Dietary Patterns Over Time and Microalbuminuria in Youth and Young Adults With Type 1 Diabetes: The SEARCH Nutrition Ancillary Study

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OBJECTIVE

We assessed the association between diet quality and microalbuminuria in youth-onset type 1 diabetes using three indices: a modified Mediterranean diet score for children and adolescents (mKIDMED), the Dietary Approaches to Stop Hypertension (DASH), and the Healthy Eating Index-2010 (HEI).

RESEARCH DESIGN AND METHODS

Youth and young adults from the SEARCH (SEARCH for Diabetes in Youth) Nutrition Ancillary Study (SNAS) diagnosed with type 1 diabetes in 2002–2008, who had repeated dietary assessments at baseline and follow-up visits and urine albumin-to-creatinine ratio (UACR) measured at the outcome visit (2012–2015) (n = 461), were selected for study. Regression models estimated the association between each longitudinally assessed diet score and UACR and microalbuminuria (UACR ≥30 μg/mg).

RESULTS

The cohort was 43% female, and at follow-up, mean age was 20 years, disease duration was 108 months, and 7% had microalbuminuria. Adherence to a higher-quality diet was low for the mKIDMED (mean 3.7 of a possible range of −3 to 12) and the DASH (mean 42 of 80) and better, for the HEI (mean 56.3 of 100). A borderline inverse association was observed between the HEI score and microalbuminuria after adjustment for caloric and protein intake and demographic and disease factors (odds ratio $[OR]_{HEI}$ 0.83, P = 0.07), which lost significance with further adjustment for HbA_{1c} and systolic blood pressure (OR_{HEI} 0.86, P = 0.19). Results were similar for continuous UACR. No significant associations were observed for diet quality characterized by the mKIDMED or DASH indices.

CONCLUSIONS

Greater adherence to the HEI may be beneficial for kidney health in youth and young adults with type 1 diabetes. Low adherence to the mKIDMED and DASH diets may explain the lack of association with microalbuminuria.

Despite substantial improvements in the management of individuals with type 1 diabetes (T1D) during the past two decades, including the introduction of renin-angiotensin system blockers, the risk of end-stage renal disease remains high in this population (1). Optimal nutrition is an important component of the recommended

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treatment plan for individuals with diabetes who have been diagnosed with kidney disease (2). However, research to date has been lagging on the role of nutrition in potentially preventing or delaying the development of diabetic kidney disease, especially in youth and young adults with T1D, in whom any dietary intervention may have a particular impact due to longer exposure periods.

Most of the research on diet and incident kidney disease has been conducted in the general population, and most studies have focused on individual nutrients, with relatively few prospectively investigating overall diet quality or dietary patterns (3–8). Findings from these general adult population studies, however, support an association between higher-quality dietary patterns and reduced risk of adverse kidney outcomes.

The dietary patterns most frequently studied relative to chronic diseases include the Mediterranean diet, the Dietary Approaches to Stop Hypertension (DASH) diet, and the Healthy Eating Index (HEI). The traditional Mediterranean diet is abundant in vegetables, legumes, fruits, nuts, cereals, and olive oil; moderately high in fish intake; regular, but moderate, intake of wine; and consists of lower intakes of dairy and meat (9). Similarly, the DASH diet is high in fruits, vegetables, nuts, and low-fat dairy products; low in saturated fat, cholesterol, sugar, and refined carbohydrates; and promotes the consumption of fish and chicken rather than red meat (10). The HEI assesses adherence to the 2010 Dietary Guidelines for Americans and includes measures of total and whole fruit intake, and intake of vegetables, greens and beans, whole grains, dairy, total protein, seafood, and plant protein, and fatty acid (11,12).

Among individuals with diabetes, data on the association between individual nutrients or dietary patterns and incident albuminuria are sparse and limited to people with type 2 diabetes (3,13–15). In normo- or microalbuminuric individuals with type 2 diabetes enrolled in the ONTARGET (Ongoing Telmisartan Alone and in Combination with Ramipril Global Endpoint Trial) study, greater adherence over 5 years to a modified alternate HEI was inversely associated with the incidence and progression of chronic kidney disease (14). In contrast, no association was observed between a Mediterranean-type diet and incident kidney disease over 5 years in the PREDIMED (Prevención con Dieta Mediterránea) trial (15). To our knowledge, there are no published data for individuals with T1D that focus on diet and risk for chronic kidney disease. Our aim was therefore to assess the association between diet quality and microalbuminuria or magnitude of the urine albumin-to-creatinine ratio (UACR) in youth and young adults with T1D participating in the SEARCH for Diabetes in Youth (SEARCH) and the SEARCH Nutrition Ancillary Study (SNAS).

RESEARCH DESIGN AND METHODS

The SEARCH cohort study (16,17) is a longitudinal, multicenter study of youth with incident diabetes diagnosed when younger than 20 years of age. Participants enrolled in the SEARCH study were identified from a population-based incidence registry network at five U.S. sites (South Carolina; Cincinnati, OH, and surrounding counties; Colorado with southwestern Native American sites; Seattle, WA, and surrounding counties; and Kaiser Permanente, Southern California). Individuals eligible for the study were newly diagnosed with T1D or type 2 diabetes in 2002–2006 or 2008 and were identified from on-going surveillance of networks of hospitals and providers. Those who could be contacted were recruited for a baseline visit (mean $\pm$ SD of 9.3 $\pm$ 6.4 months after diagnosis) and invited to return for research visits at 12, 24, and 60 months to measure risk factors for diabetes complications (Fig. 1*A*). A subset of participants with at least a baseline visit that had at least 5 years of diabetes duration, aged 10 years and older, were recruited for an outcome visit between 2012 and 2015 (mean 7.9 $\pm$ 1.9 years from diagnosis). SNAS, an ancillary to the SEARCH study, aims to investigate the role of dietary factors on T1D-associated health outcomes. A flowchart depicting included and excluded participants is shown in Fig. 1*B*. The study was approved by Institutional Review Boards with jurisdiction. Parents and adult participants provided consent, and minors provided assent.

A first-morning urine sample was collected as part of the 2012–2015 outcome visit. Thus, the present analyses comprise data from patients with incident T1D diagnosed between 2002 and 2008 who provided a first-morning urine sample for the assessment of UACR during 2012–2015. Diabetes type was determined using an etiological classification (18,19) based on one or more positive diabetes autoantibodies and estimated insulin sensitivity score (euglycemic clamp–validated equation including waist circumference, hemoglobin A_{1c} [HbA_{1c}], and triglyceride levels) at the baseline visit (18). T1D was defined as at least one positive antibody, regardless of insulin sensitivity, or no positive antibodies and insulin sensitivity (score $\geq$8.15).

Data included sociodemographic (e.g., sex, age, self-reported race/ethnicity, and parental education), anthropometric, and clinical information, including diabetes duration and treatment regimen, dose and type of insulin therapy, and frequency of insulin injections. Blood pressure was measured following a standardized protocol by trained and certified staff. BMI was calculated as weight in kilograms divided by height in meters squared. Age- and sex-specific BMI percentiles were determined based on the 2000 Centers for Disease Control and Prevention Growth Charts (20), and overweight and obesity were defined as a BMI in the 85th to $<$95th percentile and $\geq$95th percentile, respectively. Physical activity was assessed using questionnaires from the Youth Risk Behavior Surveillance System (YRBSS) (www.cdc.gov/healthyyouth/data/yrbs/index.htm), and activity level was classified as vigorous activity 0–2 or 3–7 days weekly.

Fasting blood samples were collected under conditions of metabolic stability, defined as no episode of diabetic ketoacidosis during the previous month. HbA_{1c} was measured in whole blood with an automated, nonporous ion-exchange high-performance liquid chromatography instrument (model G-7; Tosoh Bioscience). Urinary creatinine was measured on the Roche Modular P autoanalyzer by the Roche enzymatic method with calibrator values traceable to the isotope dilution mass spectroscopy reference procedure. Two quality-control samples were analyzed in each run, and the interassay coefficient of variation was consistently $<$2%. Urine albumin was measured immunochemically using Siemens reagent on a Siemens BNII nephelometer. The interassay coefficient of variation was $<$5% for the high and $<$6.5% for the low-level quality-control sample.

The UACR was calculated, and microalbuminuria was defined as a UACR 30–300 μg/mg. Estimated glomerular filtration rate (eGFR) was computed at the outcome visit

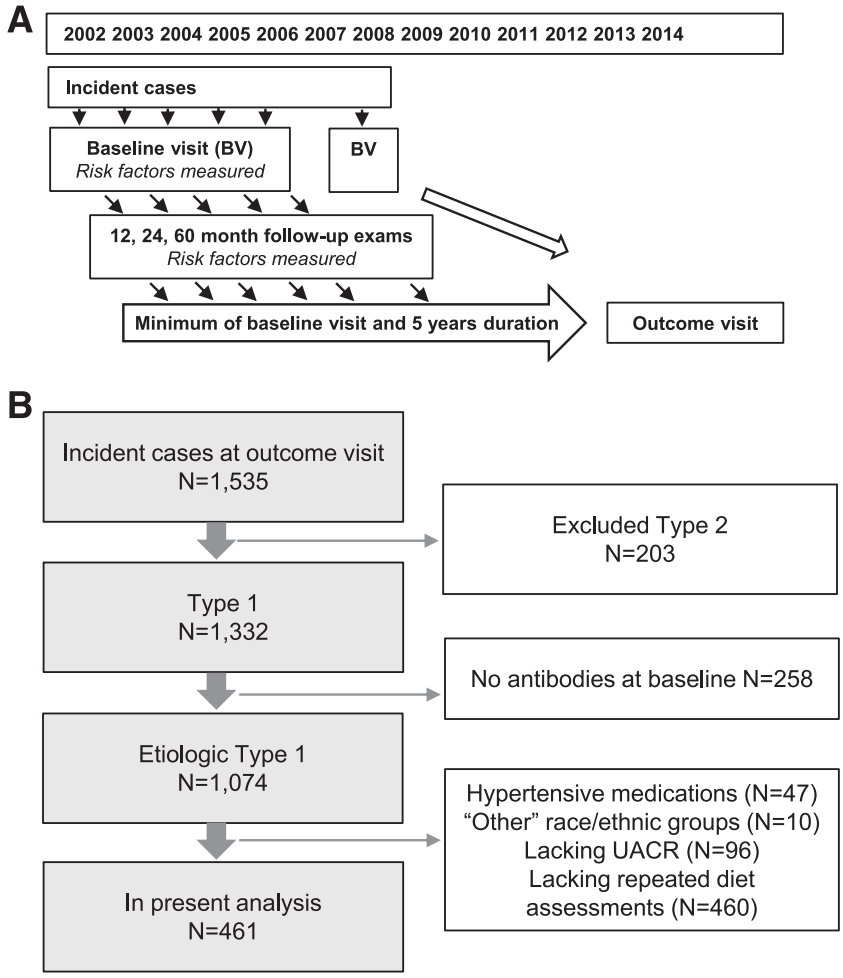

Figure 1—Flowchart of study procedures shows participant enrollment and follow-up flow (*A*) and participant selection for statistical analysis (*B*).

using the Bouvet serum creatinine–cystatin C equation due to its superior accuracy in the higher ranges of eGFR, including hyperfiltration, which were expected in this young cohort with limited diabetes duration (21). Diabetic retinopathy was determined by grading 45° Color digital fundus photographs centered on the disc and macula of both eyes taken using a nonmydriatic camera (Visucam Pro N; Carl Zeiss Meditech, Jena, Germany) under standardized procedures. The University of Wisconsin Ocular Epidemiology Reading Center centrally trained and certified study staff, and read the photographs for the presence and severity of diabetic retinopathy. Diabetic retinopathy severity was based on the worse eye and categorized as none, minimal nonproliferative diabetic retinopathy, or mild to moderate nonproliferative diabetic retinopathy to proliferative (22).

A validated food frequency questionnaire (FFQ) was administered to participants age 10 and older at study baseline (2002–2008), 12- and 60-month follow-up visits, and the 2012–2015 outcome visit (23,24). Adherence to a Mediterranean type diet was assessed using the KIDMED index, a 16-item survey validated for use in children and adolescents, with the final score ranging from −3 to 12 (25). However, as described in detail by Zhong et al. (26), the SEARCH FFQ was not designed to assess adherence to a Mediterranean diet using the KIDMED index, and thus, five modifications were required (mKIDMED). Adherence to the DASH diet was assessed with an index score ranging from 0 to 80 (10,27), and diet quality according to the 2010 Dietary Guidelines was assessed by the HEI score, with a maximum value of 100 (12).

Statistical Analysis

All analyses were performed using SAS 9.3 software (SAS Institute, Cary, NC). As mentioned in the RESEARCH DESIGN AND METHODS, whereas UACR was assessed only at the 2012–2015 follow-up examination, dietary data were also available at baseline and at the 12- and 60-month assessments. To take advantage of the repeated exposure measurements, analyses evaluated the association between a longitudinally assessed diet score (i.e., time-weighted average score over all available dietary assessments, covering a period of 2–12 years) and microalbuminuria or UACR at the 2012–2015 outcome visit. There were 518 participants with a T1D diagnosis confirmed by autoantibodies at baseline, UACR at the 2012–2015 outcome visit, and at least one previous FFQ. The number of previous FFQs ranged from two to four, with 196 (38%) having two, 190 (37%) having three, and 132 (25%) having completed all four. The time covered by these dietary assessments was a median of 7.5 years (IQR 2.5). Participants on antihypertensive medications (n = 47) were excluded from analyses (Fig. 1*B*). In addition, because of the very small sample size of race/ethnic groups other than non-Hispanic white, non-Hispanic black, and Hispanic, "other" minority groups were also excluded from the analyses (n = 10), yielding a final sample of 461. Of these, 450 also had data available for eGFR at the outcome visit.

We used descriptive statistics (means, medians, and proportions, as appropriate) to assess characteristics of the study participants by microalbuminuria status. Pearson correlation coefficients were used to assess the presence and strength of an association among the three diet scores. Logistic regression models were used to assess the independent association of each of the dietary indices with microalbuminuria status and hyperfiltration (eGFR >130 mL/min/1.73 m^2) as the outcomes of interest. Because the number of people with microalbuminuria was small, limiting the statistical power of the logistic models, multivariable linear regression models were also constructed with logarithmically transformed UACR as a continuous outcome variable. Covariates included in multivariable models were total caloric intake, protein intake, smoking status, age, sex, maximum parental education, diabetes duration, insulin regimen, systolic blood pressure, and HbA_{1c}.

RESULTS

Of 461 youth and young adults with T1D included in these analyses, 32 (7%) met the criterion for microalbuminuria. Table 1

presents participant characteristics by microalbuminuria status. Study participants with microalbuminuria were significantly more likely to be non-Hispanic black ($P = 0.002$), underweight ($P < 0.0001$), and to have higher HbA_{1c} concentrations ($P < 0.0001$). Participants with microalbuminuria also had lower scores for the longitudinally assessed DASH ($P = 0.03$) and HEI diets ($P = 0.01$) but not the mKIDMED diet ($P = 0.74$). Mean eGFR was 130 mL/min/1.73 m^2 (range 82–217) and 46% (207 of 450) exhibited hyperfiltration. Neither mean eGFR nor the proportion with hyperfiltration differed by albuminuria status.

Adherence to a Mediterranean-type diet (mean 3.7, range −2 to 10; with 5.1% [$n = 65$] scoring ≥8) and the DASH diet (mean 41.0 of 80, range 14.1–69.5) was low in this cohort. Adherence to the HEI (mean 57.1 of 100, range 22.6–88.9) was better, although still "in need of improvement" (11). Given considerable overlap in the defining features of the dietary indexes used, we assessed the presence of a correlation among the three dietary patterns at the 2012–2015 outcome visit. Although all were statistically significant ($P < 0.001$), stronger correlations were noted with the HEI score compared with mKIDMED ($r = 0.51$) and DASH ($r = 0.67$), whereas the correlation between the mKIDMED and DASH scores was moderate ($r = 0.41$).

In logistic regression models with microalbuminuria status used as a dichotomous outcome variable, no association was observed for the mKIDMED diet score in the unadjusted or adjusted analyses (Table 2). A significant univariate inverse association between the DASH diet score and microalbuminuria (unadjusted OR 0.82, $P = 0.03$) was no longer significant after multivariable adjustments. In addition, the inverse association between the HEI and microalbuminuria (unadjusted OR 0.80, $P = 0.02$) remained borderline significant after multivariable adjustments ($P = 0.07$), with the exception of adjustment for HbA_{1c} and systolic blood pressure.

Findings were similar when the logarithmically transformed UACR was used as a continuous outcome variable (Table 3). Thus, the borderline inverse association observed for the longitudinally assessed DASH score became nonsignificant after multivariable adjustments. The significant univariate association observed between the longitudinally assessed HEI and UACR was weakened after adjustment for daily caloric intake, demographic factors, and diabetes factors, although as for microalbuminuria, adding HbA_{1c} and systolic blood pressure to the model dramatically reduced the significance of the association.

The models for hyperfiltration showed no association between any of the longitudinally assessed diet scores and the odds of eGFR >130 mL/min/m^2 (results not shown).

CONCLUSIONS

In this cohort of children, adolescents, and young adults with youth-onset T1D, we observed that habitually consuming a higher quality diet, as assessed by greater adherence to the federal dietary guidelines (i.e., greater HEI score), is inversely associated with the presence of microalbuminuria. Adjustment for HbA_{1c} and systolic blood pressure rendered this association nonsignificant, suggesting that these factors may either mediate or confound the association. Unfortunately, we did not have adequate power to conduct a full mediation analysis. Neither the mKIDMED nor the DASH diet was associated with microalbuminuria in this cohort, and none of the three dietary indices were related to hyperfiltration, although statistical power was limited in the latter analyses.

These results may appear surprising given that all three indexes emphasize intake of fruits, vegetables, plant-based proteins, and whole grains and because there was a strong correlation between scores in the population under study. However, differences exist in the components used to construct each score and in the scoring method (28). Thus, the DASH is the only diet not emphasizing consumption of poly- and monounsaturated over saturated fats; HEI is the only one not emphasizing nut consumption; mKIDMED ignores while the HEI and DASH accentuate reduced sodium intake, and they allow for a higher intake of meat/meat equivalents than the mKIDMED score. Notably, whereas mKIDMED and DASH use median- or quintile-based cutoffs, focusing on the absolute amounts of food consumed, the HEI uses a density-based, linear scoring system (e.g., per 1,000 calories). Hence, this method that is independent of energy requirements offers an evaluation of the quality of the mix of consumed foods (12), which may be a more important determinant of health status. Finally, from a statistical perspective, the much smaller degree of variability in the DASH and, especially, the mKIDMED score, compared with the HEI, could have contributed to the absence of an association with the presence of microalbuminuria in this population.

These findings carry significant implications because the development of microvascular complications, including kidney disease, among children, adolescents, and young adults with T1D is not uncommon, even under the more intensive diabetes management protocols established in recent years (17,29). Over the first 5–10 years of T1D, the annual incidence of microalbuminuria currently appears to slightly exceed 2% (30), although higher rates (>4%) have also been reported (31). The importance of early prevention and intervention in albuminuria is greatly underscored by its significant effect on the risk for cardiovascular events (32) and all-cause, premature mortality (32,33). Encouragingly, findings suggest that survival in T1D in the absence of increased albuminuria is similar to that of the general population (34), highlighting the importance of prevention through lifestyle factors such as diet. The realization, however, that kidney disease risk remains high in diabetes, notwithstanding the dramatic improvements in management, suggests that for prevention efforts to have an effect, they will have to be multidimensional, simultaneously targeting multiple risk factors.

Nutrition, an important element of T1D management, is also central for the management of individuals with a diagnosis of kidney disease. However, the role of nutrition in preventing or delaying the development of kidney disease, especially in the presence of diabetes, is not as well studied. A difficulty in conducting such studies may relate to the vast numbers of nutrients or foods potentially associated with renal outcomes. In recent years, researchers have turned to the assessment of dietary patterns, rather than individual nutrients, which offers a more holistic evaluation of an individual's diet and enables the investigation of the interactive effects of dietary exposures while avoiding problems generated by high correlations among nutrients. A priori developed dietary indexes are often based on regional dietary patterns, such as the Mediterranean diet; alternatively, they are constructed on the basis of existing knowledge of

Table 1—Descriptive characteristics of 461 participants with T1D at the final cohort visit stratified by microalbuminuria status: SNAS

	No microalbuminuria (n = 429)	Microalbuminuria (n = 32)	P value
Age at outcome visit (years)	20.6 (3.24)	20.9 (3.4)	0.65
Diabetes duration (months)	108.1 (16.7)	113.1 (13.1)	0.10
Sex, n (%)			0.43
Females	184 (42.9)	16 (50.0)	
Males	245 (57.1)	16 (50.0)	
Race/ethnicity, n (%)			0.002
Non-Hispanic black	31 (7.2)	8 (25.0)	
Non-Hispanic white	344 (80.2)	20 (62.5)	
Hispanic	54 (12.6)	4 (12.5)	
Maximum parental education, n (%)			0.20*
Less than high school	15 (3.6)	2 (6.7)	
High school	53 (12.5)	6 (20.0)	
Some college/associate degree	123 (29.1)	10 (33.3)	
Bachelor's degree or greater	232 (54.9)	12 (40.0)	
Insulin regimen, n (%)			0.07
Pump	217 (50.8)	10 (31.3)	
Basal/bolus-multiple daily injections	103 (24.1)	9 (28.1)	
Other	107 (25.1)	13 (40.6)	
BMI (z score)	0.68 (0.85)	−0.47 (1.39)	<0.0001
Weight status, n (%)			<0.0001*
Underweight	11 (2.6)	10 (31.3)	
Normal	251 (58.8)	20 (62.5)	
Overweight	110 (25.8)	1 (3.1)	
Obese	55 (12.9)	1 (3.1)	
Smoking status, n (%)			0.1
Never	200 (48)	13 (41)	
Former	127 (30)	7 (22)	
Current	91 (22)	12 (38)	
Retinopathy, n (%)			0.9
None	391 (92.9)	29 (90.8)	
Mild/moderate	30 (7.1)	3 (9.4)	
eGFR (mL/min/m^2)	129.8 (20.4)	132.5 (25.6)	0.48
eGFR >130 mL/min/m^2, n (%)	193 (46.2)	14 (43.7)	0.79
HbA_{1c} (%)	8.88 (1.86)	11.11 (1.87)	<0.0001
Blood pressure (mmHg)			
Systolic	109.6 (10.4)	106.8 (14.3)	0.14
Diastolic	70.83 (8.44)	70.08 (10.53)	0.64
Cholesterol (mg/dL)			
Total	170 (36)	161 (24)	0.19
HDL	54 (13)	55 (15)	0.90
LDL	97 (29)	87 (23)	0.07
Triglycerides (mg/dL)	93 (66)	97 (48)	0.77
Total caloric intake (kcal/day)	1,734 (751)	1,641 (808)	0.50
Physical activity, n (%)			0.70
0–2 days/week	196 (46.5)	16 (50.0)	
3–7 days/week	226 (53.6)	16 (50.0)	
Longitudinally assessed diet scores			
mKIDMED score	3.7 (1.5)	3.6 (1.5)	0.74
DASH score	41.7 (6.3)	39.1 (6.5)	0.03
HEI score	56.6 (8.8)	52.6 (9.8)	0.01

Data are means (SD) unless otherwise noted. Data available for participants in the no microalbuminuria and microalbuminuria cohorts: n = 423 and 30 for parental education; n = 427 and 32 for insulin regimen, blood pressure, BMI, and weight status; n = 427 and 32 for HbA_{1c}; n = 412 and 31 for fasting blood lipids; n = 422 and 32 for physical activity. *Due to small cell counts, the lowest two education groups and the highest two BMI groups were combined before the χ^2 tests.

favorable/adverse health effects of foods, such as the DASH or HEI indices.

Numerous studies have evaluated the association between each of these three dietary patterns and health outcomes. Many have focused on the Mediterranean diet, providing evidence to suggest inverse associations with overall mortality (35–37) and with the incidence of chronic diseases such as cardiovascular disease (35,36,38). Adherence to a Mediterranean-type dietary pattern has also been associated

Table 2—Logistic regression models between longitudinally assessed diet scores with microalbuminuria from first-morning voids: SNAS

	mKIDMED score		DASH score		HEI score	
Model	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Crude model	0.97 (0.81, 1.16)	0.74	0.82 (0.69, 0.98)	0.03	0.80 (0.66, 0.96)	0.02
Model 1	0.97 (0.78, 1.21)	0.77	0.87 (0.71, 1.06)	0.17	0.83 (0.68, 1.02)	0.07
Model 2	0.98 (0.77, 1.24)	0.84	0.88 (0.71, 1.09)	0.25	0.86 (0.69, 1.08)	0.19

Longitudinal diet was assessed via the area under the curve estimate of the average score over the study duration (2–12 years) for 461 participants with T1D. The ORs reflect the change in the odds associated with a 1/2 SD increase in the diet score. Model 1: Adjusted for kcal/day, protein intake, smoking status, demographic factors (age, sex, race, parental education), and disease factors (disease duration, insulin regimen). Model 2: Adjusted for variables in model 1 plus systolic blood pressure and HbA_{1c}.

with cardiovascular health in both youth (26) and adults with T1D (39).

The DASH diet has also been inversely associated with all-cause and cardiovascular mortality (36,37). In youth with T1D, adherence to the DASH diet has been associated with improved glycemic control and lower levels of cardiovascular risk factors (27,40). Greater adherence to the HEI has also been linked to a lower prevalence of cardiovascular risk factors (41). Recent studies investigating the effect of adherence to the HEI and alternative HEI have also suggested inverse associations with all-cause and cardiovascular mortality (36,37). Prospective data among individuals with T1D are currently limited to a randomized clinical trial of a behavioral nutrition intervention suggesting an association between HEI and improved glycemic control (42). Should our observed association between HEI and microalbuminuria be mediated by improved glycemic control and/or blood pressure among those adhering to the HEI diet, it might explain the loss of significance of this association after adjustment for these factors in our study.

In terms of renal outcomes, higher dietary quality or adherence to healthier dietary patterns has also been associated with a lower risk of developing chronic kidney disease in the general population (3–8). Three prospective studies have provided data for an association between greater adherence to the Mediterranean diet and a lower incidence of kidney disease (4,6,8). Despite inconsistencies (3–8), studies evaluating the DASH diet have generally also suggested inverse associations with declining kidney function (6,7). The only current prospective data on the ability of HEI to predict kidney disease incidence come from a single study, suggesting an association between greater adherence to this index and reduced risk of incident dialysis or renal death over 14 years (6). Our observation of an inverse association between the HEI diet and the presence of microalbuminuria in youth and young adults with T1D is consistent with these previous findings.

Of studies conducted in or reporting results by diabetes status, all focused on individuals with type 2 diabetes (3,13–15). Three of these studies considered the Mediterranean, DASH, and HEI dietary patterns in their investigations. In the PREDIMED randomized nutritional intervention trial, none of the three dietary interventions evaluating a Mediterranean diet (supplemented with extra-virgin olive oil or mixed nuts, or a low-fat control diet), significantly related to the 6-year incidence of diabetic nephropathy (15). Similar to the PREDIMED trial, we also did not observe an association between mKIDMED and microalbuminuria, although the current study was not a clinical trial, and adherence to the assessed Mediterranean type diet was especially low. Thus, no conclusions can be made from our study on whether higher adherence could potentially be inversely associated with microalbuminuria in youth and young adults with type 1 diabetes.

In the Nurses' Health Study, women in the top quartile of the DASH score had decreased risk of rapid decline in eGFR, but no association was found with microalbuminuria, a finding that did not differ by diabetes status (3). Although we were unable to assess rapid decline in glomerular filtration in our population of youth and young adults with T1D, in concordance with findings from the Nurses' Health Study, we also failed to observe an independent association between the DASH diet and microalbuminuria. Finally, in the ONTARGET study, the modified alternate HEI was related to decreased incidence and progression of chronic kidney disease in type 2 diabetes (13). Similarly, the HEI score was the only significant correlate of microalbuminuria prevalence in our cohort of T1D, although this association lost significance after adjusting for HbA_{1c} and systolic blood pressure.

As with any research, there are limitations also in the current study. There was a low prevalence of microalbuminuria, which greatly limited our power to detect an effect or infer mediation effects from the clinical covariates of HbA_{1c} or systolic blood pressure. An important weakness is the focus on microalbuminuria prevalence, which does not allow inferences regarding risk or causation. A single first-morning urine sample was obtained as part of the SEARCH protocol,

Table 3—Linear regression models between longitudinally assessed diet scores with UACR from first-morning voids: SNAS

	mKIDMED score		DASH score		HEI score	
Model	β (SE)	*P* value	β (SE)	*P* value	β (SE)	*P* value
Crude model	−0.0203 (0.0247)	0.41	−0.0118 (0.006)	0.048	−0.0096 (0.0042)	0.02
Model 1	−0.0038 (0.0268)	0.89	−0.007 (0.0062)	0.26	−0.0063 (0.0043)	0.15
Model 2	0.0182 (0.0257)	0.48	−0.0028 (0.0059)	0.64	−0.0018 (0.0042)	0.66

Longitudinal diet scores were assessed via the area under the curve estimate of the average score over the study duration (2–12 years) in 461 participants with T1D. Model 1: Adjusted for kcal/day, protein intake, smoking status, demographic factors (age, sex, race, and parental education), and disease factors (disease duration and insulin regimen). Model 2: Adjusted for variables in model 1, plus systolic blood pressure and HbA_{1c}.

although given the day-to-day variability in urine albumin excretion, two of three urine samples would have been preferable for the diagnosis of microalbuminuria. In addition, measurement error relating especially to energy intake is a limitation of assessing dietary intake via a FFQ, although how measurement error may affect the dietary indices studied is not known.

Our study also has multiple strengths, including a nationally representative and ethnically diverse cohort of individuals with T1D characterized soon after diagnosis. Urine specimens were from a first-morning sample, reducing variability of urine albumin excretion (43). Although our outcome measure was microalbuminuria prevalence, we had repeated, longitudinal measures of the FFQ, strengthening our measure of dietary exposure.

We conclude that children, adolescents, and young adults with T1D have low adherence to healthy diets and that this may have blunted and/or obscured the association between diet quality and microalbuminuria. Despite the generally poor diet, we still identified a significant association between the HEI score and microalbuminuria, which, although nonsignificant after adjustment for HbA_{1c} and blood pressure, reinforces the importance of appropriate nutrition in a population vulnerable to poor long-term health outcomes. Subsequent prospective studies are needed that should further evaluate whether adherence to a healthier diet may also reduce the rate of kidney function decline.

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