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REVIEW ARTICLE

The Impact of Sugar-Sweetened Beverages on Type 2 Diabetes Mellitus: A Scoping Review

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ABSTRACT

Background: The increasing consumption of sugar-sweetened beverages (SSBs) has become a major public health concern due to its link with metabolic diseases, particularly Type 2 Diabetes Mellitus (T2DM). Understanding the relationship between SSB consumption and the risk and progression of T2DM, particularly in adult populations, is crucial for developing targeted interventions. This scoping review aims to summarize observational studies that investigate the association between SSB consumption and T2DM risk and progression in adult populations. **Methods**: This scoping review included nine studies published between 2017 and 2023. The inclusion criteria were studies that involved adult populations (≥18 years) and explored the relationship between SSB consumption and T2DM. Databases such as PubMed and Google Scholar were searched using keywords like 'sugar-sweetened beverages,' 'type 2 diabetes,' and 'adult,' and 'progression. **Results**: The studies reviewed consistently showed a positive association between frequent SSB consumption and the risk of developing T2DM. Overall, the evidence supports that SSBs contribute significantly to the incidence and progression of T2DM, often through weight gain and increased insulin resistance. **Conclusions**: This review shows the strong association between SSBs and T2DM, urgent public health interventions are needed to regulate consumption, particularly among high-risk groups. Future research is needed to examine the long-term impact of SSB on diabetes.

Keywords: Adult, Type 2 Diabetes Mellitus, Scoping review, Sugar Sweetened Beverages

INTRODUCTION

Type 2 diabetes is acknowledged as a significant public health challenge that profoundly affects population health and the expenses associated with healthcare. The acceleration of economic growth and urbanization has led to increased incidence of diabetes in regions across the globe. Diabetes impairs individuals' functional capacities and quality of life, resulting in significant morbidity and premature mortality. Recent analyses have highlighted that over one-third of fatalities to diabetes occur among adults younger than 60 years of age (Cooppan, 2016).

The growing consumption of sugar-sweetened beverages in Indonesia has become an important issue, as it contributes to the rising cases of non-communicable diseases such as diabetes, obesity, heart disease, and cancer. High blood sugar levels can lead to vascular damage, which in turn affects vital organs like the liver, eyes, kidneys, and nerves, often resulting in severe complications (Lu et al., 2023). Diabetes, in particular, is becoming increasingly common across all age groups. In 2015, an estimated 415 million people aged 20–79 were living with diabetes, and this number is expected to climb to 642 million by 2040, with most cases occurring in low- and middle-income countries

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(Ogurtsova et al., 2017). This number is projected to rise to 642 million by 2040, with the majority of cases occurring in low- and middle-income countries (Ogurtsova, 2020). The increasing prevalence of diabetes poses significant challenges to global health systems, with substantial economic implications.

Drinks take a key part in an adult's diet partly because they help to maintain the body hydrated; some types of drinks even contain vitamins and minerals. However, some drinks, called sugar-sweetened beverages (SSB), have calories but lacking in nutritional value (Miller et al., 2017). Sugar-Sweetened Beverages (SSBs) are a leading source of added dietary sugar, that can lead to weight gain and obesity, the well-known risk factors for Diabetes Mellitus Type 2 (Huang et al., 2017). Several prospective cohort studies further showed that consumption of SSBs is significantly associated with an increased risk for type 2 diabetes (Wang et al., 2015). In 2021 about 537 million adults worldwide had diabetes and this number is projected to rise to 783 million by 2045 (Ma et al., 2023). Association recommendations suggest that nonnutritive sweeteners could replace added sugar within an established diet to maintain appropriate body weight and avoid risk; however, the evidence is inconclusive on the risks and benefits of nonnutritive sweeteners, including artificially sweetened beverages (ASBs).

According to global data from the International Diabetes Federation (IDF) in 2019, around 463 million people worldwide were living with diabetes. This is a serious concern, as the number is expected to grow significantly, potentially reaching 700 million by 2045. The rising number of individuals with diabetes is partly attributed to lifestyle factors, including the unrestricted consumption of SSB. The associated issues and concerns stemming from the consumption of these beverages highlight the need for greater attention to this public health challenge (Nasution et al., 2022).

Given the increase in SSB consumption and its impact on the prevalence of T2DM, a more comprehensive understanding of the relationship between SSB consumption and the risk and progression of T2DM is needed, particularly in the adult population. Therefore, this study aims to summarize the evidence from observational studies that explore the association between SSB consumption and T2DM, to provide deeper insights for future public health interventions and SSB consumption control policies.

METHODS

A flow diagram based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) was used to illustrate the study selection process, from the initial search to the final selection of studies. The study approach was implemented to identify the relationship between SSB and T2DM.

The focus of the research were: 1) Which evaluation instruments are used to assess Sugar Sweetened Beverages consumption in adult?; 2) What is the relation between Sugar Sweetened Beverages and the risk of developing Type 2 Diabetes Mellitus?

The electronic databases, including Google Scholar and PubMed, were utilized to conduct a thorough electronic search. An extensive examination was conducted of all full-text accessible scholarly journals published in English from 2017 to 2023 that pertained to the subject matter. The search encompassed a diverse array of research design methodologies, including cross-sectional studies, cohort studies, and prospective household-based investigations.

During a thorough review, the papers were decided on given the data related: 1) the study population consisting of adults; 2) the prevalence of T2DM in Adult; 3) the relation between Sugar-Sweetened Beverages and Diabetes Mellitus Type 2; We use key search terms Sugar-Sweetened Beverage AND Diabetes Mellitus AND Adult.

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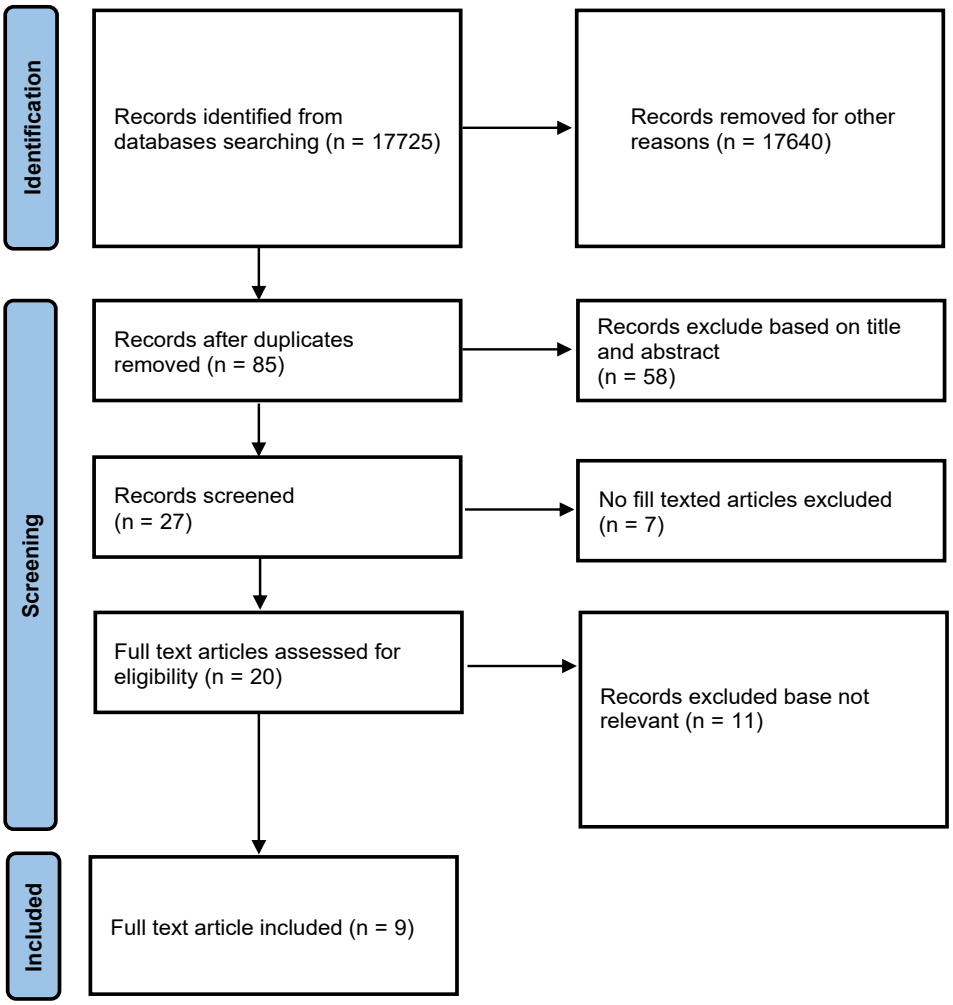

Figure 1. Flowchart of Scoping Review

RESULTS AND DISCUSSION

During the search process, nine studies were selected for the final screening, as shown in Figure 1. This review summarizes the findings on the assessment of SSB, T2DM, and the result of the study, as presented in Table 1.

Table 1. Review Summary of Review

Country: Authors	Study Design	Sample	Participant Characteristics	Assessment Tool	Results
United States; Seung Hee Lee, et al, (2023)(Lee et al., 2023)	cross-sectional study	658	18 - 50 years old	The Omnibus survey	Nearly 7 of 10 adults reported consuming an SSB (1–6 times) in the past 7 days, and more than a third (38%) reported doing so once or more per day (on average). Over half of respondents (56%) reported they consume SSBs because

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Country: Authors	Study Design	Sample	Participant Characteristics	Assessment Tool	Results
					they enjoy the taste. Younger adults (18–34 years old) were more likely to consume SSBs in social settings than older adults (≥50 years old). Younger and middle-aged adults were more likely to consume SSBs due to cravings and the enjoyment of the carbonation compared to older adults.
United States; Jee-Young Moon, et al., (2021)(Moon et al., 2022)	cross-sectional	9965	18 - 74 years old	Two 24-h dietary recalls and a food propensity questionnaire.	Larger consumption of sugar-sweetened beverages among Hispanic/Latino people in the United States was linked to an elevated risk of prediabetes and higher glucose metabolism indicators. Consuming large amounts of sugar-sweetened beverages has been linked to greater T2D prevalence.
United States; Fang Xu, et al., (2018)(Xu et al., 2017)	cross-sectional study	13 268 adults with diabetes and 9330 adults with prediabetes	≥18 years	-	In this study, 1 in 5 adults with diabetes, 2 in 5 adults with prediabetes, and approximately 1 in 3 adults without diabetes or prediabetes reported consuming sugar-sweetened beverages (SSBs) at least once a day. Regular consumption of SSBs is linked to a higher incidence of Type 2 diabetes.
Thailand; K Papier, et al., (2017)(Papier et al., 2017)	Cohort Study	39,175 Thai adults	24-30 years old	-	In this prospective cohort of Thai people, SSB consumption corresponded with an elevated risk of T2DM in women, and this risk increased with greater amounts of consumption. Results revealed that BMI mediated a moderate fraction of the SSB-T2DM connection (23%), with the proportion rising with increasing BMI.
United States; Kristin M Hirahatake, et al. (2018)(Hirahatake et al., 2019)	Cohort study	4719 Black and White Men and Women	18-30 years old	Recall, CARDIA diet history	There is a positive correlation between higher intake of artificially sweetened beverages (ASB), sugar-sweetened beverages (SSB),

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Country: Authors	Study Design	Sample	Participant Characteristics	Assessment Tool	Results
					and total sweetened beverages (TSB) and the risk of developing Type 2 Diabetes (T2D) over a span of 30 years. SSB consumption has often been associated with weight gain and an increased risk of T2D in observational studies.
China; Yanping Li, et al. (2017)(Li et al., 2017)	Prospective household-based study	4,400 households with a total of 26,000 individuals in nine provinces.	20 years and older	-	In a large and representative adult Chinese population, the number of diabetes cases attributed to modifiable risk factors, such as high BMI and sugar-sweetened beverages (SSBs), was estimated. This explains why individuals in China tend to have a higher risk of diabetes, with increases in insulin resistance and other diabetes risk factors for each unit increase in BMI.
Japan; Sakurai, et al.,(2017)(Sakurai et al., 2014)	cohort study	2037	35–55 years old	a self-administered diet history questionnaire.	Individuals who consumed larger quantities of sugar-sweetened beverages (SSBs) were notably younger and had higher BMI, fasting insulin levels, HOMA-IR, and total energy intake. They also had lower serum HDL-cholesterol levels and reduced energy-adjusted dietary fiber intake.
United States, Mengna Huang, et al., 2017(Huang et al., 2017)	Cohort study	93,676 women	50-79 years	FFQ	Both artificially sweetened beverages (ASBs) and sugar-sweetened beverages (SSBs) were linked to a higher risk of diabetes, independent of several known risk factors, including BMI, changes in BMI, and total energy intake at the beginning of the follow-up period.
United States, Le Ma, et al., 2023(Ma et al., 2023)	Cohort study	15,486 men and women	30-55 years old	FFQ	Researchers stated that higher consumption of sugar-sweetened beverages (SSBs) was linked to increased all-cause mortality, including deaths from cardiovascular diseases (CVD) and Type 2 diabetes mellitus.

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The findings of this scoping review indicate a strong and consistent association between SSB consumption and an increased risk of T2DM. Multiple observational studies reviewed in this study found that frequent SSB intake contributes to weight gain, insulin resistance, and an overall higher likelihood of developing T2DM. This aligns with previous meta-analyses that have established excess sugar intake as a key driver of metabolic disturbances, particularly through its role in increasing visceral fat accumulation and impairing glucose homeostasis (Wang et al., 2015; Kelishadi et al., 2014). The current review further highlights that younger adults (18–34 years old) have the highest consumption rates, suggesting that early dietary patterns could significantly influence long-term metabolic health outcomes. These findings emphasize the need for early prevention strategies targeting young populations, given the rising global prevalence of diabetes.

BMI serves as a key mediator in the relationship between sugar-sweetened beverage (SSB) consumption and type 2 diabetes (T2DM) risk. Several studies indicate that the impact of SSBs on diabetes is partially or fully explained by weight gain, reinforcing the idea that excess calorie intake from SSBs contributes to obesity, which in turn increases diabetes risk (Veit et al., 2022; Malik & Hu, 2022;Tseng et al., 2021). However, recent research confirms that SSBs remain an independent risk factor for T2DM and cardiovascular disease (CVD), even after adjusting for adiposity (Malik, 2017; Malik & Hu, 2019, 2022).

Beyond weight gain, other mechanisms such as adverse glycemic effects and increased hepatic fructose metabolism also play a role. The SSB-T2DM association remains strong even after BMI adjustment, suggesting that SSBs affect metabolic health beyond their impact on weight. Interestingly, previous research found that adjusting for body fat percentage, rather than BMI, weakened the SSB-T2DM association, indicating that BMI may not fully capture adiposity-related effects. Thus, evaluating the health impact of SSBs requires considering both weight-related and broader metabolic factors (Malik & Hu, 2019; Malik, 2017; Hu & Malik, 2010; Greenwood et al., 2014).

Another critical aspect of the discussion is the dose-response relationship between SSB intake and T2DM risk. A dose-response meta-analysis found that each additional daily serving of SSBs raised the risk of type 2 diabetes (T2D) by 27% and cardiovascular diseases by 9% (Meng et al., 2021). This aligns with earlier findings showing a 26% higher T2D risk for those consuming 1-2 SSB servings daily compared to less than monthly (Malik et al., 2010). The evidence consistently links SSB intake to weight gain, T2D, and coronary heart disease, independent of adiposity (Malik & Hu, 2019). While some studies report no negative effects, most epidemiological research strongly indicates that frequent SSB consumption contributes to metabolic syndrome development over time(Deshpande et al., 2017). These findings underscore the importance of reducing SSB intake to improve cardiometabolic health at both individual and population levels (Malik & Hu, 2019).

The reviewed studies also provided important insights into demographic and geographic variations in SSB-related diabetes risk. Meta-analyses studied have shown that high SSB consumption is associated with a 26% increased risk of developing type 2 diabetes(Malik et al., 2010).This risk is particularly pronounced in certain populations, with studies in Thailand revealing that women who consume SSBs daily have 2.4 times higher odds of developing diabetes over 8 years (Papier et al., 2017). The Latinx population in the United States also exhibits higher rates of SSB consumption and related health issues (Castellanos et al., 2022). These disparities underscore the need for targeted interventions and policy actions to reduce SSB intake, especially in low- and middle-income countries where consumption is increasing due to urbanization and economic growth (Malik & Hu, 2022; Lara-Castor et al., 2023; Santos et al., 2022). Addressing these challenges requires comprehensive strategies that consider socio-ecological factors influencing SSB consumption patterns.

Overall, the findings of this review reinforce the well-established role of SSBs as a modifiable risk factor for T2DM and emphasize the urgent need for public health strategies to reduce consumption.

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Implementing SSB taxation policies, restricting marketing to vulnerable populations, and promoting healthier beverage alternatives have been shown to be effective strategies in various countries. Additionally, more research is needed to explore long-term intervention outcomes, the impact of sugar substitutes, and potential genetic influences on SSB metabolism. Given the growing prevalence of diabetes, future studies should also investigate the effectiveness of comprehensive lifestyle interventions that combine dietary modifications with physical activity and behavioral changes. By addressing these gaps, policymakers and healthcare providers can develop more effective strategies to combat the rising global diabetes epidemic.

Behavioral and social aspects within a population play a crucial role in shaping consumption patterns of SSBs. Individual taste preferences, desires, and the hedonistic appeal of sweet drinks have consistently been reported as strong drivers of consumption(Farrar & Papies, 2024). Meanwhile, social influences, including peer norms, family environments, and marketing exposure, further reinforce repeated intakes (Calabro et al., 2023). Other factors such as socioeconomic status and accessibility significantly determine purchasing behavior with low-income groups often having greater consump of SSB (Purohit et al., 2023). These findings underscore the need for community-based interventions that address not only individual behaviors but also the broader social and environmental determinants of health. Labeling, restrictions on advertising to children, and health education campaigns tailored to local cultures are effective measures to reduce SSB consumption in the community (Rostami et al., 2024).

Despite the strengths of this scoping review in summarizing evidence on the relationship between sugar-sweetened beverage (SSB) consumption and type 2 diabetes mellitus (T2DM), several limitations should be acknowledged. First, the review relies primarily on observational studies, which can establish associations but not causation. The absence of randomized controlled trials (RCTs) limits the ability to infer direct causal mechanisms. Second, the studies included were conducted in diverse populations with varying dietary patterns and lifestyle factors, making it challenging to generalize findings globally. Third, potential confounding factors, such as physical activity levels, total dietary intake, genetic predisposition, and socioeconomic status, were not uniformly controlled across the studies, which could influence the observed associations. Lastly, the review only included studies published between 2017 and 2023, potentially excluding older but still relevant research that might provide additional insights into long-term trends and mechanisms.

Another limitation is the potential for publication bias. Most of the included studies were peer-reviewed and observational, which may favor the reporting of positive associations between SSB intake and T2DM risk, while studies showing null or negative results might be underrepresented. This selective availability of evidence could lead to an overestimation of the strength of the association reported in this review. Future research should aim to mitigate this bias by incorporating unpublished studies, grey literature, and ongoing clinical trial data. In addition, systematic reviews employing funnel plots and sensitivity analyses can further help assess and adjust for the impact of publication bias in the evidence base. Future research should address these limitations by incorporating more rigorous study designs, including prospective cohort studies and randomized interventions, to strengthen the evidence base.

CONCLUSIONS

This scoping review confirms a strong association between SSB consumption and an increased risk of T2DM, primarily through its effects on obesity, insulin resistance, and metabolic dysfunction. While younger adults and specific demographic groups are particularly vulnerable, findings suggest that frequent SSB intake may independently contribute to diabetes risk beyond weight gain. Despite limitations such as reliance on observational studies and potential confounding factors, the evidence underscores the urgent need for regulatory policies, public health campaigns,

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and clinical interventions to reduce SSB consumption. Implementing taxation, clear labeling, marketing restrictions, and community-based education can help reshape dietary habits and lower the global burden of diabetes and other metabolic diseases.

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