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Dietary Quality in Relation to Physical Functioning among Individuals with Chronic Kidney Disease in the United States

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2021

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Abstract

Dietary Quality in Relation to Physical Functioning among Individuals with Chronic Kidney Disease in the United States

By Lauryn Cravens

Background: Chronic kidney disease (CKD) is a growing health burden on individuals and populations across the world. The physiological changes that may occur from CKD can result in physical functioning impairments, including limitations in mobility and carrying out daily activities. Dietary patterns are important modifiable risk factors for those with CKD and for delaying functional impairments in older adults. While recent studies have focused on the associations between specific foods and micronutrients as they relate to CKD, the present study examined the associations between overall dietary patterns and physical functioning among those already living with the disease.

Objective: The objective of the study is to assess the association between dietary patterns using the 2015 Healthy Eating Index (HEI-2015) and physical functioning among those with CKD by examining data from a nationally representative sample of U.S. adults.

Methods: This study utilized data from the National Health and Nutrition Examination Study (NHANES) from1999-2016, a nationally representative sample of the US population, to assess the association between diet quality and physical functioning in individuals with chronic kidney disease (CKD). The study included 5,160 participants who met inclusion criteria, and dietary data were obtained via a 24-hour dietary recall interview and analyzed using the HEI-2015. The primary outcome of interest was physical functioning (grouped into two sets of participants: those with above and below the median number of reported physical functioning difficulties). A multivariable analysis was conducted to assess the association between dietary patterns using HEI-2015 and physical functioning. The HEI-2015 was categorized into tertiles, and the first model adjusted for age, gender, race/ethnicity, poverty, education, and marital status. The second model additionally adjusted for smoking, drinking, physical activity, and body mass index (BMI).

Results: The first model found that poorer diet was significantly associated with lower physical functioning (β=-0.077, $p < 0.001$), along with older age, female gender, greater poverty, and non-married states. The second model found that smoking, more infrequent physical activity, higher BMI, older age, female gender, and greater poverty were all significant predictors of lower physical functioning, while the associations between dietary patterns and physical functioning were no longer significant.

Conclusion: The study suggests that maintaining a healthy diet may have a positive impact on physical functioning in individuals with CKD, along with notable modifiable risk factors including smoking, physical activity, and BMI. Future studies should aim to investigate the associations between diet and physical functioning in individuals with CKD additionally adjusting for fasting glucose, systolic blood pressure, and total cholesterol, as well as the association between dietary patterns and physical functioning in individuals with CKD outside of the United States.

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INTRODUCTION & RATIONALE

Introduction

As the world population continues to age, there is a growing concern about maintaining functional independence in daily life. One important factor that has been shown to impact physical functioning is diet (*Ageing and Health*, n.d.). A growing body of evidence maintains that unhealthy dietary patterns, such as those high in saturated fats, added sugars, and processed foods, are associated with decreased physical functioning and increased risk of chronic diseases, such as diabetes, hypertension, and heart disease (World Health Organization, 2015; American Heart Association, 2021; Centers for Disease Control and Prevention, 2021).

This problem is particularly relevant for individuals with chronic kidney disease (CKD), as they often must adhere to specific dietary restrictions to manage their condition. CKD is a major public health issue, affecting millions of people worldwide. In the United States alone, an estimated 37 million adults have CKD, and it is a leading cause of morbidity and mortality (Alfego et al., 2021). As such, understanding the relationship between dietary patterns and physical functioning in individuals with CKD is crucial for developing effective interventions to improve their quality of life and reduce the burden of the disease.

Purpose Statement

Using data from six consecutive cycles of the 2009-2016 National Health and Nutrition Examination Surveys (NHANES) administered by the Centers for Disease Control and Prevention (CDC), the purpose of this study is to investigate the association between dietary patterns and physical functioning in American adults with CKD. It aims to investigate this

association in the presence of other potentially related factors including race, poverty, smoking, drinking, etc.

Research Question

What are the independent effects of dietary patterns using the 2015 Healthy Eating Index (HEI-2015) on physical functioning among American adults with CKD who participated in the 2009-2016 NHANES cycles? Do these effects of dietary patterns on physical functioning hold in the presence of other health, sociodemographic, and behavioral factors?

Significance Statement

Although previous studies have suggested that diet quality may influence physical functioning, there is limited evidence exploring this relationship among individuals with CKD. Furthermore, it is unclear how other lifestyle factors, such as smoking, alcohol consumption, physical activity, and body mass index (BMI), may modify this relationship. This knowledge gap is essential to develop effective interventions to improve physical functioning in CKD patients and ultimately improve their quality of life.

LITERATURE REVIEW

The global aging population is growing at an unprecedented rate (He et al., 2015). It is estimated that currently 8.5% of the world's population is over the age of 65, and this percentage is projected to rise to 17% by 2050 (He et al., 2015). The physiological changes that occur during the aging process can result in physical functioning impairments, including limitations in

mobility and carrying out daily activities (i.e., eating, toileting, bathing, and dressing) (Rauch et al., 2008). Decline in functional abilities substantially affects the independence and quality of life for older adults and increases societal and economic burdens (Gabriel & Bowling, 2004, Plassman et al., 2008). Therefore, identifying modifiable factors, such as diet, associated with functional impairments is a key first step in preventing or delaying and preventing the onset of functional physical impairments in adults.

While the epidemiology and mechanisms between diet and physical functioning are still being discovered and honed, adherence to healthier diets (defined by various measures explored later in the paper) had been found by numerous studies to be associated with better physical functioning in Americans, especially in elderly populations. However, the effect of dietary quality on physical functioning remains obscure.

Several lines of research have linked dietary quality/dietary patterns to physical functioning outcomes. While the National Health and Nutrition Examination Survey (NHANES) has described their physical functioning section in questionaries (variable name prefix PFQ) as "self-reported data on functional limitations caused by long-term physical, mental, and emotional problems or illness… can be used to assess an individual's level of disability", studies have chosen various elements of physical functioning as the basis for their analysis. For example, Xu et al. used performance-based measures including gait speed and knee extensor power. Gait speed was measured with a timed 20-foot walk test where participants were allowed to use a walker or cane if needed and right knee extensor force production was measured using an isokinetic dynamometer (Xu et al., 2012). Another study assessed physical functioning using the Short Physical Performance Battery, which included three examinations of lower body performance: repeated chair stands, progressive standing balance, and usual gait speed

(Talegawkar et al., 2021). A study examining Mediterranean diet and physical functioning in older adults in Spain assessed three different domains of physical function: agility, mobility, and overall physical functioning. Persons were defined as having impaired agility when they answered “a lot” to questions like: “On an average day with your current health, would you be limited in bending and kneeling?”. Another study examined only grip strength from the NHANES dataset as a measure of physical functioning; grip strength was measured three times in each hand in a standing position (Pikosky et al., 2022). Finally, several studies assessed physical functioning as a composite score from the NHANES physical functioning questionnaire that used self-reported physical limitations for 19 discrete physical tasks (Fanelli et al., 2021; Krok-Schoen et al., 2019; Yang et al., 2018; Zbeida et al., 2014).

The studies that utilized data from NHANES, a cross-sectional, multistage probability, nationally representative sample of the noninstitutionalized US population conducted by the National Center for Health Statistics (NCHS) of Centers for Disease Control and Prevention, all found significant associations between dietary quality and physical functioning. Two studies using data from NHANES 1999–2002, found that healthier diets were associated with improved physical function (as defined by the composite 19 physical task score and gait speed/knee extension power) (Talegawkar et al., 2021; Zbeida et al., 2014).

Interestingly, several studies found key associations between protein intake and physical functioning. In a study that used NHANES 1994-2004, researchers found that dietary protein and vitamin intake were associated with physical function in older adults with sarcopenia (Yang et al., 2018). However, the results were not consistent across sex: only dietary or supplemental intake of vitamin C and E, but not protein, was associated with physical functioning in older males with sarcopenia, and in females, only intake of higher amounts of protein, but not

vitamins, was associated with physical functioning. Krok-Schoen et al. found using NHANES 2005-2014, that low protein was associated with more functional limitations across all age groups. Similarly, Pikosky et al., using NHANES 2011–2014, found that dietary protein and leucine intake quartiles was related to grip strength. However, the increase in grip strength was more pronounced for animal protein than plant protein. Grip strength also increased ($p < 0.05$) with increasing the number of meal occasions containing >20 g of dietary protein. Fanelli et al. also showed that low protein and poorer diet was related to functional limitations among adults with diabetes using NHANES 2005-2016.

For studies that examined NHANES data, dietary data were obtained via a 24-hour dietary recall interview. Dietary interviews were administered to all examinees by a trained dietary interviewer. The dietary intake data were obtained from the types and amounts of foods and beverages consumed during the 24-hour period before the interview (midnight to midnight) to estimate intakes of energy, nutrients, and other food components from those foods and beverages. Multiple studies assessed diet quality assessed using the Healthy Eating Index, which was created to assess the adherence to the US Dietary Guidelines for Americans (Fanelli et al., 202l; Krok-Schoen et al., 2019; Talegawkar et al., 2021; Xu et al., 2012). The HEI-2005, for example, comprises twelve nutrient and food-based components.

Other studies measured individuals' adherence to a Mediterranean diet. Struijk et al. used two scores to measure accordance with a Mediterranean-style diet: the Mediterranean Diet Score (MDS) and the Mediterranean Diet Adherence Screener (MEDAS). The MDS is based on nine different items (vegetables, fruit and nuts, legumes, grains, fish and seafood, the ratio of unsaturated fatty acids to saturated fatty acids, meat and poultry, dairy, and alcohol). Zbeida et al. also examined adherence to a Mediterranean diet and used the same MDS score. While the

former study's prospective design adds strength to potential causal relationships between Mediterranean diet and physical functioning, Zbeida et al. used a cross-sectional design that does not allow the conclusion of temporal or causal relations.

Most examined studies utilized a single day of recall for dietary intake for their assessment of dietary quality. This method may be subjective to recall bias and social desirability bias and may lead to under- and over-reporting of food intakes (Fanelli et al., 202l; Krok-Schoen et al., 2019; Pikosky et al., 2022; Xu et al., 2012; Zbeida et al., 2014). Additionally, self-reported physical functioning limitations may also be subject to bias.

The biological mechanisms linking dietary quality and physical functioning in adults remains unclear, but several mechanisms have been proposed. Some researchers believe that reduced oxidation and inflammation, specifically related to accordance with the Mediterranean diet and diets high in fruits and vegetables and low in foods high in saturated fat and added sugar, may lead to improved physical function. Additionally, homocysteine, a sensitive marker for a deficiency in B vitamins, has been found to be independently associated with physical function (Struijk et al., 2018; Landi et al., 2016). Consuming generous amounts of fruits and vegetables on a regular basis may provide protective effects through antioxidants; researchers have found associations between low serum or plasma carotenoid concentrations and lower gait speed, and greater risk of poor hip, knee, and grip muscle strength. Antioxidants (including the carotenoids, vitamin C, vitamin E, and other polyphenols) may work against the age-dependent increases in oxidative stress and promote creatine kinase activity, prompting increased skeletal muscle repair (Xu et al., 2012; Gehlich et al., 2020).

Existing literature has demonstrated associations between adherence to healthier diets (as defined by scores such as HEI and adherence to a Mediterranean diet) and higher intakes of

protein with better physical functioning in adults. These results were especially pronounced in elderly populations. However, recommendations for populations to follow healthier diets are often made without consideration of cultural, regional, and socioeconomic factors that may impact adherence to nutritional advice. Additionally, all examined studies in this review were conducted in populations that were primarily white and in countries in North America and Europe. As the mechanisms between diet and physical functioning continue to be understood and explored, further cohort and intervention studies may shed more light on temporal and causal relationships, as well as studies conducted in populations not traditionally targeted for such research. These findings will provide important insight into the complex relationships between diet and physical functioning as global populations age and the costs associated with caring for the elderly and those with functional impairments rise.

MATERIALS & METHODS

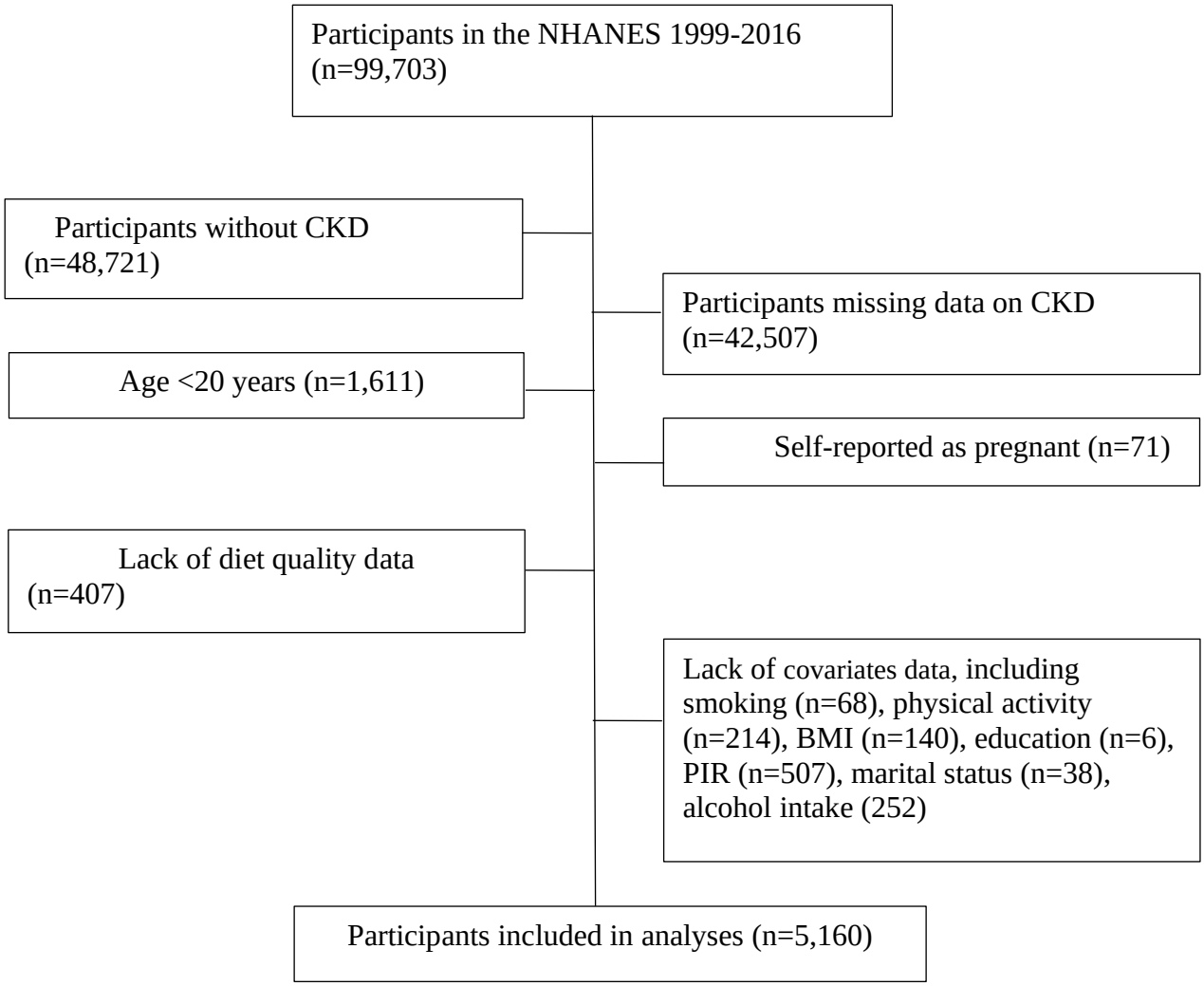
Data Source

Participants for this study were drawn from the NHANES study (1999-2016). The NHANES is a cross-sectional, multistage probability, nationally representative sample of the noninstitutionalized US population conducted by the National Center for Health Statistics (NCHS) of Centers for Disease Control and Prevention. The program evaluates the health and nutritional status of Americans, and demographics, dietary, medical examination, laboratory, and questionnaire data were collected. All participants provided informed consent. The design of the NHANES study is detailed elsewhere.

Study Sample

Participants in the NHANES dataset were included from nine continuous cycles from 1999-2016 (n=99,703). Participants were excluded if they were without CKD (n=48,721), missing data on CKD (n=42,507), aged less than 20 years (n=1,611), self-reported as pregnant (n=71), lacked information on diet quality (n=407), and lacked covariate data on smoking (n=68), physical activity (n=214), BMI (n=140), education (n=6), Poverty Income Ratio (PIR) (n=507), marital status (n=38), and alcohol intake (252). Finally, we analyzed data from 5,160 participants that met the inclusion criteria in the present study (**Figure 1**).

Figure 1. Flowchart of inclusion and exclusion of study participants.



Dietary Assessment

Dietary data were obtained via a 24-hour dietary recall interview. Dietary interviews were administered to all examinees by a trained dietary interviewer. The dietary intake data were obtained from the types and amounts of foods and beverages consumed during the 24-hour period before the interview (midnight to midnight) and to estimate intakes of energy, nutrients, and other food components from those foods and beverages. Diet quality was assessed using the 2015 Healthy Eating Index, which was created to assess the adherence to the 2015-2020 US Dietary Guidelines for Americans. Dietary scores were split into tertiles. HEI-2015 consists of 13 components and provides a measure of the overall quality of the diet, and scores range from 0-100, with higher scores indicating healthier dietary patterns. The HEI-2015 score was divided into tertiles, with the lowest tertile representing the lowest quality of diet and the highest tertile representing the highest quality of diet.

Outcomes

Physical functioning is a common outcome variable used in health research to assess the overall ability of individuals to perform activities of daily living. The physical functioning outcome variable in this study was measured using data from NHANES 1999-2016. The physical functioning data were collected using a questionnaire that included questions on limitations in mobility, activities of daily living, and instrumental activities of daily living. Physical functioning questions were included in the analysis that were present across all cycles from 1999-2016. These included: Do you have an impairment or health problem that limits your ability to walk or run?; Are you limited in any way in any activity because of a physical, mental or emotional problem?; Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?; Does you receive

Special Education or Early Intervention Services?; Does a physical, mental or emotional problem now keep you from working at a job or business?; Are you limited in the kind or amount of work you can do because of a physical, mental or emotional problem?; Because of a health problem, do you have difficulty walking without using any special equipment?; Are you limited in any way because of difficulty remembering or because you experience periods of confusion?; and By yourself and without using any special equipment, do you have difficulty managing your money?

The data were processed and combined from multiple NHANES datasets to create a single dataset for analysis. If a respondent answered yes for experiencing a particular functional difficulty, the result was coded 1. If a respondent answered no for experiencing a particular functional difficulty, the result was coded 0. These physical functioning values were then summed for each participant.

The median score of the physical functioning variables across participants was subsequently used to create a new variable that divided all participants into two groups: those who reported more physical functioning difficulties (coded as 1) and those who experienced fewer physical functioning difficulties (coded as 0).

Potential Confounders

In all statistical models, NHANES cycles, age (continuous, years), and gender (male and female) were adjusted for. In Model 1, age, gender, race/ethnicity (Hispanic, non-Hispanic white, non-Hispanic black, and others), family poverty-to-income ratio (PIR, <1.3, 1.3-3.5, >3.5 where a lower ratio indicates greater poverty), education (less than high school, high school and college or higher), and marital status (married, separated, and never married) were adjusted for. Model 2

further adjusted for smoking (Never, former, current), alcohol intake (None, Moderate, Heavy), physical activity (continuous, min/week), and BMI (continuous, kg/m^2).

Statistical Analysis

All statistical analyses were performed using R (version 4.2.1). All calculations considered the complex survey design of the NHANES database. Participants were divided into tertiles based on their dietary scores according to the HEI-2015. Descriptive statistics of baseline participant characteristics were summarized by tertiles of each dietary score to assess means and standard deviations of continuous variables (age, BMI, HEI-2015 score, physical functioning score) using $\chi 2$ tests and analysis of variance. Frequencies were used to determine the percentages of categorical variables (gender, ethnicity, education, marital status, household income categories, medical conditions, CKD diagnoses and physical functioning).

A multivariable regression analysis was performed in Model 1 to examine the association between physical functioning (higher versus lower) and Healthy Eating Index (HEI) tertiles, adjusted for age, gender, race/ethnicity, poverty-income ratio (PIR), education, and marital status. The survey design was accounted for in the analysis. While Model 1 adjusted for age, gender, race/ethnicity, PIR, education, marital status, Model 2 additionally adjusted for smoking, alcohol drinking, physical activity, and BMI. The median value of the dietary score was used within each tertile to calculate a P value for a linear trend test. $P < 0.05$ was considered statistically significant. The analysis was conducted using a survey design object, adjusting for survey weights.

This analysis was determined to be IRB-exempt by Emory University's Institutional Review Board as the study is an analysis of secondary data, and all data were de-identified prior to analysis.

RESULTS

Baseline Characteristics

Out of 5,160 included NHANES participants with CKD, the mean age of participants was 59.4 years, and 46.18% were male. The majority were non-Hispanic white (70.04%), non-smokers (70.23%), and had a college education or higher (50.16%). Participants who had higher dietary scores, indicating healthier diet based on the HEI-2015, were more likely to be non-Hispanic white, married, educated at the college level or higher, have a PIR > 3.5, never smoke, and drink alcohol moderately (**Table 1**).

Table 1. Baseline characteristics of participants with chronic kidney disease in NHANES [add years here] (N =5160).

Characteristics	Total	Quartile of Healthy Eating Index-2015				*P*
		1	2	3	4	
No. of participants, n (%)	5,160 (100.00)	1,242 (24.14)	1,297 (25.20)	1,318 (25.61)	1,289 (25.05)	
Age, years, mean (SE)	59.40 (0.38)	53.36 (0.71)	58.50 (0.66)	60.85 (0.66)	64.89 (0.68)	<0.001
Gender, Male, n (%)	2,627 (46.18)	647 (45.78)	698 (48.25)	665 (48.00)	617 (42.69)	0.122
Race, n (%)						<0.001
Hispanic	1,188 (12.16)	276 (12.87)	302 (13.51)	330 (13.18)	280 (9.06)	
Non-Hispanic white	2,588 (70.04)	612 (67.98)	610 (66.32)	657 (70.01)	709 (75.85)	
Non-Hispanic black	1,076 (11.96)	290 (13.48)	312 (14.01)	267 (11.92)	207 (8.42)	
Others	294 (5.85)	64 (5.67)	73 (6.16)	64 (4.90)	93 (6.67)	
Marital status, n (%)						0.007
Married	2,652 (54.32)	620 (51.19)	647 (53.66)	656 (53.29)	729 (59.13)	
Separated	1,993 (35.16)	457 (35.06)	531 (36.51)	537 (36.65)	468 (32.43)	
Never married	501 (10.52)	165 (13.75)	119 (9.83)	125 (10.06)	92 (8.44)	
Education, n (%)						<0.001
Less than high school	1,777 (24.46)	463 (28.09)	462 (26.23)	475 (25.59)	377 (17.92)	
High school	1,224 (25.38)	318 (28.36)	316 (24.29)	314 (26.59)	276 (22.29)	
College or higher	2,145 (50.16)	461 (43.56)	519 (49.48)	529 (47.81)	636 (59.79)	
Poverty Income Ratio (PIR), n (%)						<0.001
< 1.3	1,783 (26.35)	496 (32.89)	464 (27.63)	472 (27.19)	351 (17.71)	
1.3 to 3.5	2,154 (41.20)	520 (40.98)	551 (42.24)	549 (41.83)	534 (39.74)	
> 3.5	1,209 (32.45)	226 (26.13)	282 (30.13)	297 (30.98)	404 (42.56)	
Smoking, n (%)						<0.001
Never	3,693 (70.23)	730 (56.02)	887 (67.24)	994 (73.37)	1,082 (84.30)	
Former	520 (10.71)	145 (11.92)	136 (11.54)	132 (10.87)	107 (8.53)	
Current	933 (19.05)	367 (32.06)	274 (21.22)	192 (15.76)	100 (7.17)	
Alcohol intake, n(%)						0.014
None	1,808 (32.65)	400 (30.74)	426 (30.72)	463 (32.45)	519 (36.67)	
Moderate	2,941 (58.13)	772 (62.88)	752 (58.82)	751 (57.28)	666 (53.55)	
Heavy	397 (9.22)	70 (6.38)	119 (10.45)	104 (10.27)	104 (9.78)	
Physical activity, min/week, mean (SE)	499.99 (21.03)	529.21 (39.68)	413.65 (49.70)	506.22 (39.03)	450.90 (27.94)	0.057
BMI, kg/m^2, mean (SE)	29.85 (0.15)	30.59 (0.31)	30.10 (0.34)	29.95 (0.27)	28.76 (0.25)	<0.001

Multivariable Analysis

The first tertile of HEI scores was used as the reference group in the models; its coefficient is not shown in the results. The coefficients for the second and third tertiles ("Lower HEI-2015" and "Higher HEI-2015", respectively) are shown. After adjusting for covariates in Model 1, the HEI tertiles were significantly associated with physical functioning (β=-0.246, $p < 0.001$). Having healthier diets (as defined by higher HEI-2015 scores) was significantly associated with better physical functioning ability (β=-0.077, $p < 0.001$) (**Table 2**).

Age and PIR were also significantly associated with physical functioning ($p < 0.001$), where older age and lower PIR were associated with decreased physical functioning. Gender ($p=0.001$) and marital status ($p=0.002$) were also significantly associated with physical functioning, with females and individuals who were separated or never married reporting worse physical functioning. However, race/ethnicity and education were not significantly associated with physical functioning in this sample (**Table 2**).

Overall, these findings suggest that maintaining a healthy diet is associated with better physical functioning, even after controlling for important sociodemographic factors. Additionally, older age, lower PIR, being female, and not being married were associated with lower physical functioning.

Table 2: Association between diet quality and physical functioning in adults with CKD adjusted for age, gender, race/ethnicity, poverty income ration, education, and marital status (Model 1)

Beta Coefficients	Estimate	SE	t values	Pr(>|t|)
(Intercept)	-0.2460474	0.0609521	-4.037	9.2e-05
Lower HEI-2015	0.0176535	0.0189778	0.930	0.35398
Higher HEI-2015	-0.0769891	0.0207720	-3.706	0.00031
Age	0.0138220	0.0003937	35.111	< 2e-16
Gender	0.0599525	0.0181013	3.312	0.00120
Race	0.0045609	0.0096280	0.474	0.63650
PIR	-0.0935697	0.0120156	-7.787	1.9e-12
Education	-0.0118410	0.0107194	-1.105	0.27136
Marital Status	0.0331149	0.0103429	3.202	0.00172

Model 1: Adjusted for age (continuous, years), gender (male=1 and female=2), race/ethnicity (Hispanic=1, non-Hispanic white=2, non-Hispanic black=3, and others=4), family poverty-to-income ratio (<1.3=1, 1.3-3.5=2, >3.5=3), education (less than high school=1, high school and college or higher=2), and marital status (married=1, separated=2, and never married=3).

Model 2 adds for four additional covariates: smoking status, alcohol drinking status, physical activity level, and BMI. The model found that smoking status, physical activity level, and BMI are all significant predictors of physical functioning. Age, marital status, and PIR continued to be significant predictors, while the associations between diet and physical functioning were attenuated and no longer significant.

Similar to the first model, this model found that although having poorer diets was associated with poorer physical functioning (β=0.031, p=0.103) and healthier diets were associated with increased physical functioning (β=-0.039, p=0.0.75), these findings were no longer statistically significant after adjusting for these further factors in the model (**Table 3**).

As in the first model, older age and lower PIR were associated with decreased physical functioning (β=0.013, p < 0.001 and β=-0.086, p < 0.001, respectively). Marital status (p=0.005)

was also significantly associated with physical functioning, with individuals who were separated or never married reporting worse physical functioning (**Table 3**).

Smoking currently or formerly was associated with decreased physical functioning (β=0.051, $p < 0.001$), while increased physical activity was associated significantly with increased physical functioning ability (β=-0.076, $p < 0.001$). Finally, an overweight and obese status was significantly associated with poorer functional ability (β=0.045, $p < 0.001$).

Overall, this model suggests that income, smoking status, physical activity, and BMI are significant predictors of physical functioning, whereas dietary pattern is no longer a significant predictor after adjusting for additional variables.

Table 3: Association between diet quality and physical functioning in adults with CKD adjusted for age, gender, race/ethnicity, poverty income ration, education, marital status, smoking, drinking, physical activity, and BMI (Model 2)

Coefficients	Estimate	SE	t values	Pr(>|t|)
(Intercept)	-0.2794267	0.0831271	-3.361	0.00103
Lower HEI-2015	0.0308943	0.0188019	1.643	0.10285
Higher HEI-2015	-0.0392595	0.0218329	-1.798	0.07454
Age	0.0133569	0.0004504	29.656	< 2e-16
Gender	0.0492098	0.0192938	2.551	0.01195
Race	0.0015145	0.0096974	0.156	0.87615
PIR	-0.0859411	0.0115592	-7.435	1.41e-11
Education	0.0012804	0.0108226	0.118	0.90601
Marital Status	0.0301296	0.0105075	2.867	0.00485
Smoking	0.0508727	0.0102989	4.940	2.43e-06
Drinking	-0.0019730	0.0156114	-0.126	0.89963
Physical Activity	-0.0762999	0.0095550	-7.985	7.53e-13
BMI	0.0447081	0.0088310	5.063	1.43e-06

Model 2: Adjusted for age (continuous, years), gender (male=1 and female=2), race/ethnicity (Hispanic=1, non-Hispanic white=2, non-Hispanic black=3, and others=4), family poverty-to-income ratio (<1.3=1, 1.3-3.5=2, >3.5=3), education (less than high school=1, high school and college or higher=2), marital status (married=1, separated=2, and never married=3), smoking (never=1, former=2, current=3), alcohol intake (none=1, moderate=2, heavy=3), physical activity (continuous, min/week) and BMI (continuous, kg/m2).

DISCUSSION

In this study, we found that having a healthier diet was significantly associated with increased physical functioning, as indicated by a β coefficient of -0.077 and a p-value < 0.001, in a model that adjusted for age, gender, race/ethnicity, poverty, education, and marital status. This finding is consistent with previous research that has suggested that diet quality may be an important factor in maintaining physical function in older adults (Kojima et al., 2019; Kelly et al., 2017). Moreover, our results also suggest that age and PIR were significant factors associated with physical functioning, consistent with prior research indicating that older age and lower income are associated with worse physical functioning (Jørgensen et al., 2017; Ke et al., 2022). However, once smoking, drinking, physical activity, and BMI were added to the model, there was no longer a relationship between dietary pattern and physical functioning.

We also found that gender and marital status were significantly associated with physical functioning, with females and individuals who were separated or never married reporting worse physical functioning. This is in line with previous research which has suggested that women and those who are unmarried are at greater risk for functional decline (Dunlop et al., 2007; Orellano-Colón et al., 2021; Melsæter et al., 2022).

However, race/ethnicity and education were not significantly associated with physical functioning in this sample. This finding is inconsistent with some prior research which has

suggested that minority populations and those with lower education levels may have worse physical functioning (Louie & Ward, 2011; Vart et al., 2015).

Smoking currently or formerly was associated with decreased physical functioning, while increased physical activity was associated significantly with increased physical functioning ability. These findings are consistent with previous research showing that smoking is a risk factor for functional decline (Agahi et al., 2018) and that physical activity can improve physical functioning and overall health in older adults (O'Hare et al., 2003; Stack et al., 2005; Beddhu et al., 2009).

Finally, an overweight and obese status was significantly associated with poorer functional ability, which is consistent with evidence showing that obesity is a risk factor for functional decline (Lopes et al., 2017).

In summary, our findings suggest that having a healthier diet, being physically active, not smoking, and maintaining a healthy weight can improve physical functioning in older adults. Moreover, our results highlight the importance of addressing socioeconomic factors such as income and marital status in efforts to promote physical functioning in this population. However, further research is needed to better understand the complex interplay of factors that contribute to physical functioning in older adults.

Overall, this study found that while healthy eating habits may be important for physical functioning, other factors such as age, socioeconomic status, smoking status, physical activity, and BMI may have a stronger impact. The findings from Model 1 and Model 2 have important public health implications, particularly in the context of chronic kidney disease (CKD) and its associated complications. Model 1 suggests that there is a significant association between adherence to a healthy dietary pattern (as measured by HEI tertiles) and physical functioning in

individuals with CKD. Specifically, the results indicate that those in the highest HEI tertile had better physical functioning compared to those in the lowest tertile. This finding has important implications for the management of CKD, as it suggests that adopting a healthy dietary pattern may help improve physical functioning in individuals with this condition.

Model 2 builds on these findings by adjusting for other lifestyle factors, such as smoking, alcohol consumption, physical activity, and BMI. The results suggest that after adjusting for these factors, the association between HEI tertiles and physical functioning remains significant. This suggests that the beneficial effects of a healthy dietary pattern on physical functioning may be independent of these other lifestyle factors, and that dietary interventions may be an important strategy for improving physical functioning in individuals with CKD, even in the presence of other risk factors.

Strengths of this study include that it used a nationally representative sample, which enhances the generalizability of the findings in the United States. The study used validated measures to assess dietary patterns and physical functioning, which improves the validity of the results, and the analysis adjusted for several confounding factors, including age, gender, race, income, education, marital status, smoking, alcohol drinking, physical activity, and BMI, which strengthens the study's internal validity.

However, several limitations should be noted. The study relied on self-reported dietary intake and physical functioning, which are subject to recall and social desirability bias. Furthermore, the study did not assess other potential confounding factors, such as medication use or comorbidities, which may influence the relationship between dietary patterns and physical functioning. Finally, the study did not assess the long-term effects of dietary patterns on physical functioning.

Overall, the findings of the present study provide important insights into the relationship between dietary patterns and physical functioning in individuals with CKD. Specifically, they suggest that dietary interventions are not effective strategies for improving physical functioning in individuals with this condition. Given the high prevalence of CKD and its associated complications, these findings underscore the importance of discouraging smoking and promoting physical activity and lowering BMI to a healthy weight as key components of CKD management. However, further research is needed to confirm these findings in populations outside the United States and to assess the long-term effects of smoking, physical activity, and BMI on physical functioning. Additionally, future studies should consider using objective measures of dietary intake and physical functioning and assessing other potential confounding factors to enhance the validity of the results.

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