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Beverage Consumption Patterns and Their Association with Metabolic Health in Adults from Families at High Risk for Type 2 Diabetes in Europe—The Feel4Diabetes Study

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Abstract: In total, 3274 adults (65.2% females) from six European countries were included in this cross-sectional analysis using data from the baseline assessment of the Feel4Diabetes study. Anthropometric, sociodemographic, dietary and behavioral data were assessed, and the existence of metabolic syndrome (MetS) was recorded. Beverage consumption patterns (BCPs) were derived via principal component analysis. Three BCPs were derived explaining 39.5% of the total variation. BCP1 was labeled as "Alcoholic beverage pattern", which loaded heavily on high consumption of beer/cider, wine and other spirits; BCP2 was labeled as "High in sugars beverage pattern" that was mainly characterized by high consumption of soft drinks with sugar, juice containing sugar and low consumption of water; and BCP3 was labeled as "Healthy beverage pattern" that was mainly characterized by high consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar. After adjusting for various confounders, BCP2 was positively associated with elevated triglycerides ($p = 0.001$), elevated blood pressure ($p = 0.001$) elevated fasting glucose ($p = 0.008$) and the existence of MetS ($p = 0.006$), while BCP1 was inversely associated with reduced HDL-C ($p = 0.005$) and BCP3 was inversely associated with elevated blood pressure ($p = 0.047$). The establishment of policy actions as well as public health nutritional education can contribute to the promotion of a healthy beverage consumption.

Keywords: metabolic health; beverage consumption patterns; principal component analysis

1. Introduction

As old infectious diseases have been largely overcome, non-communicable diseases (NCDs) have emerged as the primary contributors to illness and death, affecting both developed and developing countries. Among these NCDs, MetS has become a significant global challenge during the last decades. Although there may be minor differences in

how MetS is defined by various healthcare organizations, it is commonly acknowledged as a group of coexisting comorbidities, including obesity, hypertension, hyperlipidemia and insulin resistance [1]. According to the estimates, the global prevalence of the MetS varies from 12.5% to 31.4% depending on the definition considered. Significant regional differences can be observed, which can be partially attributed to variations in lifestyle habits and ethnic backgrounds, as well as a country's level of income [2]. The development of MetS involves a complex interplay of factors such as genetic and epigenetic determinants, the gut microbiome, caloric imbalance, diet as well as lifestyle choices. Among these factors, an imbalance in calorie intake and energy expenditure is a key contributor to MetS, with diet playing a crucial role and being a major modifiable factor [3].

Various dietary patterns, including moderate–high-protein diets, plant-based diets, the Mediterranean and DASH (Dietary Approaches to Stop Hypertension) diet, as well as the intermittent fasting, have been linked with improvements in MetS criteria [4,5]. On the other hand, added sugars as well as heavy alcohol consumption have been positively linked to the coexisting comorbidities, also increasing the risk of developing the MetS [5,6]. Part of the added sugar intake comes from sugar-sweetened beverages (SSBs) consumption, including soft drinks, bottled fruit juices, as well as energy drinks [5,6]. The World Health Organization (WHO) has highlighted the consumption of SSBs as a major risk factor for the chronic diseases associated with the MetS and advice reducing their intake for improved health outcomes. At the same time, evidence, including that from meta-analyses, during the last decades has shown that SSBs consumption is associated with a higher risk of MetS in adults. In a very recent systematic review and meta-analysis, nine cross-sectional and five cohort studies were included, indicating that the consumption of SSBs was positively associated with an increased risk of MetS [7]. In terms of alcohol, the association between its consumption and the prevalence of MetS and its components is not always consistent. In a recent cross-sectional analysis of data obtained from 12,285 men and women, a current consumption of >30 g of alcohol/day was significantly associated with a higher risk of MetS and its components in men [8]. On the other hand, in a prospective study of 7483 Caucasian men from USA, all levels of alcohol consumption provided significant inverse associations with incidence of MetS [9].

Several studies have examined the effects of specific beverage item consumption and of the total alcohol consumption on weight gain, cardiovascular diseases as well as MetS. However, there is a lack of studies, especially for the European population, regarding BCPs and their association with metabolic health. Thus, the present study aimed to investigate the association of BCPs with metabolic health in adults from families at high risk for type 2 diabetes (T2D) in Europe.

2. Materials and Methods

2.1. Study's Design

This study was a cross-sectional analysis of baseline data of high-risk families participating in the large pan-European population-based cohort, the Feel4Diabetes Study (Families across Europe following a healthy Lifestyle for Diabetes prevention). Feel4Diabetes was a large school- and community-based intervention among families from vulnerable groups in six European countries, undertaken from 2016 to 2018 [National Clinical Trial number, NCT02393872; https://feel4diabetes-study.eu/ (accessed on 5 June 2024)]. The aim of the intervention was to promote a supportive social and physical environment in home and school settings to assist families in adopting a healthy and active lifestyle. In Bulgaria and Hungary (i.e., low- and middle-income countries—LMICs), all families were considered vulnerable and eligible to participate in the study, while in Belgium, Finland, Greece and Spain (i.e., high-income countries—HICs), families from municipalities with the lowest educational level or the highest unemployment rate (as retrieved from official resources and authorities) were included as vulnerable groups.

During the first-stage screening in each country, primary schools located in the selected "vulnerable" areas were used as the entry point to the community. Children attending

the first three grades of compulsory education as well as their parents and grandparents (wherever feasible) were recruited to the study. Of these recruited families, the "high-risk families" were identified based on T2D risk estimation, using the Finnish Diabetes Risk Score (FINDRISC) questionnaire. A family was regarded as "high-risk" if at least one parent fulfilled the country-specific cut-off point for FINDRISC that indicated increased T2D risk (for the majority of countries, considering the young age of the participants, that was set as a FINDRISC score ≥ 9). Self-administrated FINDRISC questionnaires were collected from 11,396 families, and then all the parents and/or grandparents of the "high-risk families", irrespectively of their individually calculated FINDRISC, were invited to undergo a more detailed assessment (second screening) delivered in local community centers or during home visits (in Belgium). From the identified "high-risk families", 3148 parents from 2535 families underwent the second screening. A detailed description of methods has been previously published [10,11].

2.2. Bioethics

The Feel4Diabetes study adhered to the Declaration of Helsinki and the conventions of the Council of Europe on human rights and biomedicine [10]. All participating countries obtained ethical clearance from the relevant ethical committees and local authorities. More specifically, in Belgium the study was approved by the Medical Ethics Committee of the Ghent University Hospital (ethical approval code: B670201524437); in Bulgaria, by the Ethics Committee of the Medical University of Varna (ethical approval code: 52/10-3-2016r) and the Municipalities of Sofia and Varna, as well as the Ministry of Education and Science local representatives; in Finland, by the hospital district of Southwest Finland ethical committee (ethical approval code: 174/1801/2015); in Greece, by the Bioethics Committee of Harokopio University (ethical approval code: 46/3-4-2015) and the Greek Ministry of Education; in Hungary, by the National Committee for Scientific Research in Medicine (ethical approval code: 20095/2016/EKU); and in Spain, by the Clinical Research Ethics Committee and the Department of Consumers' Health of the Government of Aragón (ethical approval code: CP03/2016). All participants gave their written informed consent prior to their enrolment in the study.

2.3. Study Population

The sample of the present cross-sectional analysis consisted of 3274 adults from the "high-risk families".

2.4. Anthropometry

For the weight measurement, the participants had to wear light clothing and remove the shoes, while for the height measurement, they had to stand in an erect position without shoes, shoulders relaxed, arms by the side and head aligned in the Frankfort plane. Weight was recorded to the nearest 0.1 kg using a calibrated SECA digital scale (SECA 813, Hamburg, Germany) and height was recorded to the nearest tenth of a centimeter (i.e., 0.1 cm) using a telescopic stadiometer (SECA 213). All volunteers were categorized by the Body Mass Index (BMI) cut-off points. BMI was calculated by the formula [weight/height^2]. Waist circumference (WC) was measured midway between the lowest rib margin and the iliac crest to the nearest 0.1 cm using a non-elastic measuring tape (SECA 201). BMI and WC were classified based on the WHO criteria [12].

2.5. Blood Indices

Blood tests were performed on the same day with the anthropometric measurements by professional staff on all participants in the morning (8:30–10:30) after 12-hour overnight fasting. Measurements of fasting plasma glucose (FPG) were acquired. Blood samples directed for glucose measurement were collected in tubes with sodium fluoride (10.0 mg) and potassium oxalate (8.0 mg) for the inhibition of glycolysis. Participants were classified according to the American Diabetes Association (ADA) criteria in the following categories:

normoglycemic (FPG < 100 mg/dL; 5.6 mmol/L), prediabetics (FPG 100–125 mg/dL; 5.6–6.9 mmol/L) and having T2D (FPG > 126 mg/dL; 7.0 mmol/L) [13]. Measurements of serum total, high-density lipoprotein (HDL) cholesterol and triglyceride (TG) levels were also acquired. Low-density lipoprotein (LDL) cholesterol was calculated using the Friedewald formula [14].

2.6. Blood Pressure Measurement

Blood pressure was measured on the right arm, in a sitting position using electronic sphygmomanometers (OMRON M6 or OMRON M6 AC) after five minutes of rest, on three occasions, at one-minute intervals. The measurements were conducted in a private, quiet place with proper temperature. The existence of hypertension (HTN) was based on elevated systolic blood pressure (SBP), diastolic blood pressure (DBP) or both according to the latest European guidelines [15].

2.7. Metabolic Syndrome

In the present study, the diagnostic criteria for MetS used were those outlined by a consensus between the American Heart Association/National Heart, Lung and Blood Institute (AHA/NHLBI) and International Diabetes Federation (IDF) (Join Interim Statement, 2009) [1]. A diagnosis was posed when three or more criteria listed below were met:

- Elevated WC: ≥102 cm (men) and ≥88 cm (women);
- Elevated TG: ≥150 mg/dL (1.7 mmol/L);
- Reduced HDL-cholesterol (HDL-C): <40 mg/dL (men); <50 mg/dL (women);
- Elevated blood pressure: Systolic ≥ 130 and/or diastolic ≥85 mm Hg;
- Elevated fasting glucose: ≥100 mg/dL.

2.8. Dietary Assessment

Dietary information was derived from adults using a questionnaire measuring the frequency of meals and snacks, the frequency and quality of consumption of certain types of food at breakfast, the reasons for skipping breakfast as well as the quantity, quality and frequency of consumption of particular types of food. Moreover, participants were asked to record the consumption per week of particular beverages over the last month (water, tea, coffee, soft drink with sugar, soft drink without sugar, fruit juice freshly squeezed or prepacked without sugar, juice containing sugar, beer/cider, wine and other spirits) [16,17].

2.9. Demographic and Behavioral Characteristics

Standardized self-reported questionnaires (translated into each local language) were used in all study participants to gather information on basic sociodemographic characteristics (age, ethnicity, education level, marital status, occupation) along with information concerning smoking, physical activity, sedentary behaviors (i.e., sitting hours, screen time) and sleep duration as well as their determinants.

2.10. Statistical Analysis

Continuous variables were checked for normality using the Kolmogorov–Smirnov test. Those that were normally distributed are presented as mean ± SD while those that were not normally distributed are presented as median and interquartile range [IQR, 25th–75th percentile]. Categorical variables are presented as frequencies. The Kruskal–Wallis test for independent samples was used to evaluate differences of the continuous variables due to non-normality of the data, and one-way-ANOVA was used to evaluate the means of the normally distributed variables. Associations between categorical variables were tested by the calculation of chi-squared test.

To obtain BCPs, factor analysis with the principal components method (PCA) was applied [18]. Dietary intake of specific beverages (i.e., water, tea, coffee, soft drinks with sugar, soft drinks without sugar, fruit juice freshly squeezed or prepacked without sugar, juice containing sugar, beer/cider, wine and other spirits) were included in the analysis.

The correlation matrix of the variables used showed that there were several correlation coefficients with absolute value >0.4; moreover, the *phi* coefficient (another measure of the inter-relationship of variables) was 0.61, and the Kaiser–Meier–Olkin criterion was 0.54 (which suggests good inter-correlation). Therefore, the factor analysis would be effective for assessing meaningful BCPs. The orthogonal rotation (*rotate* with *varimax* option) was used to derive optimal non-correlated components (i.e., beverage consumption patterns). The correlation matrix was used for the extraction of the components. The information was rotated in order to increase the representation of each variable to a component [18]. According to the criterion proposed by Kaiser, i.e., the number of components that should be retained is equal to the number of eigenvalues that are greater than one, since these components explain more information than the individual variables. It was also concluded that the first two components should be extracted here. Based on the principle that the component scores (loadings) are interpreted similarly to correlation coefficients [18], and thus, higher absolute values indicate that the variable contributes most to the construction of the component, the components (patterns) were named according to scores of the variables that were >0.4.

Furthermore, multiple logistic regression analysis was applied to evaluate the association of the BCPs derived with metabolic health. The analysis accounted for the potential confounding effect of the following characteristics: age, sex, education (measured in years) as a proxy of social status, smoking status (never smoked/former smoker/current smoker) and body mass index (measured in kg/m^2). Three different models were applied for each beverage consumption pattern (BCP). Model 1: adjusted for age and sex; Model 2: age, sex, education level and smoking; Model 3: age, sex, education level, smoking and country. The results are presented as odds ratios (OR) and their corresponding 95% confidence intervals (95%CI). All reported *p*-values were based on two-sided tests. Statistical calculations were carried out using SPSS 25 software (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Characteristics of the Participants

Table 1 presents the basic characteristics of the 3274 participants stratified by country category. The median age of the participants was 41 (IQR: 37–45) and most of them were women (65.2%). The majority of participants had more than 12 years of education (73%) with these percentages being statistically significantly higher in HICs compared with other country categories ($p < 0.001$), and almost one-quarter of them were current smokers (25.9%), with these percentages being statistically significantly lower in HICs compared with other country categories ($p < 0.001$). Regarding anthropometric characteristics, participants were overweight ($p < 0.001$) while the median for the WC was 95 units (IQR: 85–105). As for the clinical characteristics of the participants, the prevalence of (pre)diabetes, HTN and MetS was 26.7%, 11.2% and 23.4%, respectively. (Table 1).

Table 1. Distribution of study participants' characteristics for the total sample and by country category.

	Total (n = 3274)	**High Income Countries (Belgium–Finland) n = 930)**	**High Income Countries under Austerity Measures (Greece–Spain) (n = 1424)**	**Low-Middle Income Countries (Bulgaria–Hungary) (n = 920)**	***p* ***
	Median * or Mean ± SD or (%)	**Median * or Mean ± SD or (%)**	**Median * or Mean ± SD or (%)**	**Median * or Mean ± SD or (%)**	
Age (years)	41 [37–45]	39 [36–44]	43 [39–46]	39 [36–44]	**<0.001**
Sex					**<0.001**

Table 1. *Cont.*

	Total (n = 3274)	**High Income Countries (Belgium–Finland) n = 930)**	**High Income Countries under Austerity Measures (Greece–Spain) (n = 1424)**	**Low-Middle Income Countries (Bulgaria–Hungary) (n = 920)**	***p* ***
	Median * or Mean ± SD or (%)	**Median * or Mean ± SD or (%)**	**Median * or Mean ± SD or (%)**	**Median * or Mean ± SD or (%)**	
Male (%)	34.8	34.9	39.7	27	
Female (%)	65.2	65.1	60.3	73	
Education					**<0.001**
≤12 years (%)	27	18.1	28.5	32.7	
>12 years (%)	73	81.9	71.5	67.3	
Smoking					**<0.001**
Never smokers (%)	46.6	56	43.8	42.5	
Former smokers (%)	27.5	31.1	28.7	22.4	
Current smokers (%)	25.9	12.8	27.5	35.2	
Body mass index (kg/m^2)	28.7 ± 6	28.5 ± 5	29.3 ± 6	27.8 ± 6	**<0.001**
Waist circumference (cm)	95 [85–105]	95 [85–104]	97 [87–106]	91 [78–103]	**<0.001**
Existence of (pre) diabetes	26.7	30.7	28.9	17.6	**<0.001**
Existence of hypertension	11.2	15.8	7.9	11.6	**<0.001**
Existence of MetS	23.4	27.2	20.6	24.3	**0.002**
Water (250 mL/week)	28 [14–42]	24 [10–36]	30 [15–45]	28 [15–42]	**<0.001**
Tea (250 mL/week)	0 [0–3]	0 [0–4]	0 [0–2]	2 [0–5]	**<0.001**
Coffee (250 mL/week)	7 [3–14]	10 [2–20]	8 [4–14]	7 [4–10]	**<0.001**
Soft drink with sugar (250 mL/week)	0 [0–2]	0 [0–2]	0 [0–1]	0 [0–2]	**<0.001**
Soft drink without sugar (250 mL/week)	0 [0–2]	0 [0–4]	0 [0–1]	0	**<0.001**
Fruit juice freshly squeezed or prepacked without sugar (250 mL/week)	1 [0–2]	0 [0–2]	1 [0–2]	1 [0–3]	**<0.001**
Juice containing sugar (250 mL/week)	0	0	0	0 [0–1.5]	**<0.001**
Beer/cider (330 mL/week)	0 [0–2]	0 [0–2]	0 [0–1]	0 [0–3]	**<0.001**
Wine (125 mL/week)	0 [0–2]	0 [0–1]	0 [0–1]	0 [0–2]	**<0.001**
Other spirits (40 mL/week)	0	0	0	0 [0–1]	**<0.001**

The reported *p*-values were calculated using the chi-square test, the Kruskal–Wallis test or the one-way ANOVA. * *p*-values indicate the significance of the differences among country categories. In bold statistically significant *p*-values at 5%. * Median: [IQR, 25th–75th percentile].

3.2. Beverage Consumption Patterns

As described above, based on the PCA, the first three components that explained the 39.5% of the total variation were studied here. The loadings for the three components (patterns) that represent the correlation of each beverage consumption variable with the corresponding component are presented in Table 2 (in bold are the coefficients with absolute loadings > 0.4, which means that they are better correlated with the component). Since the higher absolute values indicate that the beverage consumption variable contributes more to the characterization of the component [18], it could be suggested that the extracted components are characterized as follows: (a) a beverage consumption pattern (BCP1) labeled as "Alcoholic beverage pattern" (component 1), which loaded heavily on high consumption of beer/cider, wine and other spirits; (b) a beverage consumption pattern (BCP2) labeled as "High in sugars beverage pattern" (component 2) that is mainly characterized by high consumption of soft drinks with sugar, juice containing sugar and low consumption of water; and (c) a beverage consumption pattern (BCP3) labeled as "Healthy beverage pattern" (component 3) that is mainly characterized by high consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar. Component 1 was the most dominant food pattern and explained 14.9% of the total variance; the second component explained 13.2% of the total variance, while the third one explained 11.4% of the total variance. Regarding the other seven components that explained the rest of the variation in beverages consumption, none of them was characterized by a specific pattern.

Table 2. Score coefficients * (loadings) derived from factor (principal components) analysis regarding beverage consumption factors in the study participants.

	Factor 1	***Factor 2***	***Factor 3***
Water	0.213	**−0.413** †	**0.496** †
Tea	−0.038	0.347	0.470
Coffee	0.284	0.042	−0.071
Soft drinks with sugar	0.154	**0.737** †	0.076
Soft drinks without sugar	−0.009	0.179	**−0.402** †
Fruit juice freshly squeezed or prepacked without sugar	0.206	−0.135	**0.560** †
Juice containing sugar	0.096	**0.634** †	0.270
Beer/cider	**0.652** †	−0.043	−0.165
Wine	**0.674** †	−0.140	0.095
Other spirits	**0.641** †	0.104	−0.282
Explained variation, %	14.9%	13.2%	11.4%

* Score coefficients are similar to the correlation coefficients. Higher absolute values indicate that the beverage consumption variable is correlated with the respective component. † In bold, loadings > |0.4|. Description of the components: *Component 1: High consumption of beer/cider, wine and other spirits. Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water. Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar.*

3.3. Beverage Consumption Patterns and Metabolic Health

Three multiple logistic regression models were estimated in order to evaluate the association between the extracted BCPs and metabolic health (Table 3). The use of these models assisted in better exploring the potential effect of various confounders in the investigated relationship. The first model included age, sex and the three BCPs derived from the principal component analysis. It was observed that the "High in sugars beverage pattern" (component 2) was positively associated with elevated triglycerides ($p = 0.004$), elevated blood pressure ($p = 0.001$), elevated fasting glucose ($p = 0.009$) and the existence of MetS ($p = 0.004$), while the "Alcoholic beverage pattern" (component 1) was inversely associated with reduced HDL-C ($p = 0.035$) and the "Healthy beverage pattern" (component 3) was inversely associated with elevated blood pressure ($p = 0.041$). In the second model,

education (measured in years) as a proxy of social status and smoking status (never smoked/former smoker/current smoker) were also entered. The detrimental effect of the "High in sugars beverage pattern" (component 2) remained unaltered for elevated triglycerides (p = 0.002), elevated blood pressure (p = 0.001), elevated fasting glucose (p = 0.009) and the existence of MetS (p = 0.006), while the "Alcoholic beverage pattern" (component 1) was again inversely associated with reduced HDL-C (p = 0.01) and the "Healthy beverage pattern" (component 3) was inversely associated with elevated blood pressure (p = 0.022). In the third model, country of residence was included with the results being similar. The detrimental effect of the "High in sugars beverage pattern" (component 2) remained unaltered for elevated triglycerides (p = 0.001), elevated blood pressure (p = 0.001), elevated fasting glucose (p = 0.008) and the existence of MetS (p = 0.006), while the "Alcoholic beverage pattern" (component 1) was again inversely associated with reduced HDL-C (p = 0.005) and the "Healthy beverage pattern" (component 3) was inversely associated with elevated blood pressure (p = 0.047).

Table 3. The association of the derived beverage consumption patterns with metabolic health. Results are presented as odds ratios and 95%CI.

Elevated Waist Circumference			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	0.90 (0.80–1.00)	0.91 (0.81–1.02)	0.94 (0.83–1.06)
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	1.03 (0.91–1.17)	0.99 (0.88–1.23)	0.97 (0.86–1.10)
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	0.92 (0.82–1.03)	0.91 (0.81–1.02)	0.95 (0.84–1.07)
Elevated Triglycerides			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	1.00 (0.89–1.13)	0.96 (0.84–1.09)	0.92 (0.81–1.05)
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	**1.20 (1.06–1.36)**	**1.22 (1.07–1.38)**	**1.25 (1.10–1.42)**
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	1.05 (0.93–1.20)	1.08 (0.95–1.23)	1.04 (0.91–1.19)
Reduced HDL-C			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	**0.88 (0.79–0.99)**	**0.85 (0.76–0.96)**	**0.84 (0.74–0.95)**
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	1.07 (0.96–1.19)	1.07 (0.95–1.20)	1.08 (0.96–1.21)
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	1.02 (0.92–1.14)	1.03 (0.93–1.15)	1.01 (0.91–1.13)

Table 3. *Cont.*

Elevated Blood Pressure			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	1.04 (0.93–1.16)	1.06 (0.95–1.19)	1.07 (0.96–1.20)
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	**1.23 (1.09–1.38)**	**1.23 (1.10–1.39)**	**1.22 (1.09–1.38)**
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	**0.89 (0.80–0.99)**	**0.88 (0.78–0.98)**	**0.89 (0.79–0.99)**
Elevated Fasting Glucose			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	1.08 (0.96–1.22)	1.07 (0.95–1.21)	1.06 (0.94–1.20)
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	**1.18 (1.04–1.33)**	**1.18 (1.04–1.33)**	**1.18 (1.05–1.34)**
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	1.02 (0.91–1.14)	1.03 (0.92–1.15)	1.02 (0.91–1.15)
Metabolic syndrome			
	Model 1	***Model 2***	***Model 3***
Component 1: High consumption of beer/cider, wine and other spirits	1.00 (0.90–1.12)	0.98 (0.88–1.10)	0.98 (0.87–1.10)
Component 2: High consumption of soft drinks with sugar, juice containing sugar and low consumption of water	**1.20 (1.06–1.36)**	**1.20 (1.05–1.35)**	**1.20 (1.05–1.36)**
Component 3: High consumption of water, tea, fruit juice freshly squeezed or prepacked without sugar and low consumption of soft drinks without sugar	0.99 (0.88–1.11)	0.99 (0.88–1.11)	0.99 (0.87–1.11)

All odds ratios and their corresponding 95% confidence intervals were calculated by performing multiple logistic regressions. *Note*: Bold indicates statistical significance ($P_{trend} < 0.05$). Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, education and smoking. Model 3: adjusted for age, sex, education, smoking and country. Abbreviations: CI, confidence interval.

4. Discussion

In this work, we aimed to examine the association of BCPs with metabolic health in 3274 adults from families at risk of T2D in Europe. The analysis revealed that the "High in sugars beverage pattern" was positively associated with elevated triglycerides, elevated blood pressure, elevated fasting glucose and the existence of MetS, while the "Alcoholic beverage pattern" was inversely associated with reduced HDL-C and the "Healthy beverage pattern" was inversely associated with elevated blood pressure.

Some other investigators have assessed BCPs in relation to metabolic health using similar multivariate techniques and identifying alike beverage consumption patterns. In the Korea National Health and Nutrition Examination Survey (KNHANES) 2008–2012 data, 19,800 Korean adults, ≥20 years old, were investigated. Three major BCPs were identified according to factor analysis: (1) the "healthy beverage" (high intake of dairy products, 100% fruit/vegetable juices and low intake of alcoholic beverages); (2) the "sugar-sweetened beverage" (high intake of sugar-sweetened beverages like soda, sweetened coffee/tea and fruit drink); and (3) the "unsweetened beverage" (high intake of unsweetened coffee) patterns. The "sugar-sweetened beverage" pattern was associated with the increased probability of abdominal obesity, elevated fasting blood glucose and blood pressure [19]. Furthermore, in a cross-sectional study conducted among 1160 Urban Mexican young adults, four beverage patterns were identified. Within these, a "juicy pattern" showed positive high factor loading scores with bottled or canned fruit juice, bottled or canned fruit nectar juice, natural juice and soy juice and was positively associated with high triglycerides [20].

The association between the intake of SSBs and chronic diseases including the MetS is noteworthy and confirmed by the scientific literature. Based on the available evidence from prospective cohort studies as well as randomized controlled trials (RCTs), robust evidence exists for an etiological relationship between intake of SSBs and weight gain, risk of T2D and cardiovascular diseases [21]. In a very recent umbrella review, aiming to synthesize the evidence linking habitual SSBs intake with MetS in adults, 16 eligible meta-analyses were identified. Comparison of the highest and lowest levels of SSBs consumption revealed an increased risk of 18%, 12%, 29% and 29% for obesity, hypertension, T2D and MetS, respectively. Consistently, the findings from dose–response analyses are in agreement with and corroborate the existing evidence that SSBs are a significant risk factor for the development of MetS and its related conditions [22].

The results of the research on the relationship between alcohol consumption, MetS and its components are often ambiguous depending on age, sex, ethnicity, cultural traditions, lifestyle as well as the level of daily drinking. In a meta-analysis involving 28,862 participants, with 3305 cases of MetS, it was suggested that heavy alcohol consumption (>35 g/day) might be associated with an increased risk of MetS, while very light alcohol consumption (0.1–5 g/day) seemed to be associated with a reduced risk of MetS [23]. Similarly, in a very recent cross-sectional study conducted on 400 participants recruited from the Outpatient Unit of the Family Medicine Department, Faculty of Medicine, Chiang Mai University, MetS was found to be significantly associated with heavy drinking and the harmful use/dependent categories. However, a J-shaped association was found between HDL-C and drinking pattern, but an inverse relationship was indicated with the risk of harm [24]. The effect of alcohol intake on increasing the concentration of HDL-C can be probably attributed to the increased liver production and/or the transport rate of HDL apolipoproteins apoA-I and apoA-II, as well as the increased cellular cholesterol outflow and cholesterol esterification in plasma [25,26].

Tea, as a beverage consumed worldwide, and its association with MetS and its components including increased blood pressure, has attracted much interest. In a very recent systematic review and meta-analysis of randomized clinical trials (RCTs) examining the effects of tea consumption on MetS, it was suggested that tea consumption has beneficial effects on DBP, black tea consumption has protective effects on systolic SBP and green tea reduces the incidence of diabetes and lowers the level of LDL-C [27]. Similarly, in a systematic review and meta-analysis of RCTs including 408 individuals, Mahdavi-Roshan et al. [28] concluded that regular tea intake resulted in the reduction of SBP and DBP. Along with tea, water can also be consumed instead of SSBs and alcohol, as the optimal beverage of hydration, which is also free of sugar and calories.

5. Conclusions

In conclusion, we identified three major BCPs of European adults and we found that the “High in sugars beverage pattern” was positively associated with elevated triglycerides, elevated blood pressure, elevated fasting glucose and the existence of MetS, while the “Alcoholic beverage pattern” was inversely associated with reduced HDL-C and the “Healthy beverage pattern” was inversely associated with elevated blood pressure. A comprehensive approach involving health promotion strategies at various governance levels is essential, alongside raising awareness campaigns and public health nutritional education. These play a crucial role in reshaping societal norms related to beverage consumption habits and potentially lower the risk of the MetS and its components in individuals following specific BCPs. A critical focus for researchers and policymakers will be the ongoing assessment of these policies to guarantee their long-term effectiveness. Additionally, longitudinal and intervention studies are needed to confirm the lasting benefits of healthier beverage consumption patterns in preventing chronic diseases and to establish evidence-based recommendations for promoting a healthy beverage consumption.

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