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Determinants of knowledge and attitudes about sugar and the association of knowledge and attitudes with sugar intake among adults: A systematic review

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Abstract

Efforts to reduce sugar intake levels have been primarily limited to increasing knowledge and changing attitudes. We conducted a systematic review to (1) identify factors influencing adults' knowledge and attitudes about sugar, and (2) determine if there is an association between knowledge and attitudes about sugar and sugar intake. We searched 15 electronic databases from inception to December 2016 for English language publications including adults with relevant exposure and outcome measures. Findings were summarised meta-narratively. Of 3287 studies, 22 studies (14 for objective one and 8 for objective two) were included. Individual (liking of sugary food), interpersonal (attitudes of peers) and environmental factors (media, health professionals and food labelling) influenced adults' knowledge and attitudes about sugar, at least to some extent. Overall, quality of the studies included in our review was weak, and evidence for the application of the Knowledge-Attitude-Behavior model for understanding sugar intake is limited. Protocol registered in the PROSPERO International prospective register of systematic reviews (registration number CRD42015027540).

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Title Page

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INTRODUCTION

High sugar intake is a risk factor for several non-communicable diseases (Gibson, 2008; Imamura et al., 2015; Sheiham & James, 2014; Te Morenga, Mallard, & Mann, 2013). Sugar (including total, added and free sugars) intake above recommended levels is a global public health concern and the World Health Organisation has recently updated its recommendations on sugar intake for children and adults (World Health Organization, 2015). However, there is variation between individual countries in recommendations about sugar intake. For example, the USA (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the UK (Scientific Advisory Committee on Nutrition, 2015) recommends up to 10% and 5% of energy intake from added sugars, while Australia (National Health and Medical Research Council, 2013) recommends limiting the intake of foods and beverages containing added sugars.

Efforts to reduce sugar consumption have primarily been limited to increasing knowledge and changing attitudes (Hattersley, Irwin, King, & Allman-Farinelli, 2009; Huffman & West, 2007). These attempts rely on the philosophy underlying most of the existing health behavior or behavior change models (including Knowledge, Attitude and Behavior (KAB) model), that acquiring knowledge and changing attitudes influences behaviour (Baranowski, 2003). This ideology also forms the basis of many health education and health promotion programs to address behavior change. However, these health behavior models often ignore the complex interplay between factors at the individual, inter-personal and environmental levels and its influence on individuals' health behaviors (Contento, 2008; Dahlgren, 1991). In fact, there is an extensive body of literature critiquing and suggesting a tenuous association between knowledge and/or attitudes, and a range of poor health behaviors (Baranowski, 2003; Kemm, 1991; Wardle, 2000) but none for sugar intake. This is important to inform whether or not the current attempts to reduce sugar consumption require an expansion in its scope.

If we are to reduce sugar intake, we need to understand the factors that influence sugar intake across individual, inter-personal and environmental levels. This includes understanding whether just increasing knowledge and changing attitudes influences sugar intake practices. We aimed to bring together all available literature by conducting a systematic review with two objectives: (1) identify factors influencing adults' knowledge and attitudes about sugar; and (2) determine if there is an association between sugar intake and adults' knowledge and attitudes about sugar.

METHODS

A review protocol was developed *a priori* and was registered in the PROSPERO International prospective register of systematic reviews (registration number CRD42015027540) (Gupta, Braunack-Mayer, Harford, Smithers, & Merlin, 2015). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline was followed for reporting this systematic review (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009) (Appendix A).

Search strategy, inclusion/exclusion criteria

The search was conducted using a range of keywords that were pilot tested and tailored for each database using relevant medical subheading (MeSH) terms. Search terms included (knowledge* OR understanding* OR awareness OR attitude* OR perception OR perceive OR belie* OR public opinion) AND (dietary sucrose OR carbonated beverage* OR carbonated drink OR soft drink* OR fruit juice* OR soda OR pop OR sugar* OR fructose corn syrup OR added sugar OR free sugar) AND (influenc* OR shape OR effect OR impact

OR risk OR social determinant*) OR (amount OR consum* OR intake OR level OR quantit*) (Appendix B).

We conducted the search in 15 electronic databases from inception to December 2016 for all peer-reviewed studies published in the English language that included adults (≥18 years). The databases searched included; PubMed, Scopus, Embase, Web of Science, Cumulative Index to Nursing and Allied Health Literature, PsycINFO, PsycARTICLES, Sociological abstracts, Australian Family and Society Abstracts, Dentistry and Oral Sciences Source, Database of Abstracts of Reviews of Effects, Cochrane Database of Systematic Reviews, Health Technology Assessment Database, Cochrane Central Register of Controlled Trials and The Joanna Briggs Institute Library. Study selection criteria, following a modified PICOS (population, intervention/exposure, comparison, outcome, and study context) format, were developed for each research objective (Table 1). For the first objective, the exposures included individual, inter-personal and environmental factors. Exposures such as genomics, metabolomics and any other 'omics' were excluded, as the purpose of the first objective was to identify modifiable determinants for informing future health interventions. The outcome for the first objective was knowledge and attitude about sugar (including total, added and free sugars). For the second objective, the exposure was knowledge and attitude about sugar (including total, added and free sugars) while the outcome measure was sugar intake (i.e. amount, frequency, percent energy intake from free sugars or practices such as adding table sugar or caloric sweeteners to food).

Table 1: PICOS criteria for inclusion and exclusion of studies for each research objective

Inclusion criteria	Exclusion criteria
Population	**Population**
All studies that included participants regardless of gender, settings, racial, ethnic, cultural or religious groups or geographical location	Restricted to age ≥18 years and to English language publications only
Intervention/exposure	**Intervention/exposure**
Objective 1: Determinants of health (this included individual, inter-personal, and environmental factors) Objective 2: Knowledge and attitude about sugar (including total, added and free sugars)	Studies with impact of genetic profile, genomic biomarkers and/or metabolomics on sugar intake
Comparator(s)/ control	**Comparator(s)/ control**
None	None
Outcome	**Outcome**
Objective 1: Knowledge and attitude about sugar (including total, added and free sugars) Objective 2: Measure of sugar intake and/or practices (amount of sugar consumed or practices such as adding table sugar or sweeteners to food)	Studies that do not report relevant outcomes
Study context	**Study context**
All studies conducted in any country around the world	No restriction

Study selection

Following the removal of duplicates and screening of titles and abstracts, full texts of potentially eligible papers were retrieved and assessed for inclusion. The reference lists of included papers were also searched for relevant articles. While AG conducted the screening of the studies for eligibility and for their full text selection, 20% of these studies were also screened by JH. All differences regarding study inclusion were then resolved by consensus between the authors.

Quality assessment and Data extraction

The quality of included studies was assessed using the Effective Public Health Practice Project (EPHPP) quality assessment tool (Effective Public Health Practice Project, 2009). AG rated the study quality as strong, moderate or weak according to the tool criteria and JH verified 10% of these. Data were extracted on publication details (e.g. author's name and year of publication), characteristics of the study (e.g. study design, country, and sample size), socio-demographic profile of the population (e.g. age, gender, education, and ethnicity), relevant exposure/intervention and outcomes. LS checked the data extraction for 10% of the included papers.

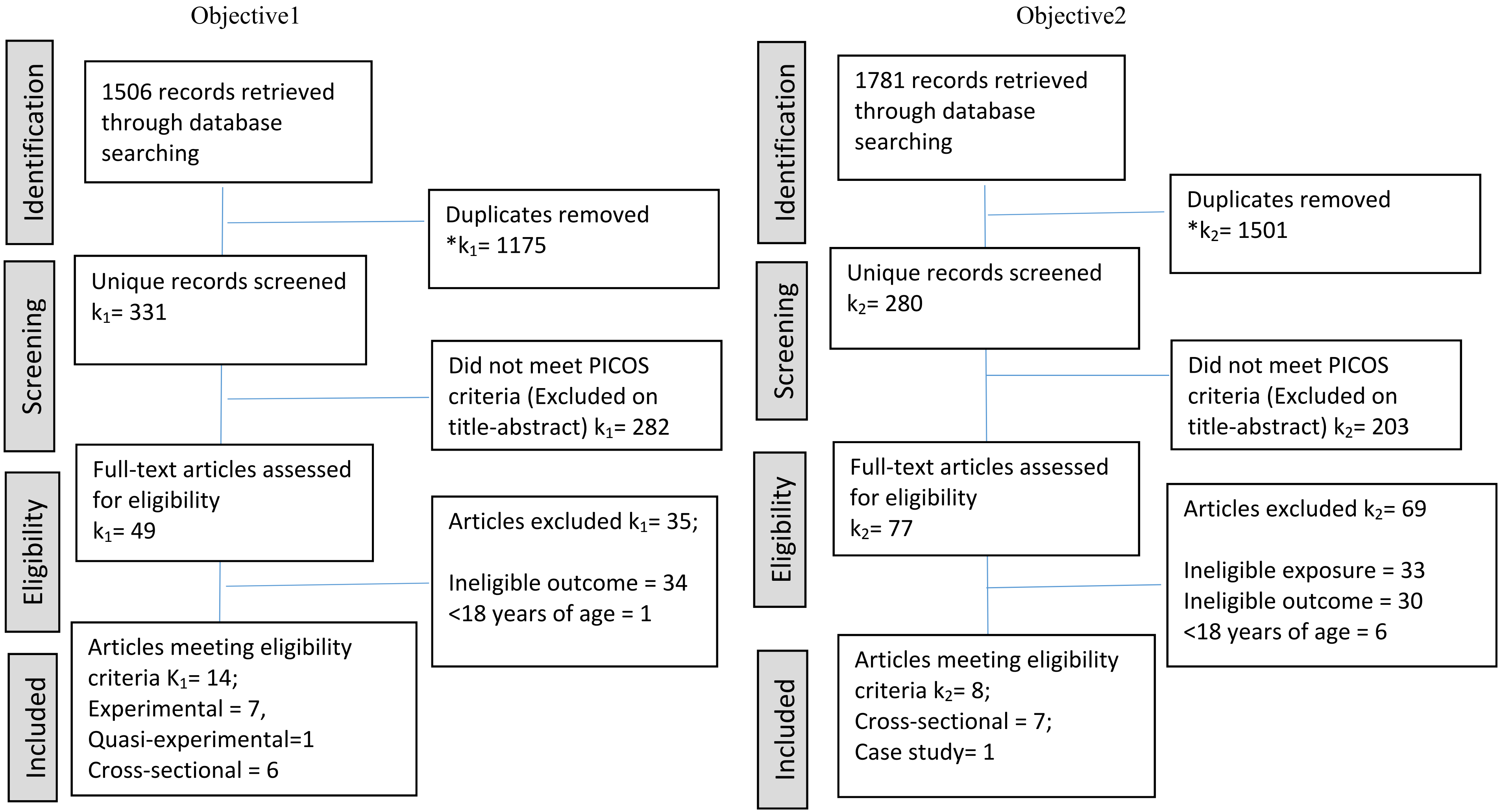
Data synthesis

A meta-narrative synthesis was undertaken according to the Realist and Meta-narrative Evidence Syntheses: Evolving Standards (RAMESES) guidelines (Wong, Greenhalgh, Westhorp, Buckingham, & Pawson, 2013). A meta-narrative synthesis is primarily driven by providing a detailed narrative account of the key dimensions of the problem under investigation. Conflicting ideas and contesting paradigms are often treated as highly important and are illustrated, explained and summarised using relevant evidence. This enables the readers to make informed judgements on the coherence and plausibility of the inferences. Meta-analysis was not conducted due to the presence of heterogeneity between studies in their study quality/design (predominantly cross-sectional and weak quality studies) and in their ways of reporting the exposure and outcome variables. Also due to a limited number of studies (such as only one study each for individual and inter-personal determinants), our ability to conduct meta-regression was also limited. A meta-narrative account of the results is presented below according to the social model of health (Dahlgren, 1991).

RESULTS

Of 3287 articles identified (1506 for objective one and 1781 for objective two), 22 (k_1=14 for objective one and k_2=8 for objective two) peer-reviewed studies were included in the review (Figure 1). Of these, seven were experimental studies, one was a quasi-experimental study, 13 were cross-sectional studies and one was a case study (Figure 1 and Table 2). Sixteen studies were conducted in the USA, three in Europe and one each in United Kingdom, Nigeria and Korea. Collectively, 17630 adults (objective one, n=7535; objective two, n=10095), with the majority being Whites, were included in the studies. Table 2 describes selected characteristics of the included studies.

Figure 1: PRISMA flow diagram of the literature search process



(*k1=number of studies for objective 1; *k2= number of studies for objective 2)

Table 2: Characteristics of the included studies

Objective 1: To identify factors influencing adults' knowledge and attitudes about sugar

Authors (Year)	Country	Study design and sample size	Sample characteristics	Exposure/ Intervention and measurement tool used	Study findings
Adams et al. (2014)	USA	Experimental study n=424 Experiment 1: n=48 Experiment 2: n=115 Experiment 3: n=125 Experiment 4: n=136	Experiment 1 30.0 ± 1.79 years Males (n=28); Females (n=20) Experiment 2 26.8 ± 5.89 years Males (n=41); Females (n=74) Experiment 3 20.54 ± 2.92 years Males (n=64); Females (n=61) Experiment 4 19.3 ± 1.84 years Males (n=92); Females (n=44)	Presentation of sugar images and content information of SSBs Intervention: In a concrete-sugar image condition: a visual representation of the amount of sugar in the beverage and a caption listing the number of sugar grams in the beverage; in the abstract-information condition: only caption was provided; in a no-information condition: neither of the above information was provided Measurement tool: Unvalidated questionnaires on attractiveness and selection of SSBs	Reduced SSB attractiveness in the concrete-sugar-image condition (2.02 ± 0.87) than abstract-information condition (2.56 ± 0.68), and no-information condition (3.11 ± 0.58). Attractiveness measured on a scale from 1 to 5 metric with 1= it makes this beverage much less attractive and 5= it makes this beverage much more attractive
Barragan et al. (2014) and Robles et al. (2015)*	USA	Cross-sectional study n=1041	18-65+ years Males 51%; Females 46% Hispanic/ Latino 40% College education 57% Overweight or obese 34%	Information about the number of sugar packets contained in SSBs Measurement tool: A validated questionnaire on knowledge and intention to reduce SSB intake	High knowledge of the number of sugar packs in SSB in the accurate range (OR 2.63; 95%CI 1.85, 3.75) and high levels of intention to reduce SSB intake (1.95; 95% CI 1.44, 2.65) among participants exposed vs non-exposed to information

Bialkova et al. (2016)	Netherlands	Experimental study n= 240	18 to 64 years Males: 103; Females 137 German	Presentation of sugar labelling and advertising claims on a cereal bar. Intervention: 30% less sugar label (present vs. absent) and benefit claims (health vs. taste vs. no benefit) Measurement tool: A unvalidated single item question on perceived healthfulness	Cereal bars with label claiming 30% less sugar perceived as less healthy (F (2,226) = 16.05, p<0.0001).
Boles et al. (2014)	USA	Cross-sectional study n=402	Young women 18 to 65+ years Males 47%; Females 53% White 84% College education 69%	Information on the amount of added sugars in SSBs, and the health impact Measurement tool: An unvalidated questionnaire on knowledge about health problems of excessive sugar intake	Individuals living with children were more likely to agree that sugar causes health problems (OR 8.32, 95%CI 1.05, 65.84) than those living without children
Guidetti et al. (2012)	UK	Cross-sectional study n=85	College students 18.8 ± 0.9 years Males 9; Females 75	Peer and parent attitudes towards sweet food intake Measurement tool: A validated two online Implicit Association Tests, a 7-point explicit attitude scale and a questionnaire on liking for sweet snacks	Students attitude were more influenced by peers' negative attitudes [implicit (β (SE), 0.09 (.11); explicit (0.31 (0.12))] than parents' positive attitude [implicit (-0.12 (0.11); explicit (0.09 (0.14))] for low sweet food intake
Jordan et al. (2012)	USA	Quasi- experimental study n=507	Primary Care givers Mothers 67%; Fathers 21% White 51% High school 36%	Messages on the adverse health implications of excess SSB intake Intervention: Three media messages Measurement tool: A validated questionnaire on intention to reduce SSBs	Increased intention to reduce SSB intake measured on a 1 to 7 metric with 1= extremely unlikely and 7 = extremely likely: Pre-intervention: (5.27 ± 1.78); Post-intervention: (5.74 ± 1.63)
Kessler et al. (1999)	USA	Cross-sectional study n=190	Adults with Diabetes 30 to 74 years Males 41%; Females	Education by health professionals on reading food label information Measurement tool: A nutrition	47% participants received food label education from health professionals. 73% of all participants knew sugar is a

			59%, Ethnicity: Caucasians 68% College education 44%	knowledge questionnaire reviewed for content validity by experts in the field of nutrition and diabetes.	form of carbohydrate and 71% knew that a label claiming 'no added sugar' may have some natural sugar
Kim et al. (2013)	USA	Experimental study n=358	19 to 65 years Males 23%; Females 77% Caucasian 72% Bachelor degree 40% Married 50%	Impact of different sugar labelling strategies Intervention: 3 different types of sugar labels assessed: 'regular sugar', 'reduced sugar', 'sugar-free' on a Chocolate milk Measurement tool: A validated utility scale for purchase intention	A 'regular sugar' label scored a utility score of 73.8 (high appealing) for purchase intent in comparison to 'reduced sugar' label (utility score of 22.0) and 'sugar-free' label (utility score of -95.8)
Roberto et al. (2016)	USA	Experimental study n= 2381	Caregivers 36 years Males 30%; Females 71% Whites 68% High school 32%	Impact of different health warning labelling strategies on SSBs Intervention: 6 conditions- 1- no warning label; 2- calorie label; 3 to 6- 4 text versions of a warning label (Safety warning, weight gain label; preventable label and type 2 diabetes label) Measurement tool: Self-reported questions on beverage perceptions and purchase intentions	Parents in the warning label condition believed that SSBs were less healthy (3.4 ± 0.04) as compared to parents in calorie label (3.7 ± 0.07) and control (3.8 ± 0.07) group. Parents in warning label condition also reported a reduced SSB purchase intention (3.4 ± 0.04) as compared to parents in calorie label (3.8 ± 0.07) and control (3.8 ± 0.07) group. Healthiness and purchase intention were measured on a scale from 1 to 7 metric with 1 = Not at all; 7 = Extremely
Sutterlin et al. (2015)	Switzerland	Experimental study n=779 Experiment 1: n=164 Experiment 2: n=202 Experiment 3: n=251 Experiment 4: n=162	Experiment 1: 55 ± 15 years Males (63%); Females (37%) Experiment 2: 54 ± 15 years Males (53%); Females	Impact of different sugar labelling strategies Intervention: Cereals with 3 different labels: 'sugar', 'fruit sugar' and 'fruit sugar and claim' Measurement tool: An online questionnaire on perception of healthiness with an internal	Breakfast cereals with 'fruit sugar' label perceived as healthiest (39.3 ± 21.5) followed by 'fruit sugar and claim' label (38.6 ± 21.1) and only 'sugar' label (29.3 ± 20.1) Perceived healthiness measured on a scale from 0 to 100 metric with 0= not

			(47%) Experiment 3 58 ± 13 years Males (59%); Females (41%) Experiment 4: 59 ± 13 years Males (67%); Females (33%) Ethnicity: Swiss-German	consistency (Cronbach's α) of 0.56.	healthy at all to 100 very healthy
Tuorila-Ollikainen et al. (1985)	Finland	Cross-sectional study n= 224	College students Males 21.0 ± 2.7 years; Females 19.2 ± 2.9 years Males 112; Females 112	Overall experience of sugary foods Intervention: Sensory test of 16 samples of sugary drinks Measurement tool: 12 statements on attitudes about sugar used with a reliability coefficient (Cronbach's α) of 0·75.	Students with increased liking of sugary drinks had unfavourable attitudes towards food with less sugar (r=-0.40 males; r=-0.36 females)
Vaala et al. (2016)	USA	Experimental study n= 608	Parents 39.5 (CI 38.5-40.4) years Males 57%; Female 43% White, non-hispanic 64% Diploma 38%	Public service advertisements (PSA) encouraging reduction in SSB intake Intervention: Videos with 3 emotional appeals of humour, fear, nurturance. Measurement tool: A validated questionnaire on emotional appeals, perceived argument strengths and intention to reduce SSB intake	Viewing humour (β (SE), -0.34 (0.11)) and nurturance-based videos (0.02 (0.10)) led to weaker argument strength for reducing SSB intake as compared to fear-based PSA (3.42 (0.09)). Higher perceptions of strong argument for reducing SSB intake was associated with stronger intentions to cut back their own SSB intake (0.97 (0.21)
Zoellner et al. (2016)	USA	Experimental Study n=296	Community-based 42.1 ± 13.4 years Males 18%; Females 82% Caucasians 95%	Education by health professionals on recommendations for all beverage categories (e.g., water, non-calorically sweetened beverages, milk).	Compared to baseline, a positive mean increase for all the Theory of Planned Behavior (TPB) constructs and SSB media literacy observed at 6 months post-intervention. A significant mean

			College education 70% Obesity 57%	Intervention: Group sessions, teach-back and clear communication session and interactive voice response calls. Measurement tool: A validated questionnaire on attitudes, subjective norms, perceived behavioral control, behavioral intentions and a media literacy scale	difference in TPB-SSB constructs from pre to post intervention included- TPB-SSB attitudes 0.7 (0.6, 0.9); TPB-SSB subjective norms 0.3 (0.1, 0.5); TPB-SSB perceived behavioral control 0.6 (0.3, 0.8); TPB-SSB behavioral intentions 1.0 (0.6, 1.3); SSB media literacy 8.2 (6.5, 9.9). TBP constructs were measured on a scale from 1 to 7 with 1 = low, 7 = high and media literacy scale ranged from 19 = low to 133 = high
Objective 2: To determine if there is an association between knowledge and/or attitudes about sugar and sugar intake or practices					
Fadupin et al. (2014)	Nigeria	Cross-sectional study n=376	Undergraduate students 22.5 ± 2.3 years Males 70.5%; Females 29.5% Yoruba 81.6%	Knowledge of health implication of excessive intake of SSBs and attitude towards drinking SSBs Measurement tool: Self-reported question on knowledge and attitudes regarding health implication of SSBs. A validated FFQ to record SSBs intake	86.7% had adequate knowledge of the health implications of excessive SSB intake. 83.5% had negative attitude about the intake of SSBs. 67.4%, 68.1%, 67.4% and 74.7% of the respondents were frequent drinkers of fruit juice, energy drinks, malt drinks, soft, carbonated and soda drinks respectively.
Gase et al. (2014)	USA	Cross-sectional study n=1041	39.6 ± 15.2 years Males 50.6%; Females 45.7% Hispanic/Latino 39.8% College education 56.8% Overweight/obese 33.7%	Knowledge of daily calorie recommendations for a typical adult Measurement tool: An unvalidated measure for SSB intake and self-reported measure knowledge of daily calorie recommendations for a typical adult	34.2% respondents who correctly identified the number of calories a typical adult consumed, on average, 9.21 fewer SSBs per month than respondents who did not (IRR 0.654; 95%CI 0.511, 0.837)
Hennessy et	USA	Cross-sectional study	Caregivers	Self-reported perception about	Perceived healthiness was associated

al. (2015)	n=371	Females 77% 40.5 (39.1, 41.2) years African-American 58% Married 47%	beverages (SSBs and non-SSBs) Beverages included soda, fruit drinks, sweetened iced tea, sports drinks and energy drinks Measurement tool: One unvalidated question on SSB intake and self-reported measure for SSB healthiness perception	with higher intake of sweetened tea, fruit drinks, and sports drinks among participants. A health rating of 10 would increase adults' per day intake for sweetened tea by 1.1 servings (β=0.11); fruit drinks by 2 servings (β=0.20) and sports drinks by 0.9 servings (β=0.09)
Huffman et al. (2007) USA	Cross-sectional study n=201	College students 19.6 ± 4.1 years Males 44%; Females 56% Caucasian 77% Overweight/obese 39%	Nutritional knowledge about SSBs Measurement tool: An unvalidated true/false and multiple choice items on nutrition knowledge about SSB; a modified, validated food frequency questionnaire (FFQ) to record SSB intake	Females had greater nutritional knowledge about SSBs (10.2 ± 1.9) than men (9.1 ± 2.1). Students reported drinking on average 8.8 ± 5.2 SSBs in the previous week. No significant relationship between knowledge about SSBs and SSB intake observed (effect estimate not reported)
Lee et al. (2016) Korea	Cross-sectional study n=250	Mothers Employed 70% Office workers 35%	Nutritional knowledge about sugar Measurement tool: Self-reported measures for questions on knowledge about sugar and frequency of 24 groups of sweet food intake	Mothers' with a high level of knowledge about sugar (HLKS) consumed less foods high in sugar content (some of which include biscuits, sweet cereal, soda, fruit juice, sports drinks, candies, caramel and ice-cream) than mothers with low knowledge about sugar (LLKS). Mean difference in HLKS and LLKS estimates as follows: Biscuits 0.6 (0.4), Sweet cereal 0.7 (0.4), Soda 1.6 (0.1), Fruit juice 0.4 (0.6), Sports drinks 0.6 (0.5), Candies 1.5 (0.1), Caramel 2.1 (0.03), Ice-cream 1.4 (0.1)

Nelson et al. (1991)	USA	Case study n=1	41 years Female College undergraduate	Education about role and function of sugar in diet Intervention: Nutrition education provided at University health centre Measurement tool: An unvalidated handout provided on the functions of sugar in the diet. A daily dietary chart used to record one teaspoon or more of processed sugar.	The average intake of processed sugar, in daily servings, at baseline (2.93 ± 1.49), at treatment (1.82 ±_0.61), and at follow-up (3.00 ± 1.36)
Park et al. (2014)	USA	Cross-sectional study n=3926	18-65 years Males 47.5 ± 1.3; Females 52.5 ± 1.3 Whites 69.5 ± 1.2 College education 74.4 ± 2.3 Married 59.4 ± 1.4	Knowledge of health implications of excessive use of SSBs Measurement tool: Self-reported measure for knowledge about health implications of SSBs and one unvalidated question on SSB intake	Adults who were neutral (neither agreed nor disagreed) or disagreed regarding the influence of SSBs on weight gain had 61% (OR 1.61; 95%CI 1.15, 2.25) and 68% (1.68; (0.94, 3.00)) higher odds of SSB intake >2 times/day respectively than adults who agreed
Zytnick et al. (2015)	USA	Cross-sectional study n= 3929	18-65 years Males 48.8 ± 1.1; Females 51.2 ± 1.1 Whites 68.6 ± 1.1 College education 57.1 ± 1.6 Married 62.7 ± 1.0	Knowledge of sugar content of sports drinks Measurement tool: Self-reported measures for agreement of whether most sports drink contain sugar and an unvalidated question on SSB intake	71% adults agreed that sports drinks contain sugar; however, no association was observed among those who agreed and their sports drink intake (OR 0.78; 95%CI 0.51, 1.21)

*Barragan et al 2014 and Robles et al 2015 analysed same cross-sectional data to report on the impact of a media campaign on knowledge and attitudes of the study participants towards sugar intake.

*Methodological quality of included studie*s

Table 3 summarises the quality assessments of the included studies across six domains of the EPHPP tool i.e. selection bias, study design, confounding, blinding, data collection, withdrawal/ drop-outs. Collectively, a majority of the studies (k[1]=16) had their study samples likely to be representative of the target population. All the experimental and quasi-experimental studies scored a strong rating for their study design while other cross-sectional studies and a case study were rated as weak. However, almost half of the studies (k=11) irrespective of their study designs, controlled for potential confounding, resulting in a strong rating on that domain. Most studies (k=15) scored a moderate rating for the blinding domain due to either reporting of partial blinding or no reporting at all in their studies. Twelve studies either reported the internal consistency of the tool used or used a previously validated data collection tool, resulting in a strong to moderate rating. The final domain of the tool, referring to the percentage of participants completing the study was not applicable for most of the studies (k=16) and therefore scored a week or moderate rating. Only five studies (Jordan, Piotrowski, Bleakley, & Mallya, 2012; Roberto, Wong, Musicus, & Hammond, 2016; Sutterlin & Siegrist, 2015; Vaala, Bleakley, Hennessy, & Jordan, 2016; Zoellner et al., 2016) scored an overall moderate rating.

[1] k=number of studies

Table 3: Study quality assessments using EPHPP tool

Author-Year	Selection Bias (Overall)	Study Design (Overall)	Confounding (Overall)	Blinding (Overall)	Data Collection (Overall)	Withdrawal dropouts (Overall)	Global Score (Overall)*
OBJECTIVE 1							
Adams et al. (2014)	Strong	Strong	Weak	Moderate	Weak	Weak	Weak
Barragan et al. (2014)	Weak	Weak	Strong	Weak	Moderate	Weak	Weak
Bialkova et al. (2016)	Weak	Strong	Weak	Moderate	Weak	Moderate	Weak
Boles et al. (2014)	Weak	Weak	Strong	Moderate	Weak	Weak	Weak
Guidetti et al. (2012)	Moderate	Weak	Weak	Moderate	Strong	Moderate	Weak
Jordan et al. (2012)	Strong	Strong	Weak	Moderate	Moderate	Moderate	Moderate
Kessler et al. (1999)	Strong	Weak	Weak	Weak	Moderate	Moderate	Weak
Kim et al. (2013)	Strong	Strong	Weak	Weak	Moderate	Moderate	Weak
Roberto et al. (2016)	Moderate	Strong	Strong	Moderate	Weak	Moderate	Moderate
Robles et al. (2015)	Weak	Weak	Strong	Weak	Moderate	Weak	Weak
Sutterlin et al. (2015)	Moderate	Strong	Moderate	Moderate	Moderate	Weak	Moderate
Tuorila-Ollikainen et al. *(*1985)	Moderate	Weak	Weak	Moderate	Moderate	Moderate	Weak
Vaala et al. (2016)	Moderate	Strong	Strong	Moderate	Strong	Weak	Moderate
Zoellner et al. (2016)	Moderate	Strong	Strong	Weak	Moderate	Moderate	Moderate
OBJECTIVE 2							
Fadupin et al. (2014)	Weak	Weak	Weak	Weak	Moderate	Moderate	Weak
Gase et al. (2014)	Weak	Weak	Strong	Moderate	Moderate	Moderate	Weak
Hennessy et al. (2015)	Moderate	Weak	Strong	Moderate	Weak	Moderate	Weak
Huffman et al. (2007)	Strong	Weak	Weak	Moderate	Weak	Moderate	Weak
Lee et al. (2016)	Moderate	Weak	Strong	Weak	Weak	Moderate	Weak
Nelson et al. (1991)	Strong	Weak	Weak	Moderate	Weak	Moderate	Weak
Park et al. (2014)	Weak	Weak	Strong	Moderate	Weak	Moderate	Weak
Zytnick *et* al. (2015)	Weak	Weak	Strong	Moderate	Weak	Moderate	Weak

* Strong (no weak ratings), Moderate (one weak rating), Weak (two or more weak ratings)

Factors influencing adults' knowledge and attitudes about sugar (Objective 1)

We classified studies into three domains: individual determinants, inter-personal determinants and environmental determinants.

Individual determinants: A single cross-sectional study was identified and included under the individual determinants (Tuorila-Ollikainen & Mahlamaki-Kultanen, 1985). This study, conducted among 19–21 year old Finnish college students, reported correlations between attitudinal and experience-based factors related to sugar intake. The participants rated the pleasantness of sweetness in drink samples with two sweetness levels and their attitudes towards sugar using 12 statements. The study found that students with increased liking of sugary drinks had unfavourable attitudes towards food with less sugar ($r = -0.40$ males; $p<0.001$ and $r = -0.36$ females; $p<0.001$). The study did not adjust for some important confounders such as socio-demographic characteristics of the participants that may have affected the study findings.

Inter-personal determinants: A single cross-sectional study was included under the inter-personal determinants (Guidetti, Conner, Prestwich, & Cavazza, 2012). This study of 85 college students found that individuals' preferences for sweet foods were influenced by their peers' negative attitudes (implicit β, 0.13 SE (0.11); explicit β, 0.35 SE (0.12)) but not their parents' attitudes (implicit β, -0.16 SE (0.11); explicit β, 0.09 SE (0.14)). While this study used a validated scale to measure attitudes (implicit and explicit), the study was small and the sample was mainly females. Furthermore, the confounding variables adjusted for in this analysis were limited to the effect of cohabitation with parent or peers and duration of friendship. Other potential confounders, such as place of residence, school type (private or public), time spent at home and school, and childhood dietary practices, were not included which may have affected the study findings.

Environmental determinants: Twelve studies investigated the influence of media tools (including campaigns and advertising materials), health professionals' advice and sugar labelling strategies on knowledge and attitudes about sugar.

Media tools had positive impacts on knowledge and attitudes about the importance of reducing the consumption of sugar from food and beverages (Barragan et al., 2014; Boles, Adams, Gredler, & Manhas, 2014; Jordan et al., 2012; Robles et al., 2015; Vaala et al., 2016). A moderate quality experimental study (Vaala et al., 2016) was conducted among parents who consumed an average of 2.8 SSB servings/day (SD = 2.9). The study aimed to identify parents' reactions to anti-SSB messages to inform the design of future media messages. The study found that adults who viewed fear-based advertisements about reducing SSB intake had a stronger emotional and cognitive reaction than those who viewed humorous or nurturing advertisements. The fear-based advertisements stressed the health risks associated with SSB consumption. The study also reported an association between participants' perceptions of argument strength ('defined as the extent to which participants perceived sound arguments for reducing SSB consumption') and stronger intentions about reducing SSB intake [β (SE), 0.97 (0.21)], following the viewing of fear-based advertisements. Similar intentions to reduce SSB intake were also observed in another moderate quality quasi-experimental study (Jordan et al., 2012) conducted among a sample of 507 caregivers of young children. This study found an increase ($p<0.05$) in the intention to reduce SSB intake among caregivers post exposure to messages (5.74 ± 1.78) than pre-exposure (5.27 ± 1.78) on the adverse health effects of SSBs.

Similar positive impacts of being exposed to a campaign focussing on the importance of reducing the consumption of SSBs were also reported in two cross-sectional studies conducted in the US (Barragan et al., 2014; Robles et al., 2015). One of them (Barragan et al., 2014) reported more than twice the likelihood of correctly reporting the quantity of sugar in a soda drink (OR 2.63, 95%CI: 1.85, 3.75) among participants exposed to the campaign compared with those not exposed to the campaign. The second (Robles et al., 2015) found that moderate consumers (1–6 sodas/week) were nearly twice as likely to reduce SSB intake (OR 1.95, 95%CI 1.44, 2.65) after exposure to the campaign, compared with heavy consumers (≥ 1 soda/day). Though both these cross-sectional studies analysed the same data and had a large sample of adults (n=1041), both may be at risk of selection bias as the sample was recruited from selected public transit locations. A similar positive finding was also observed in yet another small cross-sectional study (Boles et al., 2014) where parents exposed to messages on the adverse health effects of SSBs were more likely to agree that sugar causes health problems (OR 8.32, 95%CI 1.05, 65.84) if they had children at home than those with no children at home. Due to the wide confidence intervals, the precision of the findings are limited.

A moderate quality experimental study (Zoellner et al., 2016) assessed the impact of receiving information through health professionals (research staff and students) on participants' knowledge and attitudes about sugar. They delivered a range of sessions for 6 months, focusing on the recommendations for various beverage intake (e.g., water, SSBs, and milk). The study found that the intervention had a positive impact on participants' attitudes, perceptions, and intentions towards reducing SSB intake. The study used validated measures and had an appropriately powered sample (n=296) for detecting a small effect size of 0.34 for the effects of intervention over 6 months. A similar cross-sectional study was conducted (Kessler & Wunderlich, 1999) where 47% participants received food label education from their health professionals (such as nurse, diabetes educator, or dieticians). Seventy-three percent of all participants knew sugar is a form of carbohydrate and 71% knew that label claiming 'no added sugar' may have some natural sugar. However, no association was assessed between receiving education and change in knowledge.

The remaining five experimental studies (Adams, Hart, Gilmer, Lloyd-Richardson, & Burton, 2014; Bialkova, Sasse, & Fenko, 2016; Kim, Lopetcharat, & Drake, 2013; Roberto et al., 2016; Sutterlin & Siegrist, 2015) explored whether products with sugar labels influence attitudes towards sugar. These studies had mixed results with three (Adams et al., 2014; Bialkova et al., 2016; Roberto et al., 2016) reporting positive effects of sugar labels on attitudes towards reduced SSB consumption, while the other two (Kim et al., 2013; Sutterlin & Siegrist, 2015) did not find such effects. The presence of a 'less than 30% sugar' label; a health-warning label ('drinking beverages with added sugar[s] contributes to obesity, diabetes, and tooth decay'); and a pictorial image of quantity of sugar in SSBs, all generated positive attitudes to reduce purchase intention and consumption of SSBs. In other words, across diverse samples in different countries (US and Netherlands), these interventions resulted in an increase in the perception of sugary products as unhealthy. By contrast, two studies (Kim et al., 2013; Sutterlin & Siegrist, 2015) that aimed to assess the participants' perceptions (with no intention to raise awareness) towards different sugar labels did not find such effects. One of them (Sutterlin & Siegrist, 2015) reported that participants perceived cereals with a 'fruit sugar' label (39.3 ± 21.5) to be healthier (a high score) ($p<0.05$) than cereals with 'sugar' label only (29.3 ± 20.1). The other (Kim et al., 2013) found chocolate milk with a ‘regular sugar’ label to be more appealing among consumers compared to the ‘reduced sugar’ or ‘sugar-free’ label.

Association between adults’ knowledge and attitudes about sugar and sugar intake (Objective 2)

We divided the studies into two groups: those that focused on the association between *knowledge* about sugar and sugar intake; and those that focused on the association between *attitudes* towards sugar and sugar intake.

Six cross-sectional studies (Fadupin, Ogunkunle, & Gabriel, 2014; Gase, Robles, Barragan, & Kuo, 2014; Huffman & West, 2007; Lee & Joo, 2016; Park, Onufrak, Sherry, & Blanck, 2014; Zytnick, 2015) and one case-study (Nelson & Hekmat, 1991) investigated the association between *knowledge* about sugar and sugar intake. Three of these cross-sectional studies (Gase et al., 2014; Lee & Joo, 2016; Park et al., 2014) reported an association between increasing knowledge about sugar and reduced consumption of food and beverages with sugar. These findings were consistent across studies conducted in two different countries (Korea and US), with varying sample sizes (n=250, 1041 and 3926) and using different data collection tools. However, the findings in these studies must be viewed in light of their limitations, including convenience sampling, single measures of nutritional knowledge, and not adjusted for potential confounders. In contrast, two studies, (Huffman & West, 2007; Zytnick, 2015) conducted in the US using self-reported data among college students (n=205) and adults (n=3929) found no association between greater knowledge about sugar and reduced SSB intake. Two other studies (Fadupin et al., 2014; Nelson & Hekmat, 1991) although proposed to investigate an association between knowledge and sugar intake, only reported separate prevalence estimates for the measures.

Only one (Hennessy, Bleakley, Piotrowski, Mallya, & Jordan, 2015) cross-sectional study assessed the association between *attitude* towards sugar and sugar intake. This study, conducted among African-American/ Non-African American female caregivers of young children, found that caregivers who perceived sugary beverages to be healthy reported a high intake of sugary beverages (see estimates in Table 2). However, the authors stated that the study was unable to determine the causal direction of the association between health rating and sugary beverage consumption. This study may also be at a risk of respondent burden due to a long beverage list and as the sample was restricted to African-American/ Non-African American caregivers its findings are non-generalizable to the larger population of American parents.

DISCUSSION

The purpose of this review was twofold: first, to identify factors influencing adults' knowledge and attitudes about sugar and, second, to assess the association between knowledge and attitudes about sugar and sugar intake. Firstly, a range of factors influenced adults' knowledge and attitudes about sugar, but only to a certain extent. These factors included individual (liking of sugary food), inter-personal (attitudes of peers) and environmental factors (media tools, health professionals and labelling strategies). Secondly, the evidence in these studies was not adequate to establish an association between knowledge and attitudes about sugar and sugar intake. Except for five moderate quality studies identified for the first objective of the review, all studies were of weak quality, mainly due to problems with study design, sampling strategies, data collection tools and potential confounding.

Among the studies reviewed under the first objective, only two studies described the relationship between individual and inter-personal factors and adults' attitudes towards sugar intake. One study found that increased liking for sugary food negatively influenced young people's perceptions, beliefs, and intentions to reduce sugar intake in adulthood. The other study found a greater influence of peers in determining the adolescents' preference for sweet food than parents. A recent review (Guidetti & Cavazza, 2010) has found that parents and peers are critical to young people's attitudes towards food, but that the mechanisms of influence are quite different. For instance, parental influence may occur through genetic transmission, restriction on certain foods and modelling. Peer influence may occur through strength of friendship and social pressure. Research has also shown that parents are more influential in long-term decisions such as education and future planning whereas peers are influential in everyday decisions such as hobbies and, to some extent, food consumption (Sebald, 1980). Parental influence is often limited after adolescence and a greater similarity to peers is often observed in the attitudes relating food and other behaviors (Becker & Curry, 2014; Sawka, McCormack, Nettel-Aguirre, & Swanson, 2015; Seo & Huang, 2012). This is consistent with the study in this review that found stronger peer influence in an adolescent population.

In this review, evidence from the moderate quality studies shows that disseminating information about recommended intakes and health implications of sugar through a variety of media tools increases knowledge and generates positive attitudes towards reducing sugar consumption. These strategies strengthened participants' perceptions of the health risks posed by SSB intake, thereby increasing the likelihood of behavior change. Simple, meaningful but confronting images and labels appeared to improve knowledge and promote positive attitudes toward reducing sugar intake. These findings suggest that, at a population level, using a variety of media tools in conjunction with advice from health professionals may change knowledge and attitudes. Similar outcomes have been reported for nutrition and other health-related interventions (Beaudoin, Fernandez, Wall, & Farley, 2007; Hammond, Fong, McDonald, Brown, & Cameron, 2004; Robinson, 1997; Wakefield, Loken, & Hornik, 2010; Witte & Allen, 2000).

The findings for the second part of our review are consistent with other literature on the limited effectiveness of theories and models of behaviour and behaviour change that focus on knowledge and attitudes (Baranowski, 2003; Kemm, 1991). Overall, we found weak and inconsistent associations between knowledge and attitudes, and sugar intake. The association is clearly more complex than that assumed by those health behaviour models that focus on knowledge and attitude. Associations between knowledge and attitudes and behavior change are likely to be restricted to specific populations such as highly motivated groups or individuals caring for young children (Baranowski, 2003), which was not the case found in our review. Furthermore as the circumstances in which people live and work have a profound influence on their health and health behaviors (Wilkinson, 2003), a focus exclusively on knowledge and attitudes alone is unlikely to explain behavior change. The physical environment, such as access and availability to food; the economic environment, in which the resources to purchase and the price of food matter; the social environment, in which social and cultural factors inform consumption patterns; and the political environment, where national or local policies influence food availability, all influences behavior (Kearney, 2010; Phelan, Link, & Tehranifar, 2010).

We conclude that knowledge and attitudes are only two among the many factors that may influence sugar intake. Sugar intake is shaped by a range of social, environmental and political factors. If the problem of consuming sugar above the recommended levels is to be resolved, we need to address the causes of sugar intake beyond individual factors.

Strengths and limitations

A thorough search conducted in 15 different databases, using well-defined selection criteria and a systematic synthesis of the data, made our review process rigorous and robust. However, the review has some limitations. Firstly, the review excluded non-English language and unpublished literature, which may have led to exclusion of relevant studies. Second, our search terms may have limited our scope in identifying relevant literature. Third, heterogeneity in study characteristics, study designs, data collection tools and reporting of outcome measures limited our ability to conduct a quantitative synthesis. The quality of the majority of the included studies was generally weak across different quality domains. The tools available for measuring nutrition knowledge are both limited and contentious (Parmenter & Wardle, 1999); therefore, we did not set conditions for the exclusion of papers using invalidated tools *a priori*, which explains the inclusion of studies with unvalidated/ unreliable data collection tools.

CONCLUSION

The role of knowledge and attitudes in determining health behaviors is much debated, and this is clearly also the case for sugar intake. This review highlights the paucity of evidence on factors influencing adults' knowledge and attitudes about sugar and the association of knowledge and attitudes with sugar intake. From the review, it is evident that the impact of knowledge and attitudes on sugar intake is limited, even though a range of determinants influences knowledge and attitude towards sugar to a certain extent. We need to take a holistic approach to consider the other factors (socio-demographic, cultural, social structure, economic conditions, taxation, trade, marketing etc.) that influence sugar intake in all our attempts to reduce sugar intake. A better understanding of the causal pathways is likely to help public health professionals and policy makers to develop appropriate public health interventions and policies to tackle our high levels of sugar intake.

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Contributors

All authors equally contributed to develop both the systematic review protocol and the systematic review manuscript. Author Gupta conducted the review process, reviewed all articles, and wrote all sections of the manuscript. Authors Harford and Smithers independently screened the articles and conducted the quality assessments. All authors provided feedback and suggestions on multiple drafts of the manuscript and all have approved the final manuscript.

Declaration of interest

The authors declare no conflicts of interest.

LEGENDS

Figures legends

Figure 1. PRISMA flow diagram of the literature search process

Table legends

Table 1. PICOS criteria for inclusion and exclusion of studies

Table 2. Characteristics of the included studies

Table 3. Study quality assessments using EPHPP tool

APPENDICES

Appendix A: PRISMA 2009 Checklist

Appendix B: Search strategy following PRISMA guidelines:

(a) Objective 1: To identify factors influencing adults' knowledge and attitudes about sugar.

(b) Objective 2: To determine if there is an association between adults' knowledge and attitudes about sugar and sugar intake

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