Dietary patterns, dietary biomarkers, and kidney disease in patients with type 2 diabetes: a repeated-measure study in Taiwan

doi: 10.6133/apjcn.042017.15
Published online: April 2017

Running title: Dietary patterns and kidney disease in diabetes

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ABSTRACT

Background and Objectives: Western dietary patterns have been linked with kidney disease. This study investigated the association between Chinese dietary patterns and kidney disease in a Taiwanese population with type 2 diabetes and evaluated dietary fatty acid patterns, a kidney-related dietary biomarker. **Methods and Study Design:** We recruited 838 patients with type 2 diabetes and used their dietary and renal data obtained from three repeated measures in 2008, 2009 and 2010. Diet was assessed using food-frequency questionnaires, and factor analysis was performed to identify dietary patterns. Albuminuria was defined by having an albumin-to-creatinine ratio ≥30 mg/g and kidney dysfunction by estimated glomerular filtration rate <60 mL/min/1.73m^2. Generalized estimating equation models were used to estimate ORs (95% CIs) of kidney disease adjusted for covariates. Erythrocyte fatty acids were only measured in blood samples collected in 2008. **Results:** Three dietary patterns were identified: high fat-meat, traditional Chinese food-snack, and fish-vegetable. In the adjusted model, the high fat-meat and traditional Chinese food-snack diets were not associated with any kidney outcomes. The fish-vegetable diet was inversely associated with kidney dysfunction (quartile 4 vs 1, OR: 0.75, 0.58-0.97), but not associated with albuminuria. A higher fish-vegetable diet factor score was associated with higher n-3 fatty acid intakes. **Conclusion:** In patients with diabetes, we found greater adherence to a fish-vegetable diet to be associated with better kidney function and greater n-3 fatty acid profiles. The inclusion of repeated dietary assessments and dietary biomarker measurements in future diet-disease research, especially in patient populations, may provide more definitive risk evaluation.

Keywords: dietary pattern, dietary biomarker, kidney disease, Chinese population, type 2 diabetes

INTRODUCTION

Chronic kidney disease (CKD) is the leading cause of cardiovascular disease (CVD).[1] Patients with type 2 diabetes have a faster renal function decline rate than individuals without this disease, even in the absence of albuminuria.[2] Taiwan has the highest prevalence of end stage renal disease (ESRD) in the world, and over 40% of ESRD cases are due to diabetes.[3] It is therefore imperative to identify modifiable lifestyle factors such as diet for this high-risk population.

Dietary intake plays a significant role in the development of kidney disease in the general and diabetic population. Most current studies focused on investigating the effect of single nutrients or specific foods, such as protein,[4,5] fat,[6] phosphate and sodium.[7,8] However, individuals do not consume isolated nutrients or foods. Instead, they consume an overall diet. Observational studies have found the Western-style diet to increase the risk of albuminuria and impaired kidney function,[9,10] while the Dietary Approach to Stop Hypertension (DASH) diet[9] and Mediterranean diet[11] to improve kidney function. However, the findings of these studies that investigated the effect of overall diet on kidney disease are limited to Western populations. No studies have examined the effects of Asian-style diets (e.g. Chinese and Japanese diets), which are considerably different. The Nutrition and Health Survey in Taiwan (NAHSIT) has reported an inverse association between a diet rich in lean meats, fish, vegetables, fruit, soybeans, and seaweed and the risk of metabolic syndrome,[12] which implies that dietary patterns play a significant role in the development of metabolic disorder in Taiwanese adults.

It is known that dietary biomarkers can serve as objective measures of recent and long-term dietary intake.[13] The concentrations of fatty acids obtained from erythrocyte blood samples have been hypothesized to be more appropriate biomarkers of long-term intake of dietary fats than those found in plasma or serum.[14] In our recent study, we have reported that high erythrocyte n-3 fatty acids protected patients with type 2 diabetes from renal function decline over time.[15] Thus, erythrocyte fatty acids could be considered as a kidney-related dietary biomarker to play a role in diet-kidney disease association.

A repeated-measure design can provide a more definitive evaluation of within-person change across time and increase statistical power. This study used the dietary and renal data obtained from the same cross-sectional survey administered to a Chinese population with type 2 diabetes in Taiwan for three consecutive years to identify their dietary patterns and to investigate the association of those patterns with kidney disease outcomes. In addition, we studied the relationship between the identified dietary patterns and concentrations of erythrocyte fatty acids to evaluate dietary patterns with kidney-related dietary biomarkers.

MATERIALS AND METHODS

Study population

This study initially recruited 1209 individuals with type 2 diabetes aged 30-70 years who had participated in the Diabetes Management through an Integrated Delivery System (DMIDS) project in Taiwan. Type 2 diabetes was diagnosed by physicians based on criteria established by the American Diabetes Association (ADA).[16] Patients were recruited from 36 clinics located in northern, middle, and southern Taiwan. Details of the study design and inclusion/exclusion criteria for the original cohort have been previously published.[17] Briefly, patients who had systemic illnesses (e.g. stroke or cancer) or severe diabetic complications (e.g. dialysis or foot amputations) were not eligible at baseline (2003-2005). Dietary data were first assessed in 2008. Thus, the present study was limited to participants providing dietary and renal data in follow-up surveys in 2008, 2009 and 2010. We excluded patients who reported implausible energy intakes (<500 or >5000 kcal/day), leaving us with 838, 827 and 785 patients in each time point. The protocol for the present study was approved by the Ethics Committees of the National Health Research Institutes and Kaohsiung Medical University Hospital, Taiwan. All participants provided written informed consent.

Dietary assessment

Diet was assessed using a semi-quantitative food frequency questionnaire (FFQ) at each survey. The FFQ, which was developed for use with Taiwanese adults, has 45 survey questions on frequency of food group consumption, serving sizes and other eating habits. Because there are too few studies currently available to assess the dietary intake of Taiwanese, we provide the details of each food group listed in the FFQ in Table 1. Methods of the dietary assessment have been previously reported.[18] Briefly, participants were asked how frequently they consumed items belonging to certain food groups over the previous 12 months, with six options ranging from “almost never” to “one or more times per day”. Certain food groups (e.g. eggs, milk, and Chinese staples) were expressed as usual portion sizes consumed per day. In our dietary pattern analysis, frequency of consumption of each food group was converted to weekly equivalents. For each patient, we determined average serving sizes of foods consumed per day and calculated energy intake.

Measurement of dietary biomarkers

Erythrocyte lipids were only extracted in 2008 (n=805) using a modified Bligh and Dyer method[19] and were derivatized to fatty acid methyl esters (FAMEs) using boron trifluoride-methanol. Details on the measurement of fatty acids have been previously published.[15] Briefly, the FAMEs were extracted by hexane and then analysed using a Hewlett-Packard 6890N gas chromatography flame ionization detector (Agilent Technologies, Santa Clara, CA, USA) equipped with a DB-225 capillary column (30 m×0.25 mm inner diameter×0.25 μm film) and with N_2 as the carrier gas. An equal weight FAME mixture (68A; Nu-Chek-Prep, Elysian, MN, USA) was used to generate response factors. C17:0 was added as an internal standard to determine the concentrations of various fatty acids (expressed as weight % of total fatty acids).

Measurement of albuminuria and kidney dysfunction

Spot urine and serum creatinine samples were collected at the time of each survey. Urinary and serum creatinine were measured by Jaffe reaction method, and urinary albumin was measured by immunoturbidimetry (Hitachi High Technologies, Tokyo, Japan). Albuminuria (marker of kidney damage) was defined in those having a urinary albumin-to-creatinine ratio (ACR) ≥30 mg/g.[1] Serum creatinine (marker of kidney function) was defined as elevated and indicative of clinically significant renal insufficiency in men at ≥1.5 mg/dL and in women at ≥1.2 mg/dL.[20,21] Glomerular filtration rate was estimated (eGFR) using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation with a four-level race variable.[22] Kidney dysfunction was defined in those with an eGFR <60 mL/min/1.73 m.[21]

Assessment of covariates

Age, sex, duration of diabetes, and education (≤6 y, >6 y) were assessed at baseline. Lifestyle factors were assessed using self-reported questionnaires at each follow-up survey. They were assessed by asking patients whether they currently smoked (yes, no), drank alcohol at least once a week in the previous six months (yes, no), and if they had got any exercise within the last two weeks (yes, no). Body mass index (BMI) and average blood pressure were measured by trained research nurses. Hypertension was defined as blood pressure ≥140/90 mmHg or self-reported use of anti-hypertensive medications (yes, no). Fasting (≥8 h) hemoglobin A1C (HbA1C) was measured using high-performance liquid chromatography (Tosoh, Kobe, Japan), and serum triglycerides were measured using an auto-analyser (Beckman Coulter, Fullerton, CA, USA).

Statistical analysis

Pearson chi-squared tests and student *t*-tests were used to compare demographic and clinical characteristics between patients with and without kidney disease. Factor analysis was used to identify dietary patterns based on each patient's answer to the food items at each survey. We used principal component extraction and varimax rotation to generate uncorrelated factors, which we called dietary patterns. Food items with a factor loading of $\geq \pm 0.3$ were considered important contributors to the pattern. A factor score for each identified pattern in each patient was calculated by multiplying food items with their corresponding factor loadings and summing these values. Correlations of factor scores between surveys were examined by Spearman's correlation to test the stability of factor scores over time. The factor scores were then categorized into quartiles (Q1 to Q4) to rank individuals by degree of adherence to the diets.

Generalised estimating equation (GEE) models (using an exchangeable correlation and a logit link function) were applied to examine the OR (95% CI) of the association between dietary patterns and kidney disease using repeated measures. Estimated renal function indicators are fluctuated and not considered to be irreversible at the earlier CKD stage. So we allow the change of renal status between surveys. The use of GEE model makes it possible to take into consideration the variations in diets, covariates, and renal status within each subject between repeated surveys and provides a more definitive evaluation of within-person change. This model also handles missing values and makes better use of all available data. So it produces a more powerful and efficient estimate. Multivariable models were adjusted for age, energy intake, sex, education, diabetes duration, smoking, alcohol, exercise, BMI, hypertension, HbA1C, and triglycerides.

ANCOVA and post-hoc tests (LSD) were performed to compare levels of erythrocyte fatty acids among the quartiles of dietary patterns adjusted for age and energy intake using measurements in 2008. All statistical operations were performed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). $p<0.05$ was considered statistically significant.

RESULTS

Baseline characteristics

Characteristics of the 838 participants in the 2008 survey are shown in Table 2. Half of subjects (47.5%) were male. The mean age was 59.5 years and average diabetes duration 8.9 years.

Median ACR was 14.0 mg/g, and mean eGFR was 87.5 mL/min/1.73m^2. Subjects with albuminuria had longer durations of diabetes, higher levels of BMI, blood pressure, HbA1C and triglycerides, lower levels of eGFR and were more likely to be taking anti-hypertensive medication than those without albuminuria (all $p<0.01$). Similarly, those with kidney dysfunction had longer durations of diabetes, were more likely to be hypertensive, and had higher concentrations of serum triglycerides than those without kidney dysfunction (all $p<0.05$); however, there were no differences in BMI. We also observed that they were older, less educated, and had a higher ACR (all $p<0.05$).

Identified dietary patterns

We identified three dietary patterns at the 2008, 2009 and 2010 surveys. There were 1) high fat-meat diet, 2) traditional Chinese food-snack diet and 3) fish-vegetable diet. Overall, the major food items contributing to the diets were similar across the three surveys. The factor scores between surveys were moderately correlated (r=~0.5, all $p<0.001$). The factor loading matrix for each diet was comparable to that identified in our recent cross-sectional analysis using a sub-sample of the 2008 survey.[18] Thus, in this study, we only present the matrix in supplementary data (Table S1).

The high fat-meat diet was characterized by white and red meats, fatty meats and skin, fried foods, seafood, processed meats, eggs, canned meats and frequently eating out. The traditional Chinese food-snack diet was characterized by soy products, processed gluten products, low nitrogen staple foods, low calorie desserts, seeds and nuts, root vegetables, starchy foods, pickled vegetables and tea. The fish-vegetable diet was characterized by light- and dark-coloured vegetables, freshwater fish and marine fish. These three patterns explained 25.9%, 24.9% and 24.7% of variance in 2008, 2009, and 2010, respectively.

Dietary patterns and albuminuria

The prevalence of albuminuria was 36.0% in 2008, 40.1% in 2009 and 43.0% in 2010. Overall, we found no significant association between any of the three diets and albuminuria (Table 3). While multivariable adjustment revealed a marginally significant association between traditional Chinese food-snack diet and albuminuria (Q4 vs Q1, OR: 0.83, 0.68-1.02, $p=0.07$). This relationship was not dose-dependent (p for trend=0.13).

Dietary patterns and kidney dysfunction

The prevalence of kidney dysfunction (eGFR <60 mL/min/1.73m^2) was 13.8% in 2008, 16.2% in 2009 and 15.0% in 2010. The high fat-meat diet was not associated with kidney dysfunction (Table 4). In the fully adjusted model, the traditional Chinese food-snack diet was marginally associated with lower odds of decreased eGFR (Q4 vs Q1, OR: 0.79, 0.61-1.03, *p*=0.08) but not significantly associated with elevated creatinine (*p*=0.12).

The fish-vegetable diet was inversely associated with kidney dysfunction. In the age and energy-adjusted model, the ORs of elevated creatinine from Q1 to Q4 were 1.00, 1.01 (0.81-1.25), 0.76 (0.61-0.95) and 0.77 (0.61-0.97) (*p* for trend=0.003), respectively, and the ORs of decreased eGFR from Q1 to Q4 were 1.00, 0.81 (0.65-1.00), 0.81 (0.66-1.00), and 0.76 (0.60-0.97) (*p* for trend=0.03). After adjusting for covariates, we found a persistent significant association between the fish-vegetable diet and better renal status, characterized by lower ORs of elevated creatinine (OR: 0.76, 0.60-0.98) and decreased eGFR (OR: 0.75, 0.58-0.97), when comparing Q4 with Q1.

Dietary patterns and erythrocyte fatty acids

We observed that patients who adhered to the fish-vegetable diet the most (Q4) had the highest levels of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), n-3 polyunsaturated fatty acid (PUFA) and n-3/n-6 PUFA ratio but the lowest levels of n-6 PUFA levels after controlling for age and energy intake (all *p*<0.01) (Table 5). Patients following the high fat-meat diet (Q4) had higher saturated fatty acid (SFA) and n-3 PUFA but lower n-6 PUFA levels (all *p*<0.05), while those following the traditional Chinese food-snack diet had higher n-6 PUFA but lower n-3 PUFA levels (both *p*<0.001).

DISCUSSION

This study investigated the associations between Chinese dietary patterns and kidney disease in Taiwanese patients with type 2 diabetes. We used a repeated-measure study design to account for variances within persons over time and to confirm the clinical findings from our previous cross-sectional analysis on a sub-sample.[18] In the current study, we used clinical cut-off points to define albuminuria and kidney dysfunction and evaluated dietary patterns with erythrocyte fatty acids. We found greater adherence to the fish-vegetable diet was associated with better kidney function but not with albuminuria. Patients following a fish-vegetable diet more frequently (Q4) also had higher levels of n-3 fatty acids. The high fat-meat and traditional Chinese food-snack diets were not found to be significantly associated with any kidney outcomes.

The inverse association we found between fish-vegetable diet and kidney disease in individuals with type 2 diabetes can be partly supported by a few intervention studies.[23-27] Clinical trials have reported that fish oil supplements improved albuminuria,[23] renal function[24] and kidney injury[25] in the diabtic population, while a predominantly vegetarian diet reduced albumin excretion rate.[26] Adherence to a Mediterranean diet (rich in vegetables, fruit, fish, olive oil, and moderate red wine) has been found to improve kidney function in subjects at high risk of CVD (>50% with diabetes).[27] Observational studies have also suggested that high daily fish intake,[28] with reduced protein intake from non-fish animal sources and increased lipid intake from vegetable sources[29] would reduce the risk of albuminuria in patients with diabetes. However, it should be noted that two large observational studies conducted in non-diabetic Western populations did not find a fish-vegetable diet[30] or a prudent diet[9] to have protective effects on either eGFR decline or albuminuria. Future prospective studies are needed to investigate the effect of a fish-vegetable diet on risk of kidney disease in other Asian populations with or without diabetes.

The presence of anti-inflammatory n-3 PUFAs found in fish and antioxidant vitamins and folic acid found in vegetables[31,32] may partially explain the renal benefits of a fish-vegetable diet to diabetes. In animal models, treating type 2 diabetic mice at the early CKD stage with EPA improved urinary ACR and attenuated mesangial matrix accumulation and tubulointerstitial fibrosis by mitigating renal inflammation, oxidative stress and expression of pro-fibrotic genes.[33] This beneficial effect of n-3 PUFAs was also found in renal failure rats in their remnant kidney.[34] Our previous study found that high erythrocyte n-3 PUFA attenuated the risk of renal function decline in Type 2 diabetes and modified the effect of pro-inflammatory IL-6 on renal risk.[15] The present study found an association between higher fish-vegetable factor score and greater erythrocyte n-3 PUFA levels, which further supports the conclusion of other studies that have reported correlation between erythrocyte fatty acids and intake of various corresponding foods and dietary fats.[14,32] Future studies might be performed to investigate the use of dietary biomarkers, including folate and carotenoids as biomarkers of a vegetarian diet,[31] as additional or substitute predictors of disease.

A Western-diet increases the risk of kidney disease[9,10] and CVD.[35] However, the high fat-meat diet we identified was not associated with any renal outcomes in this study using repeated measurements over three years. In the dietary biomarker analysis, although the high fat-meat diet was associated with erythrocyte SFA, the differences in SFA between the highest and the lowest quartile of dietary scores were not remarkable. Another explanation could be that our patients who participated in the DMIDS study had received nutritional education advising them to consume less saturated fats, salt and sugar for better diabetic control. Continued participation in this education program could result in under-reporting of their intake of unhealthy foods and energy.

The traditional Chinese food-snack diet was marginally associated with better renal function status, but there was no dose-response relationship. This traditional diet comprises some specific Taiwanese foods primarily consisting of plant protein and fat (e.g. soy products, processed gluten products and seeds) and foods high in carbohydrates (e.g. rice, porridge and starchy soup). We observed a higher level of n-6 PUFA in patients adhering to this plant-based diet. The Taiwanese diet is unlike those of previously studied diets including the DASH and Mediterranean diets. One recent review study has suggested that substitution of plant protein for animal protein may delay the development of kidney damage in patients with diabetes.[36] However, these traditional high plant-protein foods and snacks, which are often sold on the streets and in the night markets in Taiwan, contain high amounts of refined carbohydrates, which may worsen glycemic status. Still, evidence is lacking as to the effect of this traditional diet on kidney status in Taiwanese adults with diabetes.

This study has some limitations. Firstly, the study period of three years was a relatively short period to observe changes in renal function or incident case of kidney disease. We could only study the contemporaneous associations between diet and kidney disease using repeated measures data. Consequently, reverse causality may exist. Secondly, although we adjusted for several lifestyle factors, the covariates were crudely measured and categorized. Residual confounding remains a possible alternative explanation for our findings. Another limitation is that the FFQ has not been directly validated against other dietary measurement methods such as 3 or 7-day dietary record, though we did evaluate specific food items and dietary patterns with dietary biomarkers. Additionally, this short FFQ only included questions on 30 food groups, thus the intake of macronutrients and energy may potentially be underestimated.

In conclusion, this study found an inverse relationship between the fish-vegetable diet and kidney dysfunction in Taiwanese adults with type 2 diabetes, suggesting that the fish-vegetable diet possibly had a beneficial effect on kidney disease in this population. Patients adhering to fish-vegetable diet had higher erythrocyte n-3 PUFA levels, supporting that the dietary patterns we identified were correlated with corresponding kidney-related dietary biomarkers. This evidence could be applied in nutrition counselling in primary care to promote a healthy diet that incorporates nutritional principles to manage diabetic kidney disease. Future prospective studies with longer peroid of follow-up are needed to investigate the assocation between Asian dietary patterns and the risk of developing kidney disease or changes in kidney function indicators in non-diebetic or diabetic populations. The inclusion of repeated dietary assessments and objective dietary biomarkers in future diet-disease research, especially in the patient population, should account for some of the variation and to provide more definitive risk evaluation.

ACKNOWLEDGEMENTS

The authors thank registered nurses Chia-Huei Lin and Yi-Ching Sung for their clinical assistance with questionnaire surveillance and Huei-Ru Jhang for her technical assistance in fatty acid analysis.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

FUNDING DISCLOSURE

This study was supported by the grants from the Taiwan National Health Research Institute (NCT00288678), the National Science Council (NSC-102-2628-B-037-008-MY3) and the Center of Excellence for Environmental Medicine, Kaohsiung Medical University (KMU-TP103A22). The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

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Table 1 The food groups listed in the food frequency questionnaire to assess dietary intakes of Taiwanese adults

Food groups listed in the FFQ	Food examples
Fatty meats and skin	Pork belly, chicken skin, fish skin, duck skin
Fried foods	Fried pork/chicken cutlet, fried salty chicken, fried fish/tofu, donuts
Eggs	Chicken, duck, bird eggs
Seafood	Prawn, pipi, calamari, crab, oyster, squid
Marine fish	Spanish mackerel, mackerel pike, salmon, *ribbon fish,* tilapia, snapper
Freshwater fish	Milk fish/white mullet, tilapia, eel
Red meats	Pork, beef, lamb
White meats	Chicken, duck, goose, poultry
Canned meats	Canned tuna, eel, seasoned meat
Processed meats	Ham, sausage, preserved meat, bacon, hot dog, salty pork, smoked meat
Milk and yogurt	Cow milk, goat milk, yogurt drinks
Processed dairy products	Cheese slices, panna cotta, ice cream
Soy products	Dried tofu, fresh tofu, soy pudding, soy milk, bean curd
Processed wheat/gluten products	Fried/roasted gluten, gluten flour, vegetable protein or products
Light-coloured vegetables	Cabbage, Chinese cabbage, Chinese radish, winter melon, loofah
Dark-coloured vegetables	Broccoli, spinach, mushroom, Chinese green vegetables, carrot
Pickled vegetables	Pickled or preserved salty cucumber or winter melon, dried bamboo shoot or radish, kimchi, other pickles
Fresh fruit	Fresh fruit
Sweetened fruit juice	Bottled juice or fresh juice with sugar, condensed juice, coconut water
Sugar-containing beverages	Coffee and tea with sugar, milk tea, soy milk with sugar, energy drink, soft drink, yakult, fruit vinegar beverage
Tea	Tea without sugar: oolong tea, black tea, puerh tea, green tea
Chinese staples	Rice, porridge, noodle, rice noodle, steamed bun
Bread	Toast, soft roll, croissant, sweet bun, red bean bun
Root vegetables	Sweet potato, potato, taro, water caltrop, lotus root, Chinese yam
Low nitrogen staple foods	Rice noodle, bean noodle, pearl sago/tapioca, tapioca starch
Starchy/thickened soup and foods	Dextrinized starch: porridge, thickened soup with cornflour or tapioca flour, curry, rice and peanut milk
Cakes and cookies	Pineapple cake, walnut cookie, cookie
Seeds and nuts	Peanut, pumpkin seeds, pistachio, almond, walnut, cashew nut, sesame
Sugar substitute use	Zero Coke, sugar-free candy or chewing gum, sorbitol, oligofrutose
Low calorie desserts and snacks	Konjac, gelatin, white fungus, agar dessert, seaweed nori

Table 2 Demographic and clinical characteristics of participants in the 2008 survey according to kidney disease status

	All	Urine ACR (mg/g)		*p*	eGFR (mL/min/1.73m^2)		*p*
		<30	≥30		≥60	<60	
n	838	536 (64.0)	302 (36.0)		722 (86.2)	116 (13.8)	
Age (years)	59.5±8.5	59.3±8.4	60.0±8.5	0.25	58.9±8.4	63.3±7.8	<0.001
Diabetes duration (years)	8.9±5.7	8.5±5.6	9.7±5.8	0.003	8.8±5.7	10.0±5.8	0.03
Male (%)	398 (47.5)	245 (45.7)	153 (50.7)	0.17	339 (47.0)	59 (50.9)	0.43
Education ≤6y (%)	457 (54.5)	285 (53.2)	172 (57.0)	0.31	383 (53.0)	74 (63.8)	0.03
Current smoker (%)	175 (20.9)	103 (19.2)	72 (23.8)	0.13	150 (20.8)	25 (21.6)	0.85
Alcohol drinker (%)	107 (12.8)	65 (12.1)	42 (13.9)	0.46	96 (13.3)	11 (9.5)	0.25
Exercise (%)	550 (65.6)	365 (68.1)	185 (61.3)	0.05	475 (65.8)	75 (64.7)	0.81
BMI (kg/m^2)	26.1±3.8	25.8±3.6	26.6±4.1	0.007	26.0±3.8	26.5±3.5	0.22
Systolic BP (mmHg)	136.6±19.4	132.7±17.5	143.6±20.7	<0.001	136.0±19.2	140.5±20.7	0.02
Diastolic BP (mmHg)	79.6±11.0	78.1±10.2	82.4±11.8	<0.001	79.7±10.7	79.0±12.6	0.58
Hypertensive medication (%)	422 (50.4)	247 (46.1)	175 (57.9)	0.001	346 (47.9)	76 (65.5)	<0.001
HbA1C (%)	8.0±1.5	7.8±1.4	8.2±1.5	<0.001	8.0±1.5	7.7±1.3	0.02
Triglycerides (mg/dL)	159.5±102.2	141.7±89.3	191.1±115.3	<0.001	152.7±97.9	201.7±117.3	<0.001
Urinary ACR (mg/g)	14.0 (5.5, 67.7)	7.2 (4.1, 13.1)	122.7 (57.3, 526.2)	<0.001	11.8 (5.0, 44.5)	89.5 (17.1, 1203.0)	<0.001
Serum creatinine (mg/dL)	0.98±0.76	0.84±0.24	1.23±1.19	<0.001	0.81±0.19	2.04±1.64	<0.001
eGFR (mL/min/1.73m^2)	87.5±23.9	92.8±18.5	78.1±29.1	<0.001	94.8±15.6	42.0±15.1	<0.001

BP: blood pressure; HbA1C: haemoglobin A1C; ACR: albumin-to-creatinine ratio; eGFR: estimated glomerular filtration rate.
Values are presented as number (%), mean±SD, or median (IQRs).

Table 3. Odds ratios for the associations between dietary patterns and albuminuria using generalized estimating equation models

	Quartile of diet factor score				Q4 vs Q1	*p* for trend
	Q1 (low)	Q2	Q3	Q4 (high)	*p*	
Albuminuria (ACR ≥30 mg/g)						
High fat-meat diet						
Age and energy intake adjusted	1.00	1.09 (0.92-1.29)	1.02 (0.85-1.21)	1.13 (0.92-1.38)	0.24	0.39
Multivariable adjusted†	1.00	1.06 (0.89-1.27)	0.95 (0.79-1.15)	1.02 (0.82-1.26)	0.85	0.86
Traditional Chinese food-snack diet						
Age and energy intake adjusted	1.00	0.91 (0.78-1.08)	0.91 (0.76-1.08)	0.86 (0.71-1.04)	0.11	0.14
Multivariable adjusted†	1.00	0.88 (0.74-1.05)	0.92 (0.76-1.10)	0.83 (0.68-1.02)	0.07	0.13
Fish-vegetable diet						
Age and energy intake adjusted	1.00	0.96 (0.81-1.12)	0.91 (0.77-1.08)	0.91 (0.75-1.10)	0.31	0.26
Multivariable adjusted†	1.00	0.97 (0.82-1.16)	0.91 (0.76-1.09)	0.92 (0.75-1.13)	0.42	0.32

ACR: albumin-to-creatinine ratio; Q: quartile.

Values are presented as OR (95% CI). Generalized estimating equation (GEE) models were performed using repeated measures data from the 2008, 2009 and 2010 survey.

†Adjusted for age, energy intake, sex, diabetes duration, education (≤6 y, >6 y), current smoker (yes, no), alcohol (yes, no), exercise (yes, no), BMI, hypertension (blood pressure ≥140/90 mmHg or taking anti-hypertensive medication), HbA1C, and triglycerides.

Table 4. Odds ratios for the associations between dietary patterns and kidney dysfunction using generalized estimating equation models

	Quartile of diet factor score				Q4 vs Q1	p for trend
	Q1 (low)	Q2	Q3	Q4 (high)	*p*	
Elevated serum creatinine (≥1.5 or ≥1.2 mg/dL)						
High fat-meat diet						
Age and energy intake adjusted	1.00	1.12 (0.94-1.34)	0.99 (0.82-1.19)	1.11 (0.85-1.45)	0.45	0.66
Multivariable adjusted†	1.00	1.11 (0.91-1.35)	0.95 (0.77-1.16)	1.06 (0.80-1.42)	0.68	0.97
Traditional Chinese food-snack diet						
Age and energy intake adjusted	1.00	0.77 (0.63-0.95)	0.78 (0.63-0.95)	0.79 (0.62-1.02)	0.07	0.06
Multivariable adjusted†	1.00	0.78 (0.63-0.96)	0.80 (0.65-0.99)	0.81 (0.63-1.06)	0.12	0.12
Fish-vegetable diet						
Age and energy intake adjusted	1.00	1.01 (0.81-1.25)	0.76 (0.61-0.95)	0.77 (0.61-0.97)	0.03	0.003
Multivariable adjusted†	1.00	1.01 (0.80-1.27)	0.73 (0.58-0.93)	0.76 (0.60-0.98)	0.03	0.004
Decreased eGFR (<60 mL/min/1.73m^2)						
High fat-meat diet						
Age and energy intake adjusted	1.00	0.96 (0.81-1.15)	0.94 (0.76-1.16)	1.00 (0.76-1.32)	0.99	0.83
Multivariable adjusted†	1.00	0.97 (0.80-1.17)	0.90 (0.72-1.13)	0.98 (0.73-1.31)	0.89	0.65
Traditional Chinese food-snack diet						
Age and energy intake adjusted	1.00	0.78 (0.63-0.97)	0.72 (0.57-0.89)	0.80 (0.62-1.03)	0.08	0.04
Multivariable adjusted†	1.00	0.79 (0.63-0.98)	0.73 (0.58-0.92)	0.79 (0.61-1.03)	0.08	0.04
Fish-vegetable diet						
Age and energy intake adjusted	1.00	0.81 (0.65-1.00)	0.81 (0.66-1.00)	0.76 (0.60-0.97)	0.03	0.03
Multivariable adjusted†	1.00	0.80 (0.64-1.00)	0.82 (0.66-1.01)	0.75 (0.58-0.97)	0.03	0.04

eGFR: estimated glomerular filtration rate; Q: quartile.
Values are presented as OR (95% CI). Generalized estimating equation (GEE) models were performed using repeated measures data from the 2008, 2009 and 2010 survey.
†Adjusted for age, energy intake, sex, diabetes duration, education (≤6 y, >6 y), current smoker (yes, no), alcohol (yes, no), exercise (yes, no), BMI, hypertension (blood pressure ≥140/90 mmHg or taking anti-hypertensive medication), HbA1C, and triglycerides.

Table 5. Erythrocyte fatty acids according to quartiles of the dietary pattern scores

	High fat-meat diet		Traditional Chinese food-snack diet		Fish-vegetable diet	
	Q1	Q4	Q1	Q4	Q1	Q4
Total SFA (weight %)	39.23 (39.10-39.37)	39.49 (39.36-39.63)*	39.47 (39.34-39.59)	39.37 (39.25-39.50)	39.41 (39.28-39.53)	39.41 (39.28-39.54)
Total USFA (weight %)	60.77 (60.63-60.90)	60.51 (60.37-60.64)*	60.54 (60.41-60.66)	60.63 (60.50-60.75)	60.59 (60.47-60.72)	60.59 (60.46-60.72)
Total n-3 PUFA (weight %)	10.25 (9.97-10.54)	10.81 (10.53-11.10)*	11.30 (11.06-11.55)	9.75 (9.51-9.99)***	10.38 (10.12-10.64)	11.28 (11.01-11.54)***
C20:5n3 (EPA) (weight %)	0.97 (0.89-1.04)	0.99 (0.91-1.06)	1.12 (1.06-1.19)	0.80 (0.74-0.87)***	0.92 (0.85-0.98)	1.12 (1.05-1.19)***
C22:6n3 (DHA) (weight %)	6.90 (6.69-7.11)	7.44 (7.23-7.64)***	7.78 (7.60-7.96)	6.61 (6.44-6.79)***	7.10 (6.92-7.29)	7.74 (7.55-7.93)***
Total n-6 PUFA (weight %)	33.40 (33.05-33.76)	32.65 (32.30-33.0)**	32.10 (31.80-32.41)	34.00 (33.70-34.30)***	33.11 (32.78-33.42)	32.40 (32.07-32.72)**
n-3 to n-6 PUFA ratio ×10	3.15 (3.03-3.27)	3.35 (3.23-3.47)*	3.58 (3.47-3.68)	2.92 (2.82-3.02)***	3.18 (3.08-3.29)	3.54 (3.43-3.64)***
SFA to USFA ratio ×10	6.46 (6.42-6.50)	6.53 (6.49-6.57)*	6.52 (6.49-6.56)	6.50 (6.47-6.53)	6.51 (6.47-6.54)	6.51 (6.47-6.54)
SFA to PUFA ratio ×10	9.00 (8.94-9.06)	9.10 (9.03-9.16)*	9.10 (9.05-9.16)	9.01 (8.96-9.07)*	9.07 (9.02-9.13)	9.03 (8.98-9.09)

Q: quartile; SFA: saturated fatty acid; USFA: unsaturated fatty acid; PUFA: polyunsaturated fatty acid; EPA: eicosapentaenoic acid; *DHA:* docosahexaenoic acid.
Values are presented as least square mean (95% CI) adjusted for age and energy intake using measurements in 2008.
*p<0.05, **p<0.01, ***p<0.001, tested by ANCOVA and post hoc analysis (LSD), comparing Q4 to Q1.

Supplementary Material

Table S1. Factor loading matrix for the three major dietary patterns identified from the food frequency questionnaire in 2008

Food groups	High fat-meat diet	Traditional Chinese food-snack diet	Fish-vegetable diet
White meats	0.64		0.23
Red meats	0.62		
Fatty meats and skin	0.61		
Fried foods	0.57	0.23	
Seafood	0.51		
Processed meats	0.49		
Eating out	0.47		-0.24
Eggs	0.35		
Canned meats	0.32		
Chinese staple foods	0.28		
Sugar-containing beverages	0.21		-0.21
Sweetened fruit juice	0.20		
Soy products		0.57	
Processed wheat/gluten products		0.50	
Low nitrogen staple foods		0.49	
Low calories desserts and snacks		0.46	
Seeds and nuts	0.23	0.43	
Root vegetables		0.42	
Starchy/thickened soup and foods	0.32	0.42	
Sugar substitute use		0.35	
Pickled vegetables		0.33	
Tea	0.28	0.33	
Cakes and cookies		0.28	
Processed dairy products		0.27	
Light-coloured vegetables			0.74
Dark-coloured vegetables			0.71
Freshwater fish		-0.32	0.61
Marine fish	0.30	-0.24	0.56
Milk and yogurt			0.25
Fresh fruit			
Bread			
Variance explained (%)	13.00%	7.05%	5.82%

Foods with a factor loading <±0.2 are not shown.