Dietary Acid Load and the Risk of Cardiovascular Disease: A Prospective Population-based Study

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Abstract

Background: Considering the established association between the dietary acid load and cardiovascular outcomes, as well as the existing inconstancies in the previous studies, we aimed to assess the association between the dietary acid load and the risk of cardiovascular diseases in the framework of the Tehran Lipid and Glucose Study.

Methods: Eligible participants (n= 2369, 19- 70 years old, 43.5% men) with no cardiovascular diseases at baseline (2006-2008) were recruited and followed up for a mean period of 6.7 ± 1.4 years. Potential Renal Acid Load and Net Endogenous Acid Production, as the two indexes of dietary acid load, were calculated based on the macronutrient and micronutrient constitutions. The Cox proportional hazard regression model was used to report the association between tertiles of Potential Renal Acid Load and Net Endogenous Acid Production, and 6-years incident risk of cardiovascular diseases.

Results: The mean age and body mass index of the participants were 38.5 ± 13.3 years and 26.6 ± 4.8 kg/m^2 at baseline, respectively. The incident rate of cardiovascular diseases was reported as 3.3% (79 cases). No significant associations were detected between the Potential Renal Acid Load and the cardiovascular diseases incidence in the crude or the adjusted models (HRs= 0.63; CI: 0.36-1.17; P trend= 0.10). Meanwhile, the Net Endogenous Acid Production index was marginally significantly associated with the crude model (HR= 0.57; CI: 0.33-0.99, P trend= 0.048).

Conclusions: Data from the current study were not in favor of an independent association between the dietary acid load and the incidence of cardiovascular diseases within the Iranian population.

Introduction

The acid-base balance within the body is likely to be affected by the dietary acid load [1]. Protein-rich animal food resources can raise the acidifying potentials of a diet [2, 3] and negatively affect the metabolic and physiologic states [1, 2]. As the acidic dietary patterns became more prevalent within the global dietary transition [4], the burden of the CVDs and the epidemic of the Cardiometabolic diseases have been on the rise in the past two decades [5, 6]. Dietary acid load is usually estimated by the two indicators of the potential renal acid load (PRAL) and net endogenous acid production (NEAP). The PRAL score takes dietary magnesium, potassium, phosphorus and calcium and protein into account, whereas the protein and potassium are the only constitutions of NEAP score

There are inconsistencies regarding the possible association between the dietary acid load and the risk of developing CVDs and Cardiometabolic risk factors [7, 8]. Although the PRAL score and CVD mortality were inversely associated among the Swedish participants [9], the majority of the findings support the negative impacts of the acidifying dietary patterns [10, 11] as a result of increased tissue metabolic acidosis. No significant associations of dietary acid load and the incident rate of CVDs were detected among the Polish and Dutch populations [12, 13]. Nevertheless, the dietary acid load was associated with changes in the glucose and lipid profiles [14, 15] and blood pressure [12, 16, 17].

So far, several lines of research have studied the dietary acid load in association with the CVD-related outcomes, however, controversies still exist in the context of large-scale cohort studies. Inadequate and inconsistent results bring unclear conclusive findings and challenge the preparation of standard global dietary guidelines. Given this, this study aimed to prospectively investigate if the dietary acid load could be a predictor of the CVD incident risk in framework of the nation-wide Tehran Lipid and Glucose Study (TLGS).

Methods

Study population

The current study investigated the dietary acid load in association with the risk of CVD in the framework of the prospective TLGS [18]. The longitudinal population-based TLGS aims to alleviate the non-communicable diseases (NCDs) and NCD-related risk factors and promote a healthier lifestyle within the community. First phase of the TLGS was initiated in 1999 and recruited 15005 participants from residents of district 13 of Tehran (≥ 3 years of age) by multistage cluster random sampling [19]. To assess any possible changes to the NCD risk factors, the collected data and required measurements were taken triennially.

This study is based on the data of phase III to VI of the TLGS (2006- 2008 to 2014). Within this period, the demographic, anthropometric, biochemical, and dietary examinations were completed by 12523 individuals and the dietary assessments were taken from a random sample of 4920 participants. The randomization reduced the cost, complexity, and the time required for data collection. With a response rate of 30%, the dietary data was obtained for 3678 individuals. Participants were subsequently excluded if they were out of the predefined age limit (below 19 and above 70 years old; n= 626), had suspected report of energy consumption (below 800 and above 4200 kcal/day; n= 579), were diagnosed with CVD history at baseline (myocardial infarction, stroke, angina, coronary revascularization; n= 90), and had any missing data or lost to follow-up (n= 14). Finally, a total of 2369 adults (1030 men and 1339 women) were selected for the analysis. Participants with full report of the food frequency questionnaire (FFQ) shared resembling baseline features with the general population of the third phase of TLGS. In this regard, the FFQs were completed by 76.7% of the participants, comparing to 82.3% in the total population of the third phase. Also, the age distribution for participants with and without CVD outcomes were 58.4 ± 9.7 and 37.4 ± 12.8 years (P = 0.001), respectively. Figure 1 illustrates the stages involved in participants' selection in details.

The protocol of the current study was approved by the ethics research council of the Research Institute for Endocrine Science, Shahid Beheshti University of Medical Science, Tehran, and all methods complied with this council's guidelines and regulations.

Demographic and anthropometric measurements

A group of trained interviewers have collected the demographic information using standardized questionnaires. Variable measurements of the TLGS are described in details elsewhere [20]. The frequency and duration of light to very intense physical activity (expressed as metabolic equivalent hours per week; MET-h/wk) was assessed by a Modifiable Activity Questionnaire (MAQ) [21]. The anthropometric measurements including weight and height were taken using digital scales and 'drop-down' tape meters, respectively, and the waist circumference was obtained in the midway between the lower border of the ribs and the iliac crest. Consequently, body mass index (BMI) was calculated by the division of weight (kg) by height the squared (m^2). Systolic (SBP) and diastolic blood pressure (DBP) were measured twice on the right arm via a standard mercury sphygmomanometer. The mean of the two measurements were considered as the final blood pressure.

Biochemical measurements

Baseline and follow-up blood samples were taken from all participants following a 12-14 hour fasting. Enzymatic colorimetric was used to measure the triglyceride (TG) level and the fasting serum glucose (FSG), using phosphate oxidase and glucose oxidase, respectively. High-density lipoprotein cholesterol (HDL-C) level was obtained following the precipitation of the apolipoprotein B containing lipoproteins with phosphotungstic acid. The Pars Azmoon kits (Pars Azmoon Inc., Tehran, Iran) and a Selectra 2 auto-analyzer (Vital Scientific, Spankeren, Netherlands) were used to perform the analysis.

Dietary assessment

Demographic, anthropometric, biochemical, and dietary data were obtained at baseline (2006- 2008). The habitual dietary intake of individuals within the past year was assessed by an expert interviewer, via a validated 168-item semi-quantitative FFQ [22]. The reliability and validity of the questionnaire were previously evaluated in a random sample and proven to be reasonable. The food and beverage consumption frequency of the participants were recorded on a daily, weekly, or monthly basis [20] and the household-measured portion sizes were then converted to grams. To analyze the energy and nutritional content of the raw food items, the US Department of Agriculture Food Composition Table (USDA FCT) was used. Since the Iranian Food Composition Table lacks the necessary data on the dietary composition of the food items, it was merely used for the traditional food items not listed within the USDA FCT [23] .

Dietary acid load calculation

The dietary PRAL is a validated proxy for renal net acid excretion that explains the contribution of a food or a diet to the NEAP [1,24]. Also, the dietary NEAP score is defined as the total nonvolatile acid load that results from endogenous acid production and gastrointestinal absorption [4]. A diet with acidifying potentials has superior PRAL and NEAP scores [16, 17]. The population distribution across the tertiles of dietary PRAL are illustrated in table 1. In this regard, 792 participants had PRAL lower than -15.3

mEq/day, 798 individuals were designated with PRAL between -15.3 to -1.14 mEq/day and the remaining acquired higher PRAL than -1.15 mEq/day. The dietary PRAL was calculated based on the protein, phosphorus, potassium, calcium, and magnesium intake values [7,24], whereas the NEAP score calculation relied merely on the consumption of protein and potassium [8].

PRAL (mEq/d) = [protein (g/d) × 0.49] + [phosphorus (mg/d) × 0.037] - [potassium (mg/d) × 0.021] - [calcium (mg/d) × 0.013] - [magnesium (mg/d) × 0.026]

NEAP (mEq/d) = [{54.5 × protein (g/d)} / potassium (mEq/d)] – 10.2

Table 1
Baseline characteristics of 2369 Iranian adults aged ≥ 19 years across tertiles of PRAL: Tehran Lipid and Glucose Study (TLGS)

	PRAL (mEq/d)			
	< -15.3 (n=792)	-15.3 to −1.14 (n=789)	>-1.15 (n=788)	P-value
Age (y)	40.2 ± 13.7	39.1 ± 13.2	36.3 ± 12.6	0.001
Sex (% male)	36.5	39.9	54.1	0.001
BMI (kg/m^2)	27.1 ± 4.8	26.6 ± 4.8	26.1 ± 4.7	0.001
Current smoker (%)	9.8	12.3	14.1	0.044
Physical activity (MET-H/week)	37.1 ± 64.6	35.1 ± 51.1	35.7 ± 58.8	0.806
Hypertension (%)	37.4	32.9	29.7	0.306
Diabetes (%)	3.9	5.7	2.6	0.010

Data are presented as mean (± SD) for continuous variables and as percentage for categorical variables.

Hypertension (HTN): systolic blood pressure (SBP) ≥ 140 mm Hg or diastolic blood pressure (DBP) ≥ 90 mm Hg, or blood pressure-lowering medication.

Type 2 diabetes (T2DM): fasting serum glucose ≥ 126 mg/dL, or 2 h-SG≥ 200 mg/dL, or anti-diabetic medication.

Definition of terms

The sex-specific “general CVD” algorithms was used to compute the CVD risk score based on age, smoking and diabetic status, total cholesterol (TC), HDL-C and SBP levels, and hypertension treatment [7]. Diabetes was defined as the FSG level over 126 mg/dL, 2-h serum glucose above 200 mg/dL or

administration of anti-diabetic medications [21]. Hypertension was also explained as SBP above 140 mm Hg, DBP higher or equal to 90 mm Hg, or concurrent treatment with antihypertensive medications [22].

Definition of outcomes

In the current study, participants were followed-up annually by telephone calls and the required information on the possible medical events were collected by a trained nurse or a physician. Further information were extracted from the medical records. The collected data were reviewed by an adjudication committee, which included a physician, an internist, an epidemiologist, a cardiologist, an endocrinologist, and associate external experts as needed. The final diagnosis was reported by a predefined coding protocol [25].

CVD-related data collection procedure is described in details elsewhere [20]. The CVD terminology was primarily defined as any history of definite fatal and non- fatal stroke, coronary heart disease (CHD) or definite fatal CHD, and CVD mortality (definite fatal myocardial infarction; MI)) [26]. The CHD was also explained by any cases of definite or probable MI, unstable angina pectoris, and sudden cardiac death [27].

Statistical Analysis

In this study, version 20.0 (SPSS Inc., Chicago, IL, USA) of IBM SPSS was used to perform the data analyses and p-values higher than 0.05 were statistically significant. The mean and the frequency of the baseline characteristics across tertiles of dietary PRAL were compared by univariate analysis or chi-square. The frequency of qualitative variables were measured by the chi-square test. The cofounders of the univariate analysis included the CVD incidence risk score, total dietary energy, and total dietary fat. The physical activity factor was eliminated from the final multivariable model due to the significant P_E value ($P_E > 0.2$). To compute the hazard ratios (HRs) and the 95% confidence intervals (CIs), the Cox proportional hazards regression model was performed with person-year as the underlying time metric. Two models were adjusted for the potentially cofounding variables and the CVD incidence risk hazard ratios were estimated across tertiles of PRAL and NEAP. The first model was adjusted for TC, HDL-c, hypertension treatment, type 2 diabetes, smoking, and age, and in accordance with the CVD incidence risk score and the general CVD algorithms specified for each gender [28]. The CVD incidence risk score validation was previously assessed among the Iranian population and remained as the leading predictor of CVD events [29]. For the second model, adjustments of total dietary energy and total fat intake were also applied. The Cox proportional hazard regression model used the median values of dietary PRAL, which was considered as a continuous variable in the assessment of overall HR trends across the tertile categories. The concept of time to event has described the onset of an event, or the completion time of the follow-up.

Results

For the purpose of this study, a total population of 2369 individuals (43.5% men) were recruited. Figure 1 illustrates the successive steps involved in population inclusion. During a follow-up period of 6.7 ± 1.4 years, 79 cases of CVD events were reported (3.3%) and angiographic proven CVD, definite MI, unstable angina and stroke were the most common outcomes. Based on the data, the mean baseline age and BMI of the participants were 38.5 ± 12.7 years and 26.6 ± 4.8 kg/m^2, respectively.

Table 1 describes the baseline characteristics of the TLGS population across tertiles of dietary PRAL. Based on the data, most cases in the top tertile of dietary PRAL were men. Also, higher PRAL was negatively associated with age and the BMI. Diabetes was less prevalent in the highest tertile of PRAL that exceeded − 1.15 mEq/day.

The dietary intake of the TLGS participants across tertiles of PRAL are reported in Table 2. The mean dietary PRAL and NEAP of the recruited participants were − 10.2 ± 21.5 mEq/d and 36.5 ± 11.3 mEq/d, respectively. Participants in the highest tertile of PRAL, had the highest consumption of animal-based food items, grains and rice and the lowest dietary intake of carbohydrate, fat, fruits and vegetables, calcium, potassium, and magnesium. In contrast, participants in the lowest tertile of PRAL had the utmost consumption of fruits and vegetables, potato and legumes.

Table 2
dietary intake of 2369 Iranian adults aged ≥ 19 years across tertiles of PRAL: Tehran Lipid and Glucose Study (TLGS)

	PRAL (mEq/d)			
	< -15.3 (n = 792)	-15.3 to − 1.14 (n = 789)	>-1.15 (n = 788)	P-value
PRAL (mEq/d)	-32.1 ± 20.2	-8.1 ± 4.1	9.4 ± 9.7	0.001
NEAP (mEq/d)	25.4 ± 5.1	34.3 ± 3.8	48.3 ± 8.7	0.001
Nutrient intake				
Energy intake (kcal)	2378 ± 673	2116 ± 686	2287 ± 774	0.001
Protein (% of energy)	13.4 ± 2.3	13.4 ± 2.1	14.2 ± 2.7	0.001
Carbohydrate (% of energy)	58.9 ± 6.5	56.7 ± 6.9	56.1 ± 7.7	0.001
Fat (% of energy)	31.3 ± 6.4	32.2 ± 7.1	31.2 ± 7.3	0.008
Fiber (gr/d)	43.2 ± 19.3	32.7 ± 16.9	34.7 ± 23.3	0.001
Calcium (mg/d)	1441 ± 604	1136 ± 470	1102 ± 482	0.001
Potassium (mg/d)	4744 ± 1479	3344 ± 1094	2976 ± 1144	0.001
Magnesium (mg/d)	420 ± 130	337 ± 120	351 ± 148	0.001
phosphorus (mg/d)	1518 ± 488	1344 ± 502	1469 ± 578	0.001
Food intake				
Meat (gr/d)	36.8 ± 28.2	35.7 ± 26.8	50.8 ± 43.2	0.001
Grains (gr/d)	339 ± 171	365 ± 176	492 ± 269	0.001
egg (gr/d)	15.3 ± 14.3	13.6 ± 13.7	16.1 ± 18.1	0.010
cheese (gr/d)	21.8 ± 17.5	20.3 ± 17.2	22.8 ± 28.5	0.079
Fish (gr/d)	10.3 ± 10.5	10.1 ± 12.2	12.7 ± 34.7	0.035
Rice (gr/d)	214.9 ± 144	235 ± 150	309 ± 232	0.001
Coffee ≥ 1 cup/d (%)	18.9	9	5.6	0.001
Fruit and vegetable (gr/d)	894 ± 417	527 ± 225	358 ± 206	0.001
Potato (gr/d)	20.6 ± 23.7	16.5 ± 19.1	14.1 ± 16.1	0.001
Legumes (gr/d)	17.6 ± 24.3	15.1 ± 18.3	15.1 ± 22.7	0.024

PRAL (mEq/d)
PRAL, potential renal acid load; NEAP, net endogenous acid production.
Data are presented as the mean ± SD or percentage

The HRs (95% CI) of CVD incidence rate across tertile categories of PRAL and NEAP are shown in Table 3. Based on the results, the association between PRAL and CVD incidence in the crude model was insignificant (HRs = 0.59; CI: 0.34–1.03; P trend = 0. 058). After adjusting for the potential cofounders, no significant associations were detected for the risk of CVD across the tertiles (HRs = 0.63; CI: 0.36–1.17; P trend = 0.10). The incident risk of CVD was marginally associated with the crude model of NEAP (HR = 0.57; CI: 0.33–0.99, P trend = 0.048), nevertheless, no statistically significant associations were observed after the adjustments (HR = 0.63; CI: 0.36–1.11, P trend = 0.11).

Table 3
HR (95% CI) for cardiovascular disease across dietary acid load tertiles (n = 2369): Tehran Lipid and Glucose Study (TLGS)

		PRAL (mEq/d)		
	T1	T2	T3	
	< -15.3 (n = 792)	-15.3 to − 1.14 (n = 789)	>-1.15 (n = 788)	P-trend
Crude	1	0.73 (0.43–1.23)	0.59 (0.34–1.03)	0.058
Model 1	1	0.74 (0.43–1.26)	0.67 (0.38–1.17)	0.144
Model 2	1	0.75 (0.44–1.29)	0.63 (0.36–1.17)	0.106
		NEAP (mEq/d)		
	T1	T2	T3	
	< 30.5 (n = 790)	30.5 to 39.4 (n = 789)	> 39.4 (n = 790)	P-trend
Crude	1	0.68 (0.40–1.56)	0.57 (0.33–0.99)	0.048
Model 1	1	0.76 (0.44–1.29)	0.68 (0.38–1.19)	0.180
Model 2	1	0.77 (0.45–1.30)	0.63 (0.36–1.11)	0.115

Cox proportional hazard regression model was used to estimate hazard ratio (HR) and 95% confidence intervals (CI) for cardiovascular disease across tertiles of dietary acid load.

PRAL, potential renal acid load; NEAP, net endogenous acid production.

Model 1: adjusted for cardiovascular disease risk score

Model 2: adjusted for variable in model 1 plus dietary energy intake (kcal/d) and total fat

Discussion

This prospective, longitudinal study did not confirm the association between the CVDs incidence risk and the dietary acid load, which can be explained by the low CVD cases within the follow-up period, relatively young study population, the potential changes in the dietary patterns of the participants over time and the varying baseline characteristics of different populations. Indeed, various populations differ in their habitual dietary intake, which results in the formation of a dietary acid load spectrum [13, 30]. This new, yet inconsistent result [30–32] calls for further focus on the dietary pattern quality besides the consumption frequency and quantity of the individual food and nutrients.

Several studies have supported dietary PRAL and NEAP as potential predictors of CVDs. In this regard, a 2016 cross-sectional study in the framework of the Korea National Health and Nutrition Examination Survey endorsed the positive association between the dietary acid load and the elevated risk of CVD [31]. Higher dietary acid load was also associated with an elevated risk of CVD mortality among Japanese [33] and Swedish individuals [9], increased 10-year mortality of patients with coronary artery bypass grafting surgery background [34] and influenced the likelihood of chronic peripheral arterial disease among the American patients [35]. In contrast, results of a large-scale study in Poland reported no independent associations between dietary acid load and CVD incidence and CVD risk factors, which was in line with our findings [13].

The dietary acid load was also associated with the risk factors of CVD. The PRAL and NEAP indices were both positively related to the serum TG level among the Iranian women [36]. PRAL was independently associated with increased TG, SBP [14], and Low-density lipoprotein cholesterol (LDL) [30] measurements, and inversely related to Fasting Blood Sugar (FBS) level [14]. In a 2018 systematic review and dose-response meta-analysis, a significant non-linear association was observed between NEAP and hypertension, and a-20 unit increase in PRAL value raised the risk of hypertension by 3% [37], which was in agreement with the results of Kruppf and colleagues [38]. Furthermore, the 2015–2017 Nutrition and Health Survey investigation in South China highlighted the gender-dependent hypotensive properties of PRAL in favor of the males, which appeared insignificant in the context of NEAP [16]. A recent meta-analysis has found a potent positive association between PRAL scores and SBP, DBP, insulin concentrations and diabetes prevalence, and reported no association between markers of glucose homeostasis with PRAL or NEAP [15]. In contrast, no cross-sectional or longitudinal association was observed between dietary acid load and various BP indices in Swedish middle-aged men [39], metabolic syndrome risk factors among Iranians [17], and risk of hypertension in older Dutch adults [12]. Results from this study confirmed the inverse association between the dietary PRAL and the prevalence of diabetes. It is believed that high dietary PRAL induces low-grade acidosis that is linked to the development of metabolic complications including diabetes and hypertension, and other renal and bone complications [40].

The mean scores of PRAL and NEAP in this study were − 10.2 ± 21.5 mEq/d and 36.5 ± 11.3 mEq/d, respectively, which confirms the dietary pattern of our population to be more acidic comparing to the Dutch (-1.5 mEq/ day) [12] and Polish (-3.85 mEq/ day) [13] populations. Nevertheless, the dietary patterns of the general Chinese populations (22.1 mEq/ day) [16] and the young Japanese women (10.4

mEq/ day) [30] appeared to be more alkalizing. The median dietary acid load is estimated as 50–75 mEq/day in several populations and vegan groups tend to have roughly neutral patterns [7, 12, 30, 32]. This study was conducted on Iranian adults with a transitional dietary patterns and estimated animal-to-plant protein ratio of approximately 1.3 to 2.1.4 [41].

In line with the previous studies, we have also observed a linear association between the dietary intake of animal protein and grains and dietary PRAL level [7]. It is evidently confirmed that animal-based food items hold acidifying properties, whereas fruits and vegetables from plant resources are more alkalizing. Western dietary patterns are major acid suppliers to the body and provide 15–17% of the average energy from animal protein [2, 3]. In contrary, the DASH pattern that is mainly comprised of plant foods and monounsaturated and polyunsaturated fats can substantially reduce the dietary acid load (NEAP; 31 mEq/d *vs.* 78 mEq/d) [42]. Inadequate consumption of low-potassium fruit and vegetables in large samples of American individuals had adverse effects on the dietary acid loads [1]. The dietary potassium received from vegetables can bind to organic anions and metabolize to bicarbonate, which is ultimately capable of reducing NEAP comparing to the rate of acid production from animal foods [43]. It is suggested that increased dietary intake of fruits and vegetables as alternatives to low-nutrient and energy-dense food items can reduce the overall NEAP regardless of the amount of protein required [44].

To date, the available data on the exact and precise mechanisms linking dietary acid load and CVD events are mostly limited to the role of hypertension, as a major CVD risk factor, and the association between chronic metabolic acidosis and hypertension [13]. A Western diet-based metabolic acidosis may increase the production of cortisol, increment ammoniagenesis and renal acid excretion, alleviate the renal function and therefore, raise the blood pressure. Similarly, a potassium-depleted dietary pattern can affect the vascular vasodilation and harm the blood vessels [45]. Restrictions in the dietary intake of potassium result in intracellular potassium deficiencies and compensatory sodium gains into the cell for the maintenance of the tonicity and volume [45]. Other mediators of metabolic acidosis and hypertension include the reduced excretion of citrate, increased releasing of calcium and cortisol, and the quality and the quantity of the dietary protein [46]. Moreover, the previous studies have shown that high dietary acid load and chronic metabolic acidosis are closely linked to reduced affinity of the insulin to its receptor, increased risk of insulin resistance and subsequently, hyperglycemia [6, 11, 18]. CVD can be autonomously promoted from insulin resistance through various pathways, including coronary microcirculatory dysfunction [47] and increased arrhythmogenesis [48].

This study has a number of strengths, which can be listed as the high follow-up rate in the framework of a prospective population-based design, and the use of a validated FFQ questionnaire for the habitual dietary intake assessment. Of the main limitations are the use of the dietary PRAL score in the measurement of diet-induced acid-based balance. Both PRAL and NEAP scores are measured indirectly from the FFQs, meaning that they can be influenced by inaccurate measurements and reports of dietary intake over time, yet these values have been commonly used in the previous studies [7, 8]. Besides, the variations in the dietary patterns over time, the actual nutrient composition of specific food items within the preparation methods, and the nutrients' absorption within the gastrointestinal tract were not taken

into account by the PRAL equation. Lastly, the lower incidence of CVD events in our population could have led to underestimations in CVD incidence.

Conclusion

The incidence and prevalence of CVDs are closely connected to the dietary status of the populations. Our results of a prospective study did not reflect any significant associations between diet-induced acid load and the incident risk of CVDs among the Iranian population. Based on the analyses, high consumption of animal meat and grains in context of Western dietary patterns can increase the risk of CVDs and related complications, whereas potassium-rich plant food items may suppress the adverse effects. While the generalization of the findings to populations with higher CVD incidence requires considerations, they can be adapted to populations with resembling dietary patterns. The global growth of CVDs prevalence and the high costs and burden, as well as the critical role of nutrition in cardiovascular health, calls for further investigations on larger-scale samples and longer follow-up durations.

Abbreviations

BMI: Body Mass Index

CHD: Coronary Heart Disease

CVD: Cardiovascular Disease

DBP: Diastolic Blood Pressure

FFQ: Food Frequency Questionnaire

FSG: Fasting Serum Glucose

HDL-C: High-density Lipoprotein Cholesterol

LDL: Low-density Lipoprotein Cholesterol

NCDs: Non-Communicable Diseases

NEAP: Net Endogenous Acid Production

PRAL: Potential Renal Acid Load

SBP: Systolic Blood Pressure

TC: Total Cholesterol

TG: Triglyceride

TLGS: Tehran Lipid and Glucose Study

Declarations

Ethics Approval and consent to participate

Written informed consents were obtained from all participants, and the study protocol was approved by the ethics research council of the Research Institute for Endocrine Science, Shahid Beheshti University of Medical Science in Tehran.

Consent for publication

Not Applicable.

Availability of data and materials

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

Competing interest

There is no conflict of interest.

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Author’s contribution

PM designed the study. SK and ZB analyzed the data from the TLGS population, SK and ZH wrote the manuscript, ZH corrected the manuscript, FA and MS revised the manuscript. All authors read and approved the final manuscript.

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Figures

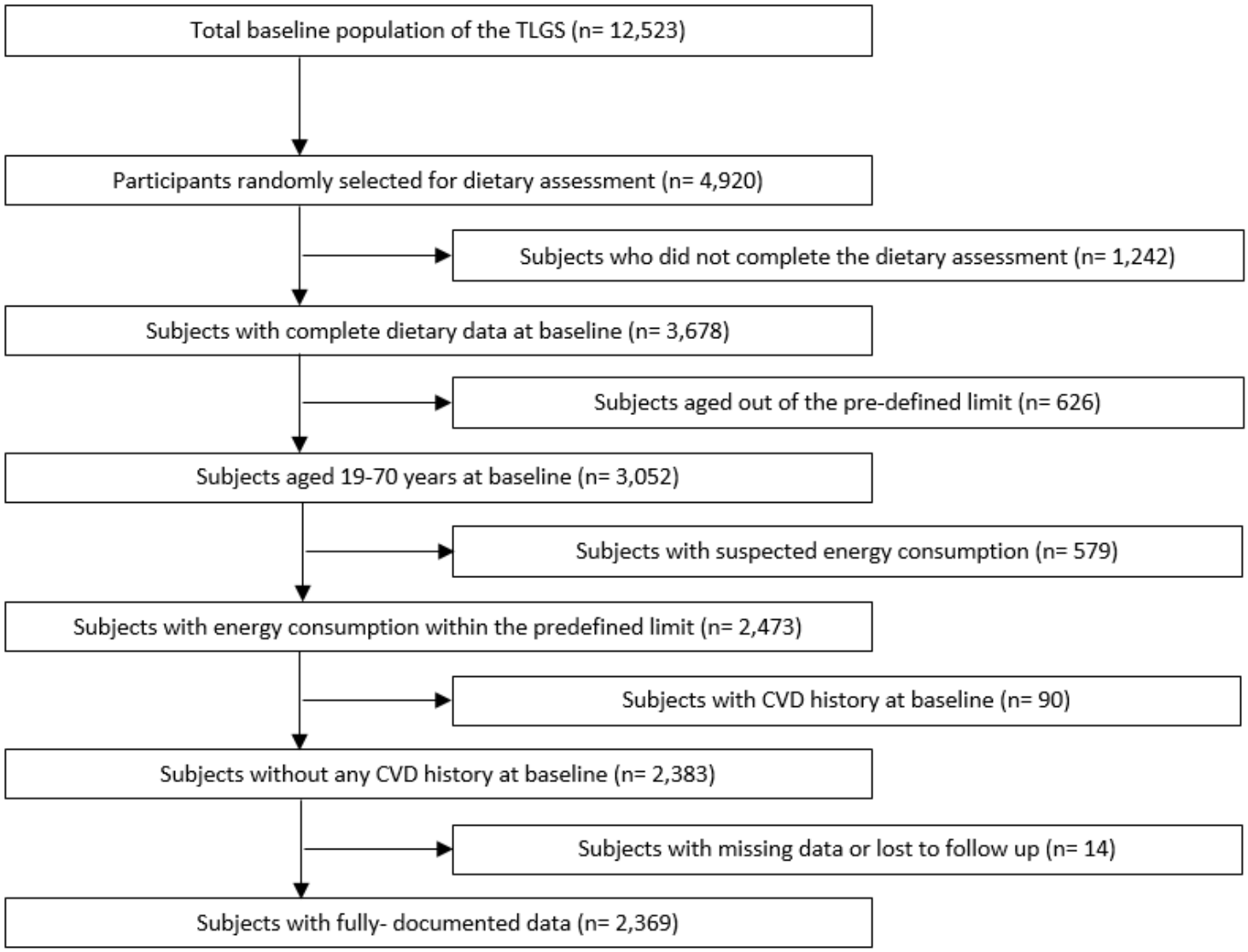

Figure 1

flowchart of the study population