retrieved from
- World Health Organization. (2005). Nutrition in adolescence: issues and challenges for the health sector: issues in adolescent health and development.
- World Health Organization. (2018, 13 December). Adolescents: health risks and solutions. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/adolescents-health-risks-and-solutions>
- World Health Organization. (2020, 9 December). The top 10 causes of death. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>

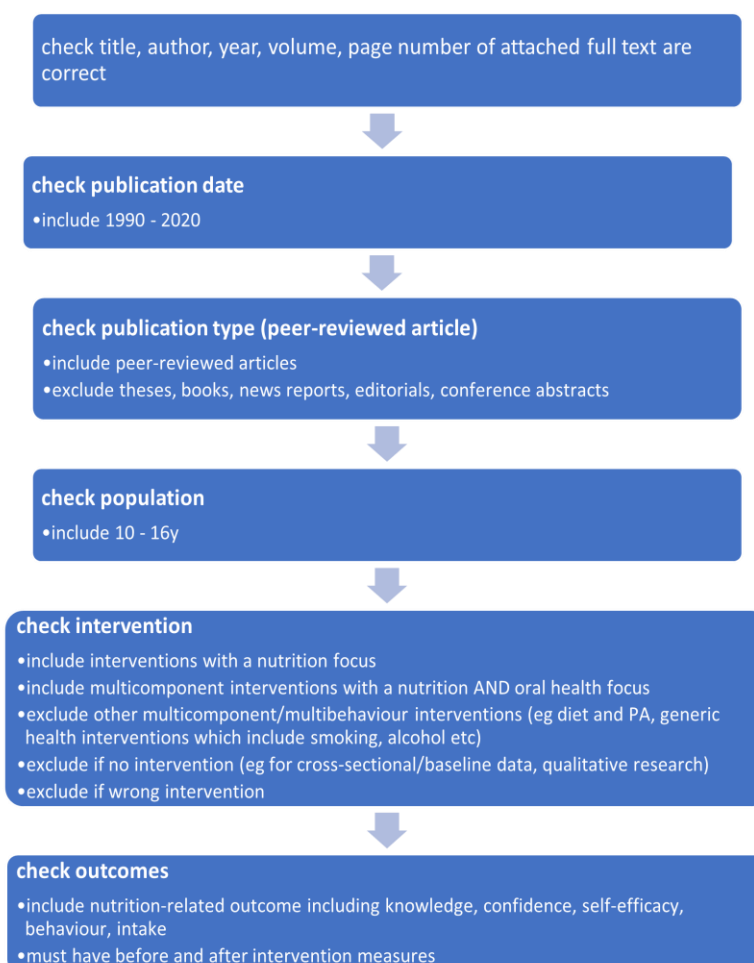
## Appendices

## Appendix A - Inclusion and Exclusion Criteria for Review

PICO	Included	Excluded
<b>Population</b>	<ul style="list-style-type: none"> <li>- Human adolescents aged 10 – 16y</li> <li>- Data reported separately for adolescents (10 – 16y)</li> <li>- Mean/median age 10 – 16y (e.g. <i>if age group 12-17 or 9-12</i>)</li> <li>- Dental caries</li> <li>- Overweight/obesity</li> </ul>	<ul style="list-style-type: none"> <li>- Participants selected on the basis of disease, or condition, e.g. physical conditions, eating disorder, psychological conditions, physical or intellectual disability,</li> <li>- e.g. ADHD, depression, anxiety, diabetes, lupus, chronic pain, HIV, anorexia, bulimia, , PCOS, cancer, down syndrome, MetS, NAFLD</li> <li>- obesity comorbidity</li> <li>- Pregnant or post-partum adolescents</li> <li>- Adults, infants, preschool children, children only</li> <li>- Animal and cell studies</li> </ul>
<b>Intervention</b>	<ul style="list-style-type: none"> <li>- Intervention <b>comprises nutrition education/training and aims to change diet outcomes of individual adolescents</b></li> <li>- Intervention delivered to adolescents but may involve others, e.g. parents, peers, friends</li> <li>- Group-based, 1:1 or combination of both (<i>delivery method</i>)</li> <li>- May involve any technology</li> <li>- Settings: clinical, community, school, including as part of the curriculum, family</li> <li>- Interventions in dental setting may be multicomponent so long as there is a <b>diet component</b> (<i>stand alone</i>)</li> <li>- Any length of intervention</li> <li>- Secondary prevention of dental caries</li> <li>- Community-based behaviour change interventions for overweight or obesity if intervention is diet only</li> <li>- Includes <b>details of intervention</b>, eg not just “diet advice”</li> <li>- Nutrition and oral health</li> </ul>	<ul style="list-style-type: none"> <li>- Interventions including pharmaceuticals or supplements</li> <li>- Interventions including surgery</li> <li>- Inpatient/institutionalised/residential, e.g. summer camps</li> <li>- Combined drug (including alcohol, tobacco and other drugs) interventions</li> <li>- Alcohol only interventions</li> <li>- Public policy only interventions, e.g. tax-based and labelling interventions</li> <li>- Environmental only interventions, e.g. school cafeteria menu, vending machine removal</li> <li>- Combined policy and environmental only interventions</li> <li>- Whole of community interventions</li> <li>- Whole of family interventions which do not target adolescents, or interventions delivered to parents alone and not adolescents</li> <li>- No intervention, e.g. cross-sectional studies, mathematical modelling, simulations</li> <li>- Clinical obesity setting: management of weight, overweight or obesity, including secondary prevention and interventions aiming for weight loss, outpatient clinics, hospital delivered/referred/recruited</li> <li>- Prescriptive diet interventions e.g. energy restriction</li> <li>- Prevention of eating disorders or body image interventions, disordered eating/weight behaviour interventions, psychological interventions eg psychotherapy</li> <li>- Food provision studies</li> <li>- Sports nutrition or performance enhancing interventions for adolescent athletes</li> <li>- Multicomponent interventions of which diet is a component, e.g. healthy lifestyle interventions, NCD primary prevention</li> </ul>
<b>Comparator</b>	<ul style="list-style-type: none"> <li>- Different intervention, including varied intensity</li> <li>- Usual care</li> <li>- Non-exposure to intervention</li> <li>- Include pre-post studies with no comparator</li> </ul>	

<b>Outcomes</b>	<ul style="list-style-type: none"> <li>- Nutrition knowledge, attitudes, beliefs, intentions, self-efficacy</li> <li>- Food and nutrition literacy</li> <li>- Diet and nutritional quality</li> <li>- Food intakes, e.g. fruit, vegetables, sweetened drinks, discretionary foods</li> <li>- Nutrient intakes, e.g. energy, carbohydrates including fibre, sugar</li> <li>- Eating habits including, snacking or eating frequency</li> <li>- At least one dietary outcome reported pre- and post-intervention for intervention and comparator groups</li> </ul>	<ul style="list-style-type: none"> <li>- Hunger, satiety, cravings, binge eating</li> <li>- Anthropometric measures (e.g. weight, BMI, BMIz, WC)</li> <li>- BP, lipids, inflammatory markers, biochemistry</li> <li>- Fitness</li> <li>- Food safety</li> </ul>
<b>Study types</b>	<ul style="list-style-type: none"> <li>- Intervention studies including randomised, controlled, quasi-experimental, pre-post designs.</li> </ul>	<ul style="list-style-type: none"> <li>- Narrative reviews (<i>qualitative</i>)</li> <li>- Protocols</li> <li>- Cross-sectional studies</li> <li>- Case studies or reports, n=1 trials</li> <li>- Patient record audits</li> </ul>
<b>Other</b>	<ul style="list-style-type: none"> <li>- English</li> <li>- Articles published 1990 – 2020</li> <li>- Full text available</li> </ul>	<ul style="list-style-type: none"> <li>- Not in English</li> <li>- Published before 1990</li> <li>- Abstract only e.g. conference presentations</li> <li>- Not peer reviewed: Theses, book chapters</li> </ul>

### Hierarchy of Exclusion



## Appendix B - Search Terms for Database Search

Database	Search
<b>Ovid MEDLINE(R)</b> ALL 1946 to January 10, 2020  Search 13 jan 2020  =3136  Limit to English and 1990-2020  =2891	1. exp adolescent behavior/ or exp adolescent health/ or Adolescen*.ti,ab. or Teen*.ti,ab. 2. exp behavior change/ or (behavio?r* adj8 change*).ti,ab. or (diet* adj8 change*).ti,ab. or (nutrition* adj8 change*).ti,ab. or (diet* adj8 behavio?r*).ti,ab. or (nutrition* adj8 behavio?r*).ti,ab. 3. exp beverages nonalcoholic/ or exp food/ or exp eating behavior/ or exp nutrition/ or exp diets/ or Diet.ti,ab. or Dietary.ti,ab. or Food*.ti,ab. or Nutrition.ti,ab. or Eating.ti,ab. or Beverage*.ti,ab. or drink*.ti,ab. or nutrient.ti,ab. or feeding.ti,ab. or sugar*.ti,ab. or fruit*.ti,ab. or vegetable*.ti,ab. 4. exp program evaluation/ or exp clinical trials/ or exp intervention/ or Intervention.ti,ab. or Trial.ti,ab. or Program*.ti,ab. 5. 1 and 2 and 3 and 4 6. limit 5 to (english language and yr="1990 -Current")
<b>PubMed</b>  Search 13/10/2020  =3514  Limit to English and 1990-2020  =3253	"adolescent"[mh] OR adolescen*[tiab] OR teen*[tiab]  AND (behavioural change*[tiab] OR behavioral change*[tiab] OR behaviour change*[tiab] OR behavior change*[tiab] OR dietary change*[tiab] OR diet change*[tiab] OR nutrition* change*[tiab] OR nutrition behaviour*[tiab] OR nutrition behavior*[tiab] OR diet behaviour*[tiab] OR dietary behaviour*[tiab] OR diet behavior*[tiab] OR dietary behavior*[tiab])  AND ("beverages"[mh] OR "food"[mh] OR "eating"[mh] OR "nutritional status"[mh] OR "diet"[mh] OR food*[tiab] OR diet[tiab] OR dietary[tiab] OR nutrition*[tiab] OR eating[tiab] OR beverage*[tiab] OR drink*[tiab] OR nutrient*[tiab] OR feeding[tiab] OR sugar*[tiab] OR fruit*[tiab] OR vegetable*[tiab])  AND ("program evaluation"[mh] OR intervention[tiab] OR program*[tiab] OR trial[tiab])  AND English[Language] AND ("1990/01/01"[Date - Publication] : "3000"[Date - Publication])
<b>Embase</b>  Search 13/10/2020  =5167  Limit to English and 1990-2020  =4839	(adolescent/de OR adolescen*.ti,ab OR teen*.ti,ab) <b>AND</b> ("behaviour change"/exp OR ((behavio*r* NEAR/8 change*).ti,ab) OR ((diet* NEAR/8 change*).ti,ab) OR ((nutrition* NEAR/8 change*).ti,ab) OR (diet* NEAR/8 behavio*r*).ti,ab OR (nutrition* NEAR/8 behavio*r*).ti,ab) <b>AND</b> ('beverage'/exp OR 'food'/exp OR 'eating'/exp OR 'nutrition'/exp OR 'diet'/exp OR diet:ti,ab OR dietary:ti,ab OR food*.ti,ab OR nutrition*.ti,ab OR eating:ti,ab OR beverage*.ti,ab OR drink*.ti,ab OR nutrient:ti,ab OR feeding:ti,ab OR sugar*.ti,ab OR fruit*.ti,ab OR vegetable*.ti,ab) <b>AND</b> ('program evaluation'/exp OR intervention:ti,ab OR program*.ti,ab OR trial:ti,ab OR 'intervention study'/exp OR 'controlled study'/exp) <b>AND</b> (1990:py OR 1991:py OR 1992:py OR 1993:py OR 1994:py OR 1995:py OR 1996:py OR 1997:py OR 1998:py OR 1999:py OR 2000:py OR 2001:py OR 2002:py OR 2003:py OR 2004:py OR 2005:py OR 2006:py OR 2007:py OR 2008:py OR 2009:py OR 2010:py OR 2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py OR 2019:py OR 2020:py) AND [english]/lim
<b>CINAHL with full text</b>  Search 13 jan 2020  = 2073  Limit to English and 1990-2020  = 2042	( MH "adolescence+" OR TI adolescen* OR TI teen* OR AB adolescen* OR AB teen* ) <b>AND</b> ( MH "behavioral changes" OR TI behavio*r* N8 change* OR AB behavio*r* N8 change* OR AB diet* N8 change* OR TI diet* N8 change* OR TI nutrition* N8 change* OR AB nutrition* N8 change* OR TI diet* N8 behavio*r* OR AB diet* N8 behavio*r* OR TI nutrition* N8 behavio*r* OR AB nutrition* N8 behavio*r* ) <b>AND</b> ( MH "beverages+" OR MH "food+" OR MH "eating+" OR MH "adolescent nutrition" OR MH "diet+" OR TI diet OR AB diet OR TI dietary OR AB dietary OR TI food* OR AB food* OR TI nutrition* OR AB nutrition* OR TI eating OR AB eating OR TI beverage* OR AB beverage* OR TI drink* OR AB drink* OR TI nutrient* OR AB nutrient* OR TI feeding OR AB feeding OR TI sugar* OR AB sugar* OR TI fruit* OR AB fruit* OR TI vegetable* OR AB vegetable* )

	<p><b>AND</b> ( MH “program evaluation” OR MH “clinical trials+” OR TI intervention OR AB intervention OR TI trial OR AB trial OR TI program* OR AB program* )</p> <p>Limiters Published Date: 19900101-20201231 Language English</p>
<p><b>Cochrane</b></p> <p>Search 13 jan 2020</p> <p>Limit to English and 1990-2020</p> <p>= 65 reviews 5486 trials</p>	<p>adolescent OR adolescen* OR teen* in Title Abstract Keyword <b>AND</b> behavio*r* OR diet change* OR dietary change* OR nutrition* change* OR nutrition behavio*r* OR diet behavio*r* in Title Abstract Keyword <b>AND</b> diet* OR food* OR beverage OR nutrition OR eating OR beverages OR diet OR food OR dietary OR drink* OR nutrient* OR feeding OR sugar* OR fruit* OR vegetable* in Title Abstract Keyword <b>AND</b> program* OR intervention OR trial OR "Program evaluation" OR "Intervention study" OR "Controlled study" in Title Abstract Keyword</p> <p>adolescent OR adolescen* OR teen* in Title Abstract Keyword AND behavio*r* OR diet change* OR dietary change* OR nutrition* change* in Title Abstract Keyword AND diet* OR food* OR beverage OR nutrition OR eating OR beverages OR diet OR food OR dietary OR drink* OR nutrient* OR feeding OR sugar* OR fruit* OR vegetable* in Title Abstract Keyword AND program* OR intervention OR trial OR "Program evaluation" OR "Intervention study" OR "Controlled study" in Title Abstract Keyword - (Word variations have been searched)</p>
<p><b>Dental and Oral Sciences Source</b></p> <p>Search 13 jan 2020</p> <p>= 5</p>	<p>( MH “adolescence+” OR TI adolescen* OR TI teen* OR AB adolescen* OR AB teen* ) <b>AND</b> ( MH “behavioral changes” OR TI behavio*r* N8 change* OR AB behavio*r* N8 change* OR TI diet* N8 change* OR AB diet* N8 change* OR TI nutrition* N8 change* OR AB nutrition* N8 change* OR TI diet* N8 behavio*r* OR AB diet* N8 behavio*r* OR TI nutrition* N8 behavio*r* OR AB nutrition* N8 behavio*r* ) <b>AND</b> ( MH “beverages+” OR MH “food+” OR MH “eating+” OR MH “adolescent nutrition” OR MH “diet+” OR TI diet OR AB diet OR TI dietary OR AB dietary OR TI food* OR AB food* OR TI nutrition* OR AB nutrition* OR TI eating OR AB eating OR TI beverage* OR AB beverage* OR TI drink* OR AB drink* OR TI nutrient* OR AB nutrient* OR TI feeding OR AB feeding OR TI sugar* OR AB sugar* OR TI fruit* OR AB fruit* OR TI vegetable* OR AB vegetable* ) <b>AND</b> ( MH “program evaluation” OR MH “clinical trials+” OR TI intervention OR AB intervention OR TI trial OR AB trial OR TI program* OR AB program* )</p>
<p><b>PsycINFO</b></p> <p>1806 to January Week 1 2020</p> <p>Search 13 jan 2020 =725</p> <p>Limit to English and 1990-2020 =677</p>	<p>(exp adolescent behavior or exp adolescent health or Adolescen*.ti,ab. or Teen*.ti,ab) <b>AND</b> (exp behavior change or (behavio?r* adj8 change*).ti,ab or (diet* adj8 change*).ti,ab or (nutrition* adj8 change*).ti,ab or (diet* adj8 behavio?r*).ti,ab or (nutrition* adj8 behavio?r*).ti,ab) <b>AND</b> (exp beverages nonalcoholic or exp food or exp eating behavior or exp nutrition or exp diets or Diet.ti,ab. or Dietary.ti,ab. or Food*.ti,ab. or Nutrition.ti,ab. or Eating.ti,ab. or Beverage*.ti,ab or drink*.ti,ab or nutrient.ti,ab or feeding.ti,ab or sugar*.ti,ab or fruit*.ti,ab or vegetable*.ti,ab) <b>AND</b> (exp program evaluation or exp clinical trials or exp intervention or Intervention.ti,ab. or Trial.ti,ab. or Program*.ti,ab)</p> <p>limit to (english language and yr="1990 -Current")</p>
<p><b>Scopus</b></p> <p>Search 13 jan 2020 = 6886</p> <p>Limit to English and 1990-2020 = 6328</p>	<p>TITLE-ABS-KEY(adolescen* OR teen*) <b>AND</b> TITLE-ABS-KEY(behavio*r* w/8 change*) OR TITLE-ABS-KEY(diet* w/8 change*) OR TITLE-ABS-KEY(nutrition* w/8 change*) OR TITLE-ABS-KEY(nutrition* w/8 behavio*r*) OR TITLE-ABS-KEY(diet* w/8 behavio*r*) <b>AND</b> TITLE-ABS-KEY(diet* OR food* OR beverage* OR nutrition OR eating OR drink* OR nutrient* OR feeding OR sugar* OR fruit* OR vegetable*)</p>

	<p><b>AND</b> TITLE-ABS-KEY(program* OR intervention OR trial OR "Program evaluation" OR "Intervention study" OR "Controlled study")</p> <p>AND ( LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO ( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO ( PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) OR LIMIT-TO ( PUBYEAR , 2011 ) OR LIMIT-TO ( PUBYEAR , 2010 ) OR LIMIT-TO ( PUBYEAR , 2009 ) OR LIMIT-TO ( PUBYEAR , 2008 ) OR LIMIT-TO ( PUBYEAR , 2007 ) OR LIMIT-TO ( PUBYEAR , 2006 ) OR LIMIT-TO ( PUBYEAR , 2005 ) OR LIMIT-TO ( PUBYEAR , 2004 ) OR LIMIT-TO ( PUBYEAR , 2003 ) OR LIMIT-TO ( PUBYEAR , 2002 ) OR LIMIT-TO ( PUBYEAR , 2001 ) OR LIMIT-TO ( PUBYEAR , 2000 ) OR LIMIT-TO ( PUBYEAR , 1999 ) OR LIMIT-TO ( PUBYEAR , 1998 ) OR LIMIT-TO ( PUBYEAR , 1997 ) OR LIMIT-TO ( PUBYEAR , 1996 ) OR LIMIT-TO ( PUBYEAR , 1995 ) OR LIMIT-TO ( PUBYEAR , 1994 ) OR LIMIT-TO ( PUBYEAR , 1993 ) OR LIMIT-TO ( PUBYEAR , 1992 ) OR LIMIT-TO ( PUBYEAR , 1991 ) OR LIMIT-TO ( PUBYEAR , 1990 ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )</p>
<p><b>Web of Science Core Collection</b></p> <p>Search 13 jan 2020</p> <p>Limit to English and 1990-2020</p> <p>= 1303</p>	<p>TI=adolescen* OR AB=adolescen* OR TI=teen* OR AB=teen* OR TS="adolescence"</p> <p><b>AND</b></p> <p>(TI=(behavio*r* NEAR/8 change*) OR AB=(behavio*r* NEAR/8 change*) OR TI=(diet* NEAR/8 change*) OR AB=(diet* NEAR/8 change*) OR TI=(nutrition* NEAR/8 change*) OR AB=(nutrition* NEAR/8 change*) OR TI=(diet* NEAR/8 behavio*r*) OR AB=(diet* NEAR/8 behavio*r*) OR TI=(nutrition* NEAR/8 behavio*r*) OR AB=(nutrition* NEAR/8 behavio*r*) OR TS="behavioural changes")</p> <p><b>AND</b></p> <p>(TI=(diet OR dietary OR food* OR nutrition* OR eating OR beverage* OR drink* OR nutrient* OR feeding OR sugar* OR fruit* OR vegetable*)) OR (AB=(diet OR dietary OR food* OR nutrition* OR eating OR beverage* OR drink* OR nutrient* OR feeding OR sugar* OR fruit* OR vegetable*)) OR (TS=("beverages" OR "food" OR "eating" OR "adolescent nutrition" OR "diet"))</p> <p><b>AND</b></p> <p>TI=(intervention OR trial OR program*) OR AB=(intervention OR trial OR program*) OR TS=("program evaluation" OR "clinical trials")</p>

### Appendix C - Sample Data Extraction Sheet

Study:	<b>Lead Author, Year</b>	
Data extraction version:	1	2      Coding
Completed by:		
Date:		

<b>METADATA</b>		
	Citation	
	Added to endnote	
	Year	
	Country	
<b>Question(s) addressed</b>		
<b>Study details</b>		
	Study design	
	Study description	
	Setting (School, Community etc)	
	Study length	
	Follow-up/s	
	Data collection points	
	Global study quality rating	
	A – Selection bias	
	B – Study design	
	C – Confounders	
	D – Blinding	
	E – Data collection methods	
	F – Withdrawals and dropouts	
	Comments	
<b>POPULATION</b>		
	Inclusion/exclusion criteria	
	Participants	
	Total sample size at baseline:	
	Country:	
	Region (urban (city)/rural):	
	Socioeconomic status: e.g. parent education/job, parent/family income	
	Gender:	
	Race/Ethnicity:	
	Age / Mean age	
	Any information on confounders	
	Any other relevant baseline statistics for each group	
<b>INTERVENTION</b> <i>(description adapted from the TIDieR Checklist)</i>		
	Number of groups/study arms	
	Group 1	
	Group 2	
<b>What</b>	Name of intervention	
	Aim	
	Content of intervention	
	Description of intervention	
	Target behaviours/outcomes - primary	



	Target behaviours/outcomes - secondary	
<b>Who provided</b>	Study personnel who delivered intervention	
<b>How</b>	Delivery mode/s of intervention	
	Individual/group/combination (if group include size)	
<b>Where</b>	Setting/s (e.g. clinical practice, school, home, community)	
	Location/s	
<b>When and How much</b>	Number of sessions	
	Length of sessions	
	Frequency of intervention sessions/contact	
	Total duration of intervention	
	Parent/ peer/ friend involvement in intervention	
	Study materials provided to participant	
<b>BEHAVIOUR CHANGE</b>		
	Behaviour change theories underpinning intervention (author reported)	
	Behaviour change techniques (author reported)	
	Incentivisation/ reward	
	Author comments on effective behaviour change components	
	Behaviour change techniques identified - mapped against BCTTv1	
	BCTs associated with effective results	
	Effect sizes	
	BCT's associated with effective results in linked study/s (if any)	
<b>CONTROL</b>		
	Sample size	
	Treatment	
<b>RESULTS</b>		
	Retention (%)	
	Diet outcome/s measured	
	Measurement methods	
	Time-points	
	Significant results ( $p < .05$ )	
	Other interesting results	
	Effective diet behaviour results	
<b>OTHER</b>		
	Participant engagement/ adherence/ completion/ withdrawals	
	Cost-effectiveness	
	Participant satisfaction/acceptability	
	Additional references e.g. protocol papers, pilot studies, baseline results, feasibility studies, secondary outcomes	
<b>ADDITIONAL INFO FROM LINKED STUDIES if any</b>		
	Lead author & Year	
	Questions addressed	
	Additional statistical data	
	Significant results ( $p < .05$ )	

## Details Re BCTs Mapped In Intervention

Behaviour change technique (BCT)	Description in text	Reason for coding/ not coding

### Appendix D - Categories and BCTs as per BCT Taxonomy v1

<b>1</b>	<b>Goals and planning</b>	<b>2</b>	<b>Feedback and monitoring</b>	<b>3</b>	<b>Social support</b>	<b>4</b>	<b>Shaping knowledge</b>
1.1	Goal setting (behavior)	2.1	Monitoring of behavior by others without feedback	3.1	Social support (unspecified)	4.1	Instruction on how to perform a behavior
1.2	Problem solving	2.2	Feedback on behavior	3.2	Social support (practical)	4.2	Information about antecedents
1.3	Goal setting (outcome)	2.3	Self-monitoring of behavior	3.3	Social support (emotional)	4.3	Re-attribution
1.4	Action planning	2.4	Self-monitoring of outcome(s) of behavior			4.4	Behavioral experiments
1.5	Review behavior goal(s)	2.5	Monitoring outcome(s) of behavior by others without feedback				
1.6	Discrepancy between current behavior and goal	2.6	Biofeedback				
1.7	Review outcome goal(s)	2.7	Feedback on outcome(s) of behavior				
1.8	Behavioral contract						
1.9	Commitment						
<b>5</b>	<b>Natural consequences</b>	<b>6</b>	<b>Comparison of behavior</b>	<b>7</b>	<b>Associations</b>	<b>8</b>	<b>Repetition and substitution</b>
5.1	Information about health consequences	6.1	Demonstration of the behavior	7.1	Prompts/cues	8.1	Behavioral practice/ rehearsal
5.2	Salience of consequences	6.2	Social comparison	7.2	Cue signalling reward	8.2	Behavior substitution
5.3	Information about social and environmental consequences	6.3	Information about others' approval	7.3	Reduce prompts/cues	8.3	(new) Habit formation
5.4	Monitoring of emotional consequences			7.4	Remove access to the reward	8.4	Habit reversal
5.5	Anticipated regret			7.5	Remove aversive stimulus	8.5	Overcorrection
5.6	Information about emotional consequences			7.6	Satiation	8.6	Generalisation of a target behavior
				7.7	Exposure	8.7	Graded tasks
				7.8	Associative learning		
<b>9</b>	<b>Comparison of outcomes</b>	<b>10</b>	<b>Reward and threat</b>	<b>11</b>	<b>Regulation</b>	<b>12</b>	<b>Antecedents</b>

9.1	Credible source	10.1	Material incentive (behavior)	11.1	Pharmacological support	12.1	Restructuring the physical environment
9.2	Pros and cons	10.2	Material reward (behavior)	11.2	Reduce negative emotions	12.2	Restructuring the social environment
9.3	Comparative imagining of future outcomes	10.3	Non-specific reward	11.3	Conserving mental resources	12.3	Avoidance/reducing exposure to cues for the behavior
		10.4	Social reward	11.4	Paradoxical instructions	12.4	Distraction
		10.5	Social incentive			12.5	Adding objects to the environment
		10.6	Non-specific incentive			12.6	Body changes
		10.7	Self-incentive				
		10.8	Incentive (outcome)				
		10.9	Self-reward				
		10.10	Reward (outcome)				
		10.11	Future punishment				
<b>13</b>	<b>Identity</b>	<b>14</b>	<b>Scheduled consequences</b>	<b>15</b>	<b>Self-belief</b>	<b>16</b>	<b>Covert learning</b>
13.1	Identification of self as role model	14.1	Behavior cost	15.1	Verbal persuasion about capability	16.1	Imaginary punishment
13.2	Framing/reframing	14.2	Punishment	15.2	Mental rehearsal of successful performance	16.2	Imaginary reward
13.3	Incompatible beliefs	14.3	Remove reward	15.3	Focus on past success	16.3	Vicarious consequences
13.4	Valued self-identity	14.4	Reward approximation	15.4	Self-talk		
13.5	Identity associated with changed behavior	14.50	Rewarding completion				
		14.6	Situation-specific reward				
		14.7	Reward incompatible behavior				
		14.8	Reward alternative behavior				
		14.9	Reduce reward frequency				
		14.10	Remove punishment				