



Trabajo Original

Epidemiología y dietética

Dietary plant protein intake alleviates the adverse effect of sedentary behavior on chronic kidney disease incidence

La ingesta de proteínas vegetales en la dieta alivia el efecto adverso del comportamiento sedentario sobre la incidencia de la enfermedad renal crónica

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Abstract

Objective: dietary plant protein exerts a preventative effect on the incidence of chronic kidney disease (CKD). However, no epidemiological study has explored whether dietary plant protein can mitigate the impact of sedentary behavior on the kidneys. This study investigates the relationship between sedentary behavior and the risk of CKD in the US population and the effect of dietary plant protein intake on CKD incidence in sedentary individuals.

Methods: data was collected from the 2007-2018 Continuous National Health and Nutrition Examination Survey (NHANES). Weighted binary logistic regression was adopted to investigate the association between sedentary behavior and CKD risk. Weighted binary logistic regression and restricted cubic spline were performed to evaluate the correlation between dietary plant protein and CKD risk in sedentary individuals.

Results: participants with higher sedentary behavior (≥ 6 h/day) had a 1.13 times higher risk of developing CKD than those with lower sedentary behavior (< 6 h/day). In participants with higher sedentary behavior, intake of a higher plant protein ratio was associated with reduced CKD risk. In a continuous model, after adjusting for all covariates, each 10 % increase in plant protein ratio decreased CKD risk by 35.4 % (odds ratio (OR), 0.646; 95 % confidence interval (CI), 0.465-0.899). Compared with the lowest quartile, the OR for the highest quartiles was 0.740 in a categorical model (95 % CI, 0.614-0.893).

Conclusion: moderate dietary plant protein can alleviate the detrimental effects of sedentary behavior on the kidneys, reducing the incidence of CKD.

Keywords:

Chronic kidney disease.
Sedentary behavior.
Plant protein. NHANES.
Incidence.

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Ethical approval: The NHANES study protocol was approved by the Research Ethics Review Board of the National Center for Health Statistics. Written informed consent was obtained from all participants.

Data availability statement: The National Health and Nutrition Examination Survey dataset is publicly available at <https://www.cdc.gov/nchs/nhanes/>.

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Resumen

Objetivo: la proteína vegetal en la dieta ejerce un efecto preventivo sobre la incidencia de la enfermedad renal crónica (ERC). Sin embargo, ningún estudio epidemiológico ha explorado si la proteína vegetal en la dieta puede mitigar el impacto del comportamiento sedentario en los riñones. Este estudio investiga la relación entre el comportamiento sedentario y el riesgo de ERC en la población de EE. UU., así como el efecto de la ingesta de proteínas vegetales sobre la incidencia de ERC en personas sedentarias.

Métodos: se recopilaron datos de la Encuesta Continua Nacional de Examen de Salud y Nutrición (NHANES) 2007-2018. Se utilizó regresión logística binaria ponderada para investigar la asociación entre el comportamiento sedentario y el riesgo de ERC. También se aplicaron regresión logística binaria ponderada y modelos con *splines* cúbicos restringidos para evaluar la correlación entre la ingesta de proteína vegetal y el riesgo de ERC en personas sedentarias.

Resultados: los participantes con mayor comportamiento sedentario (≥ 6 horas/día) tuvieron un riesgo 1,13 veces mayor de desarrollar ERC en comparación con aquellos con menor comportamiento sedentario (< 6 horas/día). En los participantes con comportamiento sedentario elevado, una mayor proporción de proteína vegetal en la dieta se asoció con una reducción del riesgo de ERC. En un modelo continuo, después de ajustar por todas las covariables, cada aumento del 10 % en la proporción de proteína vegetal redujo el riesgo de ERC en un 35,4 % (razón de probabilidades (OR), 0,646; intervalo de confianza (IC) del 95 %, 0,465-0,899). En un modelo categórico, en comparación con el cuartil más bajo, la OR para el cuartil más alto fue de 0,740 (IC del 95 %, 0,614-0,893).

Conclusión: una ingesta moderada de proteína vegetal en la dieta puede aliviar los efectos perjudiciales del comportamiento sedentario sobre los riñones, reduciendo la incidencia de la enfermedad renal crónica.

Palabras clave:

Enfermedad renal crónica. Comportamiento sedentario. Proteína vegetal. NHANES. Incidencia.

INTRODUCTION

Chronic kidney disease (CKD) affects approximately 8-16 % of the population (1). In 2017, over 1 million people died from CKD, with global mortality increasing by 41.5 % since 1990 (2,3). As diabetes, hypertension, and obesity become more prevalent, along with an aging global population, CKD has reached epidemic proportions (4), posing a significant public health concern.

As workplaces evolve and transportation and the internet become more widespread, sedentary lifestyles are becoming increasingly common globally. Defined as any waking activity with energy expenditure ≤ 1.5 metabolic equivalents (METs) while sitting or reclining (5), prolonged sedentary behavior poses a growing health risk. The effects of sedentary behavior on health are cumulative and long-lasting, increasing the risk of chronic non-communicable diseases, such as cardiovascular disease (CVD), metabolic disorders, musculoskeletal disorders (6-8), and CKD (9-11). However, these studies have focused primarily on middle-aged or older adults. Moreover, Lynch et al. found no significant relationship between the highest television viewing time and reduced estimated glomerular filtration rate (eGFR) levels after adjusting for covariates (12). Therefore, understanding the impact of sedentary behavior on CKD risk is crucial as it is a lifestyle that can be modified.

Plant-based diets comprise primarily plant-based foods with or without small amounts of meat. Hence, the protein source is plant-based. Increasing evidence suggests that these diets are beneficial for myriad conditions, including CVD, diabetes, metabolic syndrome, and various cancers (13-15). Moreover, many studies have shown that plant-based diets can slow CKD progression and delay dialysis (16), with higher plant-based protein intake associated with lower mortality in patients with CKD (17). Despite the growing attention to these individual factors, research on the combined impact of sedentary behavior and plant protein intake on CKD risk is limited.

This study investigates the relationship between sedentary behavior and CKD risk in the US population. Additionally, it explores the effect of plant protein intake on CKD incidence in individuals with a sedentary lifestyle.

METHODS

STUDY POPULATION

This study utilized data from the National Health and Nutrition Examination Survey (NHANES) database, which assesses health and nutritional data for adults and children throughout the US. Survey data covering six cycles between 2007 and 2018 were extracted from the Continuous NHANES.

A total of 59,842 individuals were enrolled in the NHANES cohort between 2007 and 2018. After excluding individuals who did not meet the eligibility criteria, as outlined in figure 1, 28,268 participants were included in the final analysis.

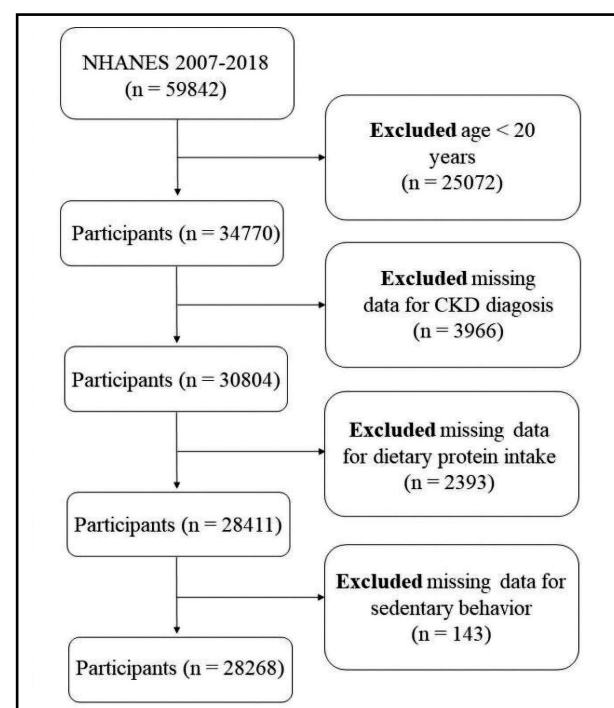


Figure 1. Participant screening flow chart.

DAILY SITTING TIME, PHYSICAL ACTIVITY, DIETARY ASSESSMENT

The NHANES study assessed daily sitting time using physical activity questionnaires. Daily sitting time was determined by asking participants about time spent at work, home, school, with friends, commuting, or engaging in recreational activities (e.g., playing cards, watching TV, and using computers) throughout a typical day. This total daily sitting time is recorded as PAD680, a variable in the NHANES dataset that quantifies self-reported sedentary behavior.

Dietary intake data were evaluated using the first 24-h dietary recall interviews conducted by NHANES's highly trained staff at mobile examination center. The United States Department of Agriculture's (USDA) automated multiple-pass method was used to estimate food intake. The Food Patterns Equivalent Database (FPED), associated with NHANES for dietary research purposes, converts American food and beverage intake from NHANES participants into 37 USDA Food pattern components. The intake levels of total protein, animal protein, and plant protein were obtained from the FPED.

DEFINITIONS

In the Continuous NHANES, serum and urinary creatinine levels were assessed using the Jaffe rate method, while urinary albumin was measured using a solid-phase fluorescent immunoassay. The eGFR was calculated using the CKD Epidemiology Collaboration (EPi) equation based on serum creatinine levels (18). ACR is the ratio of urinary albumin to urinary creatinine (19). Patients with CKD were defined by an eGFR < 60 mL/min/1.73 m² or ACR ≥ 30 mg/g (19). A sedentary time over 6 h/day is more likely to cause adverse health conditions than less than 6 h/day (20). Therefore, sedentary behavior was defined as high (≥ 6 h/day) or low (< 6 h/day). Total protein intake was the sum of the plant and animal proteins, while the plant-protein ratio was defined as the ratio of plant protein intake to total protein intake.

COVARIATES

Covariates were collected with a structured questionnaire, including age, sex, ethnicity, education level, family income (poverty index ratio [PIR]), marital status, and total calories. Smoking status was classified as a former smoker, non-smoker, or current smoker. Alcohol consumption was defined as former, heavy, moderate, mild, or never (21). Physical activity levels were defined as active (≥ 500 MET min/week), somewhat active (> 0 to < 500 MET min/week), or inactive (no reported physical activity data) (22). The body mass index (BMI) was determined using the height and weight of participants. Diabetes was defined as a self-reported diagnosis of diabetes and/or the use of antidiabetic medication. Hypertension was defined as mean systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure

≥ 90 mmHg, a self-reported diagnosis of hypertension, and/or the use of antihypertensive medication. Stroke and CVD were defined based on self-reported medical history.

STATISTICAL ANALYSIS

The sample weight recommended by NHANES was adopted, specifically the sample weight on a dietary day, with the selected weight record (WTDRD1). Since NHANES employs a complex probability sample design, individual sample weights were calculated as $1/6 \times \text{WTDRD1}$, covering six cycles from 2007 to 2018. Continuous variables were expressed as mean ± standard deviation (SD) when analyzing the baseline characteristics; those conforming to a normal distribution were compared using an independent sample *t*-test. Categorical variables were expressed as frequencies (percentages) and analyzed using the Chi-square test.

Weighted binary logistic regression was used to investigate the associations between sedentary behavior and CKD risk. Additionally, the relationship between plant protein intake and CKD risk was assessed in participants with high sedentary behavior. Plant protein ratio was included as a continuous variable in the continuous models, providing odds ratios (ORs) and 95 % confidence intervals (CIs). The plant protein ratio was transformed into a categorical variable by quartiles, and the *p*-value for the trend was calculated. Four models were applied: the crude model was not adjusted for confounding variables; Model 1 was adjusted for age, ethnicity, sex, educational level, PIR, and marital status; Model 2 was further adjusted for BMI, physical activity, smoking status, and alcohol consumption; Model 3 was adjusted for diabetes, hypertension, stroke, and CVD based on Model 2. A restricted cubic spline explored the non-linear association between the plant protein ratio and CKD in high sedentary behavior.

Sensitivity analysis was conducted by modifying the outcome indicators. Weighted ordinal logistic regression was performed using CKD progression risk as the outcome. CKD progression was assessed based on eGFR and albuminuria categories, divided into low risk, moderately increased risk, high risk, and very high risk. The graphical method recommended by Harrell was used to assess the parallel slope assumption in constructing the ordinal logistic regression. All analyses were performed using R version 4.2.1, and statistical significance was determined using a two-sided *p*-value < 0.05.

RESULTS

BASELINE CHARACTERISTICS OF THE STUDY POPULATION

In total, 28,268 participants (male: female, 13,812: 14,456) were included in the study, with a mean age of 47.449 ± 0.253 years; 5003 (17.698 %) had CKD. Additionally, 13,448 participants (51.263 %) reported a sedentary time of ≥ 6 h/day (Table I).

Table I. Baseline characteristics of the study participants

Characteristic	Overall (<i>n</i> = 28,268)	Non-CKD (<i>n</i> = 23,265)	CKD (<i>n</i> = 5003)	<i>p</i> -value
Demographic characteristics				
<i>Age, n (no. weighted %)</i>				
20-35	7094 (27.727)	6696 (30.568)	398 (10.485)	< 0.001 [†]
35-50	7147 (26.826)	6507 (28.875)	640 (14.390)	
50-65	7444 (27.104)	6213 (27.421)	1231 (25.183)	
≥ 65	6583 (18.343)	3849 (13.136)	2734 (49.942)	
<i>Sex, n (no. weighted %)</i>				
Female	14,456 (51.665)	11,856 (50.845)	2600 (56.644)	< 0.001 [†]
Male	13,812 (48.335)	11,409 (49.155)	2403 (43.356)	
<i>Ethnicity, n (no., weighted %)</i>				
Mexican American	4374 (8.864)	3713 (9.095)	661 (7.461)	< 0.001 [†]
Non-Hispanic Black	5796 (10.736)	4693 (10.522)	1103 (12.036)	
Non-Hispanic White	11,904 (66.585)	9531 (66.220)	2373 (68.800)	
Other	6194 (13.815)	5328 (14.162)	866 (11.703)	
<i>Education, n (no., weighted %)</i>				
High school	6438 (23.061)	5223 (22.704)	1215 (25.308)	< 0.001 [†]
Less than high school	6753 (15.267)	5238 (14.244)	1515 (21.527)	
More than high school	15,055 (61.622)	12,788 (63.052)	2267 (53.166)	
<i>PIR, n (no., weighted %)</i>				
< 1	5456 (13.730)	4434 (14.508)	1022 (16.388)	< 0.001 [†]
1-3	10,903 (33.092)	8709 (34.380)	2194 (43.066)	
≥ 3	9430 (46.111)	8089 (51.112)	1341 (40.546)	
<i>BMI, n (no., weighted %)</i>				
< 25	7883 (29.056)	6742 (30.137)	1141 (23.537)	< 0.001 [†]
25-30	9288 (32.809)	7744 (33.438)	1544 (30.209)	
≥ 30	10,888 (37.602)	8654 (36.426)	2234 (46.254)	
Lifestyle characteristics				
Plant protein intake, g/d	37.987 ± 0.800	39.117 ± 0.822	31.129 ± 1.410	< 0.001 [†]
Total protein intake, g/d	193.751 ± 1.455	197.538 ± 1.597	170.765 ± 2.356	< 0.001 [†]
Plant protein ratio, %	18.352 ± 0.330	18.605 ± 0.339	16.814 ± 0.626	0.004 [*]
Calorie intake, kcal/d	2160.485 ± 8.210	2200.160 ± 9.311	1919.711 ± 16.239	< 0.001 [†]
<i>Marital status, n (no., weighted %)</i>				
Married/cohabiting	16,958 (62.822)	14,201 (63.529)	2757 (58.659)	< 0.001 [†]
Never married	5115 (18.799)	4589 (20.078)	526 (11.077)	
Widowed/divorced/separated	6184 (18.350)	4467 (16.393)	1717 (30.264)	
<i>Smoking status, n (no., weighted %)</i>				
Former smoker	6834 (24.783)	5183 (23.441)	1651 (32.990)	< 0.001 [†]
Non-smoker	15,750 (55.596)	13,225 (56.357)	2525 (51.112)	
Current smoker	5671 (19.586)	4848 (20.202)	823 (15.898)	
<i>Alcohol use, n (no., weighted %)</i>				
Former	4045 (11.713)	2931 (11.293)	1114 (20.975)	< 0.001 [†]
Heavy	5321 (20.506)	4729 (23.533)	592 (13.340)	
Mild	8829 (34.183)	7327 (36.725)	1502 (37.808)	
Moderate	4078 (16.469)	3571 (18.538)	507 (12.964)	
Never	3616 (9.829)	2828 (9.910)	788 (14.912)	

(Continues on next page)

Table I (cont.). Baseline characteristics of the study participants

Characteristic	Overall (<i>n</i> = 28,268)	Non-CKD (<i>n</i> = 23,265)	CKD (<i>n</i> = 5003)	<i>p</i> -value
<i>PA, n (no., weighted %)</i>				
Active	17,437 (66.590)	15,116 (69.167)	2321 (50.948)	< 0.001 [†]
Inactive	7332 (21.378)	5333 (19.193)	1999 (34.633)	
Somewhat active	3499 (12.032)	2816 (11.639)	683 (14.418)	
<i>Sedentary behavior, n (no., weighted %)</i>				
Low (< 6 h/day)	14,820 (48.737)	12,408 (49.448)	2412 (44.420)	< 0.001 [†]
High (≥ 6 h/day)	13,448 (51.263)	10,857 (50.552)	2591 (55.580)	
Comorbidity				
<i>Diabetes, n (no., weighted %)</i>				
No	24,263 (89.486)	20,919 (92.351)	3344 (72.102)	< 0.001 [†]
Yes	4005 (10.514)	2346 (7.649)	1659 (27.898)	
<i>Hypertension, n (no., weighted %)</i>				
No	19,382 (63.754)	17,641 (68.626)	1741 (34.330)	< 0.001 [†]
Yes	13,211 (36.242)	9159 (31.374)	4052 (65.670)	
<i>Stroke, n (no., weighted %)</i>				
No	27,141 (96.941)	22,640 (97.908)	4501 (91.688)	< 0.001 [†]
Yes	1098 (2.969)	606 (2.092)	492 (8.312)	
<i>CVD, n (no., weighted %)</i>				
No	25,202 (91.340)	21,544 (93.780)	3658 (76.551)	< 0.001 [†]
Yes	3063 (8.656)	1720 (6.220)	1343 (23.449)	
Blood biochemistry indexes				
eGFR, mL/min/1.73 m ²	94.558 ± 0.329	98.065 ± 0.306	73.276 ± 0.582	< 0.001 [†]
Scr (μmol/L)	77.795 ± 0.275	74.491 ± 0.215	97.842 ± 1.196	< 0.001 [†]

CKD: chronic kidney disease; PIR: poverty income ratio; BMI: body mass index; PA: physical activity; CVD: cardiovascular disease; eGFR: estimated glomerular filtration rate; Scr: serum creatinine. Missing rates were 0.039 % for marital status, 0.078 % for education, 8.770 % for PIR, 0.739 % for BMI, 0.046 % for smoking status, 8.416 % for alcohol use, 0.004 % for hypertension, 0.103 % for stroke and 0.011 % for CVD. *p-value < 0.01; †p-value < 0.001.

SEDENTARY BEHAVIOR AND CHRONIC KIDNEY DISEASE INCIDENCE

Three binary logistic regression models (weighted) were constructed. The fully adjusted model identified a positive

relationship between sedentary behavior and CKD (OR = 1.130, 95 % CI = 1.009-1.265). Participants with high sedentary behavior were more prone to develop CKD, with a likelihood 1.13 times that of participants with low sedentary behavior (Table II).

Table II. Weighted binary logistic regression for the association between sedentary behavior and CKD risk

Sedentary behavior	Crude model OR (95 % CI)	p-value	Model 1 OR (95 % CI)	p-value	Model 2 OR (95 % CI)	p-value	Model 3 OR (95 % CI)	p-value
Low	1.000 (ref)	-	1.000 (ref)	-	1.000 (ref)	-	1.000 (ref)	-
High	1.256 (1.137, 1.386)	< 0.001 [†]	1.298 (1.165, 1.447)	< 0.001 [†]	1.173 (1.051, 1.310)	0.005 [†]	1.130 (1.009, 1.265)	0.035*

Crude Model: adjusted for no potential confounders; Model 1 was adjusted for age, ethnicity, sex, education, PIR and marital status; Model 2 was adjusted for age, ethnicity, sex, education, PIR, marital status and alcohol use. Model 3 was adjusted for age, ethnicity, sex, education, PIR, marital status, BMI, PA, smoking status, alcohol use, diabetes, hypertension, stroke and CVD. CKD: chronic kidney disease; PIR: poverty income ratio; BMI: body mass index; PA: physical activity; CVD: cardiovascular disease. *p-value < 0.05. †p-value < 0.01. ‡p-value < 0.001.

SEDENTARY BEHAVIOR, PLANT PROTEIN INTAKE, AND CHRONIC KIDNEY DISEASE INCIDENCE

In participants with high sedentary behavior, increased plant protein ratio was associated with a reduced risk of CKD. In a continuous model, each 10 % increase in plant protein ratio reduced the risk of CKD by 35.4 % (OR, 0.646; 95 % CI, 0.465-0.899) after adjusting for all considered covariates (Table III). Binary logistic regression analysis was conducted on the quartile of the plant protein ratio. Compared with the lowest quartile, the OR (95 % CIs) for the highest quartiles was 0.740 (95 % CI, 0.614-0.893; Table III). The inverse trend of the plant protein ratio with CKD risk was

statistically significant in the fully adjusted model for all covariates (p -trend < 0.05). The restricted cubic spline model indicated a non-linear association between plant protein ratio and CKD risk (Fig. 2). The optimal intake ranges for plant protein ratios were 0.000-59.296 %, which could reduce the risk of CKD.

SENSITIVITY ANALYSIS

In sensitivity analysis, the robustness of the results was confirmed when CKD prognosis was used in place of CKD risk (Table IV).

Table III. Weighted binary logistic regression for the association between plant protein and CKD risk in high sedentary behavior participants

	Categorical models				Continuous models		
	Plant protein ratio						
	Q1 OR (95 % CI)	Q2 OR (95 % CI)	Q3 OR (95 % CI)	Q4 OR (95 % CI)	p-trend	OR (95 % CI)	p-value
Crude model	1.000 (Ref)	0.787 (0.534, 1.158)	0.799 (0.682, 0.934)	0.734 (0.620, 0.868)	< 0.001 [‡]	0.618 (0.463, 0.823)	0.001 [†]
Model 1	1.000 (Ref)	0.811 (0.516, 1.273)	0.848 (0.721, 0.997)	0.684 (0.568, 0.824)	< 0.001 [‡]	0.562 (0.405, 0.780)	< 0.001 [‡]
Model 2	1.000 (Ref)	0.826 (0.520, 1.314)	0.885 (0.754, 1.039)	0.728 (0.602, 0.881)	0.002 [†]	0.616 (0.442, 0.857)	0.005 [†]
Model 3	1.000 (Ref)	0.847 (0.528, 1.357)	0.885 (0.750, 1.045)	0.740 (0.614, 0.893)	0.002 [†]	0.646 (0.465, 0.899)	0.010 [*]

Associations are given in the form of odds ratio (95 % confidence interval). Q1 (0.000, 0.000), Q2 (0.000, 1.379 %), Q3 (1.379 %, 28.634 %), Q4 (28.634 %, 100.000 %). * p -value < 0.05; [†] p -value < 0.01; [‡] p -value < 0.001. Crude Model: adjusted for no potential confounders. Model 1 was adjusted for age, ethnicity, sex, education, PIR and marital status. Model 2 was adjusted for age, ethnicity, sex, education, PIR, marital status, BMI, PA, smoking status and alcohol use. Model 3: was adjusted for age, ethnicity, sex, education, PIR, marital status, BMI, PA, smoking status, alcohol use, diabetes, hypertension, stroke and CVD. CKD: chronic kidney disease; PIR: poverty income ratio; BMI: body mass index; PA: physical activity; CVD: cardiovascular disease.

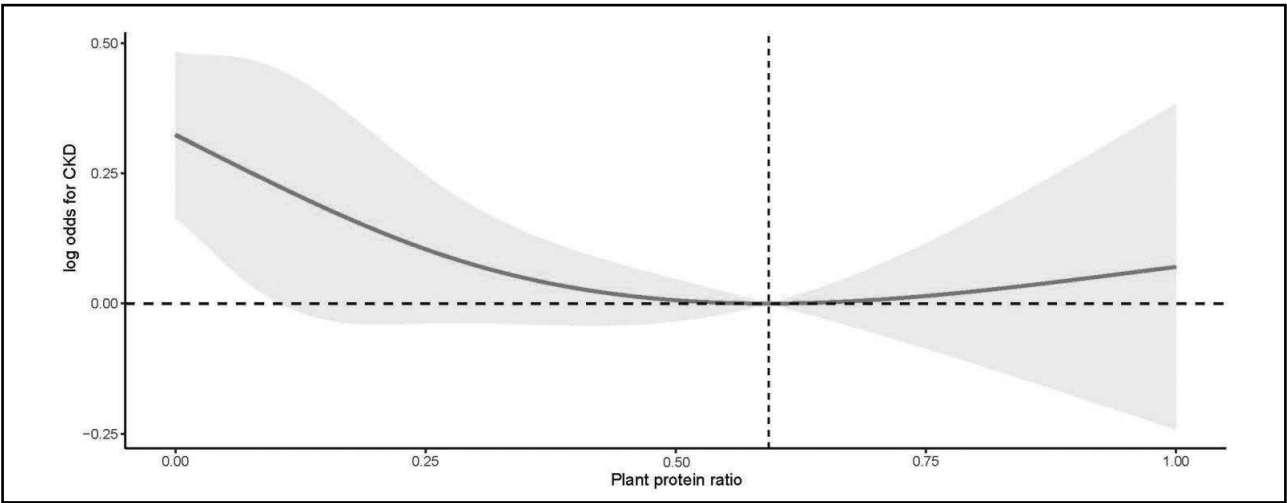


Figure 2. Restricted cubic spline of the association between dietary plant protein and CKD risk in sedentary participants.

Table IV. Weighted ordinal logistic regression for the association between plant protein ratio and CKD prognosis in high sedentary behavior participants

	OR (95 % CI)	p-value
Crude Model	0.615 (0.465, 0.813)	< 0.001 [†]
Model 1	0.546 (0.400, 0.745)	< 0.001 [†]
Model2	0.594 (0.435, 0.810)	0.001*
Model 3	0.624 (0.458, 0.850)	0.003*

Crude model: adjusted for no potential confounders; Model 1 was adjusted for age, ethnicity, sex, education, PIR and marital status; Model 2 was adjusted for age, ethnicity, sex, education, PIR, marital status, BMI, PA, smoking status and alcohol use; Model 3 was adjusted for age, ethnicity, sex, education, PIR, marital status, BMI, PA, smoking status, alcohol use, diabetes, hypertension, stroke and CVD. CKD: chronic kidney disease; PIR: poverty income ratio; BMI: body mass index; PA: physical activity; CVD: cardiovascular disease. *p-value < 0.01. [†]p-value < 0.001.

DISCUSSION

To our knowledge, this is the first study to examine how sedentary behavior and plant protein intake affect CKD risk in a nationally representative adult population (> 20 years old). A relationship was identified between sedentary behavior and CKD risk, as well as between plant protein intake and CKD risk in participants with high sedentary behavior.

The global rise of chronic non-communicable diseases and the aging population has made CKD the twelfth leading cause of mortality worldwide (23). Given that CKD is a progressive and irreversible disease, an urgent need exists to identify at-risk individuals early and implement interventions. A sedentary lifestyle, recognized as a risk factor for various diseases (24), is associated with increased CKD risk (9). This aligns with the current study results. CKD is defined by decreased renal function (eGFR < 60 mL/min/1.73 m²) and kidney damage (albuminuria ≥ 30 mg/24 h). Sedentary behavior may cause extensive endothelial dysfunction and capillary rarefaction (25). It is also associated with adverse health outcomes, including higher blood pressure, larger waist circumference, higher BMI, higher levels of triglyceride and glucose levels, and metabolic syndrome, which individually or collectively strain the kidneys and increase CKD risk.

The daily diet of patients with CKD has been extensively researched to identify patterns conducive to optimal kidney health. High salt intake exacerbates a decrease in kidney function by negatively affecting blood pressure and blood vessels (26). However, due to prolonged observation periods and strict dietary interventions during trials, no randomized controlled studies have specifically sought to prevent CKD among healthy individuals.

Consumption of red and processed meat is associated with an increased risk of developing CKD among Iranian and US participants (27,28). Conversely, legume and nut consumption is linked to a lower risk of CKD development (27). In individuals with normal renal function, diets rich in plant-based sources are associated with decreased production of uremic toxins, such as *p*-cresyl sulfate and indoxyl sulfate (29). Uremic toxins are linked to the progression of kidney disease, inflammation, and CVD (30). Furthermore, dietary patterns that tend to be plant-based, such as the Mediterranean diet and the Dietary Approaches to Stop Hypertension (DASH), have garnered widespread attention. Adherence to these diets is associated with a lower risk of developing CKD and can decelerate its progression (31–34). This emphasizes the benefits of plant-derived protein over animal-derived protein for kidney health. Moreover, a recent longitudinal study of participants with no history of CKD reported that greater dietary plant protein intake is inversely related to incident CKD (35). However, no study has examined the protective effect of plant protein on kidney health in sedentary individuals.

In the current study, a high plant protein ratio was associated with a lower risk of CKD in individuals with high sedentary behavior (≥ 6 h/d). Furthermore, the restricted cubic spline model was used to explore the optimal range of plant protein intake, revealing that, in sedentary individuals, a dietary plant protein ratio between 0.000 and 59.296 % was associated with a reduced risk of incident CKD. Various mechanisms have been proposed to explain the benefits of plant protein intake on kidney health. Hypertension, type 2 diabetes *mellitus*, and obesity all contribute to kidney disease. Meanwhile, compared to animal proteins, plant-based food intake is linked to lower blood pressure, weight loss, and a lower risk of type 2 diabetes *mellitus* (36,37). A study of ten healthy individuals who consumed an equivalent amount of animal or plant protein for 3 weeks showed that plant protein intake decreased renal plasma flow, fractional clearance of albumin, and IgG while increasing renal vascular resistance (38). The variation in amino acid consumption from plant versus animal proteins could explain their differing effects on kidney health (39,40).

This study has certain limitations. First, NHANES is a cross-sectional survey, preventing causal relationships from being determined. Second, the dietary data were based on self-reported first 24-h dietary recall, which may not reflect normal or long-term dietary behavior and may be influenced by memory bias. Finally, although the models adjusted for numerous potential confounding factors, residual confounding factors cannot be fully excluded.

CONCLUSION

This study suggests that high sedentary behavior increases the risk of CKD; however, a higher dietary plant protein ratio lowers this risk. These results provide dietary guidance for preventing CKD in sedentary individuals.

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