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Research Article

Prospective Health Outcomes of Sugar-Sweetened Beverage Consumption Patterns Associated with Sociodemographic and Ethnic Factors among Chinese Adults

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Abstract: Background: The consumption rate of artificially sweetened beverages, 100% fruit juices, and soft drink products has been proliferating since the 1980s among the Chinese population. Sugar-sweetened beverages (SSBs) prevalence and high intake of SSBs are associated with several noncommunicable chronic diseases (NCDs). This trend presents a serious public health threat to the Chinese population. **Purpose:** The present cross-sectional study examined the association between added sugar-sweetened beverage consumption patterns and prospective adverse health outcomes among Chinese sociodemographic and ethnic groups. **Methods:** The study population of 662 male and female adults partook in the study. The study cohort was randomly drawn from four Chinese cities in three provinces. Participants responded to an adapted cross-sectional self-administered paper-and-pencil 24-hour dietary intake recall protocol questionnaire, including 23 closed-ended questions on the type and frequency of the beverage consumed, sociodemographic characteristics, and ethnic group affiliation. A t-test was conducted to analyze the interactions between the parametric variables and Chi-square analyses were performed to determine interactions between the nonparametric variables. **Results:** The consumption frequency of sugar-sweetened beverages at least once/day was examined. For all respondents, water consumption was employed as a benchmark for a healthy beverage compared to all other sugar-sweetened beverage consumption. Findings suggest that water was the most frequently consumed beverage with the highest rate of intake (53.17%) compared to sugar-sweetened beverages consumption Regarding ethnicity, Han's water consumption was reported at (67.94%) compared to sugar-sweetened beverage consumption combined at (32.06%). Concerning Huis, water consumption was (60.56%) contrasted with sugar-sweetened beverage consumption of (39.44%). Hans were more likely to consume both water and sugar-sweetened beverages compared to Hui participants. Males' water consumption rate was at (66.74%) juxtaposed with sugar-sweetened beverage consumption of (36.26%). Females' water consumption rate was (66.51%) contrasted with a sugar-sweetened beverage consumption rate of (39.44%). There were no significant differences in the water and sugar-sweetened beverages between men and women. Married respondents' water consumption was (65.44%) compared to sugar-sweetened beverage consumption rate (34.55%). Regarding marital status, the single respondents' water consumption was (64.89%) compared to sugar-sweetened beverage consumption of (33.49%). There were no significant differences in water and sugar-sweetened beverage consumption between the marital status groups. **Conclusions:** There is a need to introduce short-term and long-term strategies to curtail sugar-sweetened beverage consumption through excise taxes, making water more readily

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accessible in public schools, and launching a public health education campaign aimed at the health risks associated with added sugar-sweetened beverage consumption.

***Keywords*:** sugar-sweetened beverages, sociodemographic factors, demographic characteristics, water intake, health effects, Han and Hui ethnic nationalities

1. Introduction

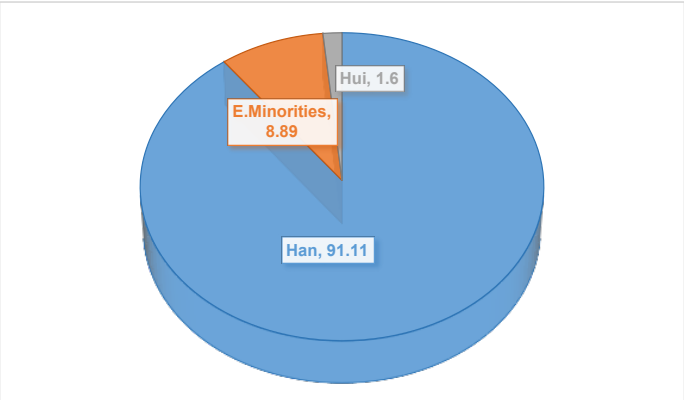
Traditionally, the most frequently consumed nonalcoholic beverages by the Chinese include green and black tea, fresh fruit, and vegetable juices. The most ubiquitously consumed beverage is boiled or lukewarm plain water, which is especially consumed when someone is feeling unwell. However, with the advent of the vast segment of middle-class Chinese with steadily growing income and purchasing power in the last three decades, China embraced more Western-styled alcoholic and nonalcoholic beverages, especially artificially sugar-sweetened beverages (SSBs) that are relatively new to the Chinese traditional food culture; however, SSBs are currently ubiquitously consumed by a substantial segment of the Chinese population. SSBs commonly include a variety of soft drinks and other carbonated and non-carbonated beverages, including energy and sports drinks that contain considerable quantities of high-energy sweeteners such as sucrose (50%), glucose (50%), and (45%-55%) high-concentration of fructose and a mixture of corn syrup and glucose, as well as sugar-sweeteners added to fruit juice concentrates that usually contain (0.25) calories per 8 fluid ounces. Some sugar-sweetened juice drinks are packed with up to 60 grams of sugar providing nearly 232 calories per serving. Australian researchers suggested that the rate of overweight and obesity in Australia is among the highest in the world. This high rate is linked to the consumption of SSB and 100% fruit juice. Findings revealed that SSB consumption is prevalent, mainly among young adults practically males, and among all the pre-packaged SSB drinks investigated, consumption of fruit juices, of any type, was the most prevalent at (38.8%). Other added sweeteners include various quantities of raw sugar, maltose, molasses, and dextrose [1-4]. Epidemiological research presented evidence of a positive association between increased consumption of SSBs with the potential to cause a myriad of adverse health effects, especially noncommunicable chronic diseases (NCDs) [5-7].

Several studies suggested a significant correlation between increased consumption of SSBs and weight gain contributing to childhood and adult obesity, hypertriglyceridemia - an abnormal concentration of triglyceride in the blood - coronary heart disease, type 2 diabetes, nonalcoholic fatty liver disease, and increased all-cause mortality rates. Because of the adverse health effects of frequently consuming SSBs, a “soda excise tax” has been recommended by the Institute of Medicine in 2009 [8-12]. A confirmed association between SSB consumption and the risks of obesity and hypertriglyceridemia was also found in children aged 7-18 years in South China suggesting that high SSB intake increases the risk of cardio-metabolic disorders [13]. Recent research on the psychological health effects of the habitual consumption of SSBs found that daily intake of SSBs is positively associated with symptoms of common mental disorders, anxiety, and depression in Chinese adolescents. In South Korea, researchers found that there is an association between soft drink intake and obesity, depression, and subjective health status (SHS), which occurs as a result of an interaction between physiological and psychosocial factors in male and female adults. A more recent Chinese investigation suggested that school-aged children who consumed higher quantities of SSBs exhibited increased rates of psychological and behavioral problems (PBPs) at both the individual and group levels. Similarly, increased consumption of SSBs has been linked to depression and mood disorders in a cognate study in London, UK. Research on SSB consumption maintained that a lower intake of raw sugar and nonnutritive sweeteners (NNS) such as aspartame, saccharin, sucralose, neotame, acesulfame-K, and stevia may be associated with better psychological and physical health outcomes [14-19].

Findings from research on the association between nutrition and chronic diseases suggested that children 10-17 years of age with select chronic health conditions were at increased risk for obesity compared to their peers without a chronic health condition. These findings also showed that childhood obesity and overweight among children aged (6-17) years reached (15%) in 2012 [9, 20]. Similarly in China, from 2002 to 2012 the rates of obesity and overweight climbed by (9.2%) and (19%) in 2016 [21, 22]. Research in the U.S. suggested that children and adolescents who receive Supplemental Nutrition Assistance Program (SNAP) benefits are more likely to consume more SSBs and more

disposed to become overweight and obese compared to their peers who receive SNAP benefits but do not consume SSBs. Similarly, Attributable to the substantial growth of SSB production and consumption, obesity prevalence rates among school-aged children have grown congruently. Chinese children and adolescents aged 6-17 years were reported to drink more SSBs than any other age group [23, 24]. Increased SSB consumption among adolescents and children has been similarly reported by a multitude of studies to be positively associated with increasingly rising rates of childhood and adult obesity and overweight, as well as higher scores of Body Mass Index (BMI), which may increase the risk for comorbidities. These results should be of practical concern to stakeholders, especially parents, policymakers, and public health professionals [25-31].

Among the 56 officially designated nationality groups in China, the two ethnic groups in the present study are Han and Hui. According to the 2020 Chinese Census, mainland China's total population is 1.41 billion, accounting for nearly (18%) of the total global population of which (91.11%) is Han Ethnic Nationality. Combined, all other ethnic minority groups constitute nearly 113.79 million, accounting for (8.89%) of the total Chinese population, including about (1.6%) of which is Hui Minority Nationality (Figure 1). The Hui Minority Nationality is the second-largest among the ten officially recognized Chinese Muslim minority nationalities. Juxtaposed with the other Chinese Muslim ethnic groups, e.g., Uyghurs, Kazaks, and Dongxiang, the Hui people portray a significant degree of integration with the Han majority group, especially in language and history. Whereas Hans and Huis share the Chinese heritage and Mandarin as their native language, by contrast, they possess distinctively diverse ethnic backgrounds, cultural identities, lifestyles, social customs, and distinguishing dietary traditions. Traditional ethnic food and beverages are deeply connected to a culture or an ethnic group and can be more enduring and difficult to change or substitute with time. Moreover, they are strongly influenced by geography, cultures, religious beliefs, socioeconomic strata, and indigenous consumption practices of the food and beverage of a culture or an ethnic group. One of the most notable differences in dietary practice between Hans and Huis is that because of their observance of prescribed Islamic dietary protocols, Huis are obligated to refrain from consuming pork, porcine byproducts, and any quantity of alcohol, as well as consuming only "Halal Food", which denotes "permissible food", especially animal-based meat that has been prepared and certified as "Halal" according to strict Islamic regulations; otherwise, the Huis enjoy consuming comparable dietary preferences as the Hans [32-35].



Key: E: ethnic minorities

Figure 1. The quantitative relation (%) between the total Chinese ethnic Han population and all other ethnic minority groups combined, including the Hui Ethnic Minority Nationality

2. Materials and methods

2.1 *Study population sampling*

The cohort of the present study comprised (N = 662) unpaid recruited representative sample of adults aged ≥ 18, including (n = 356, 54.07%) male and (n = 306, 45.93%) female participants. Among them, (71.54%) of Han Ethnic Nationality and (28.4%) of Hui Ethnic Nationality. They were randomly sampled from four urban cities in three

provinces namely: Kaifeng, Henan Province (n = 264, 39.88%); Zhengzhou, Henan Province (n = 241, 36.40%); Xi'an, Shaanxi, Province (n = 85, 12.84%); and Jinan, Shandong Province (n = 72, 10.88%). All cities are located within or coterminous with the Yellow River Basin's fertile Central Plains in Midwestern and Mideastern China (Figure 2). Participants responded to a modified cross-sectional self-administered paper-and-pencil-based food history and beverage consumption questionnaire, including water intake. The study questionnaire included a 24-hour recall protocol of food and beverage consumption, including plain water intake, sociodemographic characteristics, and ethnic group affiliation status.

Source: Adapted and reprinted from TCT, January 10, 2022
Retrieved from: https://www.topchinatravel.com/china-map/china-city-maps.htm

Figure 2. Map of the four cities, Kaifeng, Zhengzhou, Xi'an, and Jinan, where the study cohort was drawn and data were collected illustrated by blue dots

2.2 *Diet history questionnaire survey development and procedures*

A cross-sectional questionnaire survey (CSQS) was employed to collect data at one point in time from a population sample selected to represent a larger cognate population. In the current study, CSQS was utilized to gather predetermined information regarding the study cohort's food and beverage intake. The study implemented an adapted version of the National Cancer Institute (NCI) Diet History Questionnaire III (DHQ III) for adults aged ≥ 18. The DHQ III is based on a compilation of the national dietary intake recall data from the National Health and Nutrition Examination Surveys (NHANES). Several studies suggested that employing a Food Frequency Questionnaire (FFQ) to obtain the frequency and portion size information concerning food and beverage intake over a designated time, ranging from the past 24 hours, a month, or a year is an effective instrument for estimating food and beverage intake of a population of interest [36, 37]. In the present study, the adapted FFQ encompassed 23 closed-ended questions [38, 39] to obtain relevant data points from the respondents to determine their food and beverage consumption history, and sociodemographic characteristics, including age, gender identification, level of education, marital status, and

employment status. SSB and water consumption were calculated based on self-reporting of frequent daily consumption of plain water, milk, artificially sugar-sweetened juice, soda, black, green, and herbal tea.

2.3 *Study population inclusion and exclusion criteria*

Participants were randomly drawn from four urban Chinese cities (Figure 2). Participants who qualified for inclusion in the present study were a cohort of 662 male and female adults aged ≥ 18, including any ethnic group affiliation with Han and Hui, any levels of education, and any marital status categories. Participants whose ages were outside the study age range of 18 years and older were excluded from participating in the study. Similarly excluded participants who were not within the Han and Hui ethnic groups affiliation. Moreover, the personal medical history, preexisting health conditions, and at the time of the study, the present health status of the participants were excluded from this study.

2.4 *Materials and cohort statistical analysis*

Employing a self-reported survey, sociodemographic characteristics, including gender, age, employment status, level of education, marital status, city of residence, as well as ethnic group affiliation were collected. The Statistical Analysis Software (SAS) Package, Version 9.3, SAS Institute Inc, Cary, NC, was employed to analyze the primary data sources collected from the participants. T-test analyses were performed to compare the statistical differences between the means of the study groups according to the nominal (classification) variables vs. ordinal variables where the nominal variable had exactly two levels (i.e., ethnicity, gender). Chi-square test (mostly 2 by 2) analyses were utilized if both variables were nominal. Certain nominal data items with multiple levels were re-coded into one of two levels before performing a 2 by 2 Chi-square test ($\chi 2$). Most of the analyses involved calculating p-values and classifying any value of a test statistic with a p-value of less than an alpha level of ($p < 0.05$) was considered statistically significant. In the present study, the tests were two-tailed.

3. Results

3.1 *Demographic characteristics*

As presented in Table 1, a cohort of 662 male and female adults aged ≥ 18 were randomly recruited for the present study, including 356 (54.07%) males and 306 (45.93%) females. Ethnographically, two ethnic groups were drawn from four urban cities across the Yellow River Basin drawn from three provinces among them, Han (71.54%) and Hui (28.4%). The statistical proportion of the Han and Hui ethnic groups closely reflects the actual proportional distribution between the two ethnic populations according to the 2020 Chinese Census, where Hans accounted for (91.11%) of the total Chinese population, whereas Huis accounted for nearly (1.6%) of the total Chinese population (Figure 1). Regarding the gender factor, Han males were (54.07%), compared to Hui males (60.11%). concerning female participants, Han females were (45.93%), whereas Hui females were (39.89%). Juxtaposed with the total respective Han and Hui populations, the relative statistical proximity between them can be explained by the fact that Huis are more likely to reside in territories riparian to the Yellow Valley. Regarding the marital status factor results, married Hans accounted for (37.01%), compared to married Hui with (22.96%). As to single Hans, they accounted for (62.53%), contrasted with single Huis of (6.09%). The relative statistical variances in the Han and Hui marital status factor fall into the general pattern of the difference between the size of their relative ethnic population of Han (91.11%) vs. Hui (1.6%). The overall level of education results (Table 1) showed that the Hans were more likely to have a college education (CE) reporting (62.53%) contrasted with (37.47%) with no college education (NCE), juxtaposed with Huis, whose reported college education (CE) was (15.93%) compared with no college education (NCE) with (84.07%). These results show a significant difference in college education between Hans and Huis. A probable explanation for the disparity in the education level between the two ethnic groups is that a greater segment of Huis live in rural areas, and they have curtailed years of education opportunities for numerous strata of the Hui population than those of the Han. Further, nearly (45%) of adult rural Hui women are not literate, and Hui parents spend fewer resources in support of their children's education than Han parents, which explains the fewer years spent on education for Huis. Educational achievement among Chinese ethnic minorities

is lagging due to poverty and parents' low level of education. Research findings revealed that (71.6%) of the ethnic minority populations in China live in the western autonomous regions, which are nationally designated poverty regions [40, 41].

Table 1. Percent (%) frequency count of Key demographic characteristics and ethnic affiliation (Han Ethnic Nationality vs. Hui Ethnic Nationality)

Independent variables	Han (%)	Hui (%)
Total respondents (N = 662)	71.54	28.46
Male respondents	54.07	60.11
Female respondents	45.93	39.89
Married respondents	37.01	22.96
Single respondents	62.99	6.09
The overall level of education (college vs. no college)	CE 62.53 NCE 37.47	CE 15.93 NCE 84.07
Habitual beverage intake (Water vs. SSBs)	W 67.94 SSBs 32.06	W 60.56 SSBs 39.44

Key: W: water intake vs. SSBs: sugar-sweetened beverages, CE: college education vs. NCE: no college education

3.2 *Sugar-sweetened beverage (SSB) consumption frequency patterns*

The present study examined the association between SSB consumption rate patterns, sociodemographic characteristics, and ethnic group affiliation factors. Further, the study investigated the connection between SSB consumption rates and prospective adverse health outcomes by employing the extrapolation research method. The aim was to infer from the existing dataset in the current study, as well as other cognate studies, to understand and extrapolate the relationship between the frequency patterns of SSB consumption and the potential causation of prospective adverse health effects, especially NCDs. Extrapolation from and representation of entirely unknown data is part of a broad and useful understanding of the external validity of the relation between a known dataset and an unknown dataset such as the consumption rate of SSBs and negative health outcomes [42-45].

Table 2 illustrates the results of the frequency of SSB consumption (times per week) for all participants. Figure 2 describes the types of SSBs and water consumption frequency (times per week) as reported by all participants. In the present study, plain water consumption is considered a non-SSB, which is a key benchmark independent variable employed for comparison with the consumption of other SSB independent variables. There is a considerable body of evidence-based consensus asserting the health benefits of water and its importance to the human body. Water is essential for life and it constitutes (75%) of body weight in infants to (55%) in adults. Water contributes to a myriad of essential physiological functions, including metabolism, production of body fluids, thermoregulation, cellular homeostasis, substrate transport across cell membranes, digestion, transport of nutrients and waste byproducts, acts as a building, and filling material, and facilitates the circulatory system function. Empirical evidence from a Chinese study maintained that dehydration had negative effects on physical endurance, muscular fatigue, short-term memory, and attention span. Conversely, after water replenishment, findings indicated that rehydration diminished fatigue and improved total mood disturbance (TMD), short-term memory, attention span, and reaction time. Similar research in Zambia reported a strong association between hydration and improved cognitive function in test scores among adults, with evidence of comparable results found among school-aged children [46-50].

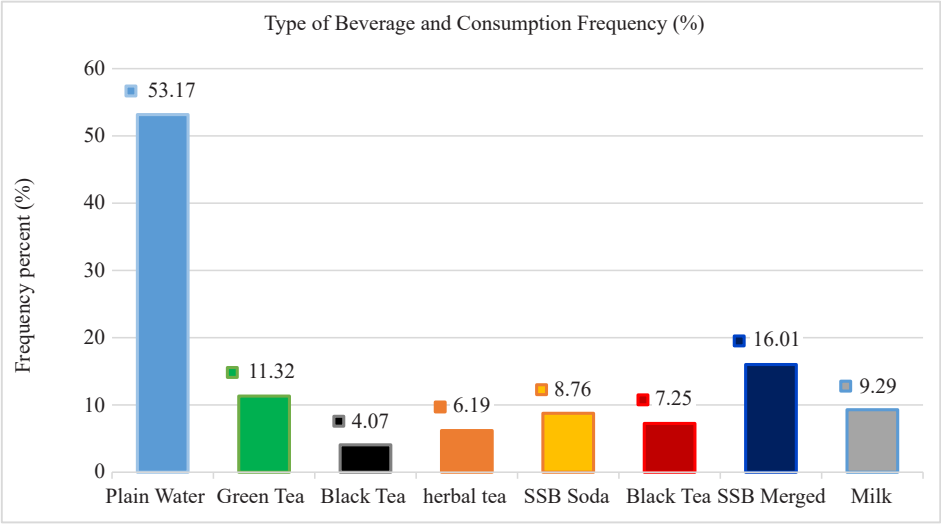
Table 2 indicates that plain water was the most frequently consumed non-SSB with the highest intake rate of (53.17%) ($p < 0.05$) juxtaposed with (16.01%) of the merged SSB consumption (Figure 3). Green tea came as the second-highest consumed beverage with a rate of (11.32%) ($p < 0.05$) contrasted with (16.01%) of the merged SSB consumption. Milk recorded the third-highest rate of consumption with (9.29%) ($p < 0.05$) compared to (16.01%)

of the merged SSB consumption. As a type of SSB, soda registered (8.76%) ($p < 0.05$), which is nearly (50%) of the merged SSB consumption of (16.01%). Juice, another type of SSB accounted for (7.25%) of consumption ($p < 0.05$) measured against (16.01%) of the merged SSB consumption. Herbal tea consumption was recorded at (6.19%) ($p < 0.05$) contrasted with (16.01%) of the merged SSB consumption. Black tea came in with the lowest frequency of consumption per week recording (4.07%) ($p < 0.05$).

Table 2. Summary statistics of beverage consumption reported by all participants

Frequency count of beverage consumption				
Typical drink	Frequency	Percent (%)	Cumulative frequency	Cumulative percent (%)
Plain water	352	53.17	352	53.17
Green tea	75	11.32	427	64.49
Black tea	27	4.07	554	68.53
Herbal tea	41	6.19	495	74.72
SSB (Soda)	58	8.76	553	83.48
SSB (Juice)	48	7.25	601	90.73
Milk	61	9.27	662	100

Key: SSB: sugar-sweetened beverage



Key: SSB: sugar-sweetened beverage, SSB merged: all kinds of soda and fruit juice

Figure 3. The frequency pattern of the consumption of the beverage was reported by all study participants

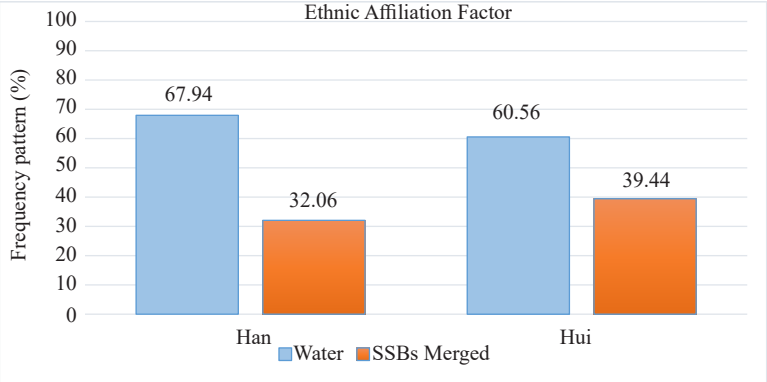
3.3 *Association between ethnic group affiliation and SSB consumption patterns*

The two ethnic groups that participated in the present study were drawn from the Chinese Han and Hui Nationalities. Figure 1 describes the relative representation of each ethnic group (Han 91.11% vs. Hui 1.6%) compared to the total Chinese population of 1.41 billion according to the 2020 Chinese Census [32]. The relative representation of

each ethnic group in the present study was (Han 71.54%) vs. (Hui 28.46%), which nearly reflects the actual proportional representation of them in the mainland Chinese overall population (Table 1).

In the present study's food frequency questionnaire (FFQ), sugar-sweetened beverages (SSBs) were collectively defined as nonalcoholic soft drinks that are artificially flavored with added sweeteners, including various quantities of raw sugar, maltose, molasses, and dextrose [1-4]. In the present study, the SSB serving size in the FFQ was estimated as (1.00 typical serving size of SSB equals 1.00 full glass that measures approximately 250 mL). The 1.00 serving glass/250 mL of SSB was then calculated based on the daily (mL) consumption and converted into a weekly frequency consumption.

Figure 4 illustrates the results of the analysis of the association between ethnic group affiliation and SSB consumption patterns by the Han and Hui participants, including Han (71.54%) and Hui (28.46%). Employing water as a key healthy benchmark average for comparison with SSB consumption, water frequency consumption among Han respondents was (67.94%), compared to SSB consumption of (32.06%) ($p < 0.05$). Hui participants reported water consumption of (60.56%) contrasted with SSB consumption of (39.44%) ($p < 0.05$). These results suggest that Han participants were more likely to consume water more frequently and SSBs less frequently than Huis who were more likely to consume less water and more likely to consume SSBs frequently than Hans ($p < 0.05$).



Key: SSB: sugar-sweetened beverage, SSBs merged: all kinds of soda and juice

Figure 4. Water vs. merged SSB frequency consumption pattern reported by the Han and Hui ethnic group participants

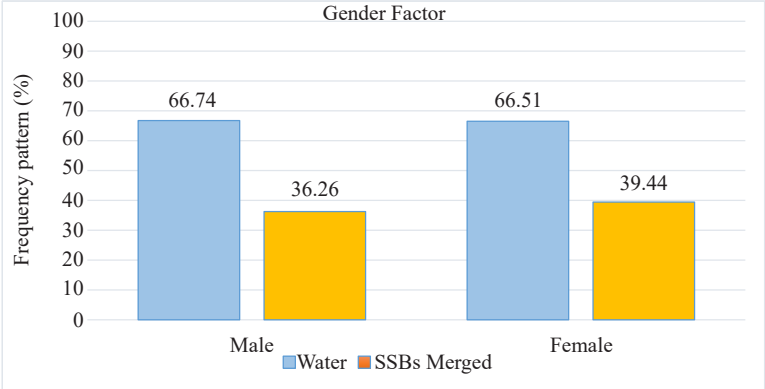
3.4 *Association between sociodemographic characteristics and SSB consumption patterns*

3.4.1 *Gender factor (male vs. female)*

Figure 5 describes the results of pooled data obtained from the analysis of the association between the gender factor and the SSB frequency consumption pattern that was reported in the two gender groups (Table 1). The pooled data show that the water consumption frequency pattern among the male respondents was (66.74%), juxtaposed with SSB consumption of (36.26%) ($p < 0.05$). The female participants' water consumption was (66.51%) juxtaposed with an SSB consumption of (39.44%) These results suggest that there were no significant differences in the water and BBS consumption between men and women ($p > 0.05$).

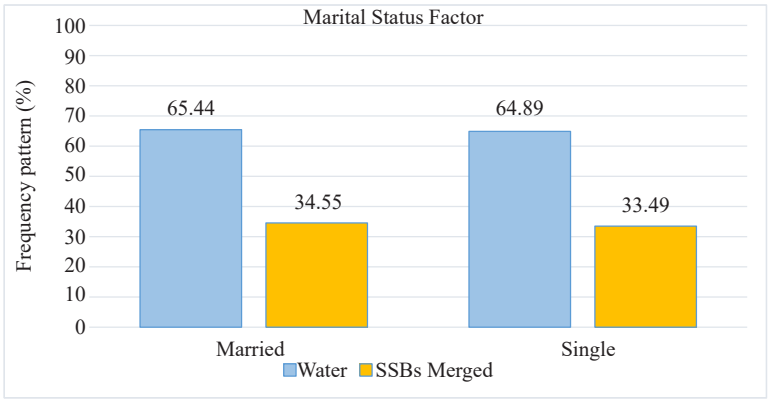
3.4.2 *Marital status factor (married vs. single)*

Figure 6 depicts the results of the pooled data obtained from the analysis of the association between the marital status factor and the frequency of the merged SSB consumption pattern that was reported in the married and single groups (Table 1). In the married participants, water consumption was (65.44%), contrasted with merged SSB consumption of (34.55%) ($p < 0.05$). For single participants, concerning water consumption, it was (64.89%) juxtaposed with a merged SSB consumption of (33.49%) These results suggest that there were no significant differences in the water and merged BBS consumption between the marital status groups ($p > 0.05$).



key: SSB: sugar-sweetened beverage, SSBs merged: all kinds of soda and juice

Figure 5. Water vs. merged SSBs frequency consumption pattern was obtained from pooled data from the analysis of the two gender groups



key: SSB: sugar-sweetened beverage, SSBs merged: all kinds of soda and juice

Figure 6. Water vs. merged SSBs frequency consumption pattern obtained from pooled data from the analysis of the two marital status groups

4. Discussion

In the present cross-sectional study, the aim was to examine the impact of the frequency of water and sugar-sweetened beverages on their prospective association with the risk factors of adverse health effects among the sociodemographic and ethnic group factors in mainland China according to the China Health and Nutrition Survey (CHNS), which was created to address major public health risk factors and health outcomes, sociodemographic, and socioeconomic factors at the individual, household, and nationwide levels [51, 52].

During the rule of the Tang Dynasty (618-907 AD), the renowned physician Sun S-Miao maintained that when a person is ill, the physician should start the treatment first by regulating the patient's diet and lifestyle [53]. This medical principle was based on the ancient Chinese concept of "medicine and food homology" (MFH), which denotes that both food and Traditional Chinese Medicine (TCM) originated from the same natural sources and that food is medicine and medicine can be found in food [54]. Over time, with centuries of practice of TCM, medical theories were developed that healthy eating and drinking habits are strongly associated with maintaining good health and healthful longevity. Furthermore, what people eat and drink can potentially protect them from developing various diseases, in the meantime, it can potentially be associated with presenting a significant threat to public health that demands ensuring the enacting of effective public health and disease prevention policies. Findings from numerous epidemiological studies presented evidence of a positive association between the increased consumption of SSBs with a myriad of NCDs [1-5]. Without an effectual policy action to educate the public regarding the negative health outcomes of the overconsumption of SSBs in

conjunction with increasing the prices of SSBs, global efforts to address the NCD-related epidemic will be challenging to achieve.

Findings from the present study suggest that compared to water consumption, which is employed in the study as a benchmark data point for healthy consumption, there was a high-frequency consumption (HFC) of SSB per week across all ethnic and socioeconomic groups at a rate of nearly (18%-20%) (Figures 4, 5, 6). This HFC of SSB consumption may raise the risk factor for NCDs, including obesity, type 2 diabetes, dental caries, certain forms of cancer, liver disease, and cardiovascular disease [55-57]. A multiple-country population-based investigation found that frequent consumption of artificial SSB was positively associated with all-cause deaths in this large European cohort [58]. Moderately frequent intake of soft drinks and juice is associated with an increased risk for the development of type 2 diabetes in Chinese men and women [59]. Similar research showed that regular consumption of artificially sweetened soft drinks and fruit juices increased the risk of developing pancreatic cancer in Chinese men and women [60]. Inconstant with the findings of [60], in a European cohort population research, SSB consumption was not found to be associated with a risk of developing pancreatic cancer; however, the study further found that artificially sweetened juice and nectar consumption might be associated with a moderately decreased risk of pancreatic cancer [61].

The results described in Figures 3-6 show that whereas water was the most frequently consumed beverage across all the ethnic and sociodemographic groups, neatly (≤ 50%) of the respondents reported consuming SSBs at least once/day up to (≥ 3) times/day. Consistent with the present study results, research presented evidence of increased SSB consumption contrasted with water consumption. In the U.S. from 2011 to 2016, (20%) of U.S. children and young adults reported no water intake on a given day; however, they consumed nearly twice the calories from SSBs as those with water intake. This caloric rate exceeds the recommended (10%) of the total calories from added sugar suggested by the World Health Organization (WHO), which is (< 50) grams of sugar/day for most adults and less for young adults and children [62]. Therefore, it is significant to employ water as a healthy key benchmark essential nutrient because increasing water intake is critical for maintaining good health, as adequate daily water intake may facilitate reducing SSB consumption and curtail childhood and adult obesity and other NCDs. SSB consumption was found to be more frequent among Chinese school-aged children, especially among males, older children, and children from urban regions, and high consumption of SSBs was found to be associated with a higher prevalence of childhood obesity and overweight. In a Chinese study, nearly (32%) of the respondents reported consuming less water than what is recommended by the Chinese Nutrition Society (≥ 1,200 mL/day), and (48.3%) of them consumed water only when they felt thirsty. Thus, it is recommended to encourage children and young adults to consume an adequate quantity of water daily to facilitate curtailing sugar intake from consuming SSBs [24, 63-65].

The increased rates of SSB consumption reported in the present study can be explained by four factors. The first is that in China, approximately 80% of advertisements on TV are focused on food and beverages. As a result, those who watch TV were heavily exposed to and targeted by these advertisements enticing them to purchase and consume more SSBs. The second factor is that parental behavior has a strong influence on SSB consumption by their children, especially mothers who are likely to have a stronger influence on the behavior of their children. Research findings suggested that children whose parents frequently consumed SSBs are likely to have a higher frequency of SSB consumption. This factor is corroborated by the findings from the present study where the married respondents' frequency of SSB consumption was (34.55%) compared to (33.49%) of single respondents (Figure 6). The third factor is the price of SSB, affordability, and education level. In China, whereas purchasing SSBs can cost more than purchasing bottled water, parents with higher socioeconomic status are more inclined to enjoy prosperous income levels and can afford to purchase SSBs for their children. The fourth factor is driven by the continuous innovation of the SSB products to meet the needs of the consumer's changing tastes and preferences, especially among young male consumers [66].

Regarding the association between the frequency of SSB consumption and the ethnic affiliation factor, Figure 4 indicated that the Hui respondents reported a higher SSB consumption of (39.44%), juxtaposed with the Han respondents who reported SSB frequency consumption of (32.66%). The level of education could have been one of the possible explanations for the higher SSB consumption rate among Huis. Table 1 shows that (62.53%) of the Han respondents have a college education contrasted with (15.93%) of the Hui respondents. The disparity of having no college education between the two ethnic groups is even wider, where Huis reported having no college education with (84.07%) juxtaposed with Hans at (37.47%). Consistent with these level of education findings, [67, 68] reported that workforces in jobs requiring less level of education such as service workers were more likely to purchase unhealthy

foods such as sugary beverages and consume less water. These results are in line with findings from earlier research that suggested that HFC of SSB is more likely to be higher among ethnic and lower-income groups, as well as positively associated with the household family size, income, and level of education factors. Similar findings posited that only the non-Hispanic White respondents reduced SSB consumption and reported a comparable increase in tap water intake. Conversely, lower-income and ethnic minority groups consumed a relative modicum of plain water. The above findings were corroborated by Dutch researchers who suggested that the association between SSB consumption rates fluctuated based on the child's ethnic background ranging from (8.7%) for respondents from Moroccan or Turkish ethnic backgrounds up to (44.4%) for respondents with Dutch background [69-72]. Beverage market research suggests that Chinese consumers and some consumers in other countries, especially children, consume substantial quantities of artificial and added sugar ingested from SSBs. Epidemiological evidence shows that this causes a myriad of NCDs and increases the cost of healthcare. Levying excise taxes on SSB purchases is one of the burgeoning solutions to curtail SSB consumption that is gaining popularity and has been generating a robust public debate. Several studies reported that soda taxes have contributed to lowering SSB purchases, and possibly a reduction in the intake of sugars, calories, and volume from taxable SSBs [73-75].

Concerning the sociodemographic characteristics, Figures 5 and 6 underscore one of the notable findings that both water and SSB consumption patterns indicated near homogeneity of the participants' responses across the sociodemographic groups, gender, and marital status. This near homogeneity of responses might be associated with the age factor of the study population sample, which is ≥ 18 years old. Children and young adults (< 18) years old were not included in the present study, which might have added more variance and less homogeneity to the responses. Another possible explanation for the homogeneity of the study population sample is that the participants were drafted from four Chinese cities contiguous to the Yellow River Valley. This might have contributed to the selection of comparable sociodemographic groups and a subgroup of interest - in the case of the Hui participants with common sociodemographic characteristics. However, one of the limitations of employing a homogenous sampling might juxtapose the reasoning for aiming at the greatest possible variation and representation in sampling. In support of the age factor line of reasoning, research by [76, 77] contended that factors strongly associated with higher consumption of SSBs included being a younger adult. Approximately (71%) of male respondents aged (25-34) reported consuming SSB at least once a week. Further, rates of SSB consumption were more prevalent and higher among undergraduate college-aged students. In China, research revealed that more than (50%) of children and adolescents frequently consumed SSBs. There is a considerable body of evidence to hypothesize that the younger the age group is the more predisposed to engage in unhealthy dietary behaviors, compared to those in older age groups similar to those groups that participated in the present study. Similar findings reported by [78] suggested that a lower intake of SSBs was found among older participants, those with a higher level of education, higher income, and females.

There is an obligation to address the limitations of the current study. One of these limitations is that the study by design is cross-sectional research; therefore, it could not establish an explicit cause-effect relationship or direction between the consumption of SSB and specific negative health effects. The study relied on employing the extrapolation methodology by inferring from the existing data to estimate and understand a prospective relationship between the frequency of consumption of SSBs and any subsequent potential association with particular adverse health outcomes; therefore, a future follow-up longitudinal research is recommended. Moreover, there is a recognition that reporting bias might occur in behavioral and consumer research, where self-reporting of data is commonly employed. This recognition leads to another limitation related to the frequency of consumption of water and SSBs, which was self-reported by the respondents, and there is a possibility that they might have some water and SSBs frequency intake and serving size recall inconsistencies. The third limitation is that whereas the study examined some of the sociodemographic factors, it did not examine the participants' lifestyle, health status, household income, other ethnic groups' affiliation except Han and Hui, or religious association. It is recommended to further examine these limitations in future longitudinal and more ethnologically diverse investigational studies.

On the other hand, the strengths of the present study include that the study was conducted in four densely populated cities from which a wide-ranging and substantial sample size was randomly recruited from a vastly diverse population. This provides the study with a strong representative sample that closely reflects the characteristics of the broader population. Another key strength, is the study questionnaire, which was carefully adapted and developed, particularly for the study population that received high rates of participants' response and near completeness of the survey because

the FFQ was administered and collected face-to-face, in real-time settings, and the study examined the association between ethnic affiliation and SSB consumption in ethnic and minority groups in China, which is under-researched and has a scarcity of evidence-based data; therefore, this study paves the way for further future research in this area to include additional different ethnic and minority groups.

5. Conclusions and future research recommendations

There is evidence-based consensus to support the conclusion that there is a strong association between SSB consumption and a myriad of NCDs [12, 55-60]. Therefore, after careful evaluation of the available data, it is reasonable to extrapolate that the participants of the present study who reported higher rates of SSB consumption and lower rates of water intake were more likely to be at risk of adverse health effects. The current study presented the results based on a cross-sectional analysis, thus future longitudinal research will be contemplated to corroborate whether sociodemographic and ethnic affiliation factors are associated with the frequency of SSB and water consumption on one hand and its connection to prospective adverse health outcomes on the other hand among Chinese adults.

Considering the sizable population and global economic influence of China, the rapidly growing SSB market and consumption pattern, as well as a myriad of associated negative health effects, there is a need to introduce short-term and long-term strategies for intervention that should include: (1) considering enacting and implementing a policy of price increases by imposing SSB consumption excise taxes; (2) encouraging drinking plain water and non-SSBs to drive down SBB consumption; (3) modifying the physical access of beverages in public spaces (e.g., fewer SSBs and more water); (4) restricting SSB sales and limiting soda vending machines availability in schools and public venues; (5) launching an innovative multi-approach public health education and wellness promotion campaign tailored to school-aged children, parents, and vulnerable minority and ethnic groups.

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Author's contributions

The author read and approved the final manuscript.

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Conflict of interest

The author declares that this research was conducted in the absence of any commercial or financial relationships that could create a potential conflict of interest. The underwriters of the current research had neither influenced nor played any role concerning the development, data analysis, interpretation of the results, or drafting of this manuscript.

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