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Association between dietary patterns and kidney function in patients with chronic kidney disease: a cross-sectional analysis of the German Chronic Kidney Disease study

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Abstract

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Author contribution statements

T.S., S.B.A, G.S. conceived this GCKD nutrition substudy. J.H., T.S., J.N. and M.S. analysed the data. J.H wrote the manuscript. Each author contributed important intellectual content during manuscript drafting and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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Objective: In the general population “healthy” dietary patterns are associated with improved health outcomes, but data on associations between observance of specific dietary patterns and kidney function in patients with chronic kidney disease (CKD) are sparse.

Methods: Dietary intake was evaluated using food frequency questionnaires in patients with moderately severe CKD under nephrology care enrolled into the observational multicenter German CKD (GCKD) study. The Dietary Approaches to Stop Hypertension (DASH) diet score, Mediterranean diet score, and German Food Pyramid Index (GFPI) were calculated and their association with estimated glomerular filtration rate (eGFR) and albuminuria was assessed by multivariable linear regression analysis, adjusted for gender, age, body mass index, energy intake, smoking status, alcohol intake, education, HDL-cholesterol, LDL-cholesterol, hypertension, and diabetes mellitus.

Results: A total of 2813 patients (41% women; age: 60.1 ± 11.6 years) were included in the analysis. High DASH diet score and GFPI were associated with lower systolic blood pressure and lower intake of antihypertensive medication, higher HDL and lower uric acid levels. Mediterranean-style diet was associated with lower prevalence of diabetes mellitus. Higher DASH and Mediterranean diet scores were associated with higher eGFR (β-coefficient = 1.226, p-value <0.001; β-coefficient = 0.932, p-value = 0.007, respectively). In contrast, GFPI was not associated with eGFR. For the individual components of the dietary patterns, higher intake of nuts and legumes, cereals, fish and polyunsaturated fats was associated with higher eGFR and higher intake of dairy, composed of low- and whole-fat dairy, was associated with lower eGFR. No association was found between dietary patterns and albuminuria.

Conclusion: Higher observance of the DASH or Mediterranean diet, but not German food pyramid recommendations, was associated with higher eGFR among patients with CKD. Improving dietary habits may offer an opportunity to better control comorbidities and kidney function decline in patients with CKD.

Keywords

chronic kidney disease (CKD); DASH diet; Mediterranean diet; German Food Pyramid

Introduction

Chronic kidney disease (CKD) affects more than one in 10 people worldwide[1], and is a growing public health issue. CKD frequently results from or is modulated by risk factors such as metabolic syndrome, diabetes mellitus and hypertension.[2] CKD itself is a major risk factor for end-stage renal disease (ESRD), cardiovascular disease and death.[3] Dietary interventions have been acknowledged as a tool to prevent or slow down the adverse prognosis of CKD directly or indirectly through their effects on kidney and CKD risk factors (hypertension, diabetes).[4] Current CKD recommendations typically focus on single macro- and micronutrients and calories, although their evidence level is weak.[5] Observance of healthy dietary patterns, which consider nutrients’ synergistic effects for chronic disease prevention,[6] might affect CKD progression more effectively than paying attention on single nutrients, and poses a readily applicable approach for CKD patients.

The Dietary Approaches to Stop Hypertension (DASH) diet is characterized by high intake of grains, fruits, vegetables and low-fat dairy, but limits intake of meat, fats and sweets.[7] Similarly, the Mediterranean diet favours high intake of cereals, vegetables, fruits, legumes, fish and unsaturated fats, whereas high intake of meat, dairy and alcohol consumption is not endorsed.[8] German dietary recommendations[9] differ in a few aspects from DASH and Mediterranean diet; e.g. favouring intake of non-alcoholic beverages. Evidence in the general population indicates that observance of a DASH or Mediterranean diet is associated with reduced risk for CKD.[10–15] Whether the conformance to German food recommendations is associated with better kidney function is unknown. The DASH diet is recommended by the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)[16] as well as the National Kidney Foundation[17] for CKD patients not on dialysis. Recently, the European Renal Nutrition (ERN) working group of the European Renal Association–European Dialysis Transplant Association (ERA-EDTA) considered the Mediterranean diet as the diet of choice for patients with CKD[18] and stated that studies among CKD patients are needed since most evidence about benefits of a Mediterranean diet on kidney health comes from studies in general populations.

Little is known about the association between different aspects of kidney function (eGFR or albuminuria) and observance of dietary patterns in patients with prevalent CKD.[13,19] The purpose of this study was to investigate whether higher observance of dietary patterns (DASH diet, Mediterranean Diet or German food recommendations) is associated with kidney health as assessed by eGFR and albuminuria and comorbidity in CKD patients from the large multicenter German Chronic Kidney Disease (GCKD) study.[20]

Subjects and Methods

Study Design

The study design was approved by the Ethics Committees in all nine participating institutions and all participants provided written documentation of informed consent. The study was conducted according to the Declaration of Helsinki. The GCKD study design has been described previously in detail.[20] In brief, this prospective observational German cohort study enrolled 5217 patients (age 18–74 years) with CKD of diverse causes on the basis of kidney function (eGFR 30–60 mL/min/1.73m^2, i.e. CKD stage G3, A1–3, or overt proteinuria in presence of an eGFR > 60 mL/min/1.73m^2, i.e. CKD stage G1–2, A3) (Supplemental Figure S1). Overt proteinuria was defined by one of the following criteria: albuminuria (> 300mg albumin/g creatinine), albuminuria (> 300mg albumin/day), proteinuria (> 500mg protein/g creatinine) or proteinuria (> 500mg protein/day). All patients were Caucasian and under nephrology care. Exclusion criteria were solid organ or bone marrow transplantation, active malignancy within 24 months prior to screening, New York Heart Association class IV heart failure and unwillingness to provide consent. The patient's medical and family history, medication use, and socio-demographic history were recorded by standardised questionnaires. Disease, comorbidity and other parameter definitions were used according to international standards.[21] Information was cross-checked by referring to the respective patient's medical records. Anthropometric measures and measurements of resting blood pressures and heart rate were ascertained as part of a physical examination.

A set of laboratory parameters was determined by a central laboratory.[21] The biochemical data, including eGFR and albumin-to-creatinine ratio (UACR), presented in this study were taken from the GCKD study follow-up visit in year 2 (2012–2014), corresponding to the time period of nutrition assessment (see below). The GFR was calculated with the 2009 CKD Epidemiology Collaboration formula using serum creatinine,[22] whereas the UACR was calculated by dividing urinary albumin (in mg) and urinary creatinine (in g).

Measurement of dietary intake

Usual dietary intake during the past 12 months was self-reported using a food-frequency questionnaire (FFQ) from the European Prospective Investigation into Cancer and Nutrition (EPIC) Potsdam study, supplied by the Human Study Center of the German Institute of Human Nutrition Potsdam-Rehbrücke (https://efbo.dife.de/ffq/page/en). Reproducibility and validity of the FFQ was tested in the German EPIC Potsdam cohort.[23,24] The FFQ captures the usual food and nutrient intake during the past 12 months, including 102 food items and frequency of consumption responses, 39 additional questions on preparation methods and 9 summation questions.

3283 out of 4754 participants who attended the GCKD follow-up study visit in year 2 (2012–2014) (69.1%) returned the FFQs. Dietary information of each participant, i.e. average intake (grams per day) of food groups and derived micro- and macronutrients intakes were calculated based on the answers in the FFQ and the German food database ("*Bundeslebensmittelschlüssel*").

Study population for present analysis

Participants who completed FFQ with 26 or more missing answers were excluded from the analysis ($n = 26$).[25] Additionally, participants who answered positive to a question about changing the diet during the past 12 months ($n = 87$) or with a missing answer to this question ($n = 34$) were excluded. Estimated energy requirement was calculated for each participant by taking into account age, gender and physical activity level (PAL).[26] Participants were assigned to PAL = 1.6 when they reported ≥30 minutes of physical activity ≥3 times per week, and to PAL = 1.4 otherwise. Finally, we excluded participants within the highest and lowest 1% of the ratio of energy intake to estimated energy requirement suggesting implausible data provision ($n = 64$).[8] Participants with missing values for the main outcome variable (eGFR) at follow-up visit in year 2 were also excluded from our analysis ($n = 259$). After all exclusions, the analytic dataset included 2813 participants (86% of those who completed FFQ).

Definition of dietary patterns

For each participant, the observance of three different dietary patterns (DASH diet, Mediterranean diet and German food pyramid recommendation) were scored using previously reported methods[7,8,27] (Supplemental Table S1). Participants were not systematically advised to follow these dietary patterns in advance, though it is possible that they received nutritional counselling from their treating nephrologist. The DASH score comprises 8 food groups, with a minimum of 0 and a maximum of 10 points when intake recommendations were fully met for grains, vegetables, fruits, dairy products, nuts, seeds

and legumes (Supplemental Table S2). The scoring system worked inversely for high intake of meat, poultry, fish, fats and oils and sweets (maximum of 10 points for low intake, minimum of 0 points for high intake). The grain and dairy group were separated into two subgroups: total grain consumption, consumption of fiber from grains, total dairy consumption, and consumption of fat from dairy products. Intakes of each food group from the minimum to the maximum recommended intake were scored proportionally, resulting in an overall score range from 0 to a maximum of 80 points. Consequently, a higher DASH score corresponded to a closer observance of the DASH diet.

We used the modified Mediterranean diet score system (Supplemental Table S3), which can also be applied to non-Mediterranean populations such as our German population.[8] Participants with consumption of beneficial components (cereal, vegetables, fruits and nuts, legumes and fish) below the gender-specific median were assigned a value of zero, and a value of one otherwise. For adverse components (meat and dairy products), individuals with consumption below the gender-specific median was given a value of one, and a value of zero otherwise. For alcohol, men consuming between 10–50 g per day and women between 5–25 g per day received a value of one, and a value of zero otherwise. For fat intake, the ratio of the sum of monounsaturated and polyunsaturated to saturated fats was calculated, with a high ratio being advantageous. Overall, the Mediterranean Diet Score ranged from zero to nine points, nine points representing maximal conformance.

The German food pyramid index (GFPI) includes eight food groups based on German food pyramid recommendations (Supplemental Table S4)[27], which was originally established in 2005 in order to combine quantitative and qualitative food recommendations within one tool.[28,29] The food groups water and juice, fruits, vegetables, cereal products, dairy products, meat, fats and oils were calculated by dividing the consumed servings per day by the recommended servings per day. For every food group, the possible score ranges from zero points (non-conformance) up to ten points (maximal conformance to the German food pyramid). For beverages, fruits and vegetables, up to ten extra points were given if intake exceeded the recommendations, suggesting potential benefits of intake beyond the recommendations. The overconsumption of cereal products, dairy products, meat and fats/oils led to a subtraction of points. Points were deducted according to the equation “recommended servings per day / consumed servings per day”. For sweet intake, reverse coding was applied by dividing the recommended servings by the consumed servings per day, thus higher sweet intake was represented by a lower score. All points were summed up resulting in an overall GFPI score range from 0 (non-conformance) up to 110 (maximal conformance).

Statistical analysis

Descriptive statistics for characteristics were expressed as means ± standard deviations or medians (interquartile range (IQR)) if not normally distributed for continuous variables, and percentages for categorical variables. Normality of data was assessed by quantile-quantile plots. Ordinal regression analysis was used to test for trends in characteristics across dietary quintiles. Correlation between DASH diet score, Mediterranean diet score and GFPI were explored with Spearman’s rank correlation coefficient. Multivariable linear

regression models were performed to evaluate the association between z-transformed DASH, Mediterranean or GFPI score and eGFR or UACR. Multivariable linear regression models were performed to evaluate the impact of individual components of the dietary scores on eGFR. All models were adjusted for age, alcohol intake, BMI, caloric intake, diabetes mellitus, high- and low-density-lipoprotein, hypertension, school education, gender and smoking. Two-sided p-values < 0.05 were considered statistically significant and statistical analysis was performed with SAS Version 9.4.

Results

Characteristics of the participants and associations with diet scores

Detailed participant characteristics and dietary factors are shown in Table 1. Fourty-one percent of our cohort were women, and the whole cohort had a mean age of 60.1 ± 11.6 years and a median BMI of 28.8 kg/m^2 (interquartile range (IQR): 7.7). As expected for a CKD population, participants were characterized by high prevalence of hypertension (95.9%) and diabetes mellitus (31.6%). Participant characteristics are presented according to quintiles of the DASH score (Supplemental Table S5), Mediterranean diet score (Supplemental Table S6) or GFPI (Supplemental Table S7). Participants with high DASH diet score or GFPI shared similar characteristics: they were more likely to be women, were more likely to be non-smokers, consumed less alcohol, had lower systolic blood pressure and were less likely to be taking antihypertensive medication, and had higher HDL and lower uric acid levels (Table 2). In contrast to participants with high DASH score or GFPI, participants with high Mediterranean diet score were more likely to be men and had higher alcohol consumption. They were also more likely to be non-diabetic, but we found no association between observance of Mediterranean diet and smoking, systolic blood pressure, antihypertensive medication, HDL or uric acid. Serum potassium was not elevated in participants who were highly observance of all of these dietary patterns. High observance of the three dietary patterns was significantly associated with higher school educational level and higher eGFR. However, albuminuria measured by UACR levels did not associate with any dietary pattern.

Diet-related characteristics of participants according to the quintiles of diet scores

Supplemental Table S8 illustrates diet-related information of the participants according to DASH quintiles. DASH diet score correlated with GFPI (Spearman rho = 0.581, p-value <0.001) and Mediterranean diet score (Spearman rho = 0.220, p-value <0.001), and Mediterranean diet score correlated with GFPI (Spearman rho = 0.407, p-value <0.001). As encouraged by the DASH diet, participants in the higher DASH quintiles had lower estimated sodium intake. Higher DASH score was associated with lower intake of protein, fat and overall energy intake (Supplemental Table S8). In contrast to DASH score, higher Mediterranean Diet score (Supplemental Table S9) and GFPI (Supplemental Table S10) were associated with higher intake of protein, fat, carbohydrates and overall energy.

Results of multivariable analysis for explanation of kidney health

We performed multivariable adjusted linear regression analyses to examine whether the observance of the dietary patterns remained significantly associated with eGFR after

adjustment for potential confounders (Table 3). One-standard deviation higher of DASH (β-coefficient = 1.226, p-value <0.001) or Mediterranean Diet score (β -coefficient = 0.932, p-value = 0.007) remained significantly associated with higher eGFR, after adjustment for gender, age, BMI, caloric intake, smoking status, alcohol consumption, school education, HDL-cholesterol, LDL-cholesterol, hypertension and diabetes mellitus status. However, we observed no association between GFPI and eGFR after adjustment for these variables. Similar to our observation in the univariable analysis, the multivariable adjusted regression analysis showed no association between albuminuria and observance of all of the dietary patterns (Table 3).

Association between components of the diet patterns and eGFR

To further understand the association between the dietary patterns and eGFR, we ran additional multivariable adjusted regression analysis to assess the association between each component of the dietary patterns and eGFR. Of the individual components of the DASH diet score, higher intake of nuts and legumes was associated with higher eGFR (β-coefficient = 13.172, p-value <0.001) (Table 4). With regard to the Mediterranean diet, high intake of cereals (β-coefficient = 1.733, p-value = 0.020), fish (β-coefficient = 1.630, p-value = 0.017), and unsaturated fats (β-coefficient = 1.755, p-value = 0.011) were associated with higher eGFR, but higher intake of dairy products (low- and whole-fat dairy) were associated with lower eGFR (β-coefficient = −1.633, p-value = 0.018) (Table 4). None of the GFPI food components were associated with eGFR (Table 4).

Discussion

In this study, we examined whether dietary habits corresponding to three different dietary patterns (DASH diet, Mediterranean diet and German food pyramid recommendations) associates with lower prevalence of comorbidities and better kidney health among patients with prevalent CKD. We found that higher observance of DASH or Mediterranean diet is associated with higher eGFR. This finding is consistent with several published epidemiologic studies, in which adherence to these dietary patterns were associated with a lower risk for CKD.[10–15] DASH and Mediterranean diets are recommended for CKD patients[18,30], although beneficial dietary effects were mainly assessed in the general population so far. Our study provides evidence that dietary patterns may have beneficial effects on kidney function in patients with prevalent CKD.

The observed associations between dietary patterns and kidney function were particularly driven by higher intake of nuts and legumes, cereals, fish, and unsaturated fats. High intake of DASH diet component nuts and legumes was clearly associated with higher eGFR. This observation is consistent with the findings from Rebholz *et al.* where consumption of nuts and legumes was associated with reduced risk for kidney disease progression in general population in a 23-years follow-up study.[15] Nuts and legumes are rich in magnesium which may contribute to the preservation of kidney function by reducing endothelial pro-inflammatory and pro-atherogenic secretion of cytokines.[31,32] We also found that high intake of cereals and fish, as quantified using the Mediterranean Diet scoring system, was associated with higher eGFR. These components have previously been shown to

be beneficial for patients with CKD.[33,34] In contrast, high intake of Mediterranean diet food component dairy, composed of low- and whole-fat dairy products, was significantly associated with lower eGFR. Intake of low-fat dairy products has been associated with reduced risk of kidney disease[15,35], but whole-fat dairy products are a major source of saturated fats, which have been presumed to adversely affect kidney function.[36,37] Therefore, one explanation for our observation is that a high dairy intake may result in high intake of saturated fats, which may associate with lower eGFR. In line with this possible explanation is our observation that a higher ratio of unsaturated fats over saturated fats is associated with higher eGFR.

Our analysis showed no association between kidney function and observance of recommendations of the German food pyramid. It has been reported that high GFPI is not associated with a decreased risk for cardiovascular disease, type 2 diabetes mellitus and cancer after multivariable adjustments, except for cardiovascular disease in men.[27] However, the authors demonstrated in another analysis using the same data set that a simple dietary index which favours high intake of fruits, vegetables, whole grain and less meat intake significantly related to reduced risk of chronic disease.[38] The results of both studies[27,38] suggest that there are other factors which influence the results. One potential factor is that the GFPI might not represent the German food pyramids' recommendations in regards to beverages as accurate as it should.[27] The GFPI counts the first juice serving as fruit and every additional juice servings, if any, as beverages. However, juices are not depicted together with water in the graphical illustration of the food pyramid. Mineral water is placed at the bottom of the pyramid, whereas undiluted juices are positioned in the middle of the pyramid and should therefore be consumed less frequently than those listed at the bottom of the pyramid.[39] Higher consumption of sugar-sweetened beverages, including fruit juices, is associated with increased risk for CKD.[40]

DASH and Mediterranean diets are associated with reductions in blood pressure, inflammation, improved lipid profile and endothelial function, resulting in lower risk for cardiovascular morbidity and mortality in the general population.[41,42] Considering the importance of endothelial function for glomerular albumin handling, these dietary patterns may have benefits in decreasing the risk of albuminuria. We analysed the association between each dietary pattern and level of albuminuria, but found no association. A previous study showed in female non-CKD participants from the Nurses' Health Study that DASH-like diet does not associate with microalbuminuria.[12] Similarly, Díaz-López *et al.* observed no association between Mediterranean diet intensification and albuminuria among participants from the PREDIMED trial.[43,44] However, these reports are in contrast with observations in younger community-based cohorts.[45,46] Taking into account that we extended the research by reporting data for a CKD cohort, it remains controversial overall whether higher adherence to DASH or Mediterranean diet is associated with lower albuminuria.

We observed that high observance of DASH diet or German food recommendation was associated with lower prevalence of CKD risk factors and complications such as lower systolic blood pressure, lower uric acid levels, and higher HDL levels. High Mediterranean diet score was associated with lower prevalence of diabetes mellitus and better control of

HbA1c values. This is consistent with findings in a large German prospective community-based cohort study in which adherence to the Mediterranean diet was associated with lower incidence of diabetes mellitus.[47] All three dietary patterns are rich in potassium, thus they are cautioned due to their potential to cause hyperkalemia in patients with CKD, but our data suggest that these dietary patterns may be safe in the range of eGFR of patients enrolled in our study since no hyperkalemia was observed in patients with high dietary pattern scores.

Our study has several strengths and limitations to acknowledge. The strengths include the large sample size and standardized questionnaires to assess participants' characteristics, in-person study visits conducted by trained study nurses and central measurements of all laboratory values to reduce performance bias. Limitations include that based on the inclusion criteria of the GCKD study, the findings apply only to Caucasian patients with moderately severe CKD under nephrology care and may not be generalizable to patients with more severe CKD or those not receiving specialist care. The GCKD study design allowed adjustment for many important confounders[20], but residual confounding as present in any observational study cannot be ruled out entirely. The positive dietary effects on kidney function might be due to increased health awareness and compliance, and not exclusively due to healthy diet, although we adjusted for many potential confounders including smoking, alcohol intake and school education. The results do not allow to derive temporal relationships due to the one-time assessment of diet and the cross-sectional study design. However, changes in diet would weaken rather than reinforce observed associations[48] and we excluded patients with dietary change within the past 12 months. We had to rely on self-reported food frequency questionnaires, but we reduced measurement error and reporting bias specifically by using validated FFQ and visual aids to represent portion sizes. The DASH and GFPI score are mainly based on absolute measures, but none of our participants achieved maximum scores and the classification into quintiles is based on ranking within a population and does not necessarily align with thresholds used in other diet scores. Hence, it remains unclear to what extent adherence to these dietary patterns is necessary in order to observe the health benefits, but given that there were small differences in diet scores between quintiles, a small improvement in diet quality may confer meaningful health benefits. Additionally, the Mediterranean diet score depends on gender-specific medians of the population under study, which might deviate substantially from other study populations.

In conclusion, our study suggests that beneficial effects of DASH- and Mediterranean-style diets on kidney function and comorbidities may also apply to patients with prevalent CKD. Our findings support promotion of these dietary patterns, which is a low-risk approach to alleviate the adverse prognosis of CKD in this high-risk population.

Practical Application

In patients with moderately severe chronic kidney disease, higher observance of the DASH or Mediterranean diet was associated with lower prevalence of comorbidities and higher eGFR. Our findings support promotion of the DASH or Mediterranean diet in clinical practice to improve the poor prognosis of patients with chronic kidney disease.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Characteristics of study participants (n = 2813).

Characteristic	Value
Age, years, mean ± SD	60.1 ± 11.6
Women (%)	41.3
BMI, (kg/m^2), median (IQR)	28.8 (7.7)
Smoking (%)	
Smoker	12.7
Former smoker	43.0
Non-Smoker	44.3
Alcohol (%)	
≥3x/week	19.2
1–2x/week	80.8
German school education (%)	
Low: ≤9th grade	52.4
Intermediate: 10th grade	29.2
High: ≥12th grade	18.4
Physical activity (%)	
<10x/week	17.2
1–2x/week	24.0
3–5x/week	31.1
>5x/week	27.7
Hypertension (%)	95.9
SBP, mmHg, mean ± SD	139.3 ± 19.7
DBP, mmHg, mean ± SD	79.6 ± 11.4
Diabetes mellitus (%)	31.6
CHD (%)	16.9
Prior stroke (%)	7.2
Cancer (%)	12.3
eGFR, (ml/min/1.73m^2), mean ± SD	45.6 ± 18
UACR, (mg/g), median (IQR)	46.5 (291)
Cholesterol, (mg/dL), mean ± SD	213.1 ± 49.6
HDL-cholesterol, (mg/dL), mean ± SD	57.5 ± 18.8
LDL-cholesterol, (mg/dL), mean ± SD	121.6 ± 42.2
Triglyceride, (mg/dL), mean ± SD	202.2 ± 131.6
Uric acid, (mg/dL), median (IQR)	7.1 (2.3)
Potassium, (mmol/L), mean ± SD	4.4 ± 0.5
Phosphorus (inorganic), (mmol/L), median (IQR)	1.1 (0.3)
Calcium, (mmol/L), median (IQR)	2.5 (0.2)
HbA1c, (%), median (IQR)	5.8 (0.7)
Antihypertensive medication (%)	89.9
ACE inhibitor (%)	39.0

Characteristic	Value
ARB (%)	42.6
Diuretics (%)	55.3
Antidiabetic medication (%)	24.2
Lipid-lowering medication (%)	48.9
Anti-gout medication (%)	35.8
DASH Diet Score, mean ± SD	32.1 ± 7.1
MED Diet Score, mean ± SD	4.4 ± 1.6
GFPI Diet Score, mean ± SD	48.1 ± 9.9
Sodium intake (g/day), median (IQR)	2.2 (1.2)
Potassium intake (g/day), median (IQR)	2.8 (1.3)
Dietary fiber (g/day), median (IQR)	19.8 (9.7)
Protein (g/day), median (IQR)	73.9 (38.4)
Fat (g/day), median (IQR)	94.5 (48.8)
Carbohydrates (g/day), median (IQR)	219 (120.1)
Energy Intake (kcal/day), median (IQR)	2152.4 (1084.6)

Note: Values are expressed as mean values ± standard deviation, medians (interquartile ranges (IRQ)) or percentages, as appropriate.
Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; BMI, body mass index; CHD, coronary heart disease; DASH, dietary approaches to stop hypertension; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate (CKD-EPI equation); GFPI, German Food Pyramid Index; HbA1c, glycated haemoglobin; HDL-cholesterol, high-density lipoprotein-cholesterol; LDL-cholesterol, low-density lipoprotein-cholesterol; MED, Mediterranean diet; SBP, systolic blood pressure; UACR, urine albumin-to-creatinine ratio. Conversion factors for units: calcium in mmol/L to mg/dL, ×4; phosphorus (inorganic) in mmol/L to mg/dL, ×3.1; potassium in mmol/L to mEq/L, ×1.

Table 2.

Univariable regression analyses of the association between diet quintiles and individual participant characteristics.

Characteristic	DASH		MED		GFPI	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age (years)	1.00 (1.00–1.01)	0.149	1.00 (0.99–1.00)	0.168	0.99 (0.98–0.99)	<0.001
Women vs. Men	2.47 (2.15–2.84)	<0.001	0.86 (0.75–0.99)	0.037	1.61 (1.41–1.85)	<0.001
BMI (kg/m^2)	1.00 (1.00–1.01)	0.373	1.00 (0.99–1.00)	0.071	1 (0.99–1.00)	0.781
Former smoker vs. Non-Smoker	0.80 (0.69–0.93)	<0.001	1.06 (0.92–1.22)	0.548	0.81 (0.7–0.93)	<0.001
Smoker vs. Non-Smoker	0.50 (0.40–0.62)		0.95 (0.76–1.18)		0.6 (0.48–0.74)	
Alcohol ≥3x/week vs. 1–2x/week	0.64 (0.54–0.76)	<0.001	1.49 (1.26–1.77)	<0.001	0.6 (0.5–0.71)	<0.001
Low vs. High school education	0.63 (0.52–0.76)	<0.001	0.60 (0.50–0.72)	<0.001	0.59 (0.49–0.71)	<0.001
Intermediate vs. High school education	0.77 (0.63–0.95)		0.74 (0.61–0.91)		0.79 (0.64–0.96)	
Physical activity						
1–2x/week vs. <1x/week	1.13 (0.92–1.40)		1.33 (1.08–1.65)		1.31 (1.06–1.62)	
3–5x/week vs. <1x/week	1.23 (1.00–1.50)	0.212	1.24 (1.01–1.52)	0.009	1.23 (1.01–1.51)	0.029
>5x/week vs. <1x/week	1.07 (0.87–1.32)		1.42 (1.15–1.75)		1.35 (1.1–1.66)	
Hypertension, yes vs. no	0.81 (0.57–1.13)	0.212	1.08 (0.76–1.52)	0.669	0.91 (0.64–1.27)	0.566
SBP (mmHg)	1.00 (0.99–1.00)	0.013	1.00 (1.00–1.00)	0.639	0.99 (0.99–1)	0.001
DBP (mmHg)	1.00 (0.99–1.00)	0.689	1.01 (1.00–1.01)	0.029	1 (1.00–1.01)	0.135
Diabetes mellitus, yes vs. no	1.00 (0.87–1.16)	0.975	0.84 (0.73–0.97)	0.020	0.89 (0.77–1.03)	0.117
CHD, yes vs. no	0.91 (0.76–1.09)	0.301	1.08 (0.90–1.30)	0.389	0.83 (0.69–0.99)	0.040
Prior stroke, yes vs. no	1.12 (0.86–1.46)	0.391	0.87 (0.66–1.13)	0.285	0.94 (0.72–1.22)	0.631
Cancer, yes vs. no	1.16 (0.95–1.43)	0.142	1.08 (0.88–1.33)	0.436	1.08 (0.88–1.32)	0.454
eGFR (ml/min/1.73m^2)	1.00 (1.00–1.01)	0.012	1.01 (1.00–1.01)	<0.001	1.01 (1.00–1.01)	0.006
UACR (mg/g)	1.00 (1.00–1.00)	0.151	1.00 (1.00–1.00)	0.652	1.00 (1.00–1.00)	0.121
Cholesterol (mg/dL)	1.00 (1.00–1.00)	0.078	1.00 (1.00–1.00)	0.747	1.00 (1.00–1.00)	0.107
HDL-cholesterol (mg/dL)	1.01 (1.01–1.02)	<0.001	1.00 (1.00–1.01)	0.074	1.01 (1.00–1.01)	<0.001
LDL-cholesterol (mg/dL)	1.00 (1.00–1.00)	0.543	1.00 (1.00–1.00)	0.707	1.00 (1.00–1.00)	0.152
Triglyceride (mg/dL)	1.00 (1.00–1.00)	0.053	1.00 (1.00–1.00)	0.569	1.00 (1.00–1.00)	0.113
Uric acid (mg/dL)	0.90 (0.87–0.93)	<0.001	0.97 (0.94–1.01)	0.190	0.95 (0.91 −0.98)	0.004
Potassium, (mEq/L), mean ± SD	0.78 (0.68–0.9)	0.001	0.95 (0.82–1.09)	0.456	0.75 (0.65–0.87)	<0.001
Phosphorus (mmol/L)	1.50 (1.12–2.01)	0.006	0.80 (0.59–1.07)	0.128	1.08 (0.81–1.45)	0.586
Calcium (mmol/L)	1.77 (1.14–2.74)	0.011	1.35 (0.87–2.09)	0.187	1.60 (1.03–2.48)	0.036
HbA1c (%)	1.00 (0.93–1.07)	0.940	0.89 (0.83–0.96)	0.003	0.94 (0.87–1.01)	0.088
Antihypertensive medication, yes vs. no	0.75 (0.60–0.94)	0.012	0.97 (0.78–1.22)	0.822	0.78 (0.63–0.97)	0.029
ACE inhibitor, yes vs. no	0.83 (0.72–0.95)	0.007	1.02 (0.88–1.17)	0.822	0.84 (0.73–0.96)	0.011
ARB, yes vs. no	0.98 (0.86–1.13)	0.817	0.92 (0.80–1.05)	0.220	0.99 (0.87–1.14)	0.912
Diuretics, yes vs. no	1.03 (0.90–1.18)	0.691	0.93 (0.81–1.06)	0.286	1.01 (0.88–1.16)	0.890
Antidiabetic medication, yes vs. no	0.98 (0.83–1.14)	0.756	0.91 (0.78–1.07)	0.256	0.87 (0.74–1.01)	0.076
Lipid-lowering medication, yes vs. no	1.05 (0.92–1.20)	0.500	1.05 (0.91–1.20)	0.515	0.93 (0.82–1.07)	0.310
Anti-gout medication, yes vs. no	0.88 (0.76–1.01)	0.070	1.10 (0.95–1.27)	0.186	0.92 (0.8–1.06)	0.242

Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; BMI, body mass index; CHD, coronary heart disease; DBP, diastolic blood pressure; estimated glomerular filtration rate (CKD-EPI equation); GFPI, German Food Pyramid Index; HbA1c, glycated haemoglobin; HDL-cholesterol, high-density lipoprotein-cholesterol; LDL-cholesterol, low-density lipoprotein-cholesterol; SBP, systolic blood pressure; UACR, urine albumin-to-creatinine ratio; Q, quintiles.

Table 3.

Multivariable adjusted linear regression models for explanation of eGFR (ml/min/1.73 m^2) and urine albumin-to-creatinine-ratio (UACR) (mg/g).

Diet score (per 1-SD increase)	eGFR (ml/min/1.73 m^2)			UACR (mg/g)		
	β-coefficient	SE	*P*- value	β-coefficient	SE	*P*- value
DASH diet score[ǂ]	1.226	0.349	<0.001	−1.462	13.539	0.914
Mediterranean diet score[ǂ]	0.932	0.347	0.007	−4.825	13.480	0.720
GFPI[ǂ]	0.252	0.362	0.486	9.170	14.019	0.486

[ǂ]adjusted for gender, age (years), BMI (kg/m^2), caloric intake (kJ/day), smoking (non-smoker, former smoker, smoker), alcohol intake (<3x/week, ≥3x/week), school education (completed ≤9^{th}, 10^{th}, ≥12^{th} grade), HDL-cholesterol (mg/dL), LDL-cholesterol (mg/dL), hypertension (yes/no), diabetes mellitus (yes/no).

Abbreviations: BMI, body mass index; DASH, Dietary Approaches to Stop Hypertension; eGFR, estimated glomerular filtration rate; GFPI, German Food Pyramid Index; HDL-cholesterol, high density lipoprotein-cholesterol; LDL-cholesterol, low density lipoprotein-cholesterol; SD, standard deviation; SE, standard error.

Table 4.

Multivariable adjusted linear regression models for explanation of eGFR (ml/min/1.73 m^2) by individual components of DASH diet score, Mediterranean diet score and German Food Pyramid Index.

DASH component (per 1-serving/day increase)	**β-coefficient**	**SE**	***P*- value**
Grains[ǂ]	0.226	0.214	0.292
Vegetables[ǂ]	0.665	0.566	0.240
Fruits[ǂ]	−0.040	0.138	0.774
Nuts and legumes[ǂ]	13.172	2.594	<0.001
Dairy products[ǂ]	0.172	0.344	0.618
Meat, sausages, fish, eggs[ǂ]	−0.176	0.119	0.141
Added fat, oil[ǂ]	−0.058	0.099	0.561
Sweets, snacks[ǂ]	−0.021	0.099	0.834
Mediterranean food component (>median intake)	**β-coefficient**	**SE**	***P*- value**
Cereals[ǂ]	1.733	0.743	0.020
Vegetables[ǂ]	−0.131	0.733	0.858
Fruits and nuts[ǂ]	0.292	0.720	0.685
Legumes[ǂ]	0.188	0.696	0.787
Fish[ǂ]	1.630	0.681	0.017
Meat[ǂ]	0.657	0.748	0.380
Dairy products[ǂ]	−1.663	0.700	0.018
Alcohol[ǂ]	0.610	0.756	0.420
Monounsaturated + polyunsaturated / saturated fats[ǂ]	1.755	0.692	0.011
GFPI component (per 1-serving/day increase)	**β-coefficient**	**SE**	***P*- value**
Water and juice[ǂ]	−0.163	0.095	0.086
Vegetables[ǂ]	1.381	0.771	0.073
Fruits[ǂ]	−0.002	0.337	0.997
Cereals[ǂ]	0.348	0.412	0.398
Dairy products[ǂ]	−0.087	0.387	0.823
Meat, sausages, fish, eggs[ǂ]	−0.247	0.239	0.306
Added fat, oil[ǂ]	0.080	0.496	0.872
Sweets, snacks[ǂ]	−0.079	0.404	0.845

[ǂ]Each component of dietary patterns was added individually into the model (not adjusted for the other food components), adjusting for gender, age (years), BMI (kg/m^2), caloric intake (kJ/day), smoking (non-smoker, former smoker, smoker), alcohol intake (<3x/week, ≥3x/week), school education (completed ≤9^{th}, 10^{th}, ≥12^{th} grade), HDL-cholesterol (mg/dL), LDL-cholesterol (mg/dL), hypertension (yes/no), diabetes mellitus (yes/no).

Abbreviations: BMI, body mass index; DASH, Dietary Approaches to Stop Hypertension; eGFR, estimated glomerular filtration rate; HDL-cholesterol, high density lipoprotein-cholesterol; LDL-cholesterol, low density lipoprotein-cholesterol; SD, standard deviation; SE, standard error.