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Investigating The Relationship Between Different Dietary Patterns And The Progression Of Chronic Kidney Disease

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Abstract
Introduction: *Chronic Kidney Disease (CKD) is a significant global health issue, influenced by genetics, environment, and lifestyle, with diet playing a key role in its progression. Research highlights the impact of dietary patterns, such as high intake of processed foods and red meat, on CKD risk, whereas diets rich in fruits, vegetables, and whole grains may reduce this risk. The study aims to investigate these relationships further, exploring how diet affects CKD through mechanisms like blood pressure regulation and inflammation.*
Methods: *This prospective cohort study tracked participants with various stages of chronic kidney disease (CKD) and a control group over two years, assessing dietary intake and kidney health biannually. Inclusion criteria targeted individuals over 18 with confirmed CKD stages 1-4, stable conditions, and no dietary restrictions from other conditions. Recruitment was from nephrology clinics and community sources. Dietary patterns were analyzed via food questionnaires and linked to changes in kidney function, informing evidence-based dietary guidelines for CKD management, with strict ethical standards upheld throughout the study.*
Results: *The Western diet is more common in CKD stages 3-4 (40%) than in stages 1-2 (30%) and least common in controls (20%). The Mediterranean diet shows the highest adherence in stages 1-2 (45%) and controls (50%), but less in stages 3-4 (35%). The Western diet significantly increases the risk of CKD progression, with a Hazard Ratio (HR) of 2.1 and a strong statistical significance ($p<0.001$). Participants following a Western diet experienced a significant decline in GFR, from a baseline of 60 ± 15 mL/min/1.73 m^2 to 45 ± 20 mL/min/1.73 m^2, with a highly significant p-value (<0.001). The Western diet significantly increases C-reactive protein levels, indicating heightened inflammation.*
Conclusion: *Our study highlights how dietary choices, particularly Western diets, accelerate CKD progression, while Mediterranean and plant-based diets offer protective benefits, recommending nutritional counseling in CKD care.*
Keywords: *Chronic Kidney Disease, Dietary Patterns, Disease Progression, Renal Health, Diet-Related Risk Factors*

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I. Introduction

Chronic Kidney Disease (CKD) is a global health concern that affects millions of people worldwide, leading to significant morbidity and mortality. It is characterized by a gradual loss of kidney function over time and can progress to end-stage renal disease (ESRD), necessitating dialysis or kidney transplantation.[1] The etiology of CKD is multifactorial, involving genetic predispositions, environmental factors, and lifestyle choices, including dietary habits.[2] Emerging evidence suggests that dietary patterns play a crucial role in the onset and progression of CKD, offering a potentially modifiable risk factor that could be harnessed in the management and prevention of this disease.[3]

Dietary patterns encompass the quantity, variety, and combination of different foods and beverages in a diet and their frequency of consumption. Studies have shown that certain dietary patterns, such as those high in processed foods, sodium, and protein from red meat, are associated with an increased risk of CKD progression.[4] Conversely, diets rich in fruits, vegetables, whole grains, and low-fat dairy products, akin to the DASH (Dietary Approaches to Stop Hypertension) diet or a Mediterranean diet, have been associated with a decreased risk of CKD progression.[5]

The influence of diet on CKD progression is thought to be mediated through various mechanisms, including blood pressure regulation, modulation of metabolic pathways, and the inflammatory and oxidative

stress response.[6] Moreover, diet can affect the acid-base balance, electrolyte levels, and the accumulation of uremic toxins, all of which have implications for kidney health.

Despite the growing body of evidence linking dietary patterns with CKD risk and progression, there remains a gap in our understanding of the specific dietary components most influential in this relationship. Additionally, the interplay between diet, genetic predispositions, and other lifestyle factors in the context of CKD progression is not fully understood. This lack of detailed knowledge hinders the development of effective dietary recommendations and interventions for individuals at risk of or living with CKD.

Furthermore, most existing studies have focused on individual nutrients or foods rather than overall dietary patterns. This approach fails to capture the complex interactions between different dietary components and their cumulative effects on health. A more holistic investigation of dietary patterns and their relation to CKD progression is needed to provide a clearer picture of the impact of diet on kidney health.

Addressing these knowledge gaps is critical, as dietary modifications are a cornerstone of CKD management. Improved dietary guidelines could not only enhance the quality of life for individuals with CKD but also potentially slow the progression of the disease, reducing the need for dialysis or transplantation and decreasing the associated healthcare costs.[7]

The primary objective of this study is to investigate the relationship between different dietary patterns and the progression of chronic kidney disease. To achieve this, the study is designed with the following specific objectives:

1. To identify prevalent dietary patterns among individuals with varying stages of CKD and compare these with patterns observed in the general population. This will involve the collection and analysis of dietary data to classify participants according to their adherence to specific dietary patterns, such as Western, Mediterranean, DASH, and plant-based diets.
2. To evaluate the association between dietary patterns and CKD progression: This objective entails a longitudinal analysis of dietary intake and kidney function over time, aiming to determine how adherence to particular dietary patterns influences the rate of CKD progression. We will assess changes in kidney function markers, including glomerular filtration rate (GFR), albuminuria, and serum creatinine levels, in relation to dietary pattern adherence.
3. To explore the mechanistic pathways linking dietary patterns with CKD progression: This involves examining the role of inflammation, oxidative stress, metabolic alterations, and other potential mediators in the relationship between diet and kidney health. Biomarkers of these processes will be measured and analyzed in the context of dietary intake.
4. To develop dietary recommendations for the prevention and management of CKD: Based on the findings, we aim to provide evidence-based dietary guidelines tailored to individuals with CKD or at risk of developing the disease. These recommendations will focus on dietary patterns shown to be beneficial in slowing CKD progression and improving overall health outcomes.

This study seeks to fill critical gaps in the current understanding of how dietary patterns affect CKD progression. By elucidating the complex relationship between diet and kidney health, this research aims to contribute to the development of effective dietary strategies for the prevention and management of CKD, ultimately improving the lives of those affected by this chronic condition.

II. Methodology

Study Design

We conducted a prospective cohort study, enrolling participants with varying stages of CKD as well as a control group from the general population. Participants were followed for a period of Two years, with biannual assessments to monitor dietary intake, kidney function, and other relevant health markers. This design allowed for the examination of temporal relationships between dietary patterns and changes in kidney health over time.

Inclusion Criteria

1. Age Range: Individuals aged 18 years and older, as chronic kidney disease (CKD) progression and dietary patterns can vary significantly across different age groups.
2. Diagnosis: Participants with a formal diagnosis of chronic kidney disease stages 1-4, confirmed by a healthcare professional using criteria such as glomerular filtration rate (GFR) and albuminuria levels.
3. Stable Condition: Participants in a stable medical condition without any acute illness or changes in their CKD treatment plan for at least 3 months prior to enrolment, to minimize confounding variables.
4. Ability to Provide Consent: Participants who are able to understand the study requirements and provide informed consent, ensuring ethical standards are met.
5. Dietary Freedom: Individuals who are not on any strict dietary regimen prescribed for other medical conditions, ensuring that the study focuses on natural dietary patterns without external restrictions.

6. Willingness to Adhere to Study Protocols: Participants willing to adhere to study protocols, including dietary reporting and attendance at follow-up appointments.

Exclusion Criteria

1. Advanced Kidney Failure: Individuals with end-stage renal disease (stage 5 CKD) or those receiving dialysis, as their dietary needs and restrictions significantly differ from those in the earlier stages of CKD.
2. Recent Hospitalization or Surgery: Participants who had been hospitalized or undergone major surgery within the last 6 months, to avoid acute changes affecting CKD progression or dietary patterns.
3. Pregnancy or Breastfeeding: Women who were pregnant or breastfeeding, due to their unique nutritional needs and potential risks to the foetus or infant.
4. Significant Comorbid Conditions: Individuals with conditions that could independently affect dietary patterns or CKD progression, such as active cancer, severe heart failure, or uncontrolled diabetes.
5. Inability to Follow Dietary Assessment Procedures: Participants who were unable or unwilling to accurately report dietary intake or adhere to dietary assessment procedures, as accurate dietary data is crucial for the study.
6. Participation in Other Interventional Studies: Individuals currently participating in other interventional studies that could influence dietary habits or CKD progression, to eliminate confounding variables.

Participants Recruitment and Selection

Participants were recruited from nephrology clinics, community health centers, and through advertisements in local media. The control group consisted of individuals without CKD, matched for age, sex, and socioeconomic status. All participants provided informed consent prior to enrolment.

Dietary Assessment

Dietary intake was assessed using validated food frequency questionnaires (FFQs) and 24-hour dietary recalls at baseline and every six months thereafter. These tools captured the quantity, variety, and frequency of food and beverage consumption, allowing for the identification of predominant dietary patterns among participants. Dietary patterns were classified into categories such as Western, Mediterranean, DASH, and plant-based diets, based on their characteristic food groups and nutrients.

Kidney Function and Biomarker Analysis

Kidney function was evaluated through measurements of glomerular filtration rate (GFR), albuminuria, and serum creatinine levels, collected at baseline and during each follow-up visit. Additionally, blood and urine samples were analyzed for biomarkers of inflammation (e.g., C-reactive protein), oxidative stress (e.g., malondialdehyde), and metabolic alterations (e.g., fasting glucose, lipid profiles) to explore potential mechanistic pathways linking dietary patterns to CKD progression.

Data Collection and Analysis

Data on demographic characteristics, lifestyle factors (e.g., physical activity, smoking status), medical history, and medication use were also collected to control for potential confounding variables. Statistical analyses included multivariate regression models to assess the association between dietary patterns and changes in kidney function over time, adjusting for confounders. Mediation analysis was conducted to investigate the role of inflammatory and oxidative stress markers in the diet-CKD progression relationship.

Development of Dietary Recommendations

Based on the findings, we developed evidence-based dietary guidelines tailored for individuals with CKD or at risk of developing the disease. These recommendations prioritized dietary patterns associated with slower CKD progression and improved health outcomes, considering cultural and individual preferences to enhance adherence and effectiveness.

Ethical Considerations

The study adhered to ethical standards in accordance with the Declaration of Helsinki and was approved by an institutional review board (IRB). Participants' privacy and confidentiality of data were strictly maintained, and they had the right to withdraw from the study at any point without any consequences to their care.

III. Results

Table 1: Baseline Characteristics of Study Participants

Characteristic	Total (N=212)	CKD Stages 1-2 (n=85)	CKD Stages 3-4 (n=97)	Control (n=30)

Age, years (mean ± SD)	55 ± 12	52 ± 11	58 ± 12	54 ± 13
Male, n (%)	108 (51%)	43 (51%)	49 (50%)	16 (53%)
BMI, kg/m^2 (mean ± SD)	28.4 ± 5.2	27.1 ± 4.9	29.8 ± 5.4	26.9 ± 4.8
Smoking status, n (%)				
- Non-smoker	162 (76%)	66 (78%)	73 (75%)	23 (77%)
- Former smoker	35 (17%)	14 (16%)	18 (19%)	3 (10%)
- Current smoker	15 (7%)	5 (6%)	6 (6%)	4 (13%)
Hypertension, n (%)	126 (59%)	45 (53%)	67 (69%)	14 (47%)
Diabetes mellitus, n (%)	74 (35%)	25 (29%)	41 (42%)	8 (27%)

Table 1 presents baseline characteristics of 212 study participants, categorized into three groups based on chronic kidney disease (CKD) stages: stages 1-2 (n=85), stages 3-4 (n=97), and a control group (n=30). The average age across the groups is 55 years, with stage 3-4 CKD patients being the oldest on average (58 years). Approximately half of the participants are male, with a slight variation across groups. Body Mass Index (BMI) averages 28.4 kg/m^2, with stage 3-4 CKD patients having the highest average BMI (29.8 kg/m^2). The majority of participants are non-smokers (76%), with a small percentage being current smokers (7%). Hypertension is more prevalent in the stage 3-4 CKD group (69%) compared to stages 1-2 (53%) and controls (47%). Diabetes mellitus is found in 35% of the total participants, with a higher occurrence in the stage 3-4 CKD group (42%) compared to the other groups.

Table 2: Prevalence of Dietary Patterns Among Participants

Dietary Pattern	CKD Stages 1-2	CKD Stages 3-4	Control
Western	30%	40%	20%
Mediterranean	45%	35%	50%
DASH	15%	10%	20%
Plant-based	10%	15%	10%

Table 2 outlines the prevalence of various dietary patterns among participants divided by chronic kidney disease (CKD) stages and a control group. The Western diet is more common in CKD stages 3-4 (40%) than in stages 1-2 (30%) and least common in controls (20%). The Mediterranean diet shows the highest adherence in stages 1-2 (45%) and controls (50%), but less in stages 3-4 (35%). The DASH diet is more prevalent in controls (20%) compared to CKD stages 1-2 (15%) and stages 3-4 (10%). The plant-based diet is slightly more common in CKD stages 3-4 (15%) than in stages 1-2 (10%) and controls (10%).

Table 3: Multivariate Analysis of Dietary Patterns and CKD Progression

Dietary Pattern	Hazard Ratio (HR)	95% Confidence Interval (CI)	P-value
Western	2.1	1.4 - 3.2	<0.001
Mediterranean	0.5	0.3 - 0.7	0.002
DASH	0.7	0.4 - 1.1	0.12
Plant-based	0.6	0.3 - 0.9	0.018

Table 3 presents a multivariate analysis assessing the impact of dietary patterns on chronic kidney disease (CKD) progression. The Western diet significantly increases the risk of CKD progression, with a Hazard Ratio (HR) of 2.1 and a strong statistical significance ($p<0.001$). Conversely, the Mediterranean and plant-based diets are associated with a decreased risk of CKD progression, with HRs of 0.5 ($p=0.002$) and 0.6 ($p=0.018$), respectively, indicating protective effects. The DASH diet, while suggesting a potential reduction in CKD progression risk with an HR of 0.7, does not reach statistical significance ($p=0.12$), indicating uncertain effect within the analyzed population.

Table 4: Changes in Kidney Function by Dietary Pattern

Dietary Pattern	Baseline GFR (mL/min/1.73 m^2)	5-year GFR (mL/min/1.73 m^2)	P-value
Western	60 ± 15	45 ± 20	<0.001
Mediterranean	58 ± 14	55 ± 18	0.03
DASH	59 ± 16	54 ± 17	0.07
Plant-based	60 ± 15	56 ± 16	0.02

Table 4 examines the impact of dietary patterns on changes in kidney function over five years, using glomerular filtration rate (GFR) as a measure. Participants following a Western diet experienced a significant decline in GFR, from a baseline of 60 ± 15 mL/min/1.73 m^2 to 45 ± 20 mL/min/1.73 m^2, with a highly significant p-value (<0.001). Those on the Mediterranean and plant-based diets showed a less pronounced decline in GFR, with mild decreases to 55 ± 18 (p=0.03) and 56 ± 16 (p=0.02), respectively, indicating a protective effect. The DASH diet's impact on GFR, decreasing to 54 ± 17, was not statistically significant (p=0.07).

Table 5: Biomarkers of Inflammation and Oxidative Stress by Dietary Pattern

Biomarker	Western	Mediterranean	DASH	Plant-based
C-reactive protein	↑↑	↓	↓	

Table 5 shows the impact of dietary patterns on biomarkers of inflammation and oxidative stress. The Western diet significantly increases C-reactive protein levels, indicating heightened inflammation. Conversely, both the Mediterranean and DASH diets are associated with reduced C-reactive protein levels, suggesting a decrease in inflammation.

IV. Discussion

The relationship between dietary patterns and the progression of chronic kidney disease (CKD) presents a compelling field of study that intersects nutrition, nephrology, and public health. Our investigation into this relationship has yielded insights that not only contribute to the existing body of knowledge but also provide actionable guidance for individuals at risk of or living with CKD.

Our study demonstrates a significant association between dietary patterns and CKD progression. The multivariate analysis revealed that adherence to a Western diet—characterized by high consumption of red meat, processed foods, and sugary beverages—significantly increases the risk of CKD progression, with a hazard ratio of 2.1. This finding is consistent with the hypothesis that diets high in processed and nutrient-poor foods can exacerbate the decline in kidney function by promoting inflammation and oxidative stress, as evidenced by elevated C-reactive protein levels among followers of the Western diet.[8]

Conversely, the Mediterranean and plant-based diets are associated with a protective effect against CKD progression. These diets, rich in fruits, vegetables, whole grains, and healthy fats, have been linked to reduced inflammation and improved endothelial function, which may explain their beneficial impact on kidney health.[9] Our findings align with the growing body of evidence suggesting that these dietary patterns can ameliorate the progression of CKD, potentially through mechanisms related to improved blood pressure control, reduced insulin resistance, and a favorable lipid profile.

The DASH diet, while showing a trend towards risk reduction in CKD progression, did not reach statistical significance in our study. This outcome might be due to the relatively small sample size or the degree of adherence among participants. However, the direction of the effect suggests that further research in larger cohorts could clarify the potential benefits of the DASH diet for individuals with CKD.

Our longitudinal analysis of kidney function provides compelling evidence that dietary choices directly impact the trajectory of CKD. The significant decline in GFR among individuals following a Western diet underscores the urgency of dietary interventions in this population. In contrast, the less pronounced decline in GFR for those adhering to Mediterranean and plant-based diets highlights the potential of nutritional therapy in CKD management and prevention.

The findings from our study resonate with the conclusions drawn by similar research endeavors. For instance, a study by Huang et al. found that a higher adherence to a Mediterranean diet was associated with a lower risk of CKD progression, echoing our observations regarding the protective effects of the Mediterranean diet.[10] Similarly, Emily A Hu et al. reported that plant-based diets were linked to slower CKD progression, further supporting our results.[11]

However, our study advances the discourse by offering a comparative analysis across multiple dietary patterns within the same cohort, thereby providing a more nuanced understanding of how specific dietary choices can influence CKD outcomes. Moreover, our investigation into biomarkers of inflammation and oxidative stress furnishes biological plausibility to the observed dietary effects, an aspect that has been less explored in previous studies.

While our study contributes valuable insights, it is not without limitations. The reliance on self-reported dietary data may introduce recall bias, and the observational nature of the study precludes causal inferences. Furthermore, our sample size, though adequate for detecting significant associations, might have limited the power to fully explore the effects of the DASH diet.

Future research should aim to validate these findings through randomized controlled trials that can establish causality and explore the mechanisms underlying the observed associations. Additionally, investigations into the role of specific nutrients or food components within these dietary patterns could offer more targeted recommendations for individuals with CKD.

V. Conclusion

Our study underscores the significant impact of dietary patterns on CKD progression, highlighting the detrimental effects of a Western diet and the protective benefits of Mediterranean and plant-based diets. These findings advocate for the integration of nutritional counseling into the standard of care for CKD patients, emphasizing the importance of dietary choices in managing and potentially mitigating the progression of chronic kidney disease.

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