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Original Research

Sugar-Sweetened Beverage Use Pattern in the First Trimester is Associated with Gestational Diabetes Mellitus

Chin-Ru Ker[1,2,†], Wei-Yun Hsu[2,†], Hui-Yu Chuang[1,2], Chien-Hung Lee[3], Shih-Han Wang[1,2], Te-Fu Chan[1,2,4,*]

[1]Department of Obstetrics and Gynecology, Graduate Institute of Medicine, College of Medicine, Kaohsiung Medical University, 807 Kaohsiung, Taiwan
[2]Department of Obstetrics and Gynecology, Kaohsiung Medical University Hospital, Kaohsiung Medical University, 807 Kaohsiung, Taiwan
[3]Department of Public Health, College of Health Science, Kaohsiung Medical University, 807 Kaohsiung, Taiwan
[4]Center of Cancer Research, Kaohsiung Medical University, 807 Kaohsiung, Taiwan
*Correspondence: Tefu.chan@msa.hinet.net (Te-Fu Chan)
†These authors contributed equally.
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Abstract

Background: Sugar-sweetened beverage (SSB) is known to increase risks for many health problems in the general population, but its association with gestational diabetes mellitus (GDM) is rarely discussed. Consumption amount of SSB could be subjected to recall biases and estimation errors, whereas psychological dependence using a standardized assessment tool would provide more persistent and objective measurements. Therefore, we hypothesize that desire of SSB may play a role in developing GDM. **Methods**: This prospective cohort study recruited 183 pregnant women, who answered self-describing questionnaires designed to depict SSB use behaviors. The desire to drink SSBs was assessed using the modified Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria for substance use disorder (SUD), with questions specific for SSB use. All participants received a 75-gram oral glucose tolerance test during 24th–28th weeks of gestation to screen for GDM. **Results**: Age, body mass index, and SSB-related SUD DSM-5 items were significant predictive factors of GDM, with odds ratios of 1.112 (95% confidence interval 1.018–1.214), 1.208 (95% confidence interval 1.079–1.353), and 1.338 (95% confidence interval 1.077–1.664), respectively. SUD DSM-5 scores positively correlate with education level (p = 0.046), frequency of dining out (p = 0.028), sedentary lifestyle (p = 0.001), and negatively with water intake amount (p = 0.033). **Conclusions**: The current study is the first to find a positive association between SSB intake pattern and GDM risk. Specifically, every SSB-related DSM point scored increases GDM risk by 33%, which did not necessarily reflect on the reported SSB consumption amount. To offer useful and specific behavioral advices, decreasing frequencies of dining out, increasing exercises and encouraging plain water intake might be helpful.

Keywords: gestational diabetes; sugar-sweetened beverage; sugar consumption; high risk pregnancy

1. Introduction

According to the global statistics reported by International Diabetes Federation (IDF), the prevalence of diabetes worldwide is 463 million in 2019 with an alarming growth rate. IDF reports that 1 in 6 livebirths is affected by hyperglycemia in pregnancy in 2019, which equates to 20 million live births, among which 84% was due to gestational diabetes [1]. If left unattended, maternal and neonatal complications are common and might increase lifetime risks of certain diseases [2–9]. Current practice guidelines recommend all pregnant women to be screened for gestational diabetes mellitus (GDM) during gestation 24–28 weeks [9–14].

Tea shops are all over the places in Taiwan and hand-shaken sugar-sweetened beverages play an important role in most of Taiwaneses daily life. However, sugar-sweetened beverages (SSB) have been found to increase risks of weight gain, obesity, metabolic syndrome, type 2 diabetes, coronary heart diseases and stroke…etc. [15–19]. More SSB consumption in middle-aged adults leads to higher incidence of prediabetes and insulin resistance [20,21]. One additional serving per day of SSBs is found to increase the risk of type 2 diabetes development in Imamura *et al.*'s study [22]. Others demonstrate reducing SSB intake decreases prevalence of obesity and its related health problems [23]. However, the association between SSB use in pregnancy and GDM has rarely been investigated in current literature. The aim of the present study is to determine a correlation between SSB use and GDM, not just simply the SSB amount consumed, but also the degree of psychological dependence for SSB by employing modified Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria for substance use disorder (SUD) [24,25]. Consumption amount could be subjected to recall biases and estimation errors, whereas psychological dependence using a standardized assessment tool would provide more persistent and objective measurements. We hypoth-

Table 1. Demographic information (Values are expressed as n, or mean ± SD).

	GDM (N = 44)	Control (N = 139)	*p* value
Education level			
High school	9	12	0.092
University	30	105	
Postgraduate	5	22	
Age (years)	35.2 ± 4.7	33.4 ± 4.4	0.023*
Body height (cm)	161 ± 5.4	160.6 ± 5.4	0.754
Body weight (kg)	62.4 ± 9.5	56.6 ± 8.9	0.000*
Body mass index (kg/m^2)	24.1 ± 3.7	21.9 ± 3.2	0.000*
SSB amount (mL/day)	302.3 ± 266.4	359.7 ± 265.2	0.213
SSB DSM-5 (items)	2.3 ± 2.1	1.9 ± 2.0	0.362
Water intake (mL/day)	771.0 ± 328.1	762.9 ± 318.3	0.884
Eat out (times/week)	6.7 ± 4.5	7.3 ± 5.2	0.465
Night snack (times/week)	1.6 ± 1.5	1.5 ± 1.9	0.808

SD, standard deviation; GDM, women with gestational diabetes mellitus; SSB, sugar-sweetened beverage; SSB DSM-5, items of the DSM-5 for substance use disorder, modified for SSB; Student' *t* test and chi-squared test were used. *$p < 0.05$.

esize that a desire to drink SSBs may contribute to the incidence of GDM. If so, it would serve as a good potential point for early recognition and intervention.

2. Materials and Methods

2.1 Study Population

This prospective cohort study recruited pregnant women aged 20 and older, who received prenatal care at Kaohsiung Medical University Hospital (KMUH) in Taiwan. Participants were asked to respond to a survey designed for capturing their sugar-sweetened beverage (SSB) use patterns. Those who refused to participate, could not comprehend Mandarin Chinese, failed to complete all questions, experienced predated termination of pregnancy, intrauterine fetal demise or lost follow up were excluded. Women with multiple gestations or overt diabetes were also excluded. A total of 183 responses were collected for analysis. The project was approved by the Institutional Review Board (IRB) of KMUH and conducted in accordance with the Declaration of Helsinki. Aprroval number wis KMUHIRB-SV(II)-20170081. All participants provided written informed consent with the objectives and methods of the project explained thoroughly.

2.2 Measurement of Covariates

In a self-describing 20-minute questionnaire, the participant's demographic information and SSB use pattern were surveyed in their first trimesters. First part of the survey collected information about the participant's age, parity, comorbidities, obstetric history, body mass index and education level. The second part of the survey assessed their SSB use amount, degree of psychological dependence and whom to drink with. The amount of SSB use was self-reported with visual analogues of common SSBs in Taiwan to assist amount estimation and recall. To delineate the degree of desire for SSB, criteria for SUD in DSM-5 were customized for SSB [26]. These 11-item diagnostic criteria assess the ability to control excessive consumption, continued use despite of negative consequences, manifestations of withdrawal, tolerance or craving (see **Supplementary Material**).

All participants were screened for gestational diabetes mellitus (GDM) at 24–28 weeks of gestation with 75-gram oral glucose tolerance test (OGTT). The diagnosis of GDM was established if the participant's fasting, postprandial 1-hour or postprandial 2-hour blood sugar level exceeded 92 mg/dL, 180 mg/dL and 153 mg/dL, respectively, according to American Diabetes Association (ADA) criteria [27].

2.3 Statistical Analysis

Statistical analyses were performed using SPSS 22 (IBM Corporation, Armonk, NY, USA). Continuous variables were presented in means and standard deviations, whereas categorical variables in numbers and percentages. Differences of clinical characteristics between the GDM and non-GDM groups were delineated using student's *t*-tests and chi-squared tests. The relationship between risk factors and GDM, with GDM as the dependent variable and their corresponding odd ratios estimated, using logistic regression analysis. Linear regression was used to evaluate correlations between the factors and the number of SSB-associated SUD DSM-5 items. The level of significance for all tests was $p < 0.05$.

3. Results and Discussion

3.1 Characteristics of the Study Population

The study group was divided into two groups according to their 75-gram OGTT results. The GDM group (n = 44) was older (35.2 ± 4.7 years old) with higher body weight (62.4 ± 9.5 kg) and body mass index (24.1 ± 3.7

Table 2. Binary logistic regression analysis using factors in the first trimester to predict GDM.

Variables (n = 183)	B	SE	Exp (β) (95% CI)	p-value
Education level				0.075
High school	Ref.	Ref.	Ref.	Ref.
University	–1.087	0.581	0.337 (0.108–1.053)	0.061
Postgraduate	–1.685	0.765	0.185 (0.041–0.830)	0.028*
Age (years)	0.106	0.045	1.112 (1.018–1.214)	0.018*
BMI (kg/m^2)	0.189	0.058	1.208 (1.079–1.353)	0.001*
SSB amount (mL/day)	–0.002	0.001	0.998 (0.996–1.000)	0.026*
SSB DSM-5 (items)	0.291	0.111	1.338 (1.077–1.664)	0.009*
Drinking partner				0.069
No drink	Ref.	Ref.	Ref.	Ref.
Drink alone	0.636	1.290	1.889 (0.151–23.661)	0.622
Drink with family	1.701	1.293	5.482 (0.435–69.076)	0.188
Drink with friends	1.570	1.404	4.805 (0.307–75.247)	0.263

GDM, women with gestational diabetes mellitus; control, women in the control group; SSB DSM-5, items of the DSM-5 for substance use disorder, modified for SSB; BMI, body mass index; CI, confidence interval; SSB, sugar-sweetened beverage; Student' t test and chi-squared test were used; β, logistic coefficient; SE, standard error; Exp (β), odds ratio; *$p < 0.05$ (Hosmer–Lemeshow test: 0.753; Nagelkerke R^2: 0.262, $p < 0.001$).

kg/m^2), compared to the control group (n = 139, 33.4 ± 4.4 years old, 56.6 ± 8.9 kg and 21.9 ± 3.2 kg/m^2, respectively). The remaining study parameters were comparable between the two groups, including education level, body height, SBB amount consumed, SSB related DSM-5 scores, frequency of eating out and night snacks (Table 1).

3.2 SSB Use Pattern in the First Trimester as a Predictor of GDM

The DSM-5 paradigm has been proposed as a model for creating diet-specific criteria [24,28]. The desire to drink SSB is comparable to eating obsession. The DSM-5 diagnostic criteria for SUD modified for SSBs is a competent evaluation tool, as it comprehensively describes substance use patterns with symptoms of overuse, dependence, tolerance, and withdrawal. It serves more than as a mere diagnostic tool, but also precise behavioral descriptors. It is also easy to use and quick to answer. The number of positive symptoms corresponds to disease severity [25]. It servs as a good objective assessment tool that allows quantification and documentation for comparison.

Binary logistic regression analysis was performed to investigate associating factors in the first trimester with GDM (Table 2). Age, body mass index (BMI), SSB intake amount, and SSB related DSM-5 scores were significantly higher in the GDM group, with odd ratios of 1.112, 1.208, 0.998 and 1.338, respectively ($p < 0.05$). The amount of SSB consumed and drinking partners did not demonstrate meaningful differences. However, postgraduate participants were negatively associated with GDM compared to high school ones.

In the general population, the association between excessive SSB consumption and the development of type 2 diabetes is well-known and demonstrated by epidemiological, clinical, and experimental studies [29–31]. De Koning *et al.* [32] reported a hazard ratio of 1.24 for developing type 2 diabetes mellitus (T2DM) after using artificial SSB in their 20-year follow up with over 40,000 subjects. Li *et al.* [29] found similar trend in China from 1990 to 2017, with more than 12,000 participants, attributing high incidence of T2DM related disability in young to middle-aged males to high SSB consumption. Free sugars promote adipogenesis and visceral fat accumulation, which would raise insulin resistance via inflammation and dysfunctional metabolism. Research efforts were devoted to elucidating the various participants involved in the mechanisms at the molecular and genomic levels.

Our analysis shows increased GDM incidence with advanced age, higher pre-pregnancy BMI and lower maternal educational status, which is in accordance with previous GDM studies [33–36]. More importantly, a positive correlation was found between GDM incidence and increased SSB-related DSM-5 scores, with 33% increased risk for every 1 extra point scored. This adds to the two reports on SSB and GDM currently available. Nurses' Health Study II in 2001 was a prospective cohort study with 13,475 women in the United States followed for 10 years. It found 22% elevated GDM risk if sugar-sweetened cola was consumed more than 5 servings per week, but not with tother SSBs or diet beverages [37]. Ten years later, Seguimiento Universidad de Navarra (SUN) project demonstrated significant association between sugar-sweetened soft drinks (adjusted odds ratio 2.03, 95% confidence interval 1.25–3.31), which

Table 3. Multiple linear regression analysis of possible factors for SSB related DSM-5 scores.

	Unstandardized coefficients		Standardized coefficients	t	p
	β	SE	β		
Independent variables					
(constant)	0.790	1.816		0.435	0.664
Education level	0.588	0.293	0.147	2.006	0.046*
Age (years)	–0.043	0.033	–0.095	–1.291	0.198
BMI (kg/m^2)	0.040	0.042	0.066	0.938	0.349
Dining out (times/week)	0.063	0.029	0.157	2.212	0.028*
Night snack (times/week)	–0.073	0.087	–0.064	–0.839	0.403
Sedentary lifestyle	0.655	0.196	0.339	3.351	0.001*
Drinking partner	–0.140	0.154	–0.064	–0.910	0.364
Meals with SSB	–0.048	0.209	–0.023	–0.230	0.818
Water intake (mL/day)	–0.001	0.000	–0.160	–2.148	0.033*

BMI, body mass index; SSB, sugar-sweetened beverage; β, logistic coefficient; SE, standard error. *$p < 0.05$ (The dependent variable is DSD DSM-5 items; r = 0.457, r^2 = 0.168, $p < 0.000$).

was note observed in the diet soft drink counterpart (adjusted ratio 0.82, 95% confidence interval 0.52–1.31) [38]. Our study is innovative in that SSB-specific DSM-5 questionnaire is utilized as a surrogate marker for SSB consumption behavior. It is an objective assessment that surpasses brands, types and recall bias that might hinder actual intake amount measurement.

3.3 SSB-Related DSM-5 Scores

High SSB-related DSM-5 scores were found with higher education level, more frequent dining out, and sedentary lifestyle with standardized coefficients of 2.006 (p = 0.046), 2.212 (p = 0.028), 3.351 (p = 0.001), respectively. SSB-related DSM-5 scores were negatively associated with the amount of water intake, with standardized coefficient –0.160 (p = 0.033) (Table 3). No correlation was found for SSB-related DSM-5 scores with age, BMI, frequency of having night snacks, drinking partners or meals with SSB.

Healthy diet, physical activities and psychological states are essential elements of a healthy lifestyle. Each component imposes influences on one another with intimate and complex ways. This is a concept long established and recently revisited during the COVID-19 pandemic [39–43]. Based on the same rationale, active behavioral counseling interventions are recommended by the US Preventive Services Task Force for those with hypertension, dyslipidemia, and metabolic syndromes [44]. Therefore, when increased SSB-related scores were found to relate to increased GDM risk, a sub-analysis was performed to investigate relevant behaviors that serve as useful consultation advices for the pregnant women (Table 3). Specifically, women should be encouraged to prepare their own meals rather than dining out; they also are advised to exercise more rather than being sedentary in their early pregnancy to decrease SSB consumption and GDM risk.

Which equally important is to encourage pregnancy women to increase plain water intake. The amount of plain water intake was inversely related to the amount of SSBs consumed and the relevant DSM-5 items. Plain water intake is the main source of total fluid ingested and increase water ingestion among adults is found with less added sugar consumption [45,46], which in turn helps reduce dietary caloric density and regulate body weight [47]. Longitudinal and cross-sectional studies found increasing one's intake of non-sugary beverages like plain water can lower the risk of developing type 2 diabetes mellitus [48]. The United States Department of Agriculture specifically advises people reduce SSB use and choose beverages with low or no added sugars such as water instead in the Dietary Guidelines for Americans [49]. Similar recommendation was made by the Norwegian health authorities in their country [50]. It is therefore another useful and specific intervention advice for the pregnant women to encourage plain water intake over SSBs in the attempt to reduce GDM risk.

This is a cross sectional study from which no causal relationship between SSB-related DSM-5 items and GDM could be deduced. The extent to which the score is predictive of the occurrence and prevention of GDM is important an avenue for further investigations. It is also of interest to examine whether withdrawal reactions would follow dietary control and SSB reduction. There was a reduced SSB intake in the GDM group, although their SSB-related DSM-5 SUD scores remained high. Further studies are needed to investigate whether these high-risk women restrain themselves from SSBs early in pregnancy or whether their high SSB-related DSM-5 scores are influenced by other dietary patterns.

4. Conclusions

This is the first study to report that increased psychological cravings for SSB in early pregnancy serve as a risk factor for GDM, measured by modified DSM-5 criteria for substance use disorder. Each additional positive item increases 33% chance of developing GDM. Pregnant women should be conscious about the health impacts of SSB cravings during pregnancy. Dining out less, exercising and drinking more water are advised to lower the risks of developing GDM and the potential sequalae (fetal, neonatal, and maternal) that might follow.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

TFC designed the research study. CRK, HYC and TFC performed the research. CHL analyzed the data. CRK and WYH wrote the manuscript. SHW helped on acquisition of the data and cases enrollment. WYH analyzed and interpretatied the data. Both CRK and WYH have been involved in revising manuscript critically for important intellectual content. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

The project was approved by the Institutional Review Board (IRB) of Kaohsiung Medical University Hospital (KMUH) and conducted in accordance with the Declaration of Helsinki. Approval number is KMUHIRB-SV(II)-20170081. All participants provided written informed consent with the objectives and methods of the project explained thoroughly.

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Conflict of Interest

The authors declare no conflict of interest. Te-Fu Chan is serving as one of the Guest editors of this journal. We declare that Te-Fu Chan had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Laura Avagliano.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.ceog5004091.

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