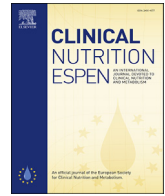




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Meta-analysis

Association between sugar-sweetened beverages and waist circumference in adult populations: A meta-analysis of prospective cohort studies



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SUMMARY

Background & aim: Based on previous studies, Sugar-Sweetened beverages (SSB) can increase the risk of obesity and obesity-related disorders. However, findings are conflicting. The aim of the present study was to summarize the association between the intake of SSB and waist circumference (WC) in adult populations.

Methods: Four electronic databases including PubMed/Medline, Web of Knowledge, Scopus, and EMBASE were considered to collect eligible papers until 31 January 2019 with English language.

Results: Finally, we reached 7 eligible cohort studies for both qualitative and quantitative synthesis. Based on the pooled 10 effect sizes, we found that the consumption of SSB can increase WC by 14%. However, it was not statistically significant and the between-study heterogeneity was high (95%CI: 0.86, 1.51; I²: 90.8%). We also observed that soda drink can increase WC by 31% (95%CI: 1.03, 1.66; I²: 0%).

Conclusion: The current systematic review and meta-analysis revealed that the consumption of SSB can increase WC by 14% in adult populations. However, this value was not statistically significant. However, more prospective studies are necessary to make a decision on the link between the consumption of SSB and abdominal obesity.

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1. Introduction

Due to global obesity epidemic, identifying factors involving in weight gain is a priority to develop effective health policies and prevent complications related to obesity [1]. Following an imbalance between energy intake and energy expenditure, excess fat in adipose tissue is accumulated [2]. Adipose tissue is a place for

storing triglyceride and releasing non-esterified fatty acids (NEFA) in fasting, but also it secretes various hormones and signaling molecules [3]. These secretions are likely to act as mediators between dietary habits and metabolic disorders that can lead to the development of chronic diseases [4].

Unhealthy dietary habits, alone or in combination with other lifestyle-related factors can provide a ground for obesity [5]. In most countries, dietary habits have been gradually changed from traditional to Westernized diets that contain the substantial amount of meat, high fat content, and sweet foods including deserts and sugar-sweetened beverages (SSB) [6,7].

The intake of SSB, that commonly contain sports drinks, soft drinks, soda and fruit drinks, is dramatically increasing across the world particularly among young adults [8]. Based on some previous studies, SSB can increase the risk of obesity and obesity-related

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disorders [9]. Conversely, the consumption of water and low-calorie beverages can reduce cardio-metabolic risk factors [7].

Some studies showed that adding SSB can increase the serum levels of triglyceride [10] and insulin resistance [11,12]. The association between SSB and adiposity is likely to be attributed to multiple factors such as intake of considerable amount of energy, less feeling of fullness, stimulating insulin secretion, and fat storage following the long-term consumption of SSB [13–15].

As prospective cohort studies can clarify the associations between the consumption of SSB and adiposity as well as their cause-effect relationships, considering such types of studies can be helpful. Some studies [16–18] revealed significant links between SSB and adiposity indices such as body mass index (BMI), waist circumference (WC), total fat mass (FM) and visceral fat, while others failed to show any associations in adult populations [19–21]. To the best of our knowledge, no systematic-reviews and meta-analyses examined this link in individuals with different ranges of age; therefore, we aimed to summarize the association between the intake of SSB and WC in adult populations and to do a meta-analysis.

2. Material & methods

2.1. Search strategy

A systematic search was conducted by an independent reviewer (Y.J.) to identify relevant publications from inception to 31 January 2019 with English language. Four electronic databases including PubMed/Medline, Web of Knowledge, Scopus, and EMBASE were considered and the following Medical Subject Headings (MeSH) and non-MeSH keywords were used:

“Weight” OR “Body Mass Index” OR “Obesity” OR “Waist Circumference” OR “Abdominal” “Adipose Tissue”[MeSH] OR “Fat” OR “Quetelet Index” OR “Visceral Fat” OR “BMI” OR “obesity” OR “overweight” OR “adipose tissue” OR “fat mass” OR “adiposity” OR “body roundness index”) AND (“Beverages” OR “Drink” OR “Soda” OR “Sweetened” OR “Juice” OR “Lemonade” OR “Squashes” OR “Punch” OR “coca cola” OR “Coca-Cola” OR “sugar-sweetened” OR “Pop” OR “Tonic” OR “Food Habits”) AND (“Longitudinal” OR “Epidemiology” OR “retrospective” OR “prospective” OR “longitudinal” OR “cohort” OR “follow-up” OR “retrospective” OR “Incidence”).

Two independent investigators (Y.J., E.A) screened publications. In addition, the reference lists of the eligible publications were examined to avoid missing any relevant studies. After collection of potentially relevant studies in Endnote library, in the first step each title and abstract was examined to clarify whether the publications were relevant or not. In the next step, studies' full texts were reviewed to reach eligible papers. Any discrepancies regarding considering papers as eligible publications were examined by the third investigator (N.N).

The present systematic review and meta-analysis presented in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [22] and has been registered in the PROSPERO database (PROSPERO registration number: CRD42019133516).

2.2. Inclusion criteria

Publications on (i) either apparently healthy (free of any cardiovascular diseases, cancer, etc) adults populations with (ii) prospective cohort design that (iii) considered any types of SSB as exposure (coca-cola, soda, total SSB) and (iv) waist circumference as a primary outcome were included. It is notable that

we only included the studies with the aforementioned characteristics in which the (iv) adjusted relative risks (RRs) or hazard ratios (HRs) and 95% confidence intervals (95% CIs) were reported. In the present study, waist circumference (WC) was considered as a primary outcome while waist-to-hip ration, waist-to-straight height, and fat mass were our secondary outcomes.

2.3. Exclusion criteria

Studies were excluded if: (i) they had study designs except prospective cohort studies such as cross-sectional studies, clinical trials, case-control, case reports, case series, (ii) studies on children and adolescents or *In vitro*/animal models; (iii) examined other anthropometric indices; (iv) grey literatures such as conference abstracts, theses, books, and interviews; (v) SSB in combination with other kinds of food including natural juice, jam, fruit; (vi) did not report the mentioned effect sizes.

2.4. Data extraction

Two independent reviewers (Y.J., E.D) extracted the characteristics of studies based on a pre-designed checklist (Table 1). In the present study, first author's last name, publication date, location, gender, sample size, number of cases, mean age at baseline, person-year, exposure, outcome, methods used for assessing dietary intake, the reported RRs, HRs, 95% CI, and adjustment for confounders. Any discrepancies were resolved by discussion.

2.5. Quality assessment

The quality of the eligible papers was examined by three independent reviewers (Y.J., N.N., E.A) using the Newcastle–Ottawa Scale [23]. Based on this checklist, each paper can obtain the maximum of nine score. In the current systematic review, we considered the quality score equal or more than 5 as high-quality and those with the score fewer than 5 were considered as low-quality studies. It is notable that any discrepancies in any process were resolved by principal investigators (L.A., B.L).

2.6. Statistical analysis

To clarify the link between SSB and WC in adult populations, a random-effect model was used to pool RR and 95% CIs for greatest vs. lowest consumption SSB. For pooling RRs, the most fully adjusted model was entered with the DerSimonian and Laird method. Between-study heterogeneity was tested using the I^2 index. If I^2 values were obtained higher than 50%, they were reported as high heterogeneity and results were interpreted with caution. To identify the main reason of heterogeneity, stratifications were occurred as a complementary analysis. If they were at least two independent studies in each category candidate for heterogeneity, subgroup analysis were done. Studies were categorized based on the type of beverages, age groups, follow-up period, and sample size. Publication bias and sensitivity analysis were also performed. Due to limited studies, publication bias was assessed using Egger's regression asymmetry test. To check the effect of each cohort study on the pooled RR as well as the robustness of findings, sensitivity analysis was used. Statistical analyses were conducted using Stata, version 11.0 (Stata Corp, College Station, TX). P-value < 0.05 was considered as statistically significant.

Table 1
Characteristics of the included prospective cohort studies.

Authors (year)	Country	Age range (y)	Gender	Characteristics of subjects	Sample size	Cases	Follow-up (y)	Exposure	Mean Or median intake	Exposure assessment	Outcome	Outcome assessment	Adjustment ¹	Quality score
Kang et al. (2017)	Korea	40–69	F	Korean adults without MetS	5012	1502	5.7	Soft drink	Not reported	103 item semi-quantitative FFQ: Interview	Abdominal obesity	Waist Circumference abdominal obesity (WC \geq 90 cm for men or \geq 80 cm for women)	Age, income level, education level, alcohol consumption, smoking status, physical activity, BMI, energy intake, percentage of fat, fiber intake and the presence of diseases	8
Appelhans et al.(2017)	USA	42–52	F	Midlife women	2870	1096	14	Energy-dense non-alcoholic beverages	205 mL/d	103 item FFQ: Interview	Abdominal obesity	Waist Circumference \geq 80 cm for Chinese and Japanese women, and \geq 88 cm for other ethnic/racial groups),	Age at baseline, ethnicity/race, study site, total energy intake, menopausal status, hormone therapy use, smoking status, depressive symptoms, education, income, and physical activity	8
Ferreira-Pêgo et al.(2016)	Spain	M: 55–80 F: 60–80	M/F	Mediterranean Population at High Cardiovascular Disease Risk	1868	930 incident cases	Median: 3.24	Sugar-sweetened beverages Artificially sweetened beverages Natural fruit juices Bottled fruit juices	The mean daily intakes during follow-up were 14.5 mL, 17.1 mL, 29.3 mL, and 16.6 mL for SSBs, artificially sweetened beverages, natural fruit juices, and bottled fruit juices	137-item semi quantitative FFQ: Interview	Abdominal obesity	Waist Circumference waist circumference \geq 88 cm in women and \geq 102 cm in men	intervention group, age in years, sex, leisure-time physical activity (metabolic equivalent tasks/d), BMI (kg/m ²), smoking status (never, former, or current), average consumption during the follow-up of dietary variables as continuous variables (vegetables, legumes, fruit, cereals, meat, fish, baked products, dairy products, olive oil, and nuts), average total energy intake during follow-up, alcohol, and alcohol squared in grams per day	8
	Spain	25–74	F/M	Spanish Adults	2112	1772	10				Abdominal obesity			9

Funtikova et al.(2014)								Soft drinks Juice	Means at baseline Soft drinks (426 109 mL/d) Juice (64 6114 mL/d)	166-item FFQ: Interview		waist circumference >102 cm for men and >88 cm for women	200 mL/d vs. no consumption	
Barrio-Lopez et al.(2013)	Spain	Mean age: 36	F/M	healthy adults	8157	361	6	sugar-sweetened beverage	Mean of Quintiles at baseline (20.646 mL/d)	118-semi-quantitative FFQ: Self-reported	Waist criterion	Waist Circumference ≥94 cm in males and ≥80 cm in females	age, sex, baseline BMI, smoking, physical activity, alcohol intake, soft drink intake at baseline, total energy intake, consumption of red meat, French fries, fast food consumption and adherence to the Mediterranean dietary pattern	7
Duffey et al. (2010)	Spain	18–30 y	M/F	healthy adults	2444	637	20	Sugar-sweetened beverage	–	Not reported its items FFQ: Interview	Cardio-metabolic outcomes	Waist Circumference As WC > 88 cm (women) or >102 cm (men)	race (black or white), sex, CARDIA (Coronary Artery Risk Development in Young Adults) exam center, and year 0 age, weight, smoking status [smoker, former smoker or never smoker (referent)], energy from food, total physical activity, energy from the 3 other beverages, and energy from alcohol	8
Nettlton al. (2009)	USA	45–84	M/F	healthy	1544	282	5	Soda	–	120-FFQ: Self-reported	Metabolic syndrome (WC)	Waist Circumference ≥102 cm if male and ≥88 cm if female	study site, age, sex, race/ethnicity, energy intake education, physical activity, smoking status, pack-years, and weekly supplement use or more	7

3. Results

3.1. Literature search

After searching PubMed, Scopus, and Web of science, 17,435 papers (containing 4529 duplicates) were retrieved up. In the first step of screening based on title and abstract, 12,666 publications were found irrelevant. In the second step of screening, 233 out of 240 papers were identified as irrelevant according to our eligibility criteria. Reasons of exclusion were presented in Fig. 1. Finally, we reached 7 eligible cohort studies for both qualitative and quantitative synthesis.

3.2. Study characteristics

Characteristics of the 7 included prospective cohort studies [16,17,19–21,24,25] for systematic review and meta-analysis are provided in Table 1. They were published between 2009 and 2017. They were conducted in Europe (n = 4) [16,21,24,25], the U.S (n = 2) [17,20], and Asia (n = 1) [19]. Participants aged between 25 and 66 years old. All studies except two [19,20] examined the link between SSB and WC in both genders. All studies examined the effects of SSB in apparently healthy subjects with the minimum follow-up period of 3.2 years [21]. Assessment tool to estimate the amount of consumed SSB was Food frequency Questionnaire (FFQ). Findings of all studies were adjusted for total energy intake and physical activity level and the RRs ranged 0.46 to 2.3. Four studies reported the association between all types of SSB in combination [20,21,24,25],

while in the remaining three studies the effect of one specific beverage including bottled juice with added sugar, soda, and soft drink were reported.

3.3. Meta-analysis

Based on the pooled 10 effect sizes (of 7 cohort studies), we found that the consumption of SSB can increase WC by 14%. However, it was not statistically significant and the between-study heterogeneity was high (95% CI: 0.86, 1.51; I²: 90.8%) (Fig. 2). To find the main reason of the heterogeneity, subgroup analyses were occurred. Due to limited studies in each type of SSB, we only were able to report the results separately for soft drink and all SSB in combination (Table 2). We observed that soda drink can increase WC by 31% (95% CI: 1.03, 1.66; I²:0%). Although after classification the heterogeneity reached the minimum level in soft drink group, we observed high between-study heterogeneity in all SSB categories (I²:96%). The link between all types of SSB and WC was 1.18; 95% CI: 0.67, 2.09.

Subgroup analysis based on age range, follow-up period, and sample size could not reduce the heterogeneity as well (Table 2).

4. Discussion

The current systematic review and meta-analysis revealed that the consumption of SSB can increase WC by 14% in adult populations. However, this value was not statistically significant. SSB can also increase WC by 19% in populations younger than 50, while

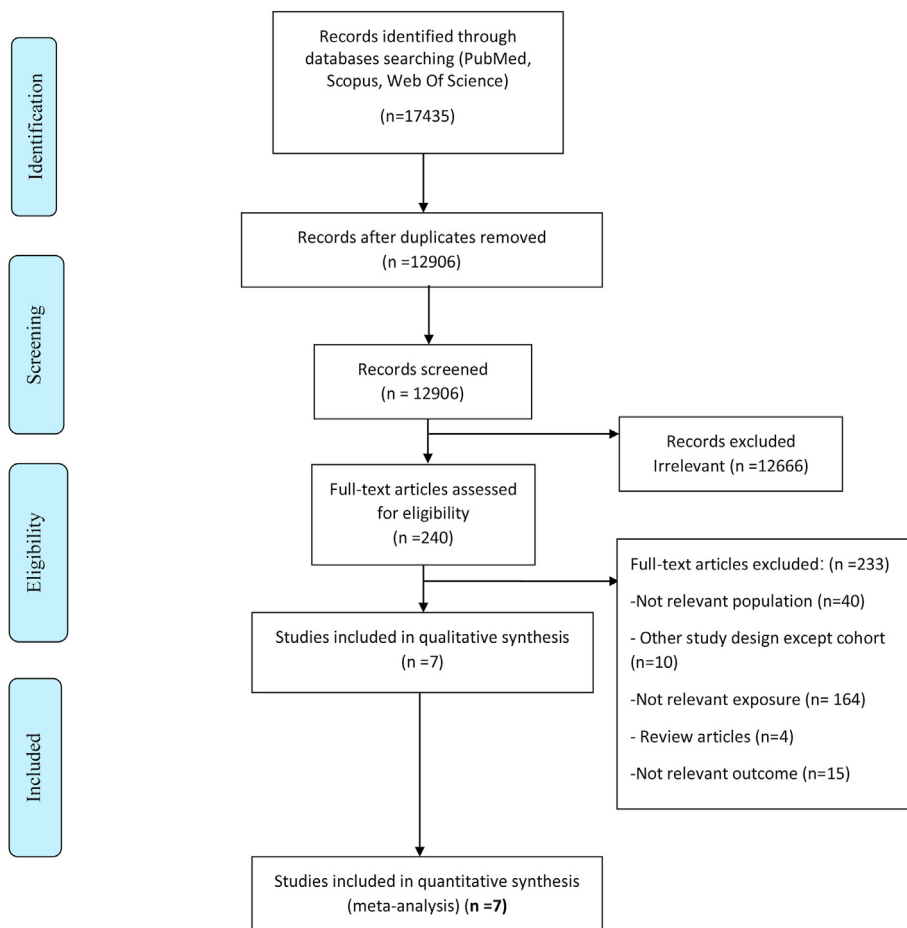


Fig. 1. Flow diagram of study selection.

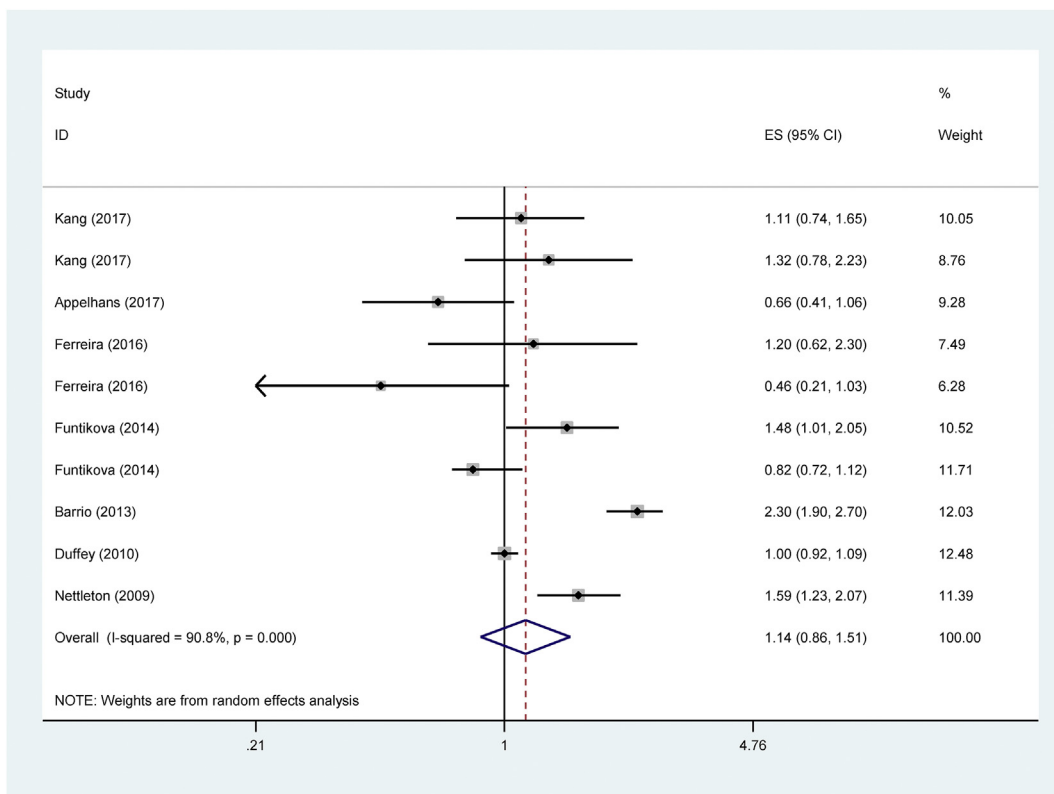


Fig. 2. Forest plot of the link between sugar sweetened beverages and waist circumference in adult populations.

it was 8% in older ones. Albeit both results were not significant. However, more prospective studies are necessary to make a decision on the link between the consumption of SSB and abdominal obesity.

To the best of our knowledge, it is the first systematic review and meta-analysis in which the link between the consumption of various SSBs and adiposity in both children and adults were examined. In the recent meta-analysis on food groups and obesity, conducted by Schlesinger et al., only 3 studies on SSB and overweight were included. They reported that the intake of SSB can increase the risk of overweight/obesity by 20% [18]. In this study, due to limited studies classifications by age groups were not performed. In our study, although the effect of SSB on adiposity in younger individuals were greater than older, its effects were significant in no categories.

In our meta-analysis, WC was considered as a measure of adiposity. Although we extracted the information related to fat mass, as a measure of adiposity, only limited studies examined this variable and we could not pool and perform a meta-analysis on fat mass. Stern and colleagues reported that in overweight/obese women the impact of changes in sugar sweetened soda on body weight was stronger compared to those with normal weight [26]. However, in the present meta-analysis due to limited studies we could not do a subgroup analysis based on BMI to evaluate this issue.

It is notable that some cohort studies assessed a particular sweetened beverage including soda, juice with added sugar or diet beverages, not sugar-sweetened beverages as a whole. Due to limited studies in each category, we only could report findings on soft drink, separately. We found that soft drink can increase the risk of adiposity by 31%. However, pooling studies on all SSBs showed odd ratio of 1.18 with adiposity. Therefore, types of SSB can affect

the association. However based on current cohort studies, this issue remained unanswered.

All the included cohort studies obtained minimum score of 5 for methodological quality. Accordingly, there is no bias on findings regarding high risk of bias. However, various categories were considered for comparisons the effects of high SSB intake verses low consumption and this point made it difficult to define a cut-off point and provide nutritional recommendations on this regard. On the other hands, sensitivity analysis showed that our findings were stable and two studies had decisive effect. Thus, findings must be interpreted by great caution.

Based on Leermakers et al., there was an association between higher SSB intake at 13 months and higher BMI up to age 6 years in girls, while it was not significant among boys [27]. They hypothesized that satiety effect of SSBs is likely to be different among girls and boys. Due to this issue, girls are expected to be more susceptible to overeating when drinking SSBs. Men usually have a good caloric compensation when eating a meal following the consumption of such beverages, whereas in women this issue has not been observed and they usually intake more calorie [27].

Moreover, based on evidence the serum levels of ghrelin, a key appetite-stimulating hormone, is linked with adiposity in girls, but not in boys [28]. In addition, differences in resting metabolic rate, body composition and growth patterns among men and women can influence the association between SSB and adiposity. However, most studies reported results in both genders. Due to limited studies in each gender separately, we could not compare the effects of SSB on each gender. Accordingly, further studies considering gender-specific effects may be warranted.

SSBs can stimulate intake of other high glycemic foods that lead to the intake of greater total calorie. Furthermore, due to high glycemic loads of SSBs, repeated high insulin is demanded. An

Table 2

Subgroup analyses of the included studies on the link between sugar sweetened beverages and waist circumference.

Subgroup	Number of effect size	RR (95%CI)
Types of beverages		
All SSB	4	1.18 (0.67, 2.09); I ² :96%, p = 0.0001
Soft drink	3	1.31 (1.03, 1.66); I ² :0%, p = 0.57
Age (year)		
≤50	5	1.19 (0.75, 1.90); I ² :94.7%, p = 0.0001
>50	5	1.08 (0.73, 1.60); I ² :81.7%, p = 0.0001
Follow-up (year)		
<8	6	1.32 (0.91, 1.90); I ² :82.1%, p = 0.0001
>8	4	0.96 (0.77, 1.21); I ² :71.6%, p = 0.01
Sample size		
<2500	8	1.05 (0.84, 1.30); I ² :74.7, p = 0.0001
>2500	2	1.64 (0.80, 3.33); I ² :90.6%, p = 0.001

increase in insulin secretion can lead to fat accumulation and weight gain [29]. Based on evidence, high-fructose maize syrup that is used for some types of SSBs can also stimulate hepatic de novo lipogenesis and substantially increase the serum levels of triglyceride [19].

Although the association between SSBs and adiposity were not statistically significant, due to an increase of 14% in adiposity following SSBs intake and no robustness of findings, recommendation regarding limiting the consumption of SSBs by health providers seems reasonable.

Among the weakness of the present meta-analysis we can point to the lack of dose-response analysis due to variation in cut-off points and comparison groups. In addition, only papers with English language were included. The strength points of the current systematic review and meta-analysis are as follows: i) examining the quality of studies based on a standard tool; and ii) including only cohort studies that can clarify the cause and effect relationships between SSB and adiposity. It is suggested to compare various types of SSB with different sweeteners including fructose and sucrose as well as beverages with various kinds of artificial sugar in the future prospective studies.

5. Conclusion

In adult populations with higher consumption of SSB, WC was 14% greater than those with lower intake. However, due to no robustness, findings should be presented by great caution. More prospective studies are needed to draw a fixed decision on the association between SSBs and adiposity among adult populations.

Ethics approval

Not applicable.

Consent for publication

Yes.

Availability of data and material

We can share our data for meta-analysis privately with reasonable reason.

Funding

None.

Authors' contributions

B.L, L.A and N.N designed the project. L.A and N.N directed the project. Y.J provided search strategies and collection of publications in Endnote, N.N, Y.J, and E.A screened publications. Y.J and E.D extracted data. Y.J, E.A and N.N assessed the quality of publications. N.N and L.A examined results and interpret findings. All authors checked and confirmed the draft of paper.

Declaration of competing interest

None.

Acknowledgment

None.

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