

Healthy Dietary Patterns and Incidence of CKD

A Meta-Analysis of Cohort Studies

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Abstract

Background and objectives Whether a healthy dietary pattern may prevent the incidence of developing CKD is unknown. This study evaluated the associations between dietary patterns and the incidence of CKD in adults and children.

Design, setting, participants, & measurements This systematic review and meta-analysis identified potential studies through a systematic search of MEDLINE, Embase and references from eligible studies from database inception to February 2019. Eligible studies were prospective and retrospective cohort studies including adults and children without CKD, where the primary exposure was dietary patterns. To be eligible, studies had to report on the primary outcome, incidence of CKD (eGFR < 60 ml/min per 1.73 m²). Two authors independently extracted data, assessed risk of bias and evidence certainty using the Newcastle–Ottawa scale and GRADE.

Results Eighteen prospective cohort studies involving 630,108 adults (no children) with a mean follow-up of 10.4 ± 7.4 years were eligible for analysis. Included studies had an overall low risk of bias. The evidence certainty was moderate for CKD incidence and low for eGFR decline (percentage drop from baseline or reduced by at least 3 ml/min per 1.73 m² per year) and incident albuminuria. Healthy dietary patterns typically encouraged higher intakes of vegetables, fruit, legumes, nuts, whole grains, fish and low-fat dairy, and lower intakes of red and processed meats, sodium, and sugar-sweetened beverages. A healthy dietary pattern was associated with a lower incidence of CKD (odds ratio [OR] 0.70 [95% confidence interval [95% CI], 0.60 to 0.82]; I²=51%; eight studies), and incidence of albuminuria (OR 0.77, [95% CI, 0.59 to 0.99]; I²=37%); four studies). There appeared to be no significant association between healthy dietary patterns and eGFR decline (OR 0.70 [95% CI, 0.49 to 1.01], I²=49%; four studies).

Conclusions A healthy dietary pattern may prevent CKD and albuminuria.

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Introduction

CKD is a growing public health concern because of the increasing prevalence worldwide (1), substantially increased risk of death from cardiovascular disease (2), and costs from treating ESKD. Dietary modification is considered one of the key modifiable risk factors for the progression of CKD (3). However, whether a healthy diet is protective against the incidence of CKD is not fully understood (4). The potential to prevent the incidence of CKD may assist in reducing the significant individual burden of disease, with over 497 million adults worldwide with CKD stages 1–5 (5).

Dietary patterns are defined as the consumption of foods that reflect habitual dietary intake. For this reason, a dietary pattern can be classified as “healthy” or “unhealthy.” Examples of healthy dietary patterns include approaches like the Mediterranean diet, the Dietary Approach to Stop Hypertension (DASH), vegetarian diets, dietary guidelines, and any approach to dietary intake that focuses on the overall pattern of eating as opposed to approaches targeting individual

(or multiple) nutrients (6). Although dietary patterns can differ in their advocated servings of food and beverages, a healthy dietary pattern share similar characteristics, typically involving a higher consumption of whole grains, fruits, vegetables, and healthy fats and the consequential intake of fiber, vitamin C, vitamin E, and carotenoids, and lower consumption of saturated fats, salt, and processed foods, and lower dietary acid load. As these healthy dietary patterns share similar characteristics, it is reasonable to assess dietary patterns collectively, recognizing the importance of the synergy of food groups and nutrients working concurrently for health outcomes. The associations of dietary patterns on health outcomes, including cardiovascular disease, have been linked to reduced inflammation from higher consumption of whole grains (7), reduced oxidative stress through increased consumption of fruits and vegetables (8), decreased circulating concentrations of inflammatory markers through a higher consumption of unsaturated fats including nuts and seeds (9), and a reduced

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dietary acid load associated with CKD progression (10). In contrast, examples of unhealthy dietary patterns include Western diets and high fat and meat diets (11). It is thought that diets high in refined starches, saturated fats, trans-fatty acids, and sodium, and lower in whole grains, fruit, vegetables, omega-3 fatty acids, and fiber may heighten the inflammatory response (12). As elevations in inflammatory markers have been suggested as a biomarker for the incidence of CKD (13), a dietary approach which lowers inflammatory markers and dietary acid load may be important for reducing the incidence of CKD.

Observational evidence supports the association between healthy dietary patterns and the primary prevention of major health conditions, including type 2 diabetes (14), cardiovascular disease, hypertension, and metabolic syndrome (15); however, it is unclear whether a healthy dietary pattern may prevent CKD. Therefore, the aim of this systematic review was to evaluate the association between healthy dietary patterns and the incidence of CKD and other kidney outcomes in adults and children.

Materials and Methods

Data Sources and Searches

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) checklist for observational studies (16) and was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; identifier CRD42017080881). MEDLINE and Embase were searched (from database inception to February 2019) without date or language restriction. Search strategies were developed by the research team with assistance from an information specialist (Supplemental Table 1). Two investigators (K.E.B. and J.T.K.) manually searched the reference lists of eligible studies, clinical practice guidelines, reviews, and other relevant studies. All citations were uploaded into an electronic reference management system. Non-English papers were translated by a native speaker of the language, and where this was not possible, these papers were electronically translated using Google Translate before assessment and data extraction.

Study Selection

Two investigators independently reviewed the studies for inclusion. The first round of study selection involved screening of title and abstracts conducted by at least two investigators (K.E.B. and J.T.K.). Potentially eligible studies were reviewed in full text primarily by one investigator (K.E.B.) and checked for accuracy by a second reviewer (K.L.C.). Methodological queries regarding study inclusion were discussed among two investigators (K.E.B. and J.T.K.). Discussion with a third investigator (K.L.C.) was used to achieve consensus.

Studies with participants without established CKD ($eGFR < 60$ ml/min²) at baseline were eligible (17). Studies were eligible if they reported a subgroup of the studied population with data specifically relating to participants without evidence of CKD. We included prospective and retrospective longitudinal cohort studies in which participants were grouped according to exposure to a healthy

dietary pattern. A healthy dietary pattern was defined as the overall habitual dietary intake of individuals on the basis of the consumption of whole foods, of more than one food group, and therefore each study had to report a dietary pattern exposure that encompassed multiple food and beverage groups. We excluded studies if they reported associations of isolated food groups or nutrients. Studies were eligible if they reported the association between healthy dietary patterns and at least one of the following kidney outcomes: (1) incidence of CKD, (2) ESKD, (3) eGFR decline, (4) progression of albuminuria, (5) eGFR or creatinine clearance at end of study follow-up, (6) serum creatinine, or (7) AKI. Studies had to report on at least one kidney outcome to be included in the review.

Data Extraction and Quality Assessment

Two authors (K.E.B. and S.K.) independently extracted data from studies using standardized data extraction forms. The same two authors applied the Newcastle–Ottawa Quality Assessment Scale (18) to assess the methodological quality of the included studies. Three domains were evaluated: selection (or representativeness) of cohorts, comparability of cohorts (because of design or analysis), and outcomes (assessment and follow-up). Included studies were rated as low, unclear, or high risk of bias for each criterion and then subsequently assigned an overall score. For each kidney outcome, confidence in the evidence (risk of bias, consistency, directness, and precision) was assessed using the Grading of Recommendations Assessment, Development and Evaluation methodology (GRADE) (19). Because of the observational cohort study design, all GRADE ratings started at low. Evidence certainty could be upgraded if there was evidence of a large and strong association, evidence of a dose response, or adjustment for plausible confounding factors. Publication bias was assessed by visual inspection of funnel plots symmetry for analyses with more than five studies included in the analysis.

Outcomes

The primary outcome was the incidence of CKD (defined as $eGFR < 60$ ml/min per 1.73 m²). The secondary outcomes were (1) ESKD (requiring dialysis or kidney transplantation or $eGFR < 15$ ml/min per 1.73 m²), (2) eGFR decline (as defined by study authors), (3) progression of albuminuria (normal or mildly increased to moderately or severely increased), (4) eGFR or creatinine clearance at the end of study follow-up, and (5) doubling of serum creatinine. The most adjusted risk estimate was extracted.

Data Synthesis and Analysis

Extracted data were entered into RevMan 5.3 for analysis. Data were summarized as hazard ratio, odds ratio (OR), or risk ratios. A random-effects inverse variance meta-analysis model was used to calculate the comparisons between the lowest and highest levels of adherence to dietary patterns. If the association compared low dietary pattern adherence with the outcome, the ratio methods were inverted and then combined into the meta-analysis. For studies reporting associations from the same cohort dataset, we included results from the cohort representing the highest number of participants.

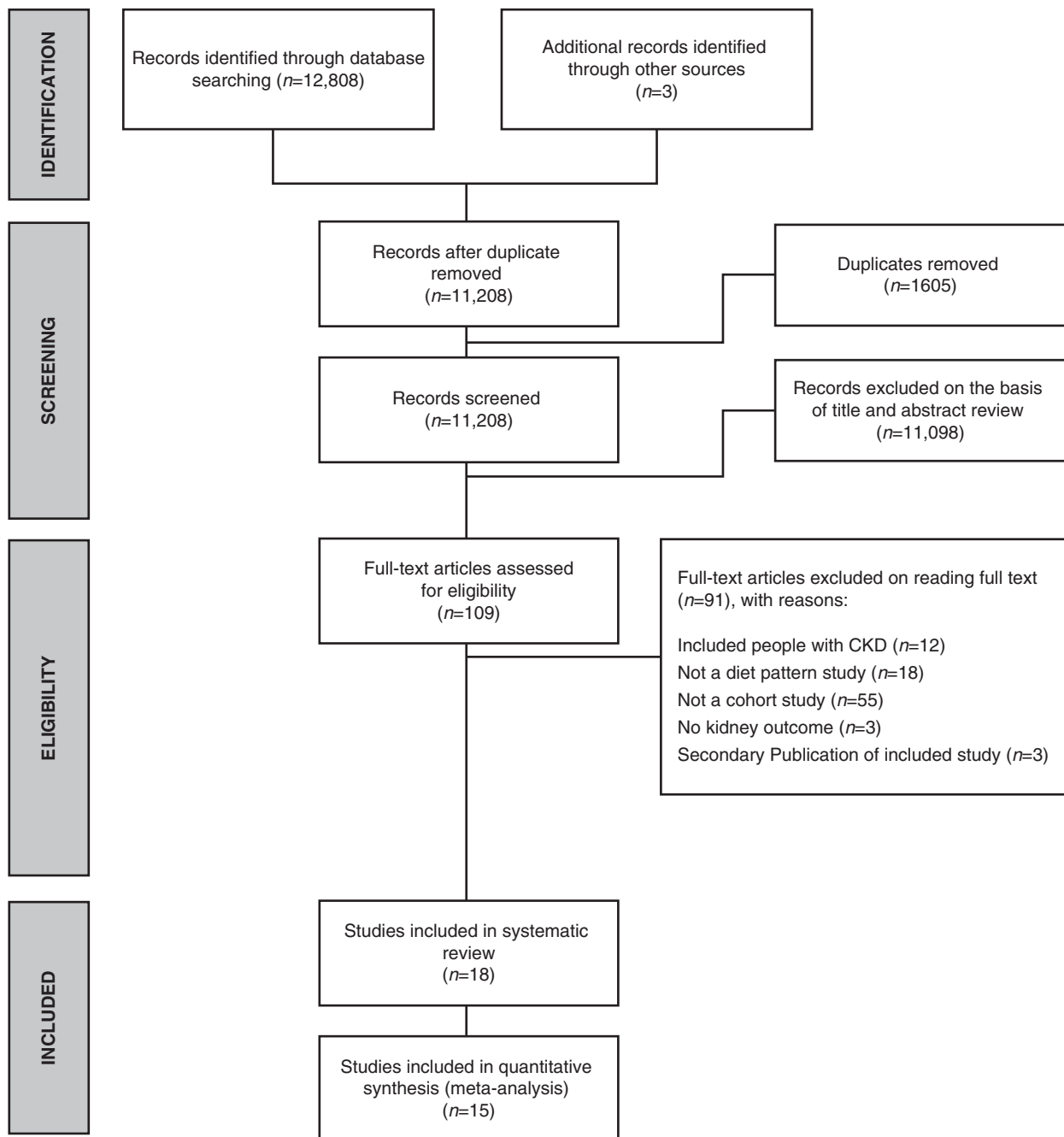


Figure 1. | PRISMA flow diagram showing the selection of studies.

The association between healthy dietary patterns and outcomes was expressed as OR together with 95% confidence interval (95% CI) for binary outcomes (incidence of CKD, ESKD, eGFR decline, and progression of albuminuria). For continuous outcomes (change in serum creatinine and eGFR at the end of the study), the mean and SD were extracted. The association of healthy dietary patterns with continuous outcomes was expressed as mean difference with 95% CI. Heterogeneity was assessed using the chi-squared test and I^2 statistic. Heterogeneity was rated according to I^2 statistic values as low (<25%), moderate (25%–75%), or high (>75%) (20). Funnel plots were visually

inspected for the evidence of small study effects in analyses of more than five studies.

To explore the sources of heterogeneity, *a priori* subgroup analyses were conducted exploring the type of ratio reported (risk ratio, OR, or hazard ratio) and the type of dietary patterns (Mediterranean diet, DASH diet, or dietary guidelines) included in each outcome. We explored other potential sources of heterogeneity using sensitivity analysis to repeat each analysis excluding studies at high risk of bias, involving ≤ 100 participants, with short-term follow-up (<6 months), possessing a high attrition rate (>20%), and any source of industry funding. We also conducted a

Table 1. Characteristics of the included studies

Study	Dietary Pattern	Country	No. of Participants	Follow-up (yr)	Age (yr)	Sex	Comorbidity	Ethnicity	Baseline eGFR (ml/min per 1.73 m ²)
Asghari, <i>et al.</i> (31)	Mediterranean diet	Iran	1212	6	30–70 (43.5)	51% male	6% diabetes 22% hypertension	NA	73.5
Asghari, <i>et al.</i> (22)	DASH	Iran	1630	6	>27 (42)	51.5% male	NA	NA	74.3
Asghari, <i>et al.</i>	Lacto-vegetarian	Iran	1630	6.1	>27 (43.4)	50.8% male	6.1% diabetes 14.5% hypertension	NA	73.7
Dunkler, <i>et al.</i> (30)	MAHEI	40 Countries	6916	5.5	61–71 (66)	68% male	100% diabetes	NA	71.5 (67% no CKD and 33% CKD)
Foster, <i>et al.</i> (28)	DGAS	United States	1802	6.6	59 (±9)	45.2% male	7.7% diabetes 38.4% hypertension	NA	NA
Khatri, <i>et al.</i> (32)	Mediterranean diet	United States	900	6.9	>40	41% male	18% diabetes 69% hypertension	65% Hispanic	83.1
Liu, <i>et al.</i> (23)	DASH	United States	1534	5	30–64	42% male	15% diabetes 42% hypertension	58% black	95.5
Rebholz, <i>et al.</i> (33)	American Heart Association: Life's Simple Seven Healthy Diet	United States	14,832	22	45–65	43% male	11.5% diabetes 32.5% hypertension	24% black	103.5
Rebholz, <i>et al.</i> (34)	Dietary acid load	United States	15,055	21	45–64	45% male	11.4% diabetes 34% hypertension	26% black	103.1
Rebholz, <i>et al.</i> (24)	DASH	United States	14,882	23	45–64	44% male	11.5% diabetes 34% hypertension	25% black	103.1
Haring, <i>et al.</i> (35)	Vegetable protein	United States	11,952	23	45–64	43% male	30.7% hypertension	22.8% black	103.1
Chang, <i>et al.</i> (25)	DASH	United States	2354	15	18–30 (34.8)	47% male	7.2% hypertension 1.5% diabetes	50% black	101.5
Smyth, <i>et al.</i> (26)	AHEI; HEI; Mediterranean diet score; RFS; DASH	United States	544,635	14.3	62.2	59% male	9.2% diabetes 43.5% hypertension	92.7% white	NA
Lin, <i>et al.</i> (21)	DASH	United States	3121	11	67	100% female	54% hypertension 23% diabetes 26.4 BMI	97% white	76
Chung, <i>et al.</i> (36)	Fish and vegetables	Taiwan	838	2	59.5	47.5% male	100% diabetes	NA	87.5
Ma, <i>et al.</i> (29)	DGAS	United States	1822	7	59.4	43.6% male	7.7% diabetes 48.8% hypertension 28 BMI	NA	86.8
Naderinejad, <i>et al.</i> (37)	Healthy diet	Iran	1521	3.7	<27 (46.2)	58% male	10.5% diabetes >120 mm Hg systolic BP >80 mm Hg diastolic BP	NA	NA
Yuzbashian, <i>et al.</i>	DASH	Iran	3472	3.1	≤30	55% male	hypertension (<i>n</i> =2,089) dyslipidemia (<i>n</i> =2,715) dysglycemia (<i>n</i> =1,100)	NA	NA

NA, not applicable; DASH, Dietary Approaches to Stop Hypertension; MAHEI, Modified Alternate Healthy Eating Index; DGAS, Dietary Guidelines Adherence Score; AHEI, Alternate Healthy Eating Index; HEI, Healthy Eating Index; RFS, Recommended Food Score; BMI, body mass index.

study-by-study sensitivity analysis substituting included studies that reported associations from the same cohort dataset, where one study cohort is removed and another study reporting an association from the same cohort added in, with the process repeated until all studies from the same cohort dataset have been rotated through the meta-analysis once.

Results

Study Selection

Electronic searching retrieved 12,810 records (Figure 1). Eighteen cohort studies involving 630,108 participants were eligible (Table 1), and 15 studies (85,473 participants) provided extractable data for meta-analysis.

Study Characteristics

The average study baseline eGFR was 87.2 ± 13 ml/min per 1.73 m^2 (range, 72–104). The range of participant ages ranged from 27 to 71 years. No studies were identified in children. Studies were published between 2011 and 2018. All studies included men and women, except one study (21), in which the participants were all women. The follow-up time was 10.4 ± 7.4 years on average (range, 2–23). The healthy dietary patterns reported in these studies included the DASH diet ($n=7$) (21–27), dietary guidelines ($n=4$) (26,28–30), Mediterranean diet ($n=3$) (26,31,32), and other dietary patterns ($n=5$) (33–38) (Supplemental Table 2). Overall, the characteristics of the healthy dietary patterns reported across the included studies encouraged higher intakes of vegetables, fruit, legumes, nuts, whole grains, fish, and low-fat dairy, and lower intakes of red and processed meats, sodium, and sugar-sweetened beverages.

Outcomes

Risk of bias and quality of evidence. The overall risk of bias for the included studies was considered low across the studies (Figure 2). Two studies had high risk of bias for two components, a possible nonrepresentative sample as a result of a younger population (25), and subjective outcome measures due to dialysis being self-reported (Supplemental Table 3) (26). The overall GRADE for CKD incidence was considered to be moderate because of the large association size. It was low for eGFR decline and incidence of albuminuria (Table 2).

CKD incidence. Fifteen studies (79,998 participants) reported incident CKD (22–24,27–38) across eight datasets (22,23,27,29,30,32,34,36). Four studies reported data from the Tehran Lipid and Glucose Study 2006–2008 (22,31,37,38), one study reported three different analyses from the Tehran Lipid and Glucose Study 2009–2011 (27), four studies reported data from the Atherosclerosis Risk in Communities study (24,33,34,39), and two studies reported data from the Framingham Offspring Cohort (28,29). In a meta-analysis including eight studies from the eight eligible cohort datasets (31,410 participants; mean, 7.1 years follow-up), adherence to a healthy dietary pattern was associated with lower odds of incident CKD (OR, 0.70; 95% CI, 0.60 to 0.82; $I^2=51\%$) with moderate certainty of evidence (Figure 3). This finding was consistent across different dietary subtypes

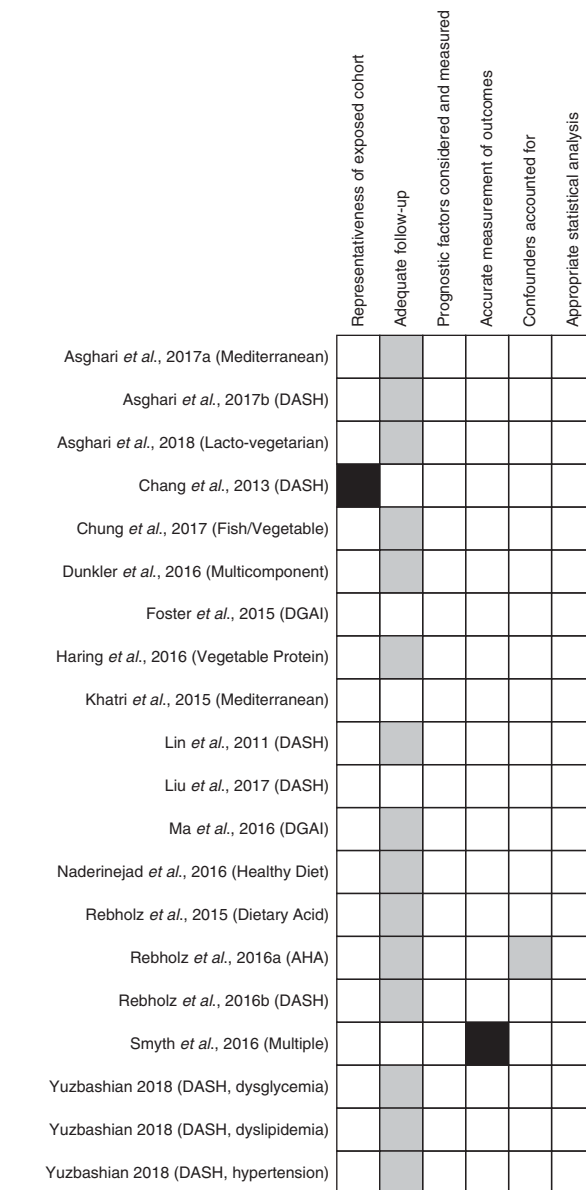


Figure 2. | Study risk of bias. Each color represents a level of risk of bias: white boxes, low risk of bias; grey boxes, unclear risk of bias; black boxes, high risk of bias. Key: Newcastle–Ottawa Scale. 1. Was there a representative and well defined sample? 2. Was the follow-up of participants sufficiently long and completed? 3. Were important prognostic factors considered and measured for? 4. Were the outcomes measured accurately? 5. Were important potential confounders accounted for? 6. Was the statistical analysis appropriate for the design of the study? AHA, American Heart Association; DASH, Dietary Approach to Stop Hypertension; DGA, Dietary Guidelines Adherence Index.

(P value for interaction =0.65). In a sensitivity analysis, repeating the analysis by rotating each study reporting associations to incident CKD from the same cohort of data one by one, there was no change to the primary finding (Supplemental Table 4).

Five studies (9179 participants) reported the outcome of eGFR decline (Figure 4) (23,28,29,32,40) across four datasets, with two studies reported data from the Framingham Offspring Cohort (28,29). The definitions of eGFR decline in

Table 2. Summary of assessment of certainty of evidence (GRADE) for different outcomes

Outcome	No. of Studies	No. of Participants	95% CI	I ²	Quality of Evidence (GRADE) ^a
Incident CKD	8	31,410	0.60 to 0.82	51%	Moderate ^b
eGFR decline	4	7377	0.49 to 1.01	59%	Low ^c
Albuminuria	4	8135	0.59 to 0.99	37%	Low ^c
ESKD ^d	1	544,635	NA	NA	NA
Serum creatinine ^d	0	0	NA	NA	NA
Creatinine clearance ^d	0	0	NA	NA	NA

Low certainty: the confidence in the estimate is limited and the true association may be different from the estimate of association (19). GRADE, Grading of Recommendations Assessment, Development and Evaluation methodology; 95% CI, 95% confidence interval; NA, not applicable.

^aModerate certainty: we are moderately confident in the association estimate and the true estimate is likely to be close to the estimate of the association; however, there is the possibility it could be different (19).

^bEvidence certainty upgraded to moderate because of the large association size.

^cEvidence quality downgraded to low because of the nonrandomized nature of the studies.

^dGRADE not possible because of the lack of data.

eligible studies were reduction from baseline ≥ 2.5 ml/min per 1.73 m² per year (32), ≥ 3.0 ml/min per 1.73 m² per year (21,23,28,29), $\geq 25\%$ (23), or $\geq 30\%$ (21). In a meta-analysis of four studies from four eligible datasets (7377 participants; mean, 7.5 years follow-up), a healthy dietary pattern was nonsignificantly associated with lower odds of eGFR decline (OR, 0.70; 95% CI, 0.49 to 1.01; I²=59%). This finding was consistent across dietary subtypes (*P* value for subgroup interaction =0.57). In a sensitivity analysis, repeating the analysis by rotating each study reporting associations to eGFR decline from the same cohort of data one by one, there was no change to the primary finding (Supplemental Table 4).

Albuminuria. Four studies (8135 participants; mean, 8.8 \pm 5.6 years follow-up) reported incidence of albuminuria (21,25,29,36). A healthy dietary pattern was associated with reduced odds of albuminuria (OR, 0.77; 95% CI, 0.59 to 0.99; I²=37%) (Figure 4).

ESKD, creatinine clearance, or serum creatinine levels. There were insufficient data to conduct a meta-analysis for ESKD or serum creatinine levels as this was only reported in one study (26). None of the included studies reported results on the outcome creatinine clearance or serum creatinine.

Publication bias. Publication bias was difficult to assess because of the small number of included studies. Within

the included studies there was no evidence of publication bias or small study effects (Supplemental Figure 1).

Subgroup analyses. The series of planned subgroup analyses are presented in Supplemental Table 5. Mediterranean diets and dietary patterns consistent with dietary guidelines were consistently associated with incident CKD, whereas DASH dietary patterns were not (Supplemental Table 5). Analysis according to the type of risk estimate reported demonstrated significant associations to incident CKD in six studies reporting the OR but not the two studies reporting the hazard ratio. Association estimates by cohort location demonstrated no significant associations in two studies using United States cohorts; however, four cohorts in other geographic locations did demonstrate significant associations to incident CKD. There was no evidence that results in the meta-analysis for incident CKD were different on the basis of duration of follow up time or sample size (Supplemental Table 5).

Discussion

This systematic review and meta-analysis evaluated the association between adherence to dietary patterns and incident CKD in adults without kidney impairment. With moderate certainty of evidence, the primary analysis demonstrated that adherence to a dietary pattern rich in

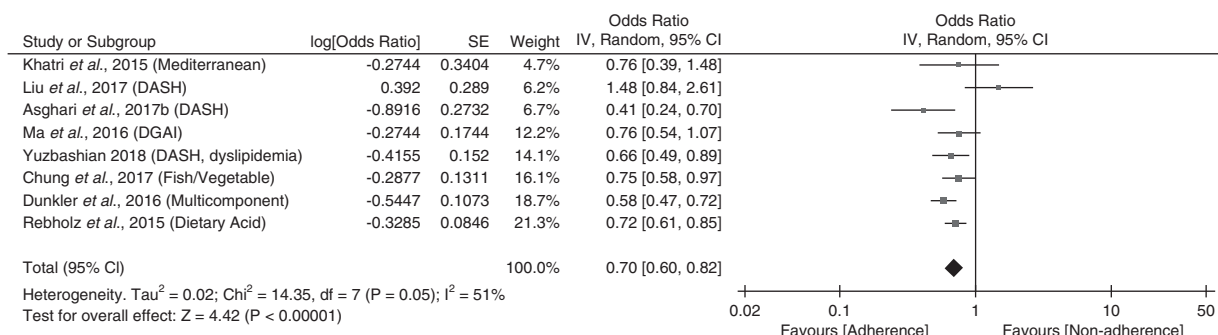


Figure 3. | Incident CKD associated with adherence to healthy dietary patterns. DASH, Dietary Approach to Stop Hypertension; IV, inverse variance.

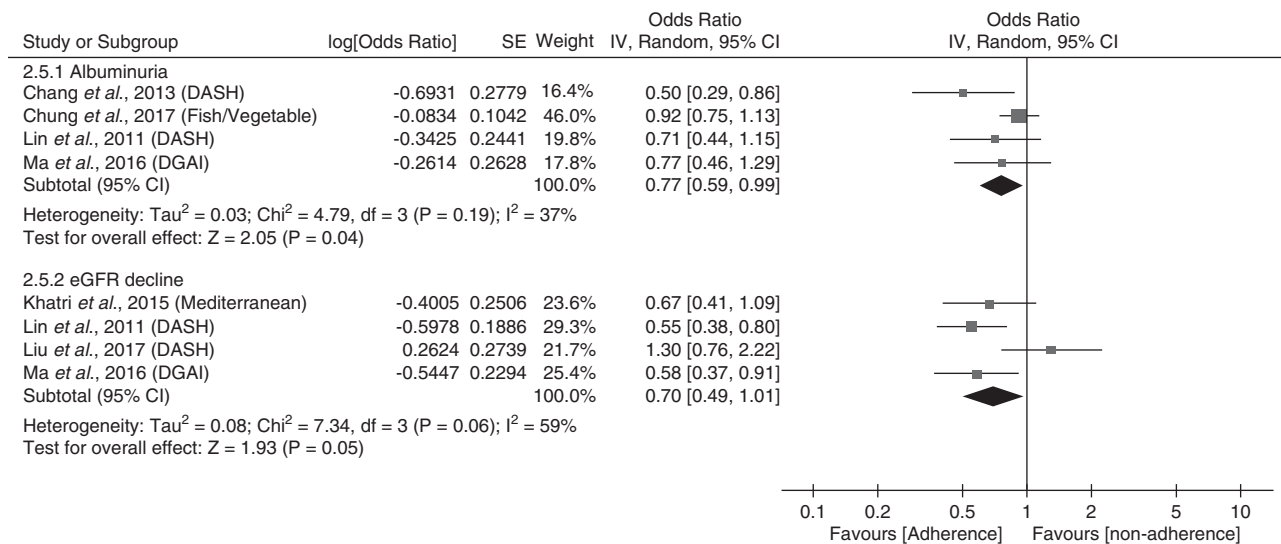


Figure 4. | Risk of albuminuria and eGFR decline associated with adherence to healthy dietary patterns. DASH, Dietary Approach to Stop Hypertension; DGAI, Dietary Guidelines Adherence Index.

whole grains, vegetables, fruit, legumes, nuts, and fish, and lower intake of red and processed meats, sodium, and sugar sweetened beverages was associated with lower odds of incident CKD, and albuminuria over an average of 10.4 years of follow-up. Across the included studies the overall risk of bias was low.

These results add to the accumulating evidence base supporting the benefits of adherence to healthy dietary patterns for chronic conditions, including those which are considered to be risk factors for the development of kidney disease such as type 2 diabetes, hypertension, cardiovascular, and increased weight (41). A systematic review of randomized controlled trials demonstrated a positive association between adhering to a Mediterranean diet and glycemic control, weight loss, and cardiovascular risk factors in individuals with type 2 diabetes (14). In a large Greek cohort study ($n=3042$), high Mediterranean diet adherence was associated with a 60% reduced 10-year incidence risk of type 2 diabetes (42). Likewise, higher adherence to the DASH diet has shown significant reductions in both systolic and diastolic BP and reductions in the incidence of cardiovascular disease, coronary heart disease, stroke, and heart failure (43). Previous findings of a meta-analysis have also supported the role of healthy dietary patterns in the prevention of CKD progression (3). Our results add to this evidence base and suggest that following healthy dietary patterns may play a protective role in the primary prevention of CKD. However, it remains unclear what type of “healthy” dietary pattern may be more beneficial, given the high heterogeneity across the studies. When a subgroup analysis of the different dietary patterns was performed, the heterogeneity was almost entirely explained by studies reporting associations to the DASH diet. Analyzing studies reporting DASH dietary pattern exposures separately in a subgroup analysis was not statistically significant, whereas studies reporting associations to the Mediterranean diet and dietary guidelines remained aligned with the primary finding of the review. It is worth noting that only two types of dietary pattern

were represented in three separate studies, whereas all others were isolated to one or two investigations. Future research is needed into the potential associations of other dietary patterns, such as vegetarian and Mediterranean diets to kidney outcomes.

This meta-analysis showed reduced odds of incident albuminuria when adhering to a healthy dietary pattern. Albuminuria is regarded as one of the early indicators of kidney damage (44) and an independent risk factor for CKD progression, cardiovascular disease, and all-cause mortality (45). The US National Health and Nutrition Examination Survey showed that the presence of microalbuminuria was the single diagnostic factor for 90% of people with stage 1 CKD (44). The results of this meta-analysis are in agreement with current literature. For example, in two cross-sectional studies, one with multi-ethnic United States adult participants ($n=6814$) (11) and the other conducted in Greek adolescent participants (46), showed that plant-based and Mediterranean dietary patterns were inversely associated with microalbuminuria. Moreover, a Western-style dietary pattern high in refined grains, high-fat dairy foods, meat, beans, and tomatoes was positively associated with albumin-to-creatinine ratio (11).

Only one of the included studies reported the risk of ESKD. Given the participants in these studies were free of CKD at baseline, this is not surprising as this is a rare outcome even among patients with established CKD. Specifically, of the 10% of the population that currently live with CKD, a much smaller proportion will progress to ESKD (47). The findings of a recent Australian CKD cohort study showed that adherence to a dietary pattern rich in fruit and vegetables reduced the risk of the composite end point of mortality, doubling of serum creatinine, and ESKD (48), although there was no association with the individual components of the composite end point (48).

This systematic review had a rigorous and extensive search of the literature, utilization of two independent reviewers for each stage of the review and adhered to the

PRISMA reporting guidelines. However, there are important limitations worth noting. First, there was a lack of standardization of dietary pattern reporting across the included studies. Generally, whole grains, fruit, and vegetables were consistently considered to be key components to a healthy dietary pattern; however, meat and milk products varied between desirable (healthy) and undesirable (unhealthy) categories. In addition, some studies included alcohol as one of their components, whereas others either did not report or did not include this component. The misclassification of dietary reporting is also important to acknowledge, particularly long-term diet intake behavior quantified using a single food frequency questionnaire measurement, which was the predominant method utilized across the included studies. Second, there was variation in measurement reporting of some outcomes, including incident CKD, albuminuria, and eGFR decline (Supplemental Table 3). Third, the results may not be generalizable to other populations around the world, as 14 of the 16 included studies were conducted in either the United States or Iran, and none of the studies were conducted in children. Finally, as this meta-analysis was on the basis of cohort studies and not randomized trials, the findings do not imply causality. The conclusions generated by this review are hypothesis-generating and indicate the need for large long-term, randomized trials.

In conclusion, this systematic review and meta-analysis indicates that adhering to a healthy dietary pattern rich in, vegetables, fruit, legumes, nuts, whole grains, fish, and low-fat dairy, and lower intakes of red and processed meats, sodium, and sugar-sweetened beverages, is associated with reduced incidence of CKD and albuminuria. On the basis of the findings from this review, a healthy dietary pattern (possibly the Mediterranean diet) and/or interventions testing the effectiveness of dietary guidelines need to be studied in randomized, controlled trials.

Acknowledgments

Dr. Kelly, Dr. Campbell, and Dr. Palmer contributed to the study conception. Mrs. Bach and Dr. Kelly conducted the literature search and data analysis. Dr. Bach and Dr. Khalesi extracted data and appraised risk of bias. Mrs. Bach was responsible for writing the first draft of the manuscript. Dr. Kelly and Dr. Campbell reviewed the first draft of the manuscript. All authors read and approved the final version of the manuscript.

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Disclosures

Mrs. Bach, Dr. Campbell, Dr. Kelly, Dr. Khalesi, Dr. Palmer, and Dr. Strippoli have nothing to disclose.

Supplemental Material

This article contains the following supplemental material online at <http://cjasn.asnjournals.org/lookup/suppl/doi:10.2215/CJN.00530119/-/DCSupplemental>.

Supplemental Table 1. List of search terms.

Supplemental Table 2. Characteristics of the dietary patterns reported in the included studies.

Supplemental Table 3. Measurement of outcomes.

Supplemental Table 4. Results from sensitivity analysis substituting data from secondary publications of the same cohort dataset. The shaded rows represent the study citation included in the primary analysis.

Supplemental Table 5. Subgroup analysis for incident CKD.

Supplemental Figure 1. Funnel plot for risk of incidence of CKD associated with adherence to healthy dietary patterns.

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