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ASSOCIATION BETWEEN SWEETENED BEVERAGES CONSUMPTION WITH THE INCIDENCE OF TYPE 2 DIABETES AND CARDIOVASCULAR DISEASE: A SYSTEMATIC REVIEW

Konsumsi Minuman Berpemanis SSB dan ASB Meningkatkan Risiko Kejadian DM Tipe 2 dan PKV: Literatur Review

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ABSTRAK

Konsumsi minuman berpemanis gula (SSB) dan pemanis buatan (ASB) telah dikaitkan dengan peningkatan risiko diabetes mellitus tipe 2 (DMT2) dan penyakit kardiovaskular (PKV). Namun, bukti mengenai dampak jangka panjang dari kedua jenis minuman ini masih bervariasi. Studi ini merupakan kajian sistematis yang dilakukan sesuai dengan pedoman PRISMA. Sebanyak 18 artikel dari studi kohort dan potong lintang yang dipublikasikan antara tahun 2015 hingga 2025, dengan subjek penelitian orang dewasa untuk menganalisis hubungan antara konsumsi SSB dan ASB dengan DMT2 dan PKV. Penilaian kualitas dilakukan menggunakan Newcastle-Ottawa Scale (NOS). Konsumsi SSB dan ASB secara konsisten dikaitkan dengan peningkatan risiko DMT2 dan CVD dengan risiko relatif (HR/OR) berkisar antara 1,06 hingga 2,40 untuk DMT2 dan 1,09 hingga 2,44 untuk CVD. Oleh karena itu, strategi kesehatan masyarakat sebaiknya tidak hanya mengalihkan konsumsi dari SSB ke ASB, melainkan menekankan pada pembatasan konsumsi keduanya secara menyeluruh melalui kebijakan regulatif, edukatif, dan fiskal.

***Kata kunci**: artificially sweetened beverages, diabetes melitus tipe 2, minuman berpemanis, penyakit kardiovaskular, sugar-sweetened beverages*

ABSTRACT

Consumption of sugar-sweetened beverages (SSBs) and artificially sweetened beverages (ASBs) has been associated with an increased risk of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD). However, evidence regarding the long-term effects of these beverages remains variable. This study is a systematic review conducted according to the PRISMA guidelines. A total of 18 cohort and cross-sectional studies published between 2015 and 2025, involving adult populations, were analyzed to examine the association between SSB and ASB consumption with T2DM and CVD. Study quality was assessed using the Newcastle-Ottawa Scale (NOS). Consumption of both SSBs and ASBs was consistently associated with an increased risk of T2DM and CVD, with relative risks (HR/OR) ranging from 1.06 to 2.40 for T2DM and from 1.09 to 2.44 for CVD. Therefore, public health strategies should not merely promote substitution of SSBs with ASBs, but rather emphasise reducing the consumption of both types of beverages through regulatory, educational, and fiscal interventions.

Keywords: artificially sweetened beverages, cardiovascular diseases, sugar-sweetened beverages, sweetened beverages, type 2 diabetes

INTRODUCTION

Consumption of sweetened beverages increased by 16% globally from 1990 to 2018[1]. In Indonesia, as many as 61.27% of the population consumes sweet drinks ≥ 1

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time per day[2]. *Sugar-sweetened beverages* (SSB) a drinks to which sugar is added during the production process[3]. According to the World Health Organization (WHO), sugar-sweetened beverages include soft drinks, fruit drinks, and drinks containing added sweeteners such as syrup, sucrose, or fruit juice concentrate[4]. SSBs are a major source of added sugars that are linked to obesity, insulin resistance, systemic inflammation, and an increased risk of diabetes and cardiovascular disease[5]. Meanwhile, Artificially Sweetened Beverages (ASB) or artificially sweetened drinks are drinks that have very low or even zero energy value[6].

Consumption of sweetened drinks, whether from sugar or artificial sweeteners, is associated with the incidence of DMT2 and CVD[7]. DMT2 and CVD are the main causes of global morbidity and mortality, with increasing prevalence in recent decades[8]. According to data from the International Diabetes Federation (IDF), the incidence of diabetes worldwide reached 537 million cases in 2021 and is estimated to reach 643 million cases by 2030[9]. CVD also experienced an increase from 271 cases in 1990 to 523 million cases in 2019[10].

Individuals who consume SSBs have a 3.1 times higher risk of developing T2DM compared to individuals who do not consume SSBs[11]. SSB consumption is also positively correlated with the risk of CVD through increased triglyceride levels[12]. ASB is widely used as an alternative low-calorie drink, which is considered safer than SSB[13]. However, some recent studies have shown that ASB may also increase the risk of metabolic disorders[14]. Individuals who consume ASB >2 servings/day experience a 54% increased risk of DMT2 compared to individuals who do not consume it[15] [16]. ASB consumption is significantly correlated with an increased risk of CVD (HR 1.012), Coronary Heart Disease (CHD) (HR 1.018), Peripheral Artery Disease (HR 1.035), and heart failure (HR 1.018) [17]. However, the findings across studies remain inconsistent, and the underlying biological mechanisms are not yet fully clarified. Considering the rising consumption of sugar-sweetened beverages worldwide, including in Indonesia, and their potential impact on metabolic and cardiovascular health, it is important to synthesize the latest evidence. Therefore, this systematic review aims to examine the association between sugar-sweetened beverage (SSB) and artificially sweetened beverage (ASB) consumption and the risk of developing T2DM and CVD.

METHODS

The research was conducted at Universitas Brawijaya, Malang, from February to April 2025. Literature sources were traced through PubMed, Springer, Science Direct, and the Cochrane Library. The keywords used are "*Sugar-sweetened Beverages*" or "*Artificially Sweetened Beverages*" or "*Artificial Sweetened Beverages*" or "*Added Sugar*" or "*Artificial Sweetener*" or "*Sugary Beverages*" or "*Sweet Beverages*" or "*Diet Beverages*" or "*High Fructose Corn Syrup*" or "*Saccharine*" and "*Type 2 Diabetes*" or "T2D" or "*Hyperglycemia*" and "*Cardiovascular Diases*" or "*Coronary Artery Disease*" or "*Peripheral Arterial Disease*" or " *Heart Failure*" or "*Stroke*"

The inclusion criteria for this review were: (1) study design: cohort and cross-sectional studies published between January 2015 and February 2025; and (2) article type: full-text and free access publications. The PECO framework guided study selection, with the population being adults, exposure defined as SSB or ASB consumption, comparator as low or no consumption, and outcomes including the incidence of T2DM and/or CVD. Studies involving animal experiments, laboratory-based research, or those not peer-reviewed were excluded.

Data extraction from eligible articles was conducted using Covidence for title and abstract screening, full-text eligibility assessment, and extraction of key study details. This systematic review followed the PRISMA guidelines, with the study selection process illustrated in Figure 1. The methodological quality of the included studies was evaluated using the Newcastle-Ottawa Scale (NOS). All eligible studies examining the association

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between SSB/ASB intake and T2DM or CVD incidence were included in the final synthesis.

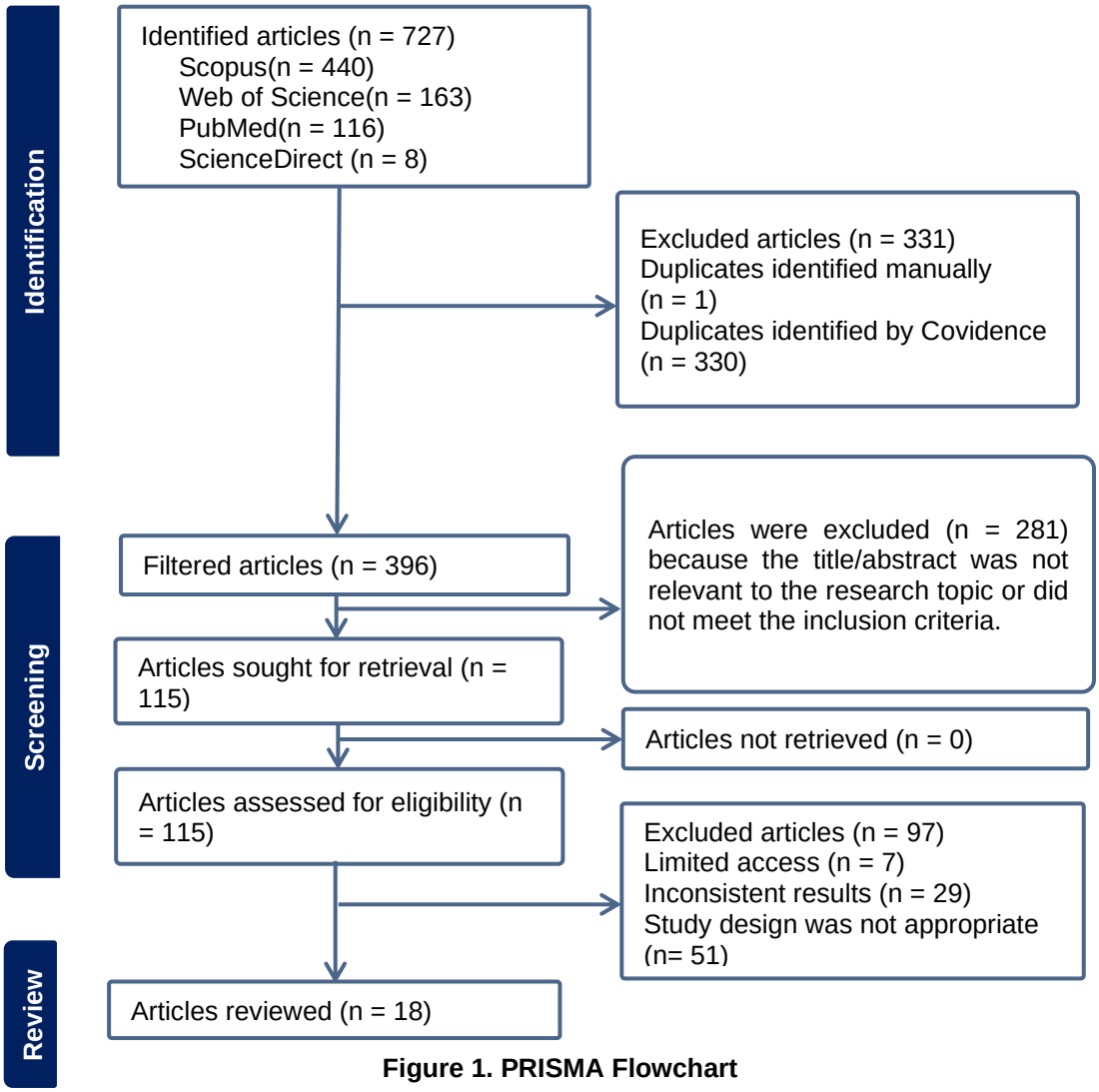

Figure 1. PRISMA Flowchart

RESULTS

The primary outcome of this review was the incidence of T2DM and CVD reported in the included studies. A secondary outcome examined the risk of cardiovascular complications among patients with type 2 diabetes in relation to SSB and ASB consumption. The quality of the selected studies was assessed using the Newcastle-Ottawa Scale (NOS), and based on the average score, 18 articles were categorized as good quality. These studies were then summarized and analyzed in Table 1.

Table 1. Article Analysis Results

No	Author, Year, Title	Objective	Population and sampling techniques	Method	Results
1	Akinbule et al. (2024). Consumption patterns of sugar-sweetened beverages among tertiary	SSB consumption patterns and factors associated with	350 students (15-29 years) in Abeokuta. The sampling technique used	• *Cross-sectional* • Using Fisher's exact test and binary logistic regression was	Consuming fruit drinks >2 times a week increases the risk of diabetes 15-fold (OR = 15.2). Consuming other types of sweetened drinks >2 times

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	institution students in Abeokuta, Nigeria and their association with the risk of developing type 2 diabetes using FINDRISC[18]	the risk of developing T2DM	stratified random sampling.	used to analyze the relationship	a week increases the risk three-fold (OR = 2.9).
2	Debras et al. (2022) Artificial sweeteners and risk of cardiovascular diseases: results from the prospective NutriNet-Santé cohort[19]	Consumption of artificial sweeteners with the risk of CVD, including coronary heart disease and cerebrovascular disease	103,388 participants from the NutriNet-Sante Cohort. Aged ≥ 18 years. Sampling technique used: volunteer sampling.	• *Prospective Cohort Study* • The effect of artificial sweetener consumption was analyzed using the Cox proportional hazards model.	Total artificial sweetener consumption increased the risk of CVD by 9% (HR = 1.09) and cerebrovascular disease by 18% (HR = 1.18). Aspartame was associated with a 17% (HR = 1.17) increased risk of cerebrovascular disease, while acesulfame potassium and sucralose increased the risk of coronary heart disease by 40% (HR = 1.40) and 31% (HR = 1.31), respectively.
3	DeChristopher et al. (2024) Disproportionately higher cardiovascular disease risk and incidence with high fructose corn syrup sweetened beverage intake among black young adults–the CARDIA study[20]	High fructose corn syrup (HFCS) sweetened beverage consumption and CVD risk and incidence in young black and white adults in the CARDIA study.	The total number of participants was 4463. The sampling technique used was stratified random sampling.	• *Retrospective Cohort Study* • Using the Cox proportional hazards model to calculate the hazard ratio (HR) and analyzing data over 35 years.	HFCS consumption ≥3 times/week was associated with a twofold increased risk of CVD in Black participants (HR = 2.1). In White participants, the increased incidence was only 9% (HR = 1.09).
4	Den Biggelaar et al. (2020) Association of artificially sweetened and sugar-sweetened soft drinks with β-cell function, insulin sensitivity, and type 2 diabetes: the Maastricht Study[21]	SSB and ASB consumption on pancreatic β-cell function, insulin sensitivity, and risk of type 2 diabetes.	2240 participants with type 2 diabetes. Aged 40 to 75 years. The sampling technique used was stratified random sampling.	• *Cross-sectional* • The analysis was performed using linear and logistic regression with adjustment for various confounding factors.	Consumption of artificially sweetened beverages was associated with decreased β-cell glucose sensitivity (β = -0.06) and total insulin secretion (β = -0.06). Daily consumption also showed similar associations with decreased β-cell sensitivity (β = -0.05) and insulin secretion (β = -0.05).
5	Ding et. al., (2024) Associations of sugary beverage intake with type 2 diabetes and the role of physical activity: a prospective cohort study [16]	Consumption of sweetened beverages (SSB, ASB, and natural juices) with the risk of type 2 diabetes	153,862 participants without diabetes aged 37–73 years using UK Biobank data. The sampling technique used was volunteer sampling.	• *Prospective Cohort Study* • Analysis using the Cox proportional hazards model to calculate the hazard ratio (HR)	Consuming more than 2 servings of SSB per day increased the risk of type 2 diabetes by 17% (HR = 1.17), while ASB increased the risk by 54% (HR = 1.54). Moderate consumption of natural juice (0–2 servings per day) was associated with a reduced risk (HR = 0.87–0.91).

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No	Author, Year, Title	Objective	Population and sampling techniques	Method	Results
6	Drouin-Chartier et al. (2019) Changes in Consumption of Sugary Beverages and Artificially Sweetened Beverages and Subsequent Risk of Type 2 Diabetes: Results From Three Large Prospective US Cohorts of Women and Men [22]	Consumption of SSB and ASB with risk of type 2 diabetes.	76,531 women in NHS, 81,597 women in NHS II, and 34,224 men in HPFS. The sampling technique used was volunteer sampling.	• *Prospective Cohort Study* • Changes in beverage consumption were calculated every 4 years from food frequency questionnaires. • Analysis using Cox proportional hazards regression models.	An increase in total consumption of sweetened beverages by more than 0.5 servings/day over 4 years was associated with a 16% increased risk of diabetes (HR = 1.16), and an 18% increased risk of ASB consumption (HR = 1.18). Replacing one serving of SSB with water, coffee, or tea reduced the risk by 2–10%, but substitution with ASB did not show a protective effect. The effect of ASB consumption may be influenced by reverse causation and surveillance bias.
7	Gardener et al. (2018) Diet Soda and Sugar-Sweetened Soda Consumption in Relation to Incident Diabetes in the Northern Manhattan Study [23]	Sugar-sweetened soda (SSB) and artificially sweetened soda (ASB) consumption with incidence of type 2 diabetes in the Northern Manhattan Study.	2019 participants aged >40 years. The sampling technique used was community-based convenience sampling.	• *Prospective Cohort Study*. • The analysis used Weibull regression models to calculate the hazard ratio (HR).	Daily consumption of SSBs increased the risk of type 2 diabetes by 15% (HR = 1.15), while consumption of ASBs increased the risk by 63% in individuals with a BMI ≥25 (HR = 1.63). Replacing SSBs with ASBs did not show a protective effect, indicating that ASBs may not be a safe alternative.
8	Hiratake et al. (2019) Cumulative intake of artificially sweetened and sugar-sweetened beverages and risk of incident type 2 diabetes in young adults: the Coronary Artery Risk Development In Young Adults (CARDIA) Study[24]	ASB and SSB consumption with risk of type 2 diabetes in young adults	4,719 participants aged 18–30 years in the Coronary Artery Risk Development in Young Adults (CARDIA) study. The sampling technique used was stratified random sampling.	• *Prospective Cohort Study* • Analysis using Cox proportional hazards regression models. • Beverage consumption was measured through the CARDIA Diet History.	ASB consumption increased the risk of type 2 diabetes by 12% per serving/day, but the association weakened after adjusting for body weight. SSB increased the risk by 6% per serving/day, and total ASB + SSB consumption increased the risk by 5%.
9	Imamura et al. (2019) Estimated Substitution of Tea or Coffee for Sugar-Sweetened Beverages Was Associated with Lower Type 2 Diabetes Incidence in Case–Cohort Analysis across 8 European Countries in the EPIC-InterAct Study[25]	SSB consumption with risk of type 2 diabetes and potential benefits of substitution with tea, coffee, fruit juice, or milk.	27,662 participants from 8 European countries from the Prospective Investigation into Cancer and Nutrition (EPIC)-InterAct case-cohort study. The sampling	• *Prospective Case-Cohort Study* • Analysis was performed using the Prentice-weighted Cox regression model to evaluate beverage substitution on the risk of T2DM.	Each 250 g/day increase in SSB consumption increased the risk of type 2 diabetes by 25% (HR = 1.25). Replacing SSBs with coffee or tea without added sugar reduced the risk by 21% and 22%, respectively. Substitution with fruit juice or milk showed no significant effect.

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			technique used was multistage stratified random sampling.		
10	Janzi et al. (2024) Added sugar intake and its associations with incidence of seven different cardiovascular diseases in 69,705 Swedish men and women. [26]	Added sugar intake and risk of some CVDs	69,705 participants from the Swedish Mammography Cohort (SMC) and the Cohort of Swedish Men (COSM). The sampling technique used was volunteer sampling.	• Prospective Cohort Study • Consumption frequency was measured using FFQ • Statistical analysis using Cox proportional hazards regression	Added sugar intake was significantly associated with an increased risk of ischemic stroke (Ptrend = 0.05) and abdominal aortic aneurysm (Ptrend < 0.01), but there was no significant association with other CVDs.
11	Malik et al. (2019) Long-Term Consumption of Sugar Sweetened and Artificially Sweetened Beverages and Risk of Mortality in US Adults [27]	SSB and ASB consumption with mortality from CVD and cancer	80,647 female participants from the NHS and 37,716 male participants from the HPFS. The sampling technique used was volunteer sampling.	• Prospective cohort study • SSB consumption was assessed using a FFQ. • Analysis using Cox proportional hazard models.	Consuming SSBs ≥2 times/day increased the risk of total mortality (HR = 1.21), CVD mortality (HR = 1.31), and cancer mortality (HR = 1.16). Consuming ASBs was only associated with an increased risk of mortality in women with high consumption (≥4 times/day), but the effect was not significant in men.
12	Mossavar-Rahmani et al. (2019) Artificially Sweetened Beverages and Stroke, Coronary Heart Disease, and All-Cause Mortality in the Women's Health Initiative [28]	ASB consumption with risk of stroke, coronary heart disease (CHD), and death in postmenopausal women	81,714 postmenopausal women (aged 50–79 years) from the Women's Health Initiative Observational Study (WHI-OS). The sampling technique used was volunteer sampling.	• Prospective cohort study. • ASB consumption was assessed through a self-reported dietary questionnaire. • Statistical analysis using the Cox proportional hazards model	Consuming ≥2 ASB per day increased the risk of all types of stroke (HR = 1.23), ischemic stroke (HR = 1.31), coronary heart disease (HR = 1.29), and all-cause mortality (HR = 1.16). The risk of ischemic stroke with small artery occlusion more than doubled in obese women (HR = 2.03) and those without a history of CVD or diabetes (HR = 2.44).
13	O'Connor et al. (2015) Prospective associations and population impact of sweet beverage intake and type 2 diabetes, and effects of substitutions with alternative beverages [29]	SSB consumption with the risk of type 2 diabetes and the impact of replacing SSB with other alternatives	25,639 adults from the EPIC-Norfolk Cohort, aged 40–79 years, who were not diagnosed with diabetes at baseline. The sampling technique used was volunteer sampling.	• Prospective cohort study. • ASB and SSB consumption was assessed through a food diary for 7 days. • Statistical analysis using the Cox proportional hazards model	Consumption of soft drinks and sweetened milk each increased the risk of diabetes by approximately 21–22%. The association between SSBs and diabetes was not significant after adjusting for adiposity. Replacing one serving of SSBs with water or unsweetened tea/coffee reduced the risk of diabetes by 25%, and reducing SSB

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					consumption prevented 15% of diabetes cases.
14	Pacheco et al. (2020) Sugar-Sweetened Beverage Intake and Cardiovascular Disease Risk in the California Teachers Study [30]	SSB consumption with risk of CVD, including myocardial infarction, stroke, and revascularizatio n	106,178 women without a history of CVD and DM at baseline, from the California Teachers Study, with 20 years of follow-up. The sampling technique used was volunteer sampling.	• Prospective cohort study • Measurement of SSB consumption using FFQ • Statistical analysis using cox proportional hazard regression.	Consuming one or more servings of SSBs per day was associated with an increased risk of CVD (HR = 1.19), revascularization (HR = 1.26), and stroke (HR = 1.21). CVD risk was also higher among those consuming more than one serving of fruit drinks (HR = 1.42) and caloric soft drinks (HR = 1.23) per day.
15	Papier et al. (2017) Consumption of sugar-sweetened beverages and type 2 diabetes incidence in Thai adults: results from an 8-year prospective study [31]	SSB consumption with DMT2 incidence	39,175 participants from the Thai Cohort Study who did not have diabetes at the start of the study. The sampling technique used was volunteer sampling.	• Prospective cohort study • SSB consumption was assessed through a FFQ. • Statistical analysis using a multivariate logistic regression test	Consuming SSBs ≥1 time per day significantly increased the risk of diabetes in women (OR = 2.4), but no significant association was found in men. Obesity acted as a mediator in the association between SSB consumption and diabetes incidence.
16	Schaefer et al. (2024) Association of sugar intake from different sources with cardiovascular disease incidence in the prospective cohort of UK Biobank participants [32]	Sugar intake from various sources with CVD incidence in the UK Biobank cohort study	176,352 participants from the UK Biobank. Aged 37–73 years. Sampling technique used: volunteer sampling.	• Prospective cohort study • Measurement of sugar intake is categorized as free sugar (FS) and intrinsic sugar (FI). • Statistical analysis using Cox proportional hazard regression	There was a linear relationship between sugar intake from beverages and increased CVD, with the highest risk (HR = 1.24) at sugar consumption of 20% of total daily energy. Consumption of soda or fruit drinks also significantly increased CVD risk (HR = 1.14 at 10%E and HR = 1.27 at 15%E). Conversely, intrinsic sugars from natural foods such as fruit were associated with a reduced CVD risk.
17	Viana-Dias et al. (2023) Consumption of sweetened beverages is associated with the incidence of type 2 diabetes in Brazilian adults (CUME project)[33]	SSB consumption is associated with the incidence of type 2 DM.	2,480 participants from the Cohort of Minas Gerais (CUME) study in Brazil. The sampling technique used was volunteer sampling.	• Prospective cohort • SSB consumption was assessed using a FFQ. • Using Generalized Estimating Equations (GEE)	SSB consumption of ≥ 47.7 kcal/day increased the risk of diabetes by 63% (OR = 1.63). This risk was also influenced by age, overweight, and low physical activity. However, overweight only mediated 4.4% of the association between SSB consumption and diabetes.
18	Zhu et al. (2024) Beverage Consumption, Genetic Predisposition,	Consumption of SSB, ASB, and	7,315 participants with T2DM from the UK Biobank	• Prospective cohort study	Consumption of ≥2 servings of SSB per day was associated with a 54%

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No	Author, Year, Title	Objective	Population and sampling techniques	Method	Results
	and Risk of Cardiovascular Disease Among Adults With Type 2 Diabetes [34]	natural juices with CVD risk	Study. The sampling technique used was volunteer sampling.	• SSB and ASB consumption using Oxford WebQ 24-h dietary recall • Statistical analysis using Cox proportional hazards regression	increased risk of CVD (HR = 1.54), and consumption of ≥2 servings of ASB/day increased CVD risk by 34%. Substitution of SSB with coffee, tea, or yogurt reduced CVD risk by 20%–46%, but substitution with ASB did not show a significant benefit.

DISCUSSION

The Relationship between SSB and ASB Consumption and DMT2 Disease

Seventeen articles were cohort studies, and one was cross-sectional. The cohort design allows for assessment of the temporal relationship between SB/ASB consumption and the incidence of T2DM and CVD, providing a more robust risk estimate. Meanwhile, cross-sectional studies also indicate a positive association, but cannot confirm the causal sequence. Therefore, findings from cohort studies provide more support for the possibility of a causal association, while cross-sectional studies complement the existing picture.

Most studies in this review demonstrated a positive association between SSB and ASB consumption and the risk of T2DM. Relative risks (RRs) in the form of HRs and ORs ranged from 1.06 to 2.40, indicating variations in the strength of the association across populations and frequency of consumption. A study by Papier et al. reported the highest risk, with an OR of 2.40, for women who consumed SSBs ≥1 time per day[31]. In a study conducted by Ding et al., it was found that increased consumption of SSB and ASB was significantly associated with an increased risk of T2DM by 17% (HR = 1.17%) and 54% (HR = 1.54), respectively[16]. A similar finding was found in the study by Drouin-Chartier et al., who analyzed three large cohorts in the United States, finding that the risk of T2DM in women and men increased by 16% (HR = 1.16%) along with increased SSB consumption compared to the group that did not or reduced SSB consumption[22]. However, one study by Akinbule et al. recorded an OR of 15.2 for consuming sweetened fruit drinks twice per week[18]. The study used a cross-sectional design, which cannot confirm causality and is highly susceptible to information bias and overestimation of associations.

ASB is often used as an alternative to SSB and is considered a healthier option because it is low in energy or even zero[13]. Based on research by Gardener et al., diet soda consumption has a positive association with the incidence of diabetes in subjects with a BMI > 25.0 (HR = 1.63)[23]. Meanwhile, in a study by Ding et al., ASB consumption > 2 servings/day increased the risk of DMT2 by 54%[16]. Cumulative ASB consumption increased the risk of T2DM in young adults in the CARDIA study (HR = 1.12)[24].ASB consumption habits are associated with beta-cell dysfunction and insulin resistance, which are major contributors to the development of diabetes mellitus[21]. These results indicate that consumption of SSB and ASB has the potential to increase the risk of diabetes, especially when consumed in large amounts.

Relationship between SSB and ASB Consumption with CVD

The association between SSB and ASB consumption and CVD has been demonstrated in several prospective cohort studies. The HRs found for CVD outcomes in these reviews ranged from 1.09 to 2.44. Consuming ≥2 servings of SSB per day increased the risk of CVD by 54% (HR = 1.54), while ASB increased the risk by 34% (HR = 1.34)[34]. Similarly, research by DeChristopher et. al. found that individuals who

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consumed high-fructose corn syrup had a 70% higher risk of developing CVD (HR = 1.7).[20]. Sugar intake from beverages contributed significantly to cardiovascular events in a UK biobank cohort study[32]. Furthermore, added sugar intake was significantly associated with the incidence of 7 types of CVD in a Swedish cohort study (HR = 1.19)[26].

The cardiovascular impact of ASB consumption remains a topic of debate and requires further research. However, several studies have shown a link between ASB consumption and CVD. The highest risk was found in a study by Mossavar-Rahmani et al., who found that obese women who consumed ASB ≥ 2 times per day had a twofold increased risk of small artery ischemic stroke (HR = 2.44)[28]. Based on a study conducted by Debras et al., it was found that artificial sweetener intake was associated with an increased risk of CVD in the NutriNet-Sante group (HR = 1.09)[19]. In postmenopausal women, increased ASB consumption was associated with increased risk of stroke (HR = 1.23), coronary heart disease (HR = 1.29), and all-cause mortality (HR = 1.16) [28]. Meanwhile, in a study conducted by Malik et al., ASB consumption had no significant association with CVD, except in the group of women with very high consumption (> 4 times a day)[27].

Biological Mechanisms of SSB and ASB Consumption with DMT2 and CVD

In several prospective cohort studies, it was found that SSB induces a glucose spike that causes pancreatic beta cell dysfunction and insulin resistance, which characterizes the development of diabetes[16], [22], [31]. In addition, individuals with higher SSB consumption showed decreased insulin sensitivity[35]. Habitual consumption of SSB triggers proinflammatory cytokines (TNF alpha, IL-6) and oxidative stress, which contribute to blood vessel damage and atherosclerosis[26], [27]. Other studies have shown that SSB consumption is associated with increased blood pressure and uric acid levels, which are independent risk factors for heart and blood vessel disease[32], [36].

Excessive ASB intake is associated with disruption of the intestinal microbiota balance and reduced microbial diversity, which has the potential to increase the risk of T2DM.[19], [37]. Changes in the gut microbiota can trigger low-grade systemic inflammation and progress to metabolic dysregulation that contributes to disease progression[21], [38]. Regular consumption of artificially sweetened soft drinks is associated with lower beta-cell glucose sensitivity, total insulin secretion, and lower beta-cell rate sensitivity[21]. In addition, ASB can trigger the cephalic phase insulin response (CPIR) and the perception of sweet taste without caloric intake, which can interfere with insulin secretion[23], [24]. However, the mechanism by which ASB causes CVD still requires further research.

Practical Implications

This systematic review consistently demonstrates that consumption of sugar-sweetened beverages (SSBs) and artificially sweetened beverages (ASBs) is associated with an increased risk of T2DM and CVD. Given the increasing prevalence of T2DM and CVD globally, interventions targeting the reduction of SSB and ASB consumption are needed. Reducing consumption of sugar-sweetened beverages should be part of national and local non-communicable disease prevention policies.

First, policies are needed to limit the consumption of sugar-sweetened beverages (SSBs), such as a tax on sweetened beverages (SSBs), sugar labeling, and regulation of sugar-sweetened beverage advertising. Taxing sugar-sweetened beverages could be an effective public health policy strategy[25], [27]. In some countries, taxes on sugary drinks are applied through an ad valorem scheme (based on a percentage) or the amount of sugar content.[39]. Taxes can reduce consumer demand for sugary drinks by raising the price of goods and creating an economic incentive to choose healthier drinks such Consuming water, unsweetened tea or coffee, unsweetened natural fruit juice, or low-fat milk has a protective effect against the occurrence of DMT2 and CVD[25], [40]. WHO

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recommends that sugar intake should be reduced to 10% and ideally <5% of total daily energy intake to provide better health benefits.[41].Community-based interventions and nutrition education are essential, particularly in the productive age group who tend to have higher SSB consumption[42]. Second, the results of various studies show that ASB is not a completely safe alternative[15], [27], [28]. Daily ASB consumption is even associated with an increased risk of stroke, coronary heart disease, and mortality.[19], [27], [28]. Therefore, the promotion of ASB as a replacement for SSB needs to be comprehensively reviewed. Third, these findings emphasize the importance of considering the biological mechanisms that may be involved, such as metabolic dysfunction, insulin resistance, chronic inflammation, and gut microbiota disturbances[43], [44].

Strengths and Limitations of the Study

This systematic review has several methodological strengths that substantially enhance the validity and generalizability of the findings. First, the inclusion of a large number of participants from multiple prospective longitudinal cohort studies provides high statistical power, reducing the likelihood of random error and increasing the statistical power to detect significant associations. Furthermore, geographic and sociodemographic differences allow for a broader exploration of the varying impacts of SSB and ASB beverage consumption across population groups.

However, there are several limitations that need to be considered. One major limitation is the differences in operational definitions of SSBs and ASBs across studies, which can lead to methodological heterogeneity and reduce the equivalence of comparisons between findings. Furthermore, the risk of residual confounding and reverse causation remains a challenge, particularly in observational studies. Unmeasured confounding variables can impact the validity of observed causal relationships. Finally, the availability of long-term randomized controlled trials (RCTs) on the impact of ASBs on health is still limited. Further research is needed to standardize the definitions of SSBs and ASBs, refine longitudinal study designs, and conduct long-term RCTs that can strengthen the scientific evidence base regarding the implications of SSB and ASB consumption for metabolic and cardiovascular health.

CONCLUSION

The results of this systematic review indicate that consumption of sugar-sweetened beverages (SSBs) and artificially sweetened beverages (ASBs) is consistently associated with an increased risk of T2DM and CVD. Based on the reviewed articles, the relative risk of T2DM due to SSB and ASB consumption ranged from 1.06 to 2.40. Meanwhile, the risk of CVD incidence ranged from 1.09 to 2.44, depending on the type of beverage, frequency of consumption, and characteristics of the population studied. Although ASBs are often considered a healthier alternative, several studies have shown adverse metabolic effects. Based on this, strategies to control SSB consumption should not focus on substitution with ASBs, but rather on limiting the consumption of both. Therefore, public policies are needed, including marketing regulations, sugar labeling, nutrition education, and fiscal policies such as the implementation of a tax on sweetened beverages to support improved public health.

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