Nutrition & Diabetes www.nature.com/nutd

ARTICLE OPEN

The Beverage Quality Index and type 2 diabetes risk in women: a prospective analysis of the Mexican Teachers' Cohort

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BACKGROUND: Individual beverages have shown divergent associations with type 2 diabetes. Whether overall beverage quality affects diabetes risk is unknown. Therefore, we estimated the association of a previously developed Beverage Quality Index (BQI) with the incidence of diabetes in Mexican women.

METHODS: We included 77,484 female participants from the Mexican Teachers' Cohort without diabetes at baseline (2006–2008). At baseline, diet was assessed using a 140-item food-frequency questionnaire. The BQI included seven components (coffee, milk, juices, sugar-sweetened beverages [SSBs], alcohol, sugar added to beverages, and energy from beverages), with a total theoretical score ranging from 0 to 70. A higher score represents a healthier beverage intake pattern. Data on diabetes incidence were available through 2018 from self-reports or cross-linkage with administrative data. We used multivariable Cox proportional-hazard models adjusted for potential confounders.

RESULTS: Participants' mean (SD) baseline age was 45.9 (7.2) years, and BQI score was 37.3 (8.6), ranging from 9.8 to 69.3. During a median follow-up of 7.6 years, 4521 participants developed diabetes. After multivariable adjustment, when comparing extreme categories (≥55 vs. <25), a higher BQI was suggestively associated with lower diabetes incidence (HR: 0.87; 95% CI: 0.71, 1.06), although the estimate was imprecise. Restricted cubic spline analysis showed no association between the BQI and diabetes incidence (p-nonlinearity = 0.20).

CONCLUSIONS: In a cohort of Mexican women, the BQI for overall beverage quality showed no consistent association with diabetes incidence. Further research on beverage quality indices for Mexican populations, including those with high SSB intake, is warranted.

Nutrition and Diabetes (2026)16:3 ; https://doi.org/10.1038/s41387-026-00410-4

INTRODUCTION

Type 2 diabetes (T2D) is a major public health problem in Mexico [1]. In 2022, the prevalence of diabetes in Mexican adults was 18.3%, with 12.6% diagnosed and 5.8% undiagnosed [2]. This prevalence is higher than the global average (10.5%) [3], and is also higher in women compared to men (20.1% vs. 16.3%) [2]. Projections indicate that diabetes prevalence is expected to increase at a higher rate in middle-income countries like Mexico (21%) compared to high- and low-income countries (~12%) by 2045 [3]. A concerning trend is the increasing onset of diabetes at a younger age, with a notably faster rise in the prevalence among young adults (aged 15–49 years) compared to those aged 50 or older over the last three decades [4]. Therefore, identifying and addressing modifiable risk factors for T2D prevention, such as poor diet, is of utmost importance in Mexico [5].

Beverage intake is an important modifiable determinant of T2D. Higher consumption of sugar-sweetened beverages (SSBs) is considered a risk factor for T2D [6], while consumption of (unsweetened) filtered coffee and tea has been associated with a reduced risk [7, 8]. Beverage patterns among Mexican adults are characterized by high intakes of beverages with added sugars [9]. In women, a significant proportion of total energy intake comes from beverages such as sodas, sweetened coffee and tea, and *aguas frescas*, a typical Mexican drink made with water, fruit, and added sugar [10]. Among Mexican adults, SSBs are the main source of added sugar [9]. Notably, 19% of cardiometabolic disease mortality, including diabetes-related deaths, has been attributed to SSBs intake [11]. Therefore, identifying the optimal beverage pattern for diabetes prevention in Mexico is a public health priority.

Indices for adherence to beverage recommendations could serve as a metric to describe beverage patterns, enabling the translation from research to health policy and consumer education [12]. In Dutch patients with a history of myocardial infarction, higher adherence to the Beverage Quality Index (BQI) was associated with lower risk of cardiovascular disease (CVD) recurrence and a potential decrease in diabetes incidence [13]. The BQI, developed in the Netherlands, is an eight-component adherence score to assess beverage quality. All components of the BQI were chosen for their established influence on health, and most of them were informed by evidence-based beverage recommendations of the 2015 Dutch dietary guidelines. Prior

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Received: 9 July 2024 Revised: 20 November 2025 Accepted: 5 January 2026

studies on beverage indices showed that higher scores on the Healthy Beverage Index (HBI) and the Healthy Beverage Score (HBS) were linked to lower cardiometabolic risk factors, less kidney function decline, and lower mortality risk in US adults [14, 15]. Compared to the HBI and HBS, the BQI may better capture beverage-related factors relevant to cardiometabolic disease risk, such as the addition of sugar to otherwise "healthy" beverages such as coffee and tea, while avoiding methodological limitations related to fluid requirement estimations.

Whether overall beverage patterns affect diabetes risk in Mexican women is not known. Therefore, we examined whether the BQI is associated with diabetes incidence in a large cohort of Mexican women.

SUBJECTS AND METHODS

Study design and population

The Mexican Teachers' Cohort (MTC) is an ongoing prospective study comprising 115,307 female teachers aged 25 years or older who reside in a culturally, geographically, and economically diverse 12-state area in Mexico, with baseline measures collected between 2006 and 2008 [16]. Extensive information on socio-demographics, reproductive history, diet, lifestyle, and clinical conditions was obtained through a self-administered questionnaire. Follow-up is carried out every 3–4 years to ascertain disease diagnosis and to update risk factor profiles. Response to the baseline questionnaire was considered informed consent. The study was approved by the Research, Ethics, and Biosecurity Committee at the National Institute of Public Health of Mexico (INSP project number 1221), and all methods were performed in accordance with the relevant guidelines and regulations.

Of the 115,307 participants recruited at baseline, we excluded those with diabetes at baseline ($n = 6172$); implausible energy intakes (<500 or >3500 kcal/day) or food-frequency questionnaires (FFQs) with more than 70 missing items and/or a staple food section missing ($n = 19,111$). We also excluded women with cancer, myocardial infarction, or stroke, and those who were pregnant at baseline ($n = 3319$), due to potential changes in diet after diagnosis and/or during pregnancy. Participants with missing follow-up data were also excluded ($n = 9220$). The sample for analysis included 77,484 participants (Supplementary Fig. 1).

Dietary assessment

Dietary intake data were collected at baseline with a 140-item semi-quantitative FFQ, which was an extended version of a previously validated 116-item FFQ for Mexican women. Participants were asked how often, on average, they consumed a specified unit or portion size of each item over the previous year. Frequencies of consumption (10 categories) ranged from never to ≥6 per day. The FFQ showed good relative validity for total energy, carbohydrate, and total fat intakes compared with four 4-day 24-h recalls (Pearson $r = 0.52$, 0.57, and 0.63, respectively) [17].

Beverages were classified into five groups: (1) coffee (instant with and without caffeine), (2) milk (skimmed milk, semi-skimmed milk, full-fat milk, yogurt drink, and *atole* with milk), (3) fruit juices (fresh orange, mandarin and grapefruit juice), (4) SSBs (cola, other carbonated or non-carbonated soft-drinks, *aguas frescas*, sweetened probiotic fermented milk drink, sweetened soy milk, and *atole* with water), and (5) alcoholic beverages (beer, wine, brandy, whiskey, rum, tequila, mezcal, pulque, and aguardiente). *Aguas frescas* are traditional Mexican beverages prepared with water, fruit, and sugar (e.g., *lemon water*), but they can also be prepared with flowers (e.g., *hibiscus water*) or grains (e.g., *horchata water*). *Atole* is a traditional hot Mexican beverage prepared with water or milk, corn or rice flour, and sugar. The proportion of participants with missing beverage items within a group was estimated to be less than 5%. When some but not all items within a beverage group were missing, missing items were imputed as zero consumption. For example, if a participant reported consuming skimmed milk, but had missing values for full-fat or semi-skimmed milk, yogurt drinks, or atole with milk, these missing items were imputed as zero. Added sugar to foods and beverages at home was assessed with one item in the FFQ. As most Mexicans do not habitually add sugar to foods, we assumed that all reported added sugar was added to beverages like coffee, tea, *aguas frescas*, and *atoles*. Total alcohol intake (g/day) was calculated as the sum of ethanol from all alcoholic beverages. Energy (kcal/day) was additionally calculated through linkage with the USA Department of Agriculture food-composition database [18], and with a

Table 1. Components and scoring system for the Beverage Quality Index (BQI).

Component	Description in guidelines	Minimum score (0)	Maximum score (10)	Proportional scores between 0 and 10[a][b]
Optimum components				
Coffee	Drink 2–4 cups of filtered coffee daily[c]	0 or ≥ 900 mL/day	300 to 600 mL/day	>0 to <300 mL/day or >600 to <900 mL/day
Milk	Consume 1 to 2 portions of dairy daily	0 or ≥450 mL/day	180 to 270 mL/day	>0 to <180 mL/day or >270 to <450 mL/day
Moderation components				
Juices	Limit consumption of sugar-containing beverages	≥250 mL/day	0 mL/day	>0 to <250 mL/day
Sugar-sweetened beverages (SSBs)	Limit consumption of SSBs	≥250 mL/day	0 mL/day	>0 to <250 mL/day
Alcohol	Drink a maximum of 1 glass daily	F: >20 g/day M: >30 g/day	≤10 g/day	F: >10 to ≤20 g/day M: >10 to ≤30 g/day
Added sugar to coffee and tea	Limit addition of sugar to beverages	≥25 g/day	0 g/day	>0 to <25 g/day
Total energy from beverages	Limit amount of energy from beverages	≥15% of TEI	<10% of TEI	>10 to <15% of TEI

Components and scores were based on beverage recommendations in the 2015 Dutch dietary guidelines and emerging scientific evidence for cardiometabolic outcomes. The tea component was excluded because data on black and green tea intake were not available. The total BQI score as used in this study, therefore, includes seven components and has a theoretical range from 0 to 70.

F female, *M* male, *TEI* total energy intake.

[a] Example of allocation of proportional scores for optimum components, e.g., milk: for intakes >0 to <180 mL/day, proportional scores were = (reported milk intake in mL/day/180) × 10. For intakes >270 to <450, proportional scores were = 10−[(reported milk intake in mL/day−270/450−270) × 10].

[b] Example of allocation of proportional scores for moderation components, e.g., SSBs: for intakes between the cut-off and threshold value, proportional scores were = 10−[(actual intake mL/day/250) × 10].

[c] One standard cup of coffee was defined as 150 mL.

database used in the ENSANUT (acronym in Spanish: Mexican National Survey of Health and Nutrition).

Beverage Quality Index (BQI)

The BQI is a measure of beverage quality based on the 2015 Dutch dietary guidelines and emerging scientific evidence [13, 19]. It consists of component scores for intakes of filtered coffee, black and green tea, milk, juices, SSBs, alcohol, added sugar to beverages, and total energy from beverages (Table 1). Water and herbal teas were not included in the BQI because they are not part of the Dutch dietary guidelines. We were unable to evaluate black and green tea intake because mostly herbal teas are consumed in Mexico (personal communication). We excluded artificially sweetened beverages from the BQI because their impact on chronic disease risk is not yet clear [20, 21]. Scores were based on adherence to the relevant component. Each component was scored from 0 to 10. A score of 10 represents total adherence, whereas a score of 0 represents non-adherence. Intermediate intakes were scored proportionately from >0 to <10. The BQI has a theoretical range from 0 to 70 points. Coffee and milk were considered optimum components, with maximum scores for intakes within the recommended range (Table 1). Juices, SSBs, alcohol, added sugar to beverages (coffee, tea, *aguas frescas*, and *atole*), and total energy from beverages were considered moderation components, with maximum scores for limited consumption.

Assessment of diabetes

Incident diabetes cases were identified through self-report in any of the follow-up questionnaires or via linkages with administrative data. Self-reported cases were defined if participants answered “yes” to two out of the following three questions: having a medical diagnosis of diabetes, use of antidiabetic medication, or date of diabetes diagnosis. The questionnaire did not specifically ask about T2D; however, given the age of diagnosis and the characteristics of the population, we assumed that reported cases were T2D. The validity of self-reported cases was evaluated in a subsample of 1222 women who reported having diabetes on follow-up questionnaires, and who responded to a supplementary questionnaire with extensive questions about diagnosis, pharmacological treatment (hypoglycaemic medication or insulin), and/or diabetes-related complications. Based on an algorithm developed for the MTC, 84% (95% confidence interval (CI): 81–86%) of women who self-reported having diabetes, confirmed a diabetes diagnosis or treatment in the supplementary questionnaire [22]. Cross-linkage with clinical databases from a healthcare provider to which 78% of participants are insured (Institute for Social Security and Services for State Workers, ISSSTE) and mortality registries, were also used to identify additional diabetes cases, including incident diabetes cases as the underlying cause of death and six contributing causes of death using the E11 code from the International Classification of Diseases 10th Revision [23]. Detailed information about the two-step cross-linkage procedure is provided elsewhere [22]. Follow-up for incident diabetes was carried up until December 31, 2018.

Assessment of covariables

Socioeconomic and sociodemographic information, lifestyle habits, dietary habits, anthropometric measures, and family history of diabetes were self-reported during baseline questionnaires. To account for income and health disparities between different regions in Mexico, we categorized participants based on their region of residence (north, central, Mexico City and the metropolitan area, and south). We used internet access at home (yes/no) and type of health insurance used for serious conditions (public, private, or other) as proxies for socioeconomic position (SEP), as these have been shown to be the most relevant indicators of SEP in this population [24]. Smoking status was reported as never, past, or current. Because different questionnaires were used to assess physical activity in 2006 and 2008, metabolic equivalents of task (METs) per week were categorized into tertiles based on multiple-choice frequency responses. This allowed for comparability across waves despite differences in assessment tools. The correlation between the MTC questionnaire and the International Physical Activity Questionnaire was 0.55 [25]. Menopausal status was defined based on information on last menstruation, hot flushes, hormonal treatments, hysterectomy, and oophorectomy. Women were classified as having postmenopause if they: [1] reported no menstruation for the past 12 months, [2] had undergone bilateral oophorectomy (surgical menopause), or [3] were over 51 years old, since over 90% of women in the cohort reach menopause by that age. Women who stopped menstruating due to hysterectomy, chemotherapy, or radiation were classified as having unknown menopausal status [26]. The following food groups were estimated from the FFQ: fruits, vegetables, red meat, processed meat, fish, and legumes (servings/day). Self-reported height (cm) and weight (kg) were used to calculate BMI (kg/m^2). The reproducibility and validity of self-reported anthropometric measurements were evaluated in a subsample of 3413 participants. Standardized technician measurements were highly correlated with self-reported ones: weight ($r = 0.93$), and height ($r = 0.84$) [27].

Statistical analysis

Baseline characteristics and dietary intakes are reported across BQI categories using mean (SD), median (IQR), or frequencies and proportions, as appropriate based on data distribution. We used Cox proportional hazards models to estimate hazard ratios (HRs) and 95% CIs for the association between categories of the BQI and diabetes incidence, using the lowest category as the reference. We defined the following categories, based on power considerations and expected number of diabetes cases: <25, ≥25 to <35, ≥35 to <45, ≥45 to <55, and ≥55. Person-years were computed from the date of response to the baseline questionnaire until the date of incident diabetes diagnosis, death, or response to their last questionnaire, whichever came first. For clinical or administrative databases, the end of follow-up was December 31, 2018. When the date of diabetes diagnosis was missing, we imputed it to the midpoint between the dates of the last diabetes-free questionnaire and the first diabetes-positive questionnaire. A directed acyclic graph (DAG) was used to identify potential confounders of the BQI–diabetes association, informed by previous literature. The final set of covariables was included in Supplementary Fig. 2. Model 1 was adjusted for age (years). Model 2 was additionally adjusted for area of residence (north, central, Mexico City and metropolitan area and south), SEP (internet access yes/no and health insurance used in case of serious conditions: public, private, or other), physical activity (tertiles of METs/week), smoking status (never, past, current and unknown), family history of diabetes (yes/no), and menopausal status (premenopausal, postmenopausal and unknown). Model 3 was additionally adjusted for energy intake (kcal/day from solid foods only) and intake of the following food groups in servings/day: fruits, vegetables, red meat, processed meat, fish, and legumes. While the DAG suggests that energy intake could potentially mediate the association between the BQI and diabetes incidence, it is important to note that energy intake was measured concurrently with the exposure. Thus, energy intake cannot be considered a mediator but rather a confounder in the association. Therefore, we decided to further adjust our multivariable model 3 for energy intake to account for its likely role as a confounder, and to minimize measurement error in dietary intake estimations [28].

Restricted cubic splines were used to examine the dose–response relationship between the BQI and diabetes incidence, using model 3. A BQI score of 25 was set as the reference, and knots were placed at the 5th, 35th, 65th, and 95th percentiles. The Wald chi-square test was carried out for testing the nonlinearity of the association [29].

We performed sensitivity analyses to test the robustness of our findings. First, we repeated the analyses using a different definition of diabetes, including only women who self reported a diagnosis plus medical treatment for diabetes. Using this definition, 87.0% (95% CI: 84.8, 89.0) of participants classified as having diabetes confirmed the diagnosis and treatment in the supplementary questionnaire. Second, to address the potential for reverse causality, where individuals may have altered their diet in response to early symptoms or a diagnosis of diabetes, we conducted a sensitivity analysis excluding participants who developed diabetes within the first 3 years of follow-up. Third, we used an alternative, data-driven categorization of the BQI in approximate deciles (<20, ≥20 to <30, ≥30 to <40, ≥40 to <50, ≥50 to <60, and ≥60) to test the robustness of our findings across finer gradients of the BQI score. Fourth, for understanding whether associations were driven by any individual component of the BQI, we repeated main analysis by excluding one of the seven BQI components at a time, and additionally adjusting for the excluded component in model 3. Fifth, we excluded energy from beverages from the BQI because of overlap with other components, e.g., SSBs. Sixth, we used an alternative BQI, moving coffee, *atole* with milk, and yogurt drink to the SSBs component, assuming they were sweetened. BMI was not included in the main analysis because it may act as a confounder, mediator, or effect modifier in the diet-diabetes associations. Nevertheless, we additionally adjusted model 3 for baseline BMI (categories: normal weight, overweight, obesity, and unknown). Eight, we examined interaction terms of the BQI with age (years), BMI (continuous and categories), and SEP (categories). Finally, we conducted prespecified subgroup analyses by age (below and above the median), BMI status (<25 and ≥25 kg/m^2), and SEP, using health insurance for serious conditions as a proxy (public and private).

We used missing indicator variables (category unknown) to handle partially missing confounder information for BMI, smoking, and menopausal status (from 3.0 to 8.9%). SAS software version 9.4 was used to calculate the BQI scores, and R version 4.0.2 was used to perform all analyses. Two-sided p values < 0.05 were considered statistically significant, also for interaction terms.

RESULTS

Compared with participants in lower BQI categories, those in the highest BQI category (≥55) were more likely to be from the northern region of the country, older, postmenopausal, current smokers, to have obesity, have greater access to the internet, and have a family history of diabetes (Table 2). Participants lost to follow-up ($n = 9244$) were more likely to be from the southern region of the country, older, and less likely to have access to the internet compared to respondents (Supplementary Table 1). BQI scores ranged from 9.8 to 69.3, with a mean (SD) of 37.3 (8.6). The most consumed beverage was SSBs [median(IQR): 315 (169–579) mL/day], while alcoholic drinks were the least consumed [0.46 (0.0–1.42) glasses/day] (Table 2). These consumption patterns are reflected in the component scores, with alcohol having the highest score, and SSBs and energy from beverages having the lowest scores (Supplementary Table 2). Dietary intakes were generally similar across BQI categories, except for total energy and fruit intakes, with participants in the lowest BQI category (<25) showing higher intakes compared to participants in higher BQI categories (Table 2).

After a median follow-up time of 7.6 years (568,346 person-years), 4521 participants developed diabetes. After adjusting for confounders (model 3), when comparing extreme BQI categories (≥55 vs. <25), a higher BQI was associated with a lower incidence of diabetes (HR: 0.87; 95% CI: 0.71, 1.06), although there was uncertainty in the estimation (Table 3). In continuous analysis (P for nonlinearity = 0.20), using restricted cubic splines, HRs were close to 1 and non-significant across the entire range of BQI values (Fig. 1).

In sensitivity analyses, using a stricter definition of incident diabetes showed a similar association (HR model 3, BQI ≥ 55 vs. <25: 0.87; 95% CI: 0.70, 1.09) (Supplementary Table 3). The estimates did not substantially change when excluding participants who developed diabetes within the first 3 years of follow-up (Supplementary Table 4), using an alternative categorization of the BQI (Supplementary Table 5), excluding individual BQI components one at a time (Supplementary Table 6), excluding the energy from beverages component of the BQI (Supplementary Table 7), moving sweetened coffee and dairy beverages to the SSBs component (Supplementary Table 8), or further adjusting for BMI (Supplementary Table 9).

The BQI–diabetes associations were consistent across subgroups of age and SEP (all $P_{\text{interaction}} > 0.05$), but not across BMI subgroups ($P_{\text{interaction}} = 0.016$) (Supplementary Tables 10–15). Among participants with overweight and obesity, a higher BQI (≥55 vs. <25) was associated with a lower incidence of diabetes (HR: 0.77; 95% CI: 0.61, 0.96) in multivariable analysis (Supplementary Table 13).

DISCUSSION

We applied the BQI to assess overall beverage intake quality in a large cohort of Mexican women. There was suggestive evidence for a lower diabetes incidence among women in the upper BQI category (indicating higher beverage quality), but findings were not statistically significant, and could not be confirmed in continuous analysis.

Research on overall beverage quality assessed with a priori developed beverage scores and cardiometabolic outcomes is limited. Two previous studies showed that higher scores on the HBI and the HBS were associated with lower cardiometabolic risk factors, less kidney function decline, and a lower risk of mortality in US populations [14, 15]. However, two other studies that used the HBI in European population-based cohorts did not find associations with cardiometabolic outcomes, including diabetes [30, 31]. In a previous study, we found that a higher BQI (T3 vs. T1) was associated with lower risk of recurrent CVD, lower risk of CVD mortality, and with a potential decrease of diabetes incidence in Dutch patients with a history of myocardial infraction from the Alpha Omega Cohort [13]. Similarly, in our population of Mexican women with different beverage patterns, a potential decrease in diabetes incidence was observed.

The BQI was developed based on the current Dutch dietary guidelines [19, 32]. Based on our findings, we conclude that the BQI may not optimally reflect guidelines or intake patterns in Mexico. Previously, Rivera et al. adapted beverage guidelines developed for the US population to the Mexican context [33]. These guidelines prioritize the consumption of water, skimmed and semi-skimmed milk, and in third place, unsweetened coffee and tea, and promote the limitation of full-fat milk intake. Unlike the Dutch dietary guidelines, which do not provide recommendations for milk with varying fat content due to insufficient evidence yet to make distinctions between high- and low-fat dairy (milk) [19], the Mexican context, characterized by a relatively high proportion of the population with overweight or obesity, may warrant differentiated scoring based on milk fat content.

Existing literature lends support to the health effects of the individual BQI components. The unhealthy beverage components of the BQI, like SSBs, have been consistently associated with a higher risk of diabetes [6]. A previous study within the MTC showed that soda consumption is associated with a higher rate of diabetes in a magnitude similar to that reported in other populations [34], and with a higher risk of other cardiometabolic diseases, such as hypertension [35]. On the other hand, coffee and tea, and possibly dairy beverages (yogurt), have been shown to be largely protective for cardiometabolic health [7, 8, 36]. However, in Mexico, healthy beverages such as coffee, tea, and dairy beverages tend to be drivers of added sugar intake. Most participants (83%) added sugar to their coffee and tea, and the Mexican beverage pattern is also characterized by added sugar in other popular beverages, such as *aguas frescas* and *atoles*, on top of high SSBs intake. Besides, the most consumed type of coffee in Mexico is instant coffee, rather than the filtered coffee consumed in the Netherlands, for which associations with cardiometabolic outcomes are not fully clear [37, 38]. Teas in Mexico tend to be (sweetened) herbal teas, in contrast to (mostly unsweetened) black tea, which is popular in the Netherlands. These factors may counteract the potential beneficial effects of dairy beverages, tea, and coffee intake. And therefore, make this index less suitable to estimate beverage quality in this population.

Moreover, the unhealthy beverage pattern among participants in the MTC, characterized by high consumption of beverages with added sugar and thus a considerable proportion of energy coming from beverages (20%), was relatively homogeneous. Almost all participants consumed SSBs (99.5%), including those in the highest BQI category. This relative homogeneity in beverage intake patterns affected the scoring, placing most participants in the central categories of the BQI, which hampered comparisons.

Results from sensitivity analyses were in line with the main findings, showing a potentially lower risk of developing diabetes at higher BQI scores. Also, excluding individual components from the BQI did not greatly change the estimates. However, when excluding the component energy from beverages, the HR decreased the most, although the uncertainty around the estimate was high. We scored calories from beverages separately from other beverage components

Table 2. Baseline characteristics of 77,484 participants of the Mexican Teachers' Cohort and average dietary intake by categories of the BQI.

		BQI score, categories				
	Total (*n* = 77 484)	**<25 (*n* = 5014)**	**≥25 to <35 (*n* = 26 789)**	**≥35 to <45 (*n* = 31 630)**	**≥45 to <55 (*n* = 11 688)**	**≥55 (*n* = 2363)**
Age, years	45.9 (7.2)	41.7 (7.3)	41.7 (7.2)	42.0 (7.2)	42.8 (7.2)	44.0 (7.1)
BMI, kg/m²	27.2 (4.7)	26.7 (4.4)	27.0 (4.6)	27.2 (4.5)	27.4 (4.6)	27.7 (4.7)
BMI, categories, %						
Normal weight	32.4	35.7	34.1	32.0	30.4	28.7
Overweight	37.2	37.9	37.4	38.5	38.7	39.2
Obesity	21.0	17.8	20.1	20.8	22.0	23.7
Unknown	9.4	8.7	8.4	8.7	8.9	8.4
Mexican regions, %[a]						
North	12.8	10.3	14.9	19.1	25.3	34.7
Central	18.2	22.9	19.3	17.1	13.9	12.7
Mexico City and the State of Mexico	15.3	25.9	23.2	23.2	23.8	25.2
South	53.7	40.9	42.6	40.6	37.0	27.4
Insurance - serious condition, %						
Social security	70.2	72.3	70.5	70.8	69.0	67.5
Private	20.3	19.1	19.0	17.6	17.7	17.6
Other	9.5	8.6	10.5	11.6	13.3	14.9
Internet access at home, %	39.5	49.0	47.8	48.4	51.9	61.9
Family history of diabetes, %	44.4	45.2	45.4	45.9	48.1	51.6
Menopausal status, %						
Premenopausal	73.9	78.1	78.3	77.7	74.6	71.9
Postmenopausal	15.9	13.3	13.2	13.3	15.7	18.0
Unknown	10.2	8.7	8.5	9.0	9.7	10.1
Physical activity, METs/week[b]						
Tertile 1, %	33.4	29.7	31.9	31.9	34.3	33.1
Tertile 2, %	33.0	32.3	33.7	34.8	33.6	32.9
Tertile 3, %	33.6	38.1	34.4	33.2	32.0	33.9
Smoking status, %						
Current smoker	10.5	7.4	8.5	9.3	10.3	14.0
Past smoker	13.4	11.5	11.1	11.5	12.6	16.4
Never smoker	72.4	78.4	77.5	76.1	74.1	66.5
Unknown	3.7	2.7	2.9	3.2	3.1	3.1
Dietary intake						
Total energy, kcal/day	1817(623)	2195 (640)	1901 (627)	1748 (591)	1676 (608)	1691 (571)
Fish, s/day	0.5 (0.3–0.8)	0.6 (0.3–0.9)	0.5 (0.3–0.8)	0.5 (0.3–0.8)	0.5 (0.3–0.8)	0.5 (0.3–0.9)
Fruit, s/day	3.1 (1.8–4.9)	4.6 (2.9–7.0)	3.3 (1.9–5.2)	2.8 (1.7–4.5)	2.8 (1.6–4.5)	2.9 (1.6–4.5)
Vegetables, s/day	2.2 (1.3–3.5)	2.7 (1.6–4.2)	2.2 (1.3–3.6)	2.0 (1.2–3.4)	2.1 (1.2–3.5)	2.3 (1.3–3.9)
Legumes, s/day	0.5 (0.2–0.8)	0.5 (0.2–0.9)	0.5 (0.2–0.8)	0.5 (0.2–0.8)	0.5 (0.2–0.8)	0.4 (0.2–0.8)
Whole grains, s/day	2.1 (1.1–3.2)	2.4 (1.2–3.2)	2.0 (1.1–3.1)	2.0 (1.1–3.1)	2.5 (1.2–3.2)	2.6 (1.2–3.6)
Processed meat, s/day	0.5 (0.3–0.9)	0.5 (0.3–0.9)	0.5 (0.3–0.9)	0.5 (0.3–0.9)	0.5 (0.3–0.9)	0.6 (0.3–0.9)
Red meat, s/day	1.2 (0.7–1.9)	1.2 (0.8–2.0)	1.2 (0.8–1.9)	1.2 (0.7–1.9)	1.1 (0.7–1.9)	1.2 (0.7–2.0)
Coffee, mL/day	103 (16–240)	20 (8–69)	40 (8–189)	111 (20–240)	189 (34–291)	240 (189–600)

Table 2. continued

		BQI score, categories				
	Total (*n* = 77 484)	**<25 (*n* = 5014)**	**≥25 to <35 (*n* = 26 789)**	**≥35 to <45 (*n* = 31 630)**	**≥45 to <55 (*n* = 11 688)**	**≥55 (*n* = 2363)**
Milk, mL/day	179 (74–282)	447 (45–634)	169 (59–409)	189 (103–259)	143 (59–240)	155 (103–237)
Juices, mL/day	36 (8–107)	196 (107–250)	36 (21–107)	21 (8–107)	21 (8–36)	8 (8–36)
SSBs, mL/day	315 (169–579)	464 (306–772)	401 (260–694)	301 (173–516)	122 (62–228)	52 (30–88)
Alcohol, glasses/day	0.46 (0–1.42)	0.46 (0–1.42)	0.46 (0–1.42)	0.46 (0–1.42)	0.46 (0–1.57)	0.46 (0–1.57)
Added sugar to beverages, g/day	8.40 (4–13)	13 (8–21)	8 (4–13)	8 (4–8)	4 (0–8)	0 (0–4)
Energy from beverages, kcal/day	362 (207)	594 (243)	442 (208)	331 (163)	206 (113)	149 (62)
BQI score[c]	37.3 (8.6)	21.7 (2.7)	30.7 (2.8)	39.5 (2.8)	48.9 (2.7)	58.6 (2.9)

Values are mean (SD) for normally distributed continuous data, median (IQR) for skewed continuous data, or % for categorical data. The proportion of missing data was 8.6% for BMI, 8.9% for menopausal status, and 3.0% for smoking.

BQI Beverage Quality Index, *METs* metabolic equivalents of task, *s* serving, *SSBs* sugar-sweetened beverages.

[a] North: Baja California, Durango, Nuevo León, Sonora; Central: Guanajuato, Hidalgo, Jalisco; South: Chiapas, Veracruz, Yucatán.

[b] Tertiles based on the total study population.

[c] BQI theoretical score ranges from 0 to 70.

Table 3. Risk of incident diabetes by categories of the BQI among 77,484 participants of the Mexican Teachers' Cohort.

	BQI score, categories				
Mean (SD)	**<25 21.7(2.7)**	**≥25 to <35 30.7 (2.8)**	**≥35 to <45 39.5 (2.8)**	**≥45 to <55 48.9 (2.7)**	**≥55 58.6 (2.9)**
***n*/Events**	**4715/299**	**25 323/1466**	**29 755/1875**	**10 950/738**	**2220/143**
Crude incident diabetes rates	7.9	7.4	8.1	8.7	8.3
Person-years	37,582	197,696	231,020	84,806	17,242
Model 1	Ref.	0.96 (0.84, 1.08)	1.05(0.93, 1.19)	1.11 (0.97, 1.27)	1.01 (0.82, 1.23)
Model 2	Ref.	0.94 (0.83, 1.07)	1.01 (0.89, 1.14)	1.03 (0.90, 1.18)	0.88 (0.72, 1.08)
Model 3	Ref.	0.93 (0.82, 1.06)	0.99 (0.88, 1.12)	1.01 (0.88, 1.16)	0.87 (0.71, 1.06)

Estimates are HR (95% CI) from Cox proportional hazards models. Model 1 was adjusted for age. Model 2 was additionally adjusted for area of residence, socioeconomic position, physical activity, smoking, family history of diabetes, and menopausal status. Model 3 was additionally adjusted for food groups intake (fruits, vegetables, red meat, processed meat, fish, and legumes) and energy intake from foods.

BQI Beverage Quality Index, *CI* confidence intervals, *HR* hazard ratios, *SD* standard deviation.

in the BQI. This approach was taken because cohort studies often adjust for total energy intake, not allowing for ad libitum intake (and overconsumption) of caloric beverages. Therefore, the role of (excessive) energy intake from beverages on chronic disease risk may be underestimated. Healthy, non-caloric alternatives (e.g., water, unsweetened coffee and tea) are available for sweetened beverages, and there is no need to quench thirst with caloric beverages, providing additional rationale for this penalty.

Upon further subgroup analysis, among participants with overweight and obesity, those with the healthiest beverage intake patterns exhibited lower diabetes incidence, with a significant interaction observed between the BQI and BMI. BMI could act as a confounder, mediator, or effect modifier in the BQI–diabetes association. Therefore, these findings need to be interpreted with caution because BMI could also be a collider (Supplementary Fig. 1), and conditioning on a collider could result in overadjustment bias [39].

Strengths of this study include its large sample size and prospective design with long-term follow-up, detailed information on risk factors for diabetes, enabling extensive control for confounding, and the conducted sensitivity analyses. Some limitations of this study should be acknowledged. Self-reported dietary intakes are prone to non-differential misclassification. In particular, the use of an FFQ, which relies on memory and provides limited food detail, leading to measurement error, may attenuate the observed BQI–diabetes associations compared to more detailed methods like 24-h recalls. However, FFQs remain the preferred method for studies like this because they capture habitual dietary intake, whereas short-term methods such as 24-h recalls may not reflect the usual diet and can also lead to misclassification. *Aguas frescas* and *atoles*, together with sweetened probiotic fermented milk drinks, were categorized as SSBs due to their added sugar content; however, their role in cardiometabolic risk is unknown. These beverages may have potential beneficial effects (probiotics, fruits) that could counterbalance the negative effects of added sugar, which may have introduced misclassification biasing the HRs towards the null. Future studies need to clarify the role of these popular beverages

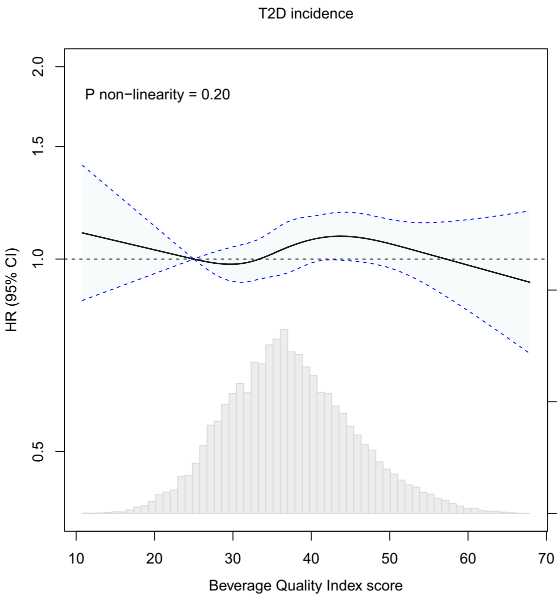

Fig. 1 Dose–response association between the BQI score and diabetes incidence in the Mexican Teachers' Cohort. The BQI score was modeled with restricted cubic splines in a multivariable dose–response model (solid lines). Dashed lines represent the 95% confidence intervals for the spline model. The multivariable model was adjusted for age, area of residence, socioeconomic position, physical activity, smoking, family history of diabetes, menopausal status, food groups intake (fruits, vegetables, red meat, processed meat, fish, and legumes), and energy intake from foods. BQI Beverage Quality Index, CI confidence interval, HR hazard ratio, T2D type 2 diabetes.

on cardiometabolic health. In the FFQ, participants were asked about their added sugar intake in foods and beverages. While we could not differentiate the specific amounts for each, we attributed all reported added sugar intake to beverages such as coffee, tea, *aguas frescas*, and *atoles*. This assumption is based on the common practice in Mexico of sweetening these beverages, whereas sugar is generally not added to foods. Most diabetes cases were identified through self-report, which may have introduced non-differential inaccuracies in outcome ascertainment due to potential underreporting or overreporting. While this may slightly attenuate observed associations, the overall impact on risk estimates is likely minimal given the study size. However, some reduction in precision and wider CIs remain possible. Although excluding early diabetes cases may have introduced selection bias [40], the minimal difference in the estimates suggest this bias is likely limited. Approximately 11% of participants did not respond to follow-up questionnaires and were considered lost to follow-up, potentially resulting in selection bias. Those lost to follow-up were slightly older and less likely to have access to the internet (proxy for socioeconomic status) at baseline compared to participants included in the study. However, no other significant differences were observed, suggesting that selection bias is unlikely. Finally, and most importantly, the BQI was not specifically created for the Mexican population; thus, it may not be the most suitable scoring system to evaluate beverage quality in populations that consume significant amounts of beverages with added sugar.

In conclusion, in a cohort of Mexican women, the BQI for overall beverage quality showed no consistent association with T2D. Future studies should explore and develop composite beverage scores that better reflect population-specific beverage intake patterns and identify optimal beverage intake patterns for cardiometabolic health.

DATA AVAILABILITY

The datasets generated during and/or analyzed in the current study are available from the corresponding author upon reasonable request.

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ACKNOWLEDGEMENTS

The authors thank Adrian Cortes and Antonio Garcia-Anaya for assistance with data management. The authors also thank ISSSTE (Social Security and Services Institute for Employees of the State) and Victor Sastre from Mexico's Ministry of Education for their technical and administrative support. In particular, the authors would like to thank Dr. Vesta Louise, Richardson López Collada from ISSSTE, for providing the MTC access to the Comprehensive Management of Diabetes by Stages (MIDE) program and the Observatory of Diabetes and Chronic Diseases (ODEC). The authors are extremely grateful to the Mexican Teachers' Cohort participants, as, without their participation, this study would not have been possible.

AUTHOR CONTRIBUTIONS

MGJC, AM, JMG, and DS conceptualized and designed the study. AM granted access to the data. MGJC and AM performed the data analysis under the supervision of DS. MGJC wrote the first draft of the manuscript, and AM, NK, TV, DS, and JMG edited, reviewed, contributed to the interpretation of results, and approved the final version of the manuscript. DS is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

FUNDING

Financial support for the Mexican Teachers' Cohort was obtained from the American Institute for Cancer Research (grant number 05B047) and the Consejo Nacional de Ciencia y Tecnología (CONACyT) (grant number S0008-2009- 1: 000000000115312). MGJC was supported by a scholarship from the CONACYT (grant number 2018-000009-01EXTF-00323).

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41387-026-00410-4.

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