Behavioral Physiology/Obesity Prevention

Interventions to reduce consumption of sugar-sweetened beverages or increase water intake: evidence from a systematic review and meta-analysis

E.J. Vargas-Garcia,[1] C.E.L. Evans,[1] A. Prestwich,[2] B.J. Sykes-Muskett,[2] J. Hooson[1] and J.E. Cade[1]

[1]Nutritional Epidemiology Group, School of Food Science and Nutrition, University of Leeds, Leeds, UK, and [2]School of Psychology, University of Leeds, Leeds, UK

Address for correspondence: CEL Evans, Nutritional Epidemiology Group, School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK.
E-mail: C.E.L.Evans@leeds.ac.uk

Summary

A systematic review and meta-analyses were conducted to evaluate the effects of interventions to reduce sugar-sweetened beverages (SSB) or increase water intakes and to examine the impact of behaviour change techniques (BCTs) in consumption patterns. Randomized and nonrandomized controlled trials published after January 1990 and until December 2016 reporting daily changes in intakes of SSB or water in volumetric measurements ($mL\ d^{-1}$) were included. References were retrieved through searches of electronic databases and quality appraisal followed Cochrane principles. We calculated mean differences (MD) and synthesized data with random-effects models. Forty studies with 16 505 participants were meta-analysed. Interventions significantly decreased consumption of SSB in children by 76 $mL\ d^{-1}$ (95% confidence interval [CI] −105 to −46; 23 studies, $P < 0.01$), and in adolescents (−66 $mL\ d^{-1}$, 95% CI −130 to −2; 5 studies, $P = 0.04$) but not in adults (−13 $mL\ d^{-1}$, 95% CI −44 to 18; 12 studies, $P = 0.16$). Pooled estimates of water intakes were only possible for interventions in children, and results were indicative of increases in water intake (MD +67 $mL\ d^{-1}$, 95% CI 6 to 128; 7 studies, $P = 0.04$). For children, there was evidence to suggest that modelling/demonstrating the behaviour helped to reduce SSB intake and that interventions within the home environment had greater effects than school-based interventions. In conclusion, public health interventions – mainly via nutritional education/counselling – are moderately successful at reducing intakes of SSB and increasing water intakes in children. However, on average, only small reductions in SSBs have been achieved by interventions targeting adolescents and adults. Complementary measures may be needed to achieve greater improvements in both dietary behaviours across all age groups.

Keywords: Nutritional epidemiology, obesity, sugar-sweetened beverages, systematic review.

Abbreviations: BCT, behaviour change technique; CENTRAL, Cochrane Central Register of Controlled Trials; CI, confidence intervals; DARE, Database of Abstracts of Reviews of Effects; df, degrees of freedom; FFQ, food frequency questionnaire; ICTRP, International Clinical Trials Registry Platform; IQR, interquartile range; MD, mean difference; $mL\ d^{-1}$, mililitres per day; mRCT, metaRegister of Controlled Trials; PAHO, Pan American Health Organization; PICO, population/intervention/comparator/outcome; PRISMA, preferred reporting items for systematic reviews and meta-analyses; PROGRESS, place of residence, race or ethnicity, occupation, gender, religion, education, socioeconomic status, social status; PROSPERO, Prospective Register Of Systematic Reviews; RCT,

randomized-controlled trial; SSB, sugar-sweetened beverages; T2DM, type 2 diabetes; TEI, total energy intake; TRoPHI, Trials Register of Promoting Health Interventions; UK, United Kingdom; WHO, World Health Organization.

Introduction

Evidence that links higher intake of sugar-sweetened beverages (SSB) with greater risk of tooth decay (1), weight gain (2), type 2 diabetes (T2DM) (3) and cardiovascular disease (4) continues to grow and supports the need for public health and community action. Indeed, it has been highlighted that over a year, for every additional daily serving of SSB, BMI increases by 0.06 kg m^{-2} and weight by 0.22 kg in children and adults, respectively (5). Furthermore, in adults, the risk of developing T2DM increases by 20% for every daily serving size of SSB, even after adjusting for confounders like adiposity (6,7). This finding is consistent across epidemiological studies, in which consumers of more than a serving per day increase their risk of T2DM by twofold in comparison to lower consumers (8,9). This evidence has underpinned the update of nutritional guidelines on sugar intake by WHO and high-income countries(10–12) to recommend daily intake of free sugars of no more than 10% of total dietary energy, to directly support dental caries reduction (13). The UK, in particular, has established a recommended population mean of no more than 5% of free sugars – with consumption of SSB being particularly discouraged (12). The term 'free sugar' was introduced by the WHO Nutrition Expert Guidance Advisory Group to refer to all monosaccharides and disaccharides added to foods and beverages by the producer, cook or consumer as well as sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (13).

Despite the amount of literature emphasizing detrimental health outcomes of higher intakes of SSB, consumption levels remain high across populations worldwide. Estimates from 2010 on global intakes found that adults consumed on average 132 millilitres (mL) per day and that upper-middle and lower-middle income countries had the highest per capita levels of consumption: 192 mL d^{-1} and 142 mL d^{-1}, respectively (14). Sugar-sweetened beverages are primary contributors of added sugars within the American diet, accounting for 8.0 and 6.9% of total energy intake (TEI) in children and young adults, respectively (15,16). The latest UK National Diet and Nutrition Survey revealed that non-alcoholic beverages (soft drinks and fruit juices) contribute to 5.8% of TEI in children, 3% in young adults and less than 2% in older adults (17). These patterns of consumption have also been observed for the Australian population (18). However, data from countries in the Americas, such as Mexico, have found that soft drinks contribute to 10% of TEIs both in children and adults and a recent report from 13 Latin American countries by the PAHO has shown a steep rise by around threefold in sales of SSB over the past decade (19).

Initiatives to reduce consumption of SSB are delivered through a variety of public health interventions and with different approaches taken. Some of these include campaigns to increase public awareness of sugar content in beverages and consequences of heavy consumption, enhanced nutritional labelling of non-alcoholic beverages or the replacement of drinks with low-sugar alternatives (often artificially sweetened or plain water) (20). Policies within educational and working environments restricting the availability of sugary beverages have also been encouraged (21,22). Further, promotion of and access to potable water as a preferred choice of beverage have been emphasized considering the potential health benefits derived by reducing energy intake when SSB are substituted with water (23,24). Whilst behaviour change interventions are considered as fundamental in public health practice (25), evidence remains scarce around the type of interventions most effective in reducing consumption of SSB and increasing water intakes across all age groups (26,27). Previous reviews in this topic have focused on establishing associations between higher intakes of SSB and detrimental health outcomes (3,5,6) or have been focused on identifying effective components in interventions aimed exclusively at children (28,29) or adolescents within specific settings (such as the school) (30). The current review extends the literature by attempting to identify the overall effects of interventions on both SSB *and* water intake, as well as the elements of these interventions (such as the behaviour change techniques (BCTs) used and the setting in which the intervention was delivered) that can influence intervention effectiveness (31).

Consequently, this review aims to evaluate the effectiveness of public health interventions to reduce SSB intake or increase water intake in children, adolescents and adults. In addition, we examine the study characteristics that could bring about change in consumption patterns.

Methods

Search strategy and selection criteria

Guided by the PRISMA specifications and following a published protocol (32) (registered with PROSPERO,

number CRD42014013436), relevant studies were identified through a systematic search in Ovid Medline, Embase, Web of Science, Scopus, Cochrane Central Register of Controlled Trials (CENTRAL), the Global Health Library, Database of Abstracts of Reviews of Effects (DARE), clinicaltrials.gov, the Trials Register of Promoting Health Interventions (TRoPHI), International Clinical Trials Registry Platform (ICTRP) and metaRegister of Controlled Trials (mRCT) from January 1, 1990, to May 19, 2014. An update was conducted in Ovid Medline from May 20, 2014, to December 31, 2016 as this is a key database for research in this area and the vast majority of relevant trials in the initial review were identified in this database. Studies that had been published in any language were included. Guided by the PICO framework (Population/Intervention/Comparator and Outcome), a combination of keywords (including medical subheadings) related to interventions, settings and outcomes was identified in the final search strategy (32).

This review included randomized-controlled trials (RCTs), cluster RCTs and non-RCTs conducted in participants (no younger than 3 years old) of predominantly community-based interventions with a minimum length of 4 weeks of follow-up (from baseline to final data collection) and with a control group available. Our primary outcome was the change in millilitres in SSB or water intakes throughout the day. A SSB was defined as a non-diet, non-alcoholic and non-dairy cold or warm drink (carbonated or still), with added sugars (including fruit drinks, nectars and cordials with less than 100% fruit juice), sports or energy beverages, ready-to-drink sweetened tea and ready-to-drink sweetened coffee (33,34). If the portion size was not reported or we were unable to obtain the information from authors, we used a portion size per drink of 240 mL. Studies that focused on other outcomes, such as dairy or fruit juice consumption or that did not use a 24-h recall, food record or food frequency questionnaire (FFQ) as the assessment measure, were excluded. Furthermore, we did not include trials focusing on water preloading before meals as a way to influence energy intake particularly if water intakes were not *ad libitum*. As per protocol, we did not include interventions addressing consumption of artificially sweetened beverages as replacement of SSB. Trials focussing on rehydration or sanitation or assessing acute hormonal responses as a result of immediate intakes of SSB were also not included. Interventions on subjects with type 2 diabetes, metabolic syndrome or cardiovascular disease were only considered if part of a RCT.

Screening, data extraction and quality assessment

Eligibility was initially verified by two independent reviewers (EJVG, JH) based on title and abstract screening, followed by retrieval and evaluation of full texts of studies meeting inclusion criteria. Any discrepancies at both stages were discussed and resolved with two senior reviewers (CELE, JEC).

We extracted data on overall study characteristics: study design, risk of bias at the study level using the Cochrane risk of bias tool (35), number of participants, intervention aims, setting, population's age, country, year of study, length of the intervention, primary and secondary outcomes, statistical measures, main results and attrition rates. Additional information on equity was collated – when available – using the PROGRESS framework (which stands for place of residence, race or ethnicity, occupation, gender, religion, education, socioeconomic status, social status) to identify if the interventions had more positive effects in certain participants or groups. To explore potentially successful components of the interventions, we identified and analysed BCTs associated with interventions' implementation and delivery processes following a 26-item taxonomy (36).

Where available, protocols were obtained and used during data extraction. With the exception of BCTs, data extraction was completed by one member of the team (EJVG) and verified by a trained undergraduate student using an adapted spreadsheet from Cochrane's Public Health Group (35) which was narrowed to the study designs and specific outcomes of interest in this review. For BCTs, data extraction was completed in duplicate using an established taxonomy (36) by two trained reviewers (EJVG, BJSM), and any disagreements were discussed with a third reviewer (AP). For the update stage, extraction of BCT was only conducted by one reviewer (BJSM). We included two further intervention techniques reported in the intervention descriptions that were not included within the taxonomy: 'environmental support' and 'parental involvement'. Behaviour change techniques were coded as '1', '−1' or '0' if present/used only in the intervention (and not in controls), only in controls (but not delivered to intervention groups) or in both/neither arms, respectively. There were no instances where a BCT was delivered only to participants in the control group.

Continuous data for primary outcomes were extracted as means and standard deviations or as the adjusted mean difference [MD] and standard error – if presented. Authors of potentially included studies were contacted electronically for further queries and data clarification if needed. When studies reported follow-up data for more than one period, we used the data from the longest follow-up period available.

Statistical analysis

A random-effects meta-analysis was conducted to account for the variation in the magnitude of effect sizes and

between-study variance using MD in millilitres of SSB or water between groups and standard error of the difference. If MD between the control and intervention group were not reported but change in intake between baseline and follow-up was reported for each group, then a paired *t*-test was carried out to calculate the MD between groups together with the standard error to use in the meta-analysis. If only baseline and follow-up results were provided with no data on change between baseline and follow-up and no data on difference between control and intervention groups, then a *t*-test was used to calculate this difference at follow-up, together with the standard error of the difference to use in the meta-analysis.

The meta-analysis was conducted in Review Manager (version 5.0, Cochrane Library) and duplicated in Stata 14.0. Results from the most adjusted multivariate models were used whenever these were available. When studies had multiple intervention arms, selection of the most representative group (such as having the most BCTs) was discussed and selected by two reviewers (EJVG and CELE). The I^2 test was used to assess heterogeneity across studies; results between 50 and 75% and above 75% were

considered to have substantial and considerable heterogeneity, respectively.

Subgroup analyses were conducted in Stata 14.0 to further explore substantial heterogeneity across studies. As per protocol, the effects of participants' age, setting of delivery and randomization on SSB and water outcomes were examined. Post-hoc analyses were undertaken on the effects of different dietary assessment tools and length of interventions on SSB intakes. We conducted moderator analyses to identify whether the use of specific BCTs was associated with greater decreases of SSB.

Results

Study selection and characteristics

Figure 1 indicates the number of studies considered at each stage of the review. After removal of duplicates (2,756), a total of 3,028 citations were screened for eligibility, leading to 272 papers identified for potential inclusion. Twenty-nine authors were contacted at this stage for further information. At the final stage, 50 studies were included in the qualitative
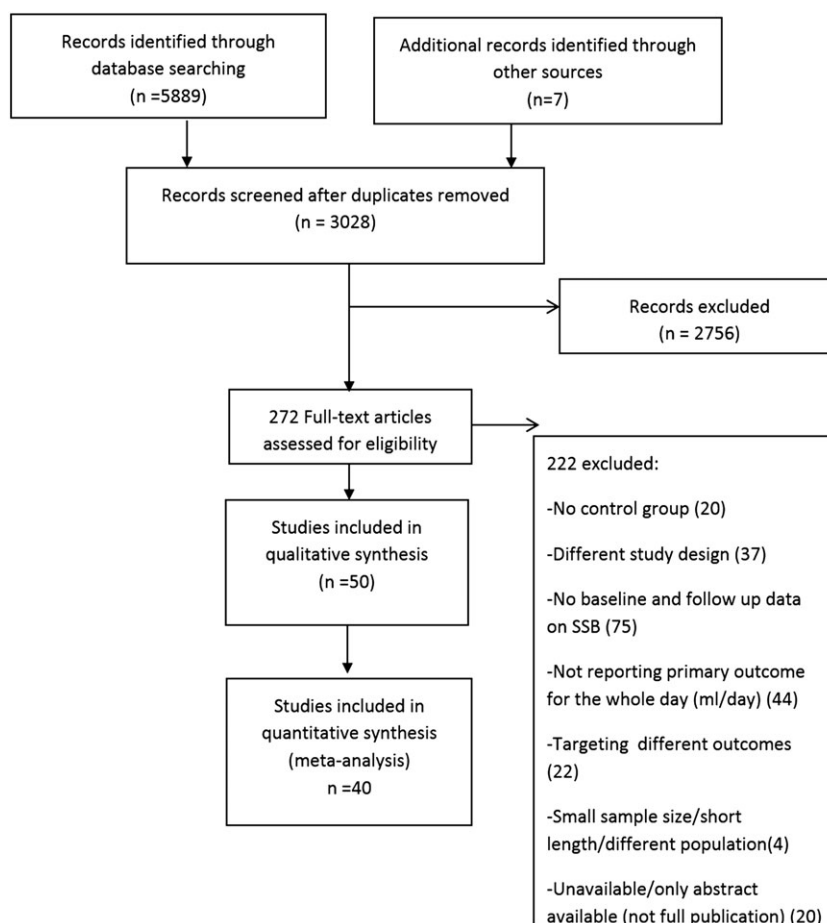

Figure 1   PRISMA flow-chart diagram.

synthesis and 40 studies in the quantitative meta-analysis (16,505 participants). The 40 quantitative studies published in 38 articles from Australia, Belgium, Brazil, Canada, Chile, Germany, Malaysia, Mexico, New Zealand, Norway, Portugal, Turkey, the Netherlands, the UK and USA provided information on daily intakes of SSB; 11 of which also had data available on water intakes. Of the 40 studies (16,505), 23 had data on children (10,964), 5 on adolescents (3,117) and 12 in adults (2,424), with one study reporting intakes on both children and adults (37) and another on both adolescents and adults (38). Characteristics of the studies and quality assessment can be found in Supporting Information Tables S1 and S2, respectively.

Settings of interventions were educational for 15 studies (39–53), home for 9 studies (37,38,54–58), community centres/locations in 11 studies (59–69) and clinical in 5 studies (70–74). Duration of interventions varied from 6 weeks to 2 years, with active periods of programme delivery ranging from 3 weeks up to 24 months and follow-up periods ranging from 4 weeks up to 22 months.

Serving sizes per amount of SSB per day varied from 165 to 375 mL across studies, and the definition of SSB mainly focused on carbonated beverages and fruit drinks. Frequency of consumption of SSB or water was analysed and transformed into 'servings per day' in 6 studies (38,48,57,60,62,73), and responses from contacted authors clarified serving sizes in 7 further studies

(39,49,52,58,64,67,72). We contacted authors of studies reporting intakes for more than one category of SSB individually to determine whether combined results for total intakes were available; this was the case for four studies (40,51,52,72). The median baseline intake of SSB in intervention groups was 599 mL d^{-1} in adolescents (IQR [interquartile range] 348 to 678; 4 studies), 195 mL d^{-1} in adults (IQR 104 to 464; 11 studies) and 235 mL d^{-1} in children (IQR 180 to 480; 21 studies). Median baseline intakes in control groups were similar: 593 mL d^{-1} in adolescents (IQR 365 to 606), 235 mL d^{-1} in adults (IQR 120 to 495) and 264 mL d^{-1} in children (IQR 137 to 446).

Meta-analysis on primary outcomes: sugar-sweetened beverages and water intakes

Interventions compared with controls significantly reduced consumption of SSBs in children by 76 mL d^{-1} (95% CI −105 to −46; $P < 0.01$), but with substantial heterogeneity ($I^2 = 93\%$, df = 22, $P < 0.01$) (Fig. 2). The reduction reflected a medium-sized effect standardized mean difference (SMD) −0.48 [95% CI: −0.73 to −0.24]. Studies in adolescents indicated significant lower intakes of SSB in intervention groups by 66 mL d^{-1} (95% CI −130 to −2; $P = 0.04$) but with considerable heterogeneity ($I^2 = 63\%$, df = 4, $P = 0.030$) and a SMD effect size of −0.05 [95% CI: −0.25 to 0.15]. Interventions in adults achieved a non-
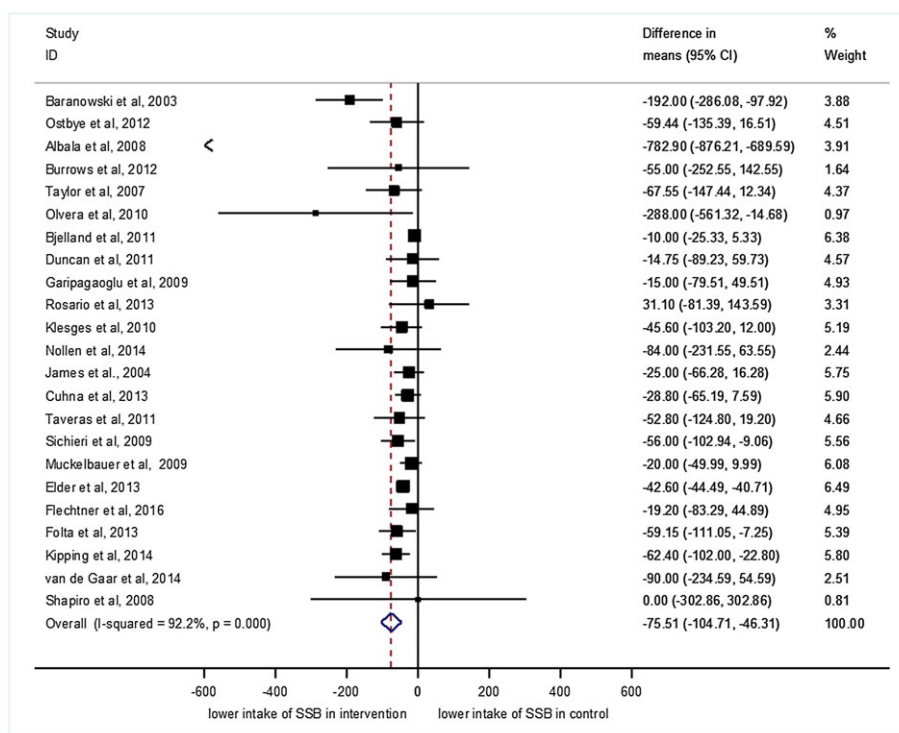

Figure 2 Meta-analysis of mean difference in SSB intake (mL per day) in children, intervention versus controls. [Colour figure can be viewed at wileyonlinelibrary.com]

significant reduction by 13 mL d^{-1} (95% CI −44 to 18; $P = 0.16$) with considerable heterogeneity ($I^2 = 54\%$, df = 11, $P = 0.01$) and a SMD effect size of −0.07 [95% CI −0.19 to 0.05] (Fig. 3a,b). Due to the small number of studies in adolescents ($n = 5$), further analyses to explore sources of heterogeneity or publication bias were only undertaken in child and adult populations.

Data on water intakes were available in 11 studies: two in adults (65,75), two in adolescents (42,55) and seven in children (40,44,59,63,69,71); thus, a meta-analysis was only possible in the child population. Findings suggested that interventions significantly increased water consumption in children by 67 mL d^{-1} (95% CI 6 to 128,

$P = 0.03$), compared with controls (Fig. 4). Heterogeneity was substantial $I^2 = 77\%$, but no further testing was possible as a result of the small number of studies.

Risk of bias within studies

Assessment of quality of included studies is shown in Table S2. Risk of bias across the 40 studies meta-analysed (in 38 existing articles) was generally medium to high, and unclear judgments were due to insufficient study details for all appraised domains; only four studies were judged to be of higher quality (48,55,63,73). The risk of bias for allocation concealment was high in 6 studies (16%) and
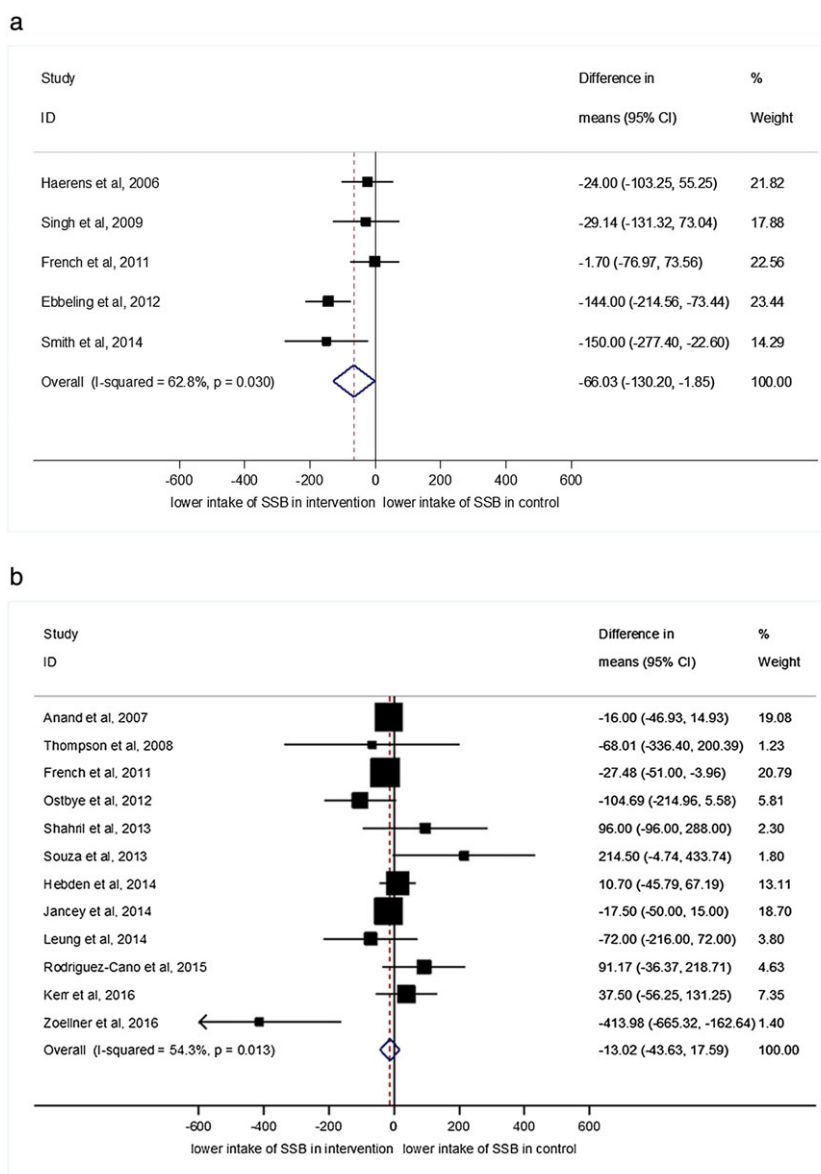
Figure 3 a. Meta-analysis of mean difference in SSB intake (mL per day) in adolescents, intervention versus controls. b. Meta-analysis of mean difference in SSB intake (mL per day) in adults, intervention versus controls. [Colour figure can be viewed at wileyonlinelibrary.com]
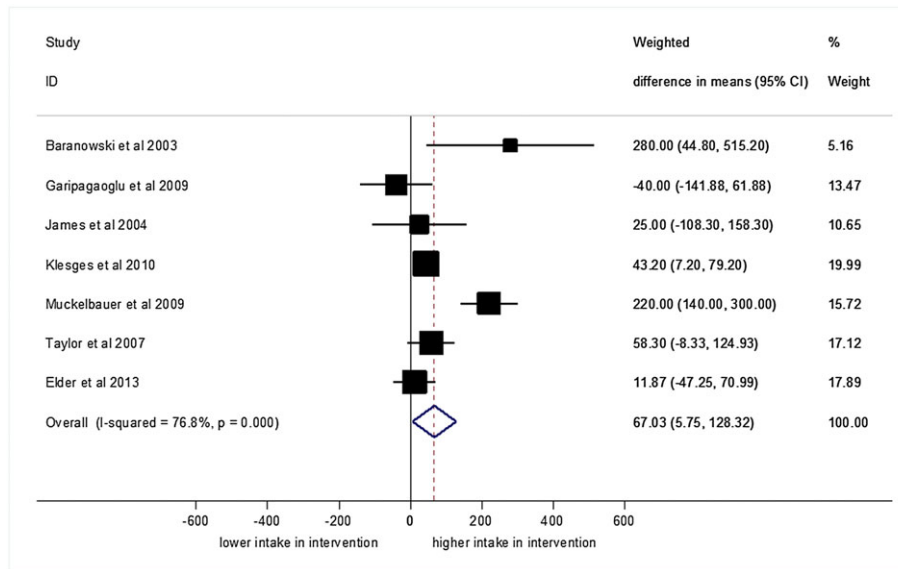
Figure 4 Meta-analysis of mean difference in water intake (mL per day) in children, intervention versus controls. [Colour figure can be viewed at wileyonlinelibrary.com]

unclear for 23 (61%) as a result of including non-randomized interventions (40,46,50,60,62,66,70). A high risk of bias was found for outcome assessment in 8 studies (20%) as many results were not reported as being adjusted for confounders or attrition rates. Accounting for the nature of interventions, blinding of participants and intervention deliverers was of concern due to a high risk of bias in 25 studies (66%). In other domains, dietary assessment of the primary outcome was classified as having high risk of bias in 32 studies (84%) because data were self-reported. Reporting bias was apparent in 5 studies that had available protocols and unclear in 27 (71%).

Subgroup analyses on primary outcomes: sugar-sweetened beverages

All age groups
Results from subgroup analyses are shown in Table S3. Subgroup analyses were only possible for SSB outcomes, due to the small number of studies on water intakes. Across all populations, subgroup analyses for changes in SSB indicated significant MD in intakes between intervention and control groups, for interventions delivered in the community (-52 mL d^{-1}, 95% CI -88 to -18; $P < 0.01$) in educational (-27 mL d^{-1}, 95% CI -42 to -12; $P < 0.01$) and in home settings (-141 mL d^{-1}, 95% CI -255 to -27 mL d^{-1}; $P = 0.02$) but not clinically based (-18 mL d^{-1}, 95% CI -55 to 18, $P = 0.32$). Differences between groups in SSB consumption were seen for interventions that used the 24-h recall and FFQ as dietary methods (-50 mL d^{-1}, 95% CI -78 to -22; $P < 0.01$ and -72, 95% CI -104 to -39; $P < 0.01$, respectively) but not

dietary records (-21 mL d^{-1}, 95%CI -52 to 11, $P = 0.20$). Studies conducted in North America (-52 mL d^{-1}, 95% CI -72 to -31; $P < 0.01$) and Europe (-18 mL d^{-1}, 95% CI -30 to -6; $P = 0.01$) also generated significant reductions but not those in South America or Australasia (-173 mL d^{-1}, 95 CI% -436 to 108, $P = 0.23$ and -18, 95% CI -50 to 14, $P = 0.28$, respectively). Studies incorporating intervention periods of more than or equal to 30 weeks or less than 30 weeks in duration both generated significant and similar effects (-41 mL d^{-1}, 95% CI -55 to -28; $P < 0.01$ and -81 mL d^{-1}, 95% CI -144 to -18, $P < 0.01$). Significant decreases were also noted across all different study designs and studies judged to have high, medium or low risk of bias (Table S3). Moderator analyses confirmed that there were no significant differences in SMD effect sizes across categories of any of these variables on SSB intakes (refer to Table S3). Asymmetry was not apparent from funnel plot inspection (refer to Fig. S1), and results from the Egger's test for publication bias were also non-significant ($P = 0.61$).

Children
Subgroup analyses in studies of children indicated interventions lasting for more than or equal to 30 weeks (-36 mL d^{-1}, 95% CI -48 to -24; $P = 0.03$), as well studies with shorter durations (less than 30 weeks), (-158 mL d^{-1}, 95% CI -353 to -38; $P < 0.01$) were both effective in reducing SSB intake. Also, significant decreases were noted for community and school-based studies (-72 mL d^{-1}, 95% CI -115 to -30; $P < 0.01$ and -28 mL d^{-1}, 95% CI -42 to -12; $P < 0.01$, respectively) but not for clinical or home based (-27 mL d^{-1}, 95% CI -66 to

12, $P = 0.16$ and $= -238.3$, 95% CI -667.18 to 190.6, $P = 0.28$, respectively), for cluster-RCT and non-RCT (-29 mL d^{-1}, 95% CI -46 to -12; $P < 0.01$ and -75 mL d^{-1}, 95% CI -122 to -28; $P = 0.02$, respectively), but not for RCTs (-160, 95% CI -345 to -25; $P = 0.09$) and with the use of the 24-h recall and FFQ as dietary methods (-55 mL d^{-1}, 95% CI -87 to -24; $P < 0.01$ and -126 mL d^{-1}, 95% CI -191 to -61; $P < 0.01$, respectively) but not for dietary records (-21 mL d^{-1}, 95% CI -52 to 11, $P = 0.20$). Significant decreases were also observed for studies judged at a low, medium and high risk of bias, and for those conducted in North America, Europe and Australasia but not South America (refer to Table S4). Meta-regressions on MD in intake, however, only showed significant effect sizes for interventions delivered within home settings relative to school settings indicating that interventions in home settings were more effective, whilst non-significant effects were documented across the remaining variables (refer to Table S4). There was suggestive asymmetry after funnel plot exploration, although results from the Egger's test were not significant for small-study effects ($P = 0.38$).

Adults

Subgroup analyses in adult studies indicated that those shorter than 30-week duration slightly reduced intakes, albeit non-significantly (-12 mL d^{-1}, 95%CI -40 to 16, $P = 0.4$) in comparison to those with longer delivery periods (more than or equal to 30 weeks), which yielded non-significant increases in SSB intake (40 mL d^{-1}, 95% CI -271 to 352, $P = 0.8$). Similar to findings in children, but without reaching statistical significance, decreases were noted for studies judged at high and medium risk of bias (-17 mL d^{-1}, 95% CI -35 to 2, $P = 0.08$ and -65 mL 95% CI -216 to 86, $P = 0.4$, respectively) and for those taking place in North America (-38 mL d^{-1}, 95% CI -83 to 8, $P = 0.1$), Australasia (-5 mL d^{-1}, 95% CI -31 to 22, $P = 0.7$) but not in South America (215 mL d^{-1}, 95% CI -5 to 434, $P = 0.06$). Study design indicated non-significant reductions for RCT and non-RCT (-12 mL d^{-1}, 95% CI 45 to 21, $P = 0.46$ and -71 mL d^{-1}, 95% CI -198.0 to 56, $P = 0.28$) whereas the only cluster RCT indicated increases in SSB by 96 mL d^{-1} (95% CI -96 to 288, $P = 0.33$). Home-based studies decreased SSB by -27 mL d^{-1} (95% CI -48 to -6, $P = 0.01$) in contrast to those conducted in the community (-27 mL d^{-1}, 95% CI 130 to 76, $P = 0.6$) or in educational or clinical settings (18 mL d^{-1}, 95% CI 37 to 72, $P = 0.53$ and 57 mL d^{-1}, 95% CI = 71 to 185, $P = 0.4$, respectively). Nevertheless, results from meta-regressions were not indicative of significantly greater effects for any of the abovementioned features (refer to Table S5). While there was some suggestive asymmetry after funnel plot exploration, results from the Egger test for publication bias were not statistically significant ($P = 0.82$).

Meta-analyses on secondary outcomes: behaviour change techniques

Regarding the 28 BCTs, all but 2 ('*Provide information about others approval*' and '*prompt self-talk*') were identified in intervention arms in at least one study. Most commonly delivered techniques given only to experimental groups (without presence in controls) were *provide information on consequences* ($n = 17$), *environmental support* ($n = 19$), *prompt barrier identification* ($n = 15$) and *provide contingent rewards* ($n = 12$). Eight different techniques in total were identified across control arms of 4 studies, with one using 7 of these techniques (56), one using two (64) and the remaining two using just one technique (48,62).The number of techniques identified across all included studies varied from 0 to 17. When exploring patterns of techniques incorporated between studies, we did not find two intervention arms using exactly the same techniques, except in a study targeting two different family members (adolescent and parent) (38).

We identified the use of one technique 'model/demonstrate the behaviour' (from the 28 considered in this review) to be associated with greater effectiveness to reduce SSB after univariate meta-regressions were conducted across all age groups (-124 mL d^{-1}, 95% CI -221 to -27, $P = 0.01$) (refer to Table S6). Furthermore, similar effects were also documented for studies in children using this technique (-173 mL d^{-1}, 95% CI -315 to -31; $P = 0.02$) (refer to Table S7). In adults' studies, no particular BCT was indicative of greater effectiveness to curb SSB consumption (Table S8).

PROGRESS/equity

We extracted data on socio-demographic features to identify the effects of interventions on health equity. All studies indicated the gender of participants at baseline; 8 studies were conducted only in females (37,39,58,59,62,63,70,74), one in a male sample (49), 11 in low-income populations (42,45,49,50,53,56,60,63,68,72,74), 15 studies reported a health condition at baseline (being overweight or obese and having metabolic-syndrome),14 studies reported race/ethnicity of participants (African–American, Native–Canadian, American–Indian, Hispanic, Caucasian). Three studies (41,43,51) analysed results by gender and one study reported economic costs of the intervention (46). No further components of the PROGRESS checklist were included for analyses in any other study. Considering the limited information available, it was not possible to evaluate the impact of interventions to decrease health inequalities across populations.

Discussion

Summary of evidence

Our systematic review and meta-analyses show that public health interventions achieve medium-sized reductions in consumption of SSB and increases in water intakes in children. In adolescents, SSB intake was significantly reduced, but the effect size was small. Although results for SSB outcomes in adults were not statistically significant, the direction of the effect was consistent. Greater reductions were achieved in studies using modelling in the intervention condition, and interventions in home settings were more effective than interventions in school settings in child populations. The size of SSB reduction, however, did not vary significantly across geographical location (i.e. effects were similar inside and outside North America); specific dietary assessment tools (i.e. effects were similar when using FFQs compared to either the 24-h recall or diet/food records); design (i.e. effects were similar in RCTs compared to either non-RCTs or cluster RCTs); intervention duration (i.e. similar effects for interventions lasting more or less than 30 weeks) and study quality (i.e. similar effects were achieved in either low or medium-risk studies compared to high-risk studies).

Variables influencing sugar-sweetened beverage intake: Target population, delivery mechanisms and behaviour change techniques

A considerable number of interventions in this review targeted children, as reducing consumption of SSB in this population stands as a priority for global and national health organizations (10,12,19). Evidence from childhood obesity-prevention programmes (76,77) has highlighted increased duration of delivery as an important feature leading to superior effects when compared to briefer strategies, as theoretically, participants are provided with more opportunities to gain information, plan, enact and reflect on the desired behaviour (76). In studies of children, we did not identify through moderator analyses, that longer interventions could be more effective in reducing intakes of SSB. Although the school stands out as one of the most common delivery channels to target obesity-related behaviours (including reduction of sweetened beverages) (77), we found that the home as a setting was more effective for reducing consumption of SSB. Home-based initiatives in this review often involved targeting the parental and child figure (37, 38, 52, 58), with engagement being facilitated through their attendance to other common settings such as playgrounds or schools. Therefore, and as means of social liaison and reaching disadvantaged populations (42,45), approaches incorporating 'whole-school initiatives' via a cohesive and collaborative network with the school's

broader community (including, staff, parents, entrepreneurs and food suppliers) and with a stronger regulatory framework, could be as effective in children as they have been documented for adolescents in reducing consumption of SSB (30). Although there were few included studies under this framework (40,66) – potentially due to their increased complexity and higher costs of delivery – they emphasize the role of multi-level approaches in providing supportive environments to influence SSB intake in which 'healthier options stand as the more reachable options' (78).

Consistent with other reviews (79–82), we hypothesized that the use of specific BCTs could also explain heterogeneity and may be associated with greater intervention effectiveness. The only technique that was associated with significantly greater reductions in SSB intake was 'model/demonstrate the behaviour'. The theory of social learning (83) suggests this technique is particularly influential in changing behaviour, especially when participants are able to model someone they like or admire and when they see the behaviour modelled by more than one person (84) (in this context, both parental figures). Drawing from the relevant studies in this review, it is possible that participants could reduce their SSB intake particularly through demonstrations on how to choose and prepare less-sweetened alternatives incorporated within the intervention activities (50,55,62,63). Indeed, Baranowski and colleagues (59) piloted a summer camp initiative in African–American girls at higher risk of obesity. Whilst changes in SSB and water intakes were discrete, their extensive process evaluation found 'interactive learning' a promising feature for participant's engagement and involvement which was also documented in a trial carried out subsequently in a similar population (63).

Other BCTs have been emphasized as important when designing obesity-related interventions, such as encouraging people to set a behavioural goal (81) or prompting intention formation (85); none of these were related to greater reductions in SSB intake across age groups in our analyses. However, the current review did not test the interactions between combinations of BCTs. This is a limitation because, for instance, prompting intention formation has been shown to be more effective in increasing healthful eating when used in combination with other techniques such as self-monitoring (79) or providing information about a behaviour and health link (81). This limitation applies not only to the review as a whole but also to individual studies within the review. For example, Martin and colleagues (28) assessed the impact of BCTs in childhood obesity prevention and management trials. Whilst other techniques were described as more efficacious (i.e. environmental restructuring, prompt practice, prompt identification as role model, etc.), they were also unable to determine if a BCT was individually effective or if it was effective only when used with other techniques.

The role of the environment as a paramount driver of consumption of sugar and SSB has been strongly emphasized by health organizations and policy makers (10,12,19,86) with types of measure involving different levels of regulation of the individual (87). Although 'environmental support' as a technique was not significantly associated with greater reductions of SSB, studies included in this review have mainly focused on altering the proximate built environment whether at school, work or home settings and have not entirely restricted or eliminated the choice/autonomy of participants. Previous work on younger populations (30,88) has advocated targeting the wider environment concomitantly with empowering individuals to more efficaciously manage and transform their behaviour and thus enable that healthier choices are taken (89). While governments play a facilitatory role in providing supportive environments aligned to address non-communicable disease risk factors (12,86), evidence is still limited on the effectiveness of an of increased state involvement (for example, through fiscal measures) on shifting populations to consume less-sweetened beverages. Indeed, it has been recognized that no single or isolated action can offer a solution to effectively reduce sugar intakes and thus consumption of SSB (89). A wide range and combination of strategies may be needed to positively affect dietary choices at individual, community and national levels (87).

Strengths and Limitations

This is the first systematic review to comprehensively summarize the impact of a range of programmes to reduce intakes of SSB and increase water intake across different age groups and to test whether use of particular BCTs leads to greater effectiveness. The present work has followed a rigorous published protocol (32) with a thorough search strategy and screening process allowing us to synthesize data on more studies than previous reviews and meta-analyses in this subject (28,29,88). Multi- and single-component programmes were included from a diversity of countries and settings. Our findings are limited, however, by the overall quality of studies. For instance, there were interventions that reported changes in more than one type of SSB, had unavailable totals or unclear definitions of SSB. It is possible, therefore, that whilst intake of certain SSB decreased, a compensation in other sugary drinks or sugar-added products could also have occurred which have not been quantified nor reported. Efforts have been made to better categorize SSB, but a clearer definition is needed so as to incorporate and differentiate between those offering better nutritional values. Although we restricted our inclusion criteria to studies that used standard methods of assessment, measuring beverage intake is challenging and prone to error (90), particularly from biased or underestimated portion sizes.

Impact of changes in sugar intakes due to reformulation of beverages was not within the scope of this review but is an aspect that requires further attention as well as substitutions in beverages and other sweetened-products that participants may consume as a result of the interventions.

Heterogeneity was high across analyses in SSB and water outcomes and, while measures were taken *a priori* to explore this variation, subgroup analyses were only partially able to explain it which is suggestive of other differences between study outcomes not explained by the variables considered in our analyses. Finally, considering the small number of studies, we were unable to explore any counterbalancing, neutral or masked effects from other BCTs or intervention components (82) on primary outcomes; a lack of compliance to original plans –which was not measured – could have also diminished observed effects.

Despite the emerging interest in water and SSB intakes by scientific bodies and policy-makers, few included studies have reported consumption of water which may relate to the lack of specific and validated tools available to measure beverage intake, as opposed to those existing for assessing food intake (91). A review by Popkin *et al.* (23) on water and health has highlighted that measurement of total fluid water consumption (that is, water consumed only through beverages) is a relatively new subject, with dietary assessment tools being widely focused on collecting data on macro and micro nutrients and not water *per se*. Currently the 24-h recall is a common method utilized in intervention studies due to its ability to capture more information on different types of beverages in comparison to the FFQ; however, it is predominantly paper based. Incorporation of innovative features from new technologies (such as those using image-based capture) could improve the estimation of liquid intakes, which is broadly needed in both large-scale trials and national/regional surveys (13,78,92).

Implications for practice

We have estimated the effects of public health interventions to influence consumption of SSB and water. Similar to estimates from previous meta-analyses on other outcomes such as dietary advice and adverse vascular risk (93), a decrease of 76 mL of sweetened drinks by children could represent a reduction of about one-third of a 240-mL portion size (equivalent to 2.5 teaspoons of sugar or 20% of energy intake from free sugars) (12) which may translate, if levels are sustained, in a potential reduction of risk factors for dental caries, type II diabetes and obesity. The need to assess behavioural change initiatives to decrease intake of free sugars and in particular of SSB has been emphasized as a research gap by health

organizations including WHO (94). Therefore, the evidence from this review serves to highlight that nutritional education – the main channel in which included interventions are delivered – could be further promoted and complemented with specific BCTs (modelling). Future evidence is warranted to understand how regulatory schemes could be best adopted and combined with different types of interventions aiming to positively affect dietary choices (95).

Conclusion

In summary, our analysis indicates that interventions achieve, on average, medium-sized reductions in consumption of SSB and increase water intakes in children, but reductions in SSB in adolescents and adults are small. The use of modelling/demonstrating the behaviour was suggestive of enhanced intervention effects in analyses conducted across all age groups combined and within studies targeting only children. Home-based interventions with children showed greater reductions in SSB. Although public health programmes on their own are moderately successful to influence intake of SSB and water, complementary strategies may be needed to effectively curb free sugar intake.

Acknowledgements

Conflict of interest statements

CELE has received funding from Sugar Nutrition UK exploring dietary patterns and free sugar consumption in the UK. JEC is a director of a University spin out company Dietary Assessment Limited. No conflict of interests were declared by other authors.

Supporting information

Additional Supporting Information may be found online in the supporting information tab for this article. https://doi.org/10.1111/obr.12580

Fig. S1. Funnel plot of comparison: consumption of SSB across all studies

Table S1. Characteristics of studies reporting changes in SSB and water intake in all age groups included in meta-analysis.

Table S2. Risk of bias of individual studies

Table S3. Subgroup analyses using random-effects models indicating change in SSB consumption in all studies ($n = 40$)

Table S4. Subgroup analyses using random-effects models indicating change in SSB consumption in children studies ($n = 23$)

Table S5. Subgroup analyses using random-effects models indicating change in SSB consumption in adult studies ($n = 12$)

Table S6. Univariate meta-regressions on BCTs indicating change in SSB consumption in all studies ($n = 40$)

Table S7. Univariate meta-regressions on BCTs indicating change in SSB consumption in children studies ($n = 23$)

Table S8. Univariate meta-regressions on BCTs indicating change in SSB consumption in adult studies ($n = 12$)

References

1. The Scientific Advisory Committee on Nutrition. Carbohydrates and health. online. London: 2015.
2. Te Morenga L, Mallard S, Mann J. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. *BMJ*. 2013; **346** e7492.
3. Malik VS, Popkin BM, Bray GA, Després J-P, Hu FB. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation*. 2010; **121**(11): 1356–1364.
4. Maersk M, Belza A, Stodkilde-Jorgensen H *et al*. Sucrose-sweetened beverages increase fat storage in the liver, muscle, and visceral fat depot: a 6-mo randomized intervention study. *Am J Clin Nutr*. 2012; **95**(2): 283–289.
5. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *Am J Clin Nutr*. 2013; **98**(4): 1084–1102.
6. Imamura F, O'Connor L, Ye Z *et al*. Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review,

meta-analysis, and estimation of population attributable fraction. *BMJ.* 2015; **351**: h3576.

7. Malik VS, Popkin BM, Bray GA, Despres JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care.* 2010; **33**(11): 2477–2483.

8. Schulze MB, Manson JE, Ludwig DS *et al.* Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA.* 2004; **292**(8): 927–934.

9. Greenwood DC, Threapleton DE, Evans CE *et al.* Association between sugar-sweetened and artificially sweetened soft drinks and type 2 diabetes: systematic review and dose-response meta-analysis of prospective studies. *Br J Nutr.* 2014: 1–10.

10. WHO. Guideline: Sugar intake for adults and children. Geneva: 2015.

11. U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans, 8th edn. The Office of Disease Prevention and Health Promotion (ODPHP): Washignton D.C., pp. 2015–2020.

12. Public Health England. Sugar reduction: the evidence for action. 2015.

13. World Health Organization. Guideline: Sugar intake for adults and children. Geneva 2015.

14. Singh GM, Micha R, Khatibzadeh S, Lim S, Ezzati M, Mozaffarian D. Estimated global, regional, and national disease burdens related to sugar-sweetened beverage consumption in 2010. *Circulation.* 2015; **132**(8): 639–666.

15. Kit BK, Fakhouri TH, Park S, Nielsen SJ, Ogden CL. Trends in sugar-sweetened beverage consumption among youth and adults in the United States: 1999–2010. *Am J Clin Nutr.* 2013; **98**(1): 180–188.

16. Welsh JA, Sharma AJ, Grellinger L, Vos MB. Consumption of added sugars is decreasing in the United States. *Am J Clin Nutr.* 2011; **94**(3): 726–734.

17. Bates BCL, Nicholson S, Page P, Prentice A, Steer T, Swan G. National Diet and Nutrition Survey Results from Years 5 and 6 (combined) of the Rolling Programme (2012/2013–2013/2014). Public Health England and Food Standards Agency: London, UK, 2016.

18. Australian Government. Obesity: Sugar-Sweetened Beverages, Obesity and Health. Agency ANPH: Canberra, 2014.

19. Pan American Health Organization. Ultra-Processed Food and Drink Products in Latin America: Trends, Impact on Obesity, Policy Implications: Washington, DC, 2015.

20. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. 2013.

21. World Health Organization. What is a health promoting school?. 2016.

22. World Health Organization. School policy framework: implementation of the WHO global strategy on diet, physical activity and health. 2008.

23. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. *Nutr Rev.* 2010; **68**(8): 439–458.

24. Pan A, Malik VS, Hao T, Willett WC, Mozaffarian D, Hu FB. Changes in water and beverage intake and long-term weight changes: results from three prospective cohort studies. *Int J Obes (Lond).* 2013; **37**(10): 1378–1385.

25. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011; **6**: 42–53.

26. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev.* 2013; **14**(8): 606–619.

27. Malik VS, Willett WC, Hu FB. Global obesity: trends, risk factors and policy implications. *Nat Rev Endocrinol.* 2013; **9**(1): 13–27.

28. Martin J, Chater A, Lorencatto F. Effective behaviour change techniques in the prevention and management of childhood obesity. *Int J Obes (Lond).* 2013; **37**(10): 1287–1294.

29. Mazarello Paes V, Hesketh K, O'Malley C *et al.* Determinants of sugar-sweetened beverage consumption in young children: a systematic review. *Obes Rev.* 2015; **16**(11): 903–913.

30. Vezina-Im LA, Beaulieu D, Belanger-Gravel A *et al.* Efficacy of school-based interventions aimed at decreasing sugar-sweetened beverage consumption among adolescents: a systematic review. *Public Health Nutr.* 2017: 1–16.

31. Prestwich A, Kenworthy J, Conner M. Health Behavior Change: Theories, Methods and Interventions. Abingdon: Routledge, 2017.

32. Vargas-Garcia EJ, El Evans C, Cade JE. Impact of interventions to reduce sugar-sweetened beverage intake in children and adults: a protocol for a systematic review and meta-analysis. *Syst Rev.* 2015; **4**: 17.

33. Gibson S. Sugar-sweetened soft drinks and obesity: a systematic review of the evidence from observational studies and interventions. *Nutr Res Rev.* 2008; **21**(2): 134–147.

34. Han E, Powell LM. Consumption patterns of sugar-sweetened beverages in the United States. *J Acad Nutr Diet.* 2013; **113**(1): 43–53.

35. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0: The Cochrane Collaboration. John Wiley & Sons: New Jersey, USA, 2011 [updated March 2011]. Available from: www.cochrane-handbook.org.

36. Abraham C, Michie S. A taxonomy of behavior change techniques used in interventions. *Health Psychol.* 2008; **27**(3): 379–387.

37. Ostbye T, Krause KM, Stroo M *et al.* Parent-focused change to prevent obesity in preschoolers: results from the KAN-DO study. *Prev Med.* 2012; **55**(3): 188–195.

38. French SA, Gerlach AF, Mitchell NR, Hannan PJ, Welsh EM. Household obesity prevention: Take Action – a group-randomized trial. *Obesity (Silver Spring).* 2011; **19**(10): 2082–2088.

39. Shahril MR, Wan Dali WPE, Lua PL. A 10-week multimodal nutrition education intervention improves dietary intake among university students: cluster randomised controlled trial. *J Nutr Metab* 2013; **2013**: 1–11.

40. Taylor RW, McAuley KA, Barbezat W, Strong A, Williams SM, Mann JI. APPLE project: 2-y findings of a community-based obesity prevention program in primary school age children. *Am J Clin Nutr.* 2007; **86**(3): 735–742.

41. Bjelland M, Bergh IH, Grydeland M *et al.* Changes in adolescents' intake of sugar-sweetened beverages and sedentary behaviour: results at 8 month mid-way assessment of the HEIA study – a comprehensive, multi-component school-based randomized trial. *Int J Behav Nutr Phys Act* 2011; **8**: 63.

42. Haerens L, De Bourdeaudhuij I, Maes L, Vereecken C, Brug J, Deforche B. The effects of a middle-school healthy eating intervention on adolescents' fat and fruit intake and soft drinks consumption. *Public Health Nutr.* 2007; **10**(5): 443–449.

43. Rosario R, Araujo A, Oliveira B *et al.* Impact of an intervention through teachers to prevent consumption of low nutrition, energy-dense foods and beverages: a randomized trial. *Prev Med.* 2013; **57**(1): 20–25.

44. James J, Thomas P, Cavan D, Kerr D. Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial. *BMJ*. 2004; **328**(7450): 1237.

45. Sichieri R, Paula Trotte A, de Souza RA, Veiga GV. School randomised trial on prevention of excessive weight gain by discouraging students from drinking sodas. *Public Health Nutr*. 2009; **12**(2): 197–202.

46. Muckelbauer R, Libuda L, Clausen K, Toschke AM, Reinehr T, Kersting M. Promotion and provision of drinking water in schools for overweight prevention: randomized, controlled cluster trial. *Pediatrics*. 2009; **123**(4): e661–e667.

47. Hebden L, Cook A, van der Ploeg HP, King L, Bauman A, Allman-Farinelli M. A mobile health intervention for weight management among young adults: a pilot randomised controlled trial. *J Hum Nutr Diet*. 2014; **27**(4): 322–332.

48. Kipping RR, Howe LD, Jago R *et al*. Effect of intervention aimed at increasing physical activity, reducing sedentary behaviour, and increasing fruit and vegetable consumption in children: active for Life Year 5 (AFLY5) school based cluster randomised controlled trial. *BMJ*. 2014; **348** g3256.

49. Smith JJ, Morgan PJ, Plotnikoff RC *et al*. Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. *Pediatrics*. 2014; **134**(3): e723–e731.

50. van de Gaar VM, Jansen W, van Grieken A, Borsboom G, Kremers S, Raat H. Effects of an intervention aimed at reducing the intake of sugar-sweetened beverages in primary school children: a controlled trial. *Int J Behav Nutr Phys Act*. 2014; **11**: 98.

51. Singh AS, Chin APMJ, Brug J, van Mechelen W. Dutch obesity intervention in teenagers: effectiveness of a school-based program on body composition and behavior. *Arch Pediatr Adolesc Med*. 2009; **163**(4): 309–317 https://doi.org/10.1001/archpediatrics.2009.2.

52. Duncan S, McPhee JC, Schluter PJ, Zinn C, Smith R, Schofield G. Efficacy of a compulsory homework programme for increasing physical activity and healthy eating in children: the healthy homework pilot study. *Int J Behav Nutr Phys Act*. 2011; **8**: 127.

53. Cunha DB, de Souza BSN, Pereira RA, Sichieri R. Effectiveness of a randomized school-based intervention involving families and teachers to prevent excessive weight gain among adolescents in Brazil. *PLoS One* 2013; **8**(2) e57498.

54. Albala C, Ebbeling CB, Cifuentes M, Lera L, Bustos N, Ludwig DS. Effects of replacing the habitual consumption of sugar-sweetened beverages with milk in Chilean children3. *Am J Clin Nutr*. 2008; **88**(3): 605–611.

55. Ebbeling CB, Feldman HA, Chomitz VR *et al*. A randomized trial of sugar-sweetened beverages and adolescent body weight. *N Engl J Med*. 2012; **367**(15): 1407–1416.

56. Nollen NL, Mayo MS, Carlson SE, Rapoff MA, Goggin KJ, Ellerbeck EF. Mobile technology for obesity prevention: a randomized pilot study in racial- and ethnic-minority girls. *Am J Prev Med*. 2014; **46**(4): 404–408.

57. Shapiro JR, Bauer S, Hamer RM, Kordy H, Ward D, Bulik CM. Use of text messaging for monitoring sugar-sweetened beverages, physical activity, and screen time in children: a pilot study. *J Nutr Educ Behav*. 2008; **40**(6): 385–391.

58. Jancey JM, Dos Remedios Monteiro SM, Dhaliwal SS *et al*. Dietary outcomes of a community based intervention for mothers of young children: a randomised controlled trial. *Int J Behav Nutr Phys Act*. 2014; **11**: 120.

59. Baranowski T, Baranowski JC, Cullen KW *et al*. The Fun, Food, and Fitness Project (FFFP): the Baylor GEMS pilot study. *Ethn Dis*. 2003; **13**(1 Suppl 1): S30–S39.

60. Leung CW, Cluggish S, Villamor E, Catalano PJ, Willett WC, Rimm EB. Few changes in food security and dietary intake from short-term participation in the Supplemental Nutrition Assistance Program among low-income Massachusetts adults. *J Nutr Educ Behav*. 2014; **46**(1): 68–74.

61. Burrows T, Morgan PJ, Lubans DR *et al*. Dietary outcomes of the healthy dads healthy kids randomised controlled trial. *J Pediatr Gastroenterol Nutr*. 2012; **55**(4): 408–411.

62. Olvera N, Bush JA, Sharma SV, Knox BB, Scherer RL, Butte NF. BOUNCE: a community-based mother–daughter healthy lifestyle intervention for low-income Latino families. *Obesity (Silver Spring)*. 2010; **18**(Suppl 1): S102–S104.

63. Klesges RC, Obarzanek E, Kumanyika S *et al*. The Memphis Girls' health Enrichment Multi-site Studies (GEMS): an evaluation of the efficacy of a 2-year obesity prevention program in African American girls. *Arch Pediatr Adolesc Med*. 2010; **164**(11): 1007–1014.

64. Souza RA, Mediano MF, Souza Ade M, Sichieri R. Reducing the use of sugar in public schools: a randomized cluster trial. *Rev Saude Publica*. 2013; **47**(4): 666–674.

65. Anand SS, Davis AD, Ahmed R *et al*. A family-based intervention to promote healthy lifestyles in an aboriginal community in Canada. *Can J Public Health*. 2007; **98**(6): 447–452.

66. Folta SC, Kuder JF, Goldberg JP *et al*. Changes in diet and physical activity resulting from the Shape Up Somerville community intervention. *BMC Pediatr*. 2013; **13**: 157.

67. Kerr DA, Harray AJ, Pollard CM *et al*. The connecting health and technology study: a 6-month randomized controlled trial to improve nutrition behaviours using a mobile food record and text messaging support in young adults. *Int J Behav Nutr Phys Act*. 2016; **13**: 52.

68. Zoellner JM, Hedrick VE, You W *et al*. Effects of a behavioral and health literacy intervention to reduce sugar-sweetened beverages: a randomized-controlled trial. *Int J Behav Nutr Phys Act*. 2016; **13**: 38.

69. Elder JP, Crespo NC, Corder K *et al*. Childhood obesity prevention and control in city recreation centres and family homes: the MOVE/me Muevo Project. *Pediatr Obes*. 2014; **9**(3): 218–231.

70. Thompson JL, Allen P, Helitzer DL *et al*. Reducing diabetes risk in American Indian women. *Am J Prev Med*. 2008; **34**(3): 192–201.

71. Garipagaoglu M, Sahip Y, Darendeliler F, Akdikmen O, Kopuz S, Sut N. Family-based group treatment versus individual treatment in the management of childhood obesity: randomized, prospective clinical trial. *Eur J Pediatr*. 2009; **168**(9): 1091–1099.

72. Taveras EM, Gortmaker SL, Hohman KH *et al*. Randomized controlled trial to improve primary care to prevent and manage childhood obesity: the High Five for Kids study. *Arch Pediatr Adolesc Med*. 2011; **165**(8): 714–722.

73. Fiechtner L, Kleinman K, Melly SJ *et al*. Effects of proximity to supermarkets on a randomized trial studying interventions for obesity. *Am J Public Health*. 2016; **106**(3): 557–562.

74. Rodriguez-Cano A, Mier-Cabrera J, Balas-Nakash M, Munoz-Manrique C, Legorreta-Legorreta J, Perichart-Perera O. Dietary changes associated with improvement of metabolic syndrome components in postmenopausal women receiving two different nutrition interventions. *Menopause*. 2015; **22**(7): 758–764.

75. Rodriguez-Ramirez S, Gonzalez de Cosio T, Mendez MA *et al*. A water and education provision intervention modifies the diet in overweight mexican women in a randomized controlled trial. *J Nutr*. 2015; **145**(8): 1892–1899.

76. Stice E, Shaw H, Marti CN. A meta-analytic review of obesity prevention programs for children and adolescents: the skinny on interventions that work. *Psychol Bull*. 2006; **132**(5): 667–691.

77. Waters E, de Silva-Sanigorski A, Burford BJ *et al.* Interventions for preventing obesity in children. *Cochrane Database of Systematic Reviews.* 2011; **12**.

78. World Health Organization. Key considerations for the use of law to prevent noncommunicable diseases in the WHO European Region. Moscow, Russia: 2016.

79. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychol.* 2009; **28**(6): 690–701.

80. Michie S, Jochelson K, Markham WA, Bridle C. Low-income groups and behaviour change interventions: a review of intervention content, effectiveness and theoretical frameworks. *J Epidemiol Community Health.* 2009; **63**(8): 610–622.

81. Dusseldorp E, van Genugten L, van Buuren S, Verheijden MW, van Empelen P. Combinations of techniques that effectively change health behavior: evidence from Meta-CART analysis. *Health Psychol.* 2014; **33**(12): 1530–1540.

82. Dombrowski SU, Sniehotta FF, Avenell A, Johnston M, MacLennan G, Araújo-Soares V. Identifying active ingredients in complex behavioural interventions for obese adults with obesity-related co-morbidities or additional risk factors for co-morbidities: a systematic review. *Health Psychol Rev.* 2012; **6**(1): 7–32.

83. Bandura A. Social Learning Theory. Prentice Hall: New Jersey, 1977.

84. Horne PJ, Greenhalgh J, Erjavec M, Lowe CF, Viktor S, Whitaker CJ. Increasing pre-school children's consumption of fruit and vegetables. A modelling and rewards intervention. *Appetite.* 2011; **56**(2): 375–385.

85. Zoellner J, Estabrooks PA, Davy BM, Chen YC, You W. Exploring the theory of planned behavior to explain sugar-sweetened beverage consumption. *J Nutr Educ Behav.* 2012; **44**(2): 172–177.

86. House of Lords. Behaviour change. Science and technology select committee, 2nd Report of Session 2010. London: The Stationery Office (on authority of the House of Lords). 2011.

87. Griffiths PE, West C. A balanced intervention ladder: promoting autonomy through public health action. *Public Health.* 2015; **129**(8): 1092–1098.

88. Avery A, Bostock L, McCullough F. A systematic review investigating interventions that can help reduce consumption of sugar-sweetened beverages in children leading to changes in body fatness. *J Hum Nutr Diet.* 2015; **28**(Suppl 1): 52–64.

89. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? *Science.* 2003; **299**(5608): 853–855.

90. Beaton GH. Approaches to analysis of dietary data: relationship between planned analyses and choice of methodology. *Am J Clin Nutr.* 1994;**59**(1 Suppl):253s–61s.

91. Carter MC, Albar SA, Morris MA *et al.* Development of a UK Online 24-h Dietary Assessment Tool: myfood24. *Nutrients.* 2015; **7**(6): 4016–4032.

92. Collins CE, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int J Obes.* 2010; **34**(7): 1103–1115.

93. Rees K, Dyakova M, Wilson N, Ward K, Thorogood M, Brunner E. Dietary advice for reducing cardiovascular risk. *Cochrane Database of Systematic Reviews.* 2013; **12**.

94. World Health Organization. Sugars Intake for Adults and Children. Guideline. World Health Organization: Geneva, Switzerland, 2015.

95. Evans CE. Sugars and health: a review of current evidence and future policy. *Proc Nutr Soc.* 2016: 1–8.