Association Between Dietary Diabetes Risk Reduction Score and Risk of Chronic Kidney Disease in Adults: Tehran Lipid and Glucose Study

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Abstract

Background: To examine the association of dietary diabetes risk reduction score (DDRRS) with chronic kidney disease (CKD) among an Iranian population.

Methods: We followed-up 2076 ≥ 20 years old participants of Tehran Lipid and Glucose Study (2006-2008), who were initially free of CKD for 5.98 years. Dietary diabetes risk reduction score was calculated on the basis of scoring eight components using a valid and reliable 168-item food frequency questionnaire. CKD was defined as eGFR<60 mL/min/1.73 m^2.A Cox proportional hazard regression model was used to assess association between the quartiles of DDRRS and incidence of CKD.

Results: Mean±SD age of the study population (53% women) was 37.6±12.61 years. A total of 357 incident cases of CKD were reported. The median (25-75 interquartile range) of DDRRS was 20 (18-22). After adjustment for age, sex, smoking status, total energy intake, body mass index, hypertension, diabetes, eGFR, and physical activity, individuals in the highest versus lowest quartile of DDRRS were 33% less likely to have CKD (OR: 0.67; 95% CI: 0.48-0.96, P for trend: 0.043).

Conclusion: Our findings suggest that higher adherence to the DDRRS-style diet can decrease the risk of incident CKD in adult population.

Introduction

Chronic kidney disease (CKD),generally diagnosed as glomerular filtration rate (GFR) < 60 ml/min/1.73 m^2 ascertained by presence of albuminuria, is a global public health problem with severe outcomes such as cardiovascular disease and high mortality rates[1].Its worldwide prevalence is 10.6% and even higher amongst diabetic individuals[2], while the overall prevalence in Iran is 18.9%, and rising at an alarming rate[3]. Diabetes, aging, high blood pressure, obesity, and poor dietary intakes have been identified as major CKD risk factors [4, 5].

As rigid control of hypertension and diabetes, and lifestyle modifications are essential in the prevention of CKD; addressing dietary issues can be of great importance in this prevention [6].Since nutrients and foods are never consumed in isolation, and every single component of diet affects other particles synergistically, assessing dietary patterns instead of individual components, by indicators of diet quality, is important [7].Dietary diabetes risk reduction score (DDRRS) is a priori dietary index, consisting of eight dietary factors previously shown to be predictive of diabetes; these factors include cereal fiber, nuts, coffee, poly unsaturated fatty acids (PUFA) to saturated fatty acids (SFA) ratio, glycemic index (GI), sugar sweetened beverages (SSB), trans fatty acids (TFA), and red and processed meat, introduced in 2015 to evaluate diet quality among women of different ethnic groups in association to incidence of diabetes [8]. The DDRRS has shown protective role against risk of diabetes among women of minority ethnic groups in the United States [8].

Previously, studies have investigated the protective role of particular nutrients and foods, including PUFA, coffee, nuts, total and cereal fiber [9–13] against the risk of incident CKD, and a direct association has been shown between CKD risk and GI, SSBs, and red and processed meat consumption as detrimental components of DDRRS [11, 12, 14]. However, to the best of our knowledge, no study has yet examined the association of DDRRS with the incidence of CKD. Therefore, we aimed to assess the relation between this dietary score and risk of CKD among Iranian adults in a population based cohort study.

Materials And Methods

Subjects

This study was performed within the framework of the Tehran Lipid and Glucose Study (TLGS), a prospective cohort of 15005urban participants aged ≥ 3 years with the aim of preventing non communicable diseases (NCD) [15]. The baseline survey was a cross-sectional study conducted from 1999 to 2001, followed by prospective surveys2 (2002–2005), 3 (2006–2008), 4 (2009–2011) and 5 (2012–2015).

From among 12519 participants who showed up in survey 3, 3656 were randomly selected for dietary assessment. For the current study, we selected men and women ≥ 20 years, who accounted for 3029 participants, of whom 2636 were CKD free. We excluded individuals who reported daily energy intakes outside the range of 800-4200 kcal/day (n=148). Furthermore, participants with a history of myocardial infarction (n=16), cerebro-vascular accident (n=4) or cancer (n=6), those having special diets for diabetes (n=75) or hypertension (n=87), and pregnant women (n=19) were excluded. Finally, 2076 participants were followed until survey 5 (response rate: 91%), with a median duration of 5.98years (Figure 1).

Measurements

Dietary assessment

A valid and reliable semi-quantitative168-item food frequency questionnaire (FFQ) was used to assess dietary intakes during the year preceding enrollment [16, 17]. During a face-to-face interview, participants' intake frequency for each food item during the previous year on a daily, weekly, or monthly basis was collected by trained and experienced dieticians. The FFQ contained usual foods with standard portion sizes commonly consumed by Iranians and their frequency of concumption on a daily, weekly or monthly basis. Portion sizes of consumed foods were then convertedto grams using house-hold measures.As the Iranian Food CompositionTable (FCT) is incomplete, the USDA FCT was referred to measure nutrients. For national foods not listed in the USDA FCT, the Iranian FCT was alternatively used.

Dietary diabetes risk reduction score was calculated according to the study by Rhee et al. [8] using eight components. For the components assumed to be beneficial e.g. cereal fiber, nuts, coffee, and PUFA to SFA ratio, we assigned a score of 1 to 4 based on the participant's quartile of intake in ascending order. On the contrary, for the detrimental components, including GI, TFA, SSBs, and red and processed meats, a score of 1 to 4 was assigned according to quartile of intake in descending order. The DDRRS was calculated as the sum of these values and ranged between 8 and 32, with higher scores indicating a healthier overall diet.

Covariates assessments

Participants were interviewed by qualified interviewers using pretested questionnaires, to collect data on socio-demographics, medical history, medication use, and smoking habits in the third survey of the TLGS.

Physical activity during the preceding year was determined using modifiable activity questionnaire (MAQ) and calculating metabolic equivalent task (MET) hours per week. The reliability and validity for the Persian translated MAQ has been confirmed previously [18]. The MET value of the activity was multiplied by each of the activities duration and all MET-hour products were summed to reach an estimate of daily physical activity, indicating energy expenditure per kilogram of body weight during an average day.

Weight was measured in light clothing with the precision of 0.1 kg on a SECA digital weighing scale (Seca 707; Seca Corporation; range0·1–150 kg). Height was also recorded without shoes with 0.1 cm precision. Body mass index (BMI) was then calculated by dividing weight (kg) by square of height (m^2). Blood pressure was also measured by means of a standardized mercury sphygmomanometer on the right arm while sitting, after a 15-min rest in the supine position. The onset of tapping Korotkoff sound marked the systolic blood pressure (SBP), while the disappearance of Korotkoff sound marked the diastolic blood pressure (DBP). It was measured twice and the mean of the two measurements was considered as the participant's blood pressure.

A 12-14 h overnight fasting blood sample was drawn from each subject for biochemical measurements. Fasting plasma glucose (FPG) and 2-h plasma glucose (equivalent to 75 g anhydrous glucose; Cerestar EP) were measured by enzymatic colorimetric method using glucose oxidase technique utilizing glucose kits (Pars Azmoon, Tehran, Iran). Both inter- and intra-assaycoefficients of variation were 2.2% for FPG. Serum creatinine was assessed by standard colorimetric Jaffe_Kinetic reaction method both at baseline and after 5.98 years of follow-up. Both intra- and inter-assay coefficients of variation were <3.1%.

Definitions

Hypertention was defined as SBP/DBP ≥140/90 mmHg in participants younger than 60 years and SBP/DBP ≥ 150/90mmHg in thoseaged 60 years or above,or current therapy for a definite diagnosis of hypertension in participants60 years or older, according to JNC 8 hypertension guidelines [19]. Diabetes was determined according to the American Diabetes Association criteria as fasting plasma glucose ≥126 mg/dl or 2-h post 75 g glucose load ≥200 mg/dl or current therapy for a definite diagnosis of diabetes [20]. We used the Modification of Diet in Renal Disease (MDRD) equation formula to express GFR in mL/min/1.73 $m^2$of body surface area [21].

$$eGFR = 186 \times (\text{Serum creatinine})^{-1.154} \times (\text{Age})^{-0.203} \times (0.742 \text{ if female}) \times (1.210 \text{ if African-American}).$$

Participantswere then categorized based on their eGFR levels according to the national kidney foundation guidelines [22]: eGFR ≥60mL/min/1.73 m^2 as not having CKD and eGFR<60 mL/min/1.73 m^2as having CKD.

Statistical analysis

Data were analyzed using the Statistical Package for Social Sciences program (SPSS) (version 15.0; SPSS Inc., Chicago, IL, USA) and STATA software package. P-values <0.05 were assumed statistically significant. The Kolmogorov–Smirnov test of normality and histogram chart were used to assess normality. DDRRS was categorized into quartile cutoff points of <18, 18-20, 21-22 and >22. Continuous variables were reported as mean ± SD and categorical variables as percentages. For the continuous variables, age adjusted mean values were calculated using analysis of covariance (ANCOVA) while generalized linear models were used for the age adjusted percentages of categorical variables. Tests of trend across quartiles of DDRRS (as median values in each quartile) were conducted using linear regression test. Median (25-75 interquartile range) follow-up time was 5.98 years (25–75 interquartile range: 5.5-6.5; Fig.1). Cox proportional hazard regression models were used to assess the hazard ratios (HRs) and 95% confidence interval (CI) of CKD across quartiles of DDRRS. Age, sex, smoking status, total energy intake, BMI, hypertension, diabetes, eGFR, and physical activity were regarded as confounders. To calculate the trend of HR across increasing quartiles of DDRRS, we considered the quartile categories as continuous variables.

Results

The mean ± SD age of the study population (53% women) was 37.6 ± 12.61 years. The median (25–75 interquartile range) of DDRRS for the total population was 20 (18–22), and the incidence rate of CKD outcomes was 32/1000 during 5.98-year of follow-up. General characteristics of study participants are presented in Table 1.No significant differences were found by means of, sex, BMI, smoking status, physical activity, diabetes, hypertension, antihypertensive medication, serum creatinine, and eGFR across quartiles of DDRRS (Table 1).

Table 1
Age adjusted general characteristics of study participants according to the quartiles of dietary diabetes risk reduction score

	dietary diabetes risk reduction score quartiles				**P for trend**
	Q1	**Q2**	**Q3**	**Q4**	
Age (years)	37.18 ± 12.75	36.78 ± 12.75	36.71 ± 12.30	39.25 ± 11.85	0.307
Women (%)	50.8	55.4	52.0	53.8	0.632
Body mass index (kg/m^2)	26.60 ± 8.20	26.62 ± 8.66	26.39 ± 9.56	27.27 ± 10.93	0.316
Current smoker (%)	25	23	21	24	0.556
Physical activity (MET h/week)	63.86 ± 50.72	57.46 ± 44.15	63.27 ± 51.87	56.59 ± 50.49	0.142
Diabetes (%)	2	2	2	4	0.066
Hypertension (%)	6	6	5	9	0.197
Antihypertensive drug (%)	0.7	0.6	0.6	1.2	0.100
Serum creatinine (mg/dL)	1.03 ± 0.46	1.02 ± 0.46	1.03 ± 0.46	1.02 ± 0.46	0.517
eGFR (mL/min/1.73 m)	75.93 ± 4.88	76.19 ± 16.40	75.89 ± 18.22	75.44 ± 20.50	0.172

Data are represented as age-adjusted mean ± SD for continuous variables and percent for categorical variables.

Dietary intakes of participants are presented in Table 2.Total energy and protein intakes were not significantly different across quartiles of DDRRS. However, participantsin the highestquartile of DDRRS had a lower intakeof animal protein,total fat, and saturated fatand higher intakeof plant protein, total carbohydrates, sugar, fiber,vitamin C, potassium, and magnesium compared with those in the lowest quartile ($P < 0.05$).

Table 2
Age adjusted dietary intakes of study participants according to the quartiles of dietary diabetes risk reduction score

	dietary diabetes risk reduction score quartiles				P for trend
	Q1	Q2	Q3	Q4	
Dietary diabetes risk reduction score (DDRRS)	16.51 ± 1.82	19.47 ± 2.28	21.45 ± 2.28	24.33 ± 2.73	
DDRRS components					
Cereal fiber (g)	16.34 ± 32.35	18.98 ± 34.63	23.76 ± 37.36	26.08 ± 43.28	0.022
Coffee (cup)	0.03 ± 0.46	0.04 ± 0.46	0.07 ± 0.46	0.12 ± 0.46	0.093
PUFA/SFA *	0.61 ± 0.46	0.65 ± 0.46	0.68 ± 0.46	0.73 ± 0.46	0.001
Nuts (serving)	0.03 ± 0.004	0.06 ± 0.004	0.08 ± 0.004	0.11 ± 0.005	0.011
red and processed meat (serving)	0.64	0.55	0.49	0.40	0.039
Glycemic index	65.21 ± 13.21	62.53 ± 14.12	60.71 ± 15.03	57.17 ± 17.31	0.002
Sugar sweetened beverages (serving)	0.20 ± 0.46	0.12 ± 0.46	0.10 ± 0.46	0.06 ± 0.46	0.076
Trans fatty acids (% energy)	0.21 ± 0.23	0.19 ± 0.23	0.16 ± 0.23	0.14 ± 0.27	0.001
Other nutritional factors					
Total energy intake (kcal/day)	2206 ± 1275	2258 ± 1367	2351 ± 1485	2351 ± 1699	0.142
Protein (% energy)	13.6 ± 4.10	13.57 ± 4.56	13.62 ± 5.01	13.92 ± 5.92	0.305
Animal protein (% energy)	2.10 ± 0.03	1.93 ± 0.03	1.80 ± 0.03	1.68 ± 0.04	0.006
Plant protein (% energy)	11.50 ± 2.50	11.64 ± 2.64	11.82 ± 2.90	12.24 ± 3.43	0.013
Carbohydrate (% energy)	55.52 ± 12.30	56.97 ± 13.67	58.47 ± 14.58	60.01 ± 16.86	0.007

Data are represented as age-adjusted mean ± SD for continuous variables or percent for categorical variables.

* Poly unsaturated fatty acids (PUFA) to saturated fatty acids (SFA) ratio

	dietary diabetes risk reduction score quartiles				P for trend
Total sugar (% energy)	19.93 ± 10.02	20.71 ± 10.94	21.44 ± 11.85	22.75 ± 13.21	0.015
Dietary fiber (g/1000 kcal)	13.90 ± 11.39	15.82 ± 13.67	18.15 ± 13.21	19.34 ± 15.0	0.007
Total fat (% energy)	32.70 ± 12.30	31.94 ± 13.21	30.66 ± 14.12	29.42 ± 16.40	0.003
Saturated fat (% energy)	11.37 ± 9.11	11.12 ± 10.02	10.08 ± 10.48	9.31 ± 12.30	0.007
Vitamin C (mg/1000 kcal)	53.92 ± 61.05	62.56 ± 65.16	66.73 ± 71.08	69.99 ± 81.10	0.046
Sodium (mg/1000 kcal)	2078 ± 2688	2024 ± 2916	1997 ± 3144	2011 ± 3599	0.143
Potassium (mg/1000 kcal)	1546 ± 756	1636 ± 811	1679 ± 879	1770 ± 1007	0.002
Magnesium (mg/1000 kcal)	151.5 ± 55.13	161.4 ± 59.23	168.8 ± 64.24	188.9 ± 73.36	0.016
Data are represented as age-adjusted mean ± SD for continuous variables or percent for categorical variables.					
* Poly unsaturated fatty acids (PUFA) to saturated fatty acids (SFA) ratio					

The association between quartiles of DDRRS and risk of incident CKD is presented in Table 3. No significant association was established between the quartiles of DDRRS and CKD risk in the crude model. However, after adjusting for age, sex, smoking, total energy intake, BMI, hypertension, diabetes, eGFR, and physical activity, the HR for participants in the highest, compared with the lowest quartile of DDRRS was 0.67(95% CI: 0.47–0.96,P for trend = 0.043).

Table 3
HRs (95% CI) of chronic kidney disease risk according to quartile of dietary diabetes risk reduction score components across participants of the TLGS

	dietary diabetes risk reduction score quartiles				**P_{trend}***
	Q1	**Q2**	**Q3**	**Q4**	
Range of DDRRS	(10–18)	(19–20)	(21–22)	(23–30)	
Case/Total	113/651	100/571	85/485	59/369	
Model 1§	Ref	1.03 (0.78–1.34)	1.01 (0.76–1.34)	0.93 (0.68–1.27)	0.676
Model 2‡	Ref	0.92 (0.68–1.24)	0.95 (0.70–1.29)	0.67 (0.48–0.96)	0.043

* P_{trend} across quartiles was calculated by exposure modeled as a continuous variable

§ The crude model.

‡ The multivariate model, adjusted for age, sex, smoking status, total energy intake, BMI, hypertension, diabetes, eGFR, and physical activity

Discussion

In this prospective cohort study, higher DDRRS was inversely associated with CKD, independent of age, sex, smoking, total energy intake, BMI, hypertension, diabetes, eGFR, and physical activity, after 5.98 years of follow-up.

Although no study has yet investigated the association between DDRRS and CKD, dietary patterns withsimilar beneficial components as DDRRS have shown an inverse relation with CKD[23, 24]. One of such patterns is DASH style diet, includinghigh intake of whole grains, nuts and legumes and low intake of red and processed meat and sweetened beverages, similar to DDRRS. Previously, it has been reportedthat DASH dietcanreduce CKD risk by 59%[23]. Mediterranean dietary pattern is another example,including high intake of fruits and nuts, vegetables, cereals, legumes, fish, monounsaturated to saturated fatty acid ratio, and low intake of meat and dairy products;this dietary pattern was associated with 47% decrease in CKD incidence [24]. Furthermore, subjects in the lower quartile of DDRRS in our study presented a more western like dietary pattern, which adversely affected the risk of CKD by being abundant in refined grains, sugary drinks, saturated and trans fat, but poor in whole grains and PUFA, according to previous studies [25].

Several components of DDRRS have been individually associatedwith kidney function [9–12, 14, 26, 27]. Gopinath et al. reported that a high GI intake increased the likelihood of having eGFR < 60 mL/min/1.73 m^2 by 55%, while the highest dietary cereal fiber intake was associated with a 50% lower CKD risk [12]. Consumption of sugar sweetened beverages was another component of DDRRS, which has been proved to increase risk of CKD [14, 26]. Findings of the current study demonstrated that higher adherence to DDRRS was accompanied by higher total carbohydrate and fiber but lower sugar consumption. According to a recent study, low-carbohydrate, high-protein diet can lead to higher CKD risk [28]. The detrimental effect of such a diet on kidney has been partly explained by the lower intake of dietary fiber. Studies have shown that dietary fiber intake can reduce the risk of CKD and enhance kidney function [13, 29–31].

The beneficial effect of DDRRS could be partly attributed to the inclusion of nuts as positive, and red and processed meat as negative components. Our findings also indicate that animal protein consumption declined and plant protein consumption increased along with higher adherence to DDRRS. Red and processed meat intake has been directly associated with risk of hypertension [32] and CKD [11]. However, intake of nuts had a protective impact on CKD risk [11]. These associations could be explained through various mechanisms, one of which is the difference in metabolism of protein sources. Cooked meat contains a high amount of Maillard Reaction Products (MRPs). MRPs increase oxidative stress and inflammation through various chemical reactions, which in turn can lead to the development of hypertension and kidney dysfunction[33]. Plant sources of protein such as nuts, legumes and whole grain result in to less dietary acid load compared with animal proteins like red and processed meat [34].

The protective role of PUFA to SFA ratio in DDRRS has been backed up by our previous study, showing a 27% increase in CKD risk for participants in the highest versus lowest quartile of PUFA [9]. Furthermore, another study on the role of fatty acids on kidney dysfunction reported a direct association between saturated fatty acids and albuminuria and CKD [27]. However, they found no significant association with TFA [27].

Coffee consumption is another component of DDRRS, considered to be beneficial. A recent study on coffee consumption and incident kidney disease demonstrated that each additional cup of coffee per day is associated with 3% decrease in CKD risk [10]. This may be due to antioxidants which protect the glomerular endothelium from oxidative stress and systemic inflammation[35], or caffeine itself, by increasing eGFR and renal blood flow[36].

Diet of participants in higher quartiles of DDRRS was richer in potassium, magnesium, and vitamin C, micronutrients previously shown to prevent CKD incident [37]. These protective effects may be due to vitamin C acting as an antioxidant [38], and magnesium and potassium lower the renal acid load [34]. High magnesium intake may reflect high plant protein consumption[34], which in turn lowers the amount of fibroblast growth factor 23 and increases bicarbonate levels; thus, protecting against CKD [39]. Furthermore, low serum magnesium concentrations have been suggested to promote endothelial dysfunction by stimulating inflammatory and pro-atherogenic cytokines which can lead to kidney dysfunction [40]. So, these might also explain why higher adherence to DDRRS was associated with a lower risk of CKD in our study.

To the best of our knowledge, this study was the first to investigate the relation between dietary diabetes risk reduction score and incident CKD. A noteworthy strength of our study was its prospective design in a large sized, population based cohort. Additionally, using a valid and reliable FFQ and physical activity questionnaire, we were able to capture habitual dietary intake. We recognize the inherent limitations of our research too, first of which was creatinine measurements which were not repeated within three months to confirm a chronic reduction in eGFR. Secondly, there were missing data on the proteinuria of participants, so we could not consider it in the CKD definition. There was also the risk of some unknown or unmeasured confounders which we might have failed to take into account.

Conclusions

Overall, we observed that a healthy diet based on DDRRS, previously shown to protect against diabetes, can be preventive of CKD as well. This is an important finding, since it can help to define a dietary pattern which is easily adhered by the public to prevent the growing poor health outcomes such as diabetes and chronic kidney disease.

List Of Abbreviations

ANCOVA: analysis of covariance

BMI: Body mass index

CI: confidence interval

CKD: chronic kidney disease

DBP: diastolic blood pressure

DRRS: dietary diabetes risk reduction score

eGFR: Estimated glomerular filtration rate

FCT: Food Composition Table

FFQ: food frequency questionnaire

FPG: Fasting plasma glucose

GI: glycemic index

HRs: hazard ratios

MET: metabolic equivalent task

MAQ: modifiable activity questionnaire

MDRD: Modification of Diet in Renal Disease

NCD: non communicable diseases

TFA: trans fatty acids

PUFA: poly unsaturated fatty acids

SFA: saturated fatty acids

SSB: sugar sweetened beverages

TLGS: Tehran Lipid and Glucose Study

SBP: systolic blood pressure

SPSS: Statistical Package for Social Sciences program

Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all participants. The study protocol was approved by the ethics research committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Consent for publication

Not applicable.

Availability of data and material

The datasets analyzed in the current study are available from the corresponding author on reasonable request

Conflict of interests

The authors declared there is no conflict of interest.

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Authors' contributions

P.M, M.R, and H.F contributed in conception, design, and statistical analysis. Zh.T and H.F contributed in data collection and manuscript drafting. G.A, and F.A supervised the study. All authors approved the final version of the manuscript.

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Figures

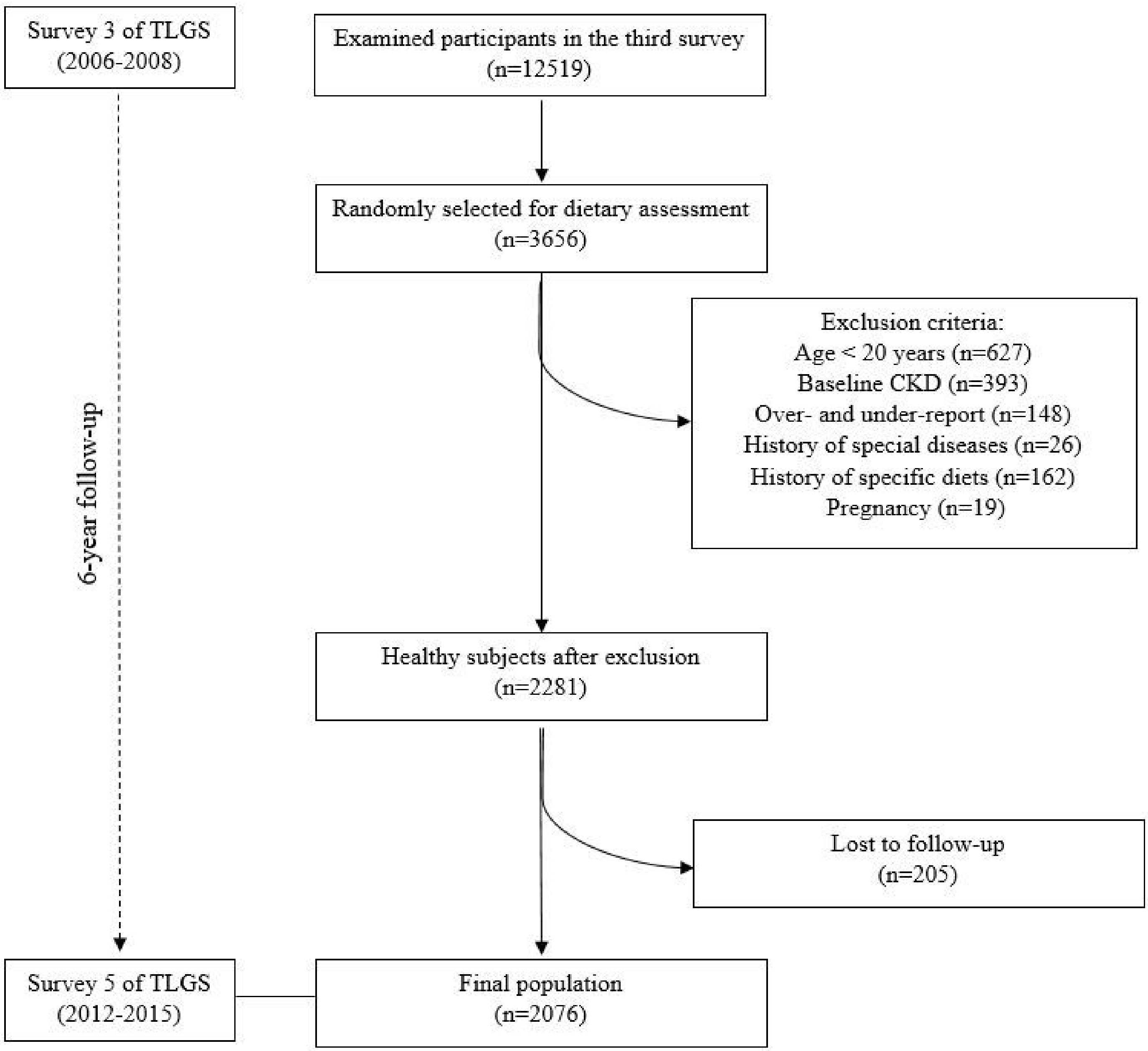

Figure 1

Flow chart of the Tehran Lipid and Glucose Study (TLGS) participants.