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(Review Article)

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Role of protein in non-dialysis kidney patients: A comprehensive review

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Abstract

This review delves into the complex relationship between protein metabolism and Chronic Kidney Disease (CKD), with a particular focus on non-dialysis patients. It examines the progressive nature of CKD and its associated complications, emphasizing the critical role of protein in dietary management to achieve optimal patient outcomes. The discussion covers various aspects, including protein-rich foods, diverse protein sources and the potential advantages of protein supplementation in maintaining muscle mass and overall well-being. By analyzing alterations in protein metabolism unique to CKD, this review explores their influence on disease progression and nitrogen balance. It further highlights the necessity of careful intake of protein to meet nutritional needs while preserving kidney function. This article underscores the essential role of healthcare professionals in developing personalized dietary strategies that align with the specific stages of CKD and the patient's overall health status.

Keywords: Chronic Kidney Disease; Dietary Management; Nitrogen Balance; Non-Dialysis Patients; Protein Metabolism; Supplementation

1 Introduction

Non-dialysis chronic kidney disease (CKD) represents a significant public health concern globally due to its high prevalence and associated morbidity and mortality. CKD is characterized by a gradual loss of kidney function over time, often progressing to end-stage renal disease (ESRD) if left untreated [1]. While dialysis and kidney transplantation are common treatment modalities for ESRD, a considerable proportion of CKD patients do not require renal replacement therapy and are managed conservatively without dialysis [2]. According to the Global Burden of Disease study, 2020, CKD affects approximately 9-13% of the global population, with substantial regional variations in prevalence rates. As per recent data, the prevalence of CKD in India has been estimated to be 17.2% approximately, with stage 3 CKD showing the highest rates, particularly in rural areas. Studies suggest that the prevalence of non-dialysis CKD is even higher, making up a substantial portion of the total CKD cases in India [3].

Numerous risk factors contribute to the development and progression of CKD, including hypertension, diabetes mellitus, obesity, smoking and genetic predisposition [4]. These risk factors increase the likelihood of developing CKD and accelerate its progression to more advanced stages. Moreover, CKD is associated with an increased risk of cardiovascular disease, infections, cognitive impairment and premature mortality, further emphasizing the need for early detection and management of the disease [5]. Another study highlighted those individuals with CKD who exhibit abnormalities in vascular structure and function thereby exacerbating their cardiovascular vulnerability. Additionally, this study also elucidates that CKD compromises the immune system rendering patients more susceptible to infections. This susceptibility is predominant in patients undertaking dialysis or kidney transplant procedures [6]. Furthermore, few symptoms such as inflammation, oxidative stress and vascular dysfunction which are commonly associated with

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CKD patients can often contribute to cognitive decline and an increased prevalence of dementia [7]. CKD substantially reduces life expectancy thereby accelerating the mortality rates when kidney functions decline significantly. Leading causes of mortality in CKD patients include vascular complications, severe infections and progression to ESRD. These findings emphasize the absolute necessity for early detection and proactive management strategies to mitigate the grave health risks associated with CKD [6, 8].

Management of non-dialysis CKD primarily focuses on controlling underlying risk factors, such as high blood pressure and elevated blood glucose levels, optimizing medication therapy and implementing lifestyle modifications [9]. Lifestyle modification encompasses dietary adjustments, including sodium and protein restriction to reduce renal strain and optimize metabolic parameters. Regular physical exercise, cessation of smoking and weight management are integral components of CKD management to promote cardiovascular health and overall well-being [10]. Regular monitoring of kidney function through estimated glomerular filtration rate (EGFR) and urinary albumin excretion is essential for assessing the disease progression and taking important decisions regarding the next step of treatments. Protein restriction, in particular, has been widely studied for its impact on slowing the decline in kidney function and managing proteinuria, a hallmark of CKD. High dietary protein intake increases the kidneys' workload due to the enhanced filtration and excretion of nitrogenous waste products and if prolonged, this enhances the probability of kidney damage by many folds. Therefore, reducing protein intake can help minimize this burden, potentially slowing the progression of kidney dysfunction [11].

Several studies have demonstrated that protein restriction in CKD patients can lead to reduced albuminuria and improvements in kidney function. This is believed to occur through several mechanisms, such as reducing glomerular hyperfiltration, lowering inflammation and decreasing the activation of pathways that lead to fibrosis. Additionally, restricting protein intake has been shown to help in managing nitrogen balance, which is crucial in preventing the accumulation of toxic metabolic by-products in the body [12].

1.1 Classifications of chronic kidney disease (CKD)

CKD is a prevalent and progressive condition characterized by the gradual loss of kidney function over time. CKD affects millions of individuals worldwide and is associated with significant morbidity and mortality. The disease is classified into different stages based on the EGFR (Table 1) and the presence of kidney damage, with stages ranging from mild (stage 1) to severe (stage 5) renal impairment. CKD can result from various etiologies, including hypertension, diabetes mellitus, glomerulonephritis and polycystic kidney disease and many more [5]. Early detection and management of CKD is crucial for preventing disease progression and reducing the risk of complications such as cardiovascular disease and renal failure. Physiologically, CKD involves hemodynamic changes, inflammation, oxidative stress and fibrosis, leading to a decline in adrenal function. Clinical manifestations range from asymptomatic in early stages to uremic symptoms and complications such as anemia and cardiovascular disease etc. Advanced CKD diagnosis relies on laboratory tests, imaging studies and renal biopsy, with management focusing on blood pressure control, glycemic management and lifestyle modifications. Pharmacological interventions include renin angiotensin aldosterone system inhibitors, diuretics and many other agents. Prognosis varies based on CKD stage and comorbidities with advanced CKD associated with risk of adverse outcomes and mortality. Ongoing research aims to improve understanding and treatment modalities for CKD, emphasizing the importance of early detection and holistic management approaches to mitigate its burden and enhance patient outcomes [13].

Table 1 Different Stages of CKD [13]

Stages of Chronic Kidney Disease	**GFR (mL/min)**
Stage 1: Normal	90 or higher
Stage 2: Mild loss	89-60
Stage 3a: Mild to moderate loss	59-45
Stage 3b: Moderate to severe loss	44-30
Stage 4: Severe loss	29-15
Stage 5: Kidney failure known as ESRD	Less than 15

1.2 Overview of protein metabolism in CKD patients

Protein metabolism is regulated intricately in individuals with CKD due to alterations in renal function and hormonal imbalances. Generally, dietary proteins are broken down into amino acids, absorbed in the intestine and transported to various tissues to synthesize proteins essential for the growth, repair and maintenance of body functions [14]. However, impaired renal clearance leads to the accumulation of uremic toxins and disrupts the equilibrium between protein synthesis and degradation in patients with CKD [15]. It is also noted that this disruption contributes to systemic complications, including cardiovascular disease, anemia, bone mineral disorders and electrolyte imbalances, all of which further aggravate renal dysfunction and decline in overall health [15].

Protein metabolism is a dynamic and intricate process essential for maintaining life and regulating various physiological functions. Proteins, composed of amino acids, serve as the building blocks of tissues, enzymes, hormones and numerous other biological molecules critical for cellular structure and function [16].

Protein metabolism in CKD patients is a complex process influenced by various factors related to impaired renal function and metabolic abnormalities. Firstly, CKD patients often undergo dietary protein restriction as part of their management to alleviate uremic symptoms and slow disease progression [17]. This reduction in protein intake has significant implications on maintaining nitrogen balance, muscle mass preservation and balancing overall nutritional status.

Secondly, alterations in gastrointestinal function leading to disruption in protein digestion and absorption is also observed in patients suffering from CKD. A study has highlighted few alterations such as changes in gut microbiota composition, gastrointestinal motility and digestive enzyme activity in their study and stated that these changes can impair the breakdown and absorption of dietary proteins, leading to decreased nutrient uptake and potential malnutrition [14]. Moreover, the accumulation of uremic toxins in CKD patients further complicates protein metabolism. Uremic toxins, such as indoxyl sulfate and p-cresyl sulfate, inhibit protein synthesis, promote protein degradation and impair mitochondrial function, contributing to muscle wasting and metabolic dysfunction [19]. In addition to uremic toxins, CKD patients often exhibit insulin resistance, which exacerbates metabolic abnormalities in terms of inhibition of protein synthesis and promotion of protein breakdown, thus leading to muscle wasting in CKD patients [20]. A separate study has also highlighted enhanced catabolism of protein leading to utilization of muscle proteins for energy production and gluconeogenesis in patients suffering from CKD. This phenomenon has naturally contributed to muscle wasting, weakness and malnutrition within the said patients, thereby compromising their overall health and well-being [21].

Additionally, proteinuria, the presence of excess protein in the urine, intensifies protein deficiency and malnutrition in patients with CKD. Loss of protein through the urine also contributes to muscle wasting, impaired renal function and metabolic abnormalities, thus hindering the management of CKD-related complications [22]. The process of protein metabolism in patients with CKD is influenced by multiple factors, including dietary protein restriction, alterations in gastrointestinal function, accumulation of uremic toxins, insulin resistance, increased protein catabolism and proteinuria. These metabolic abnormalities emphasize the importance of implementing comprehensive management strategies aiming at optimized nutritional intake, preserving lean body mass and improving clinical outcomes in patients with CKD [23]. Patients who have lost their protein reserves may exhibit symptoms such as low body weight, decreased mid-arm circumference, reduced triceps skinfold thickness and diminished muscle mass. Additionally, they may experience reductions in serum albumin and serum cholesterol levels, indicating poor nutritional status. Such patients are at a significantly higher risk of mortality as their protein reserves become critically depleted.

1.3 Complications of CKD

CKD can result in a range of complications that affect various physiological functions in the body. One of these complications is elevated blood pressure (BP) level, since the kidney plays a crucial role in regulating BP. This elevated BP may lead to further kidney damage [24]. Additionally, CKD can lead to retention of fluid as can be manifested as swelling in the legs, ankles and face known as pulmonary edema owing to reduced kidney output. Electrolyte imbalances are another common complication of CKD. These imbalances can also interfere with the proper functioning of neurons and muscles. In advanced stages, CKD can lead to uremic syndrome characterized by accumulation of waste products in the blood. Symptoms of this syndrome include nausea, vomiting, itching and cognitive impairment etc. [25].

1.4 Protein-energy wasting syndrome

Protein-energy wasting syndrome (PEWS) is a multifactorial and prevalent complication observed in patients with CKD, particularly those undergoing dialysis or in advanced stages of the disease. PEWS is characterized by the progressive loss of muscle mass, malnutrition and altered metabolism, leading to impaired physical function, increased morbidity and mortality among CKD patients [26]. According to Ikizler (2007), one of the primary contributors to PEWS in CKD patients is the dysregulation of protein metabolism, resulting from a combination of factors such as inflammation, hormonal imbalances, metabolic acidosis and inadequate nutrient intake.

Additionally, the chronic inflammation commonly observed in CKD patients plays a pivotal role in the pathogenesis of PEWS. Inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), induce muscle protein breakdown and inhibit protein synthesis, contributing to the development of malnutrition and cachexia [27]. Moreover, hormonal abnormalities, including insulin resistance and decreased levels of anabolic hormones such as insulin-like growth factor 1 (IGF-1) and testosterone, further exacerbate muscle wasting and metabolic derangements in CKD patients [28]. These hormonal disturbances disrupt the balance between protein synthesis and degradation, leading to the progressive loss of lean body mass and functional decline. The consequences of PEWS extend beyond nutritional deficiencies, impacting overall health outcomes and quality of life in CKD patients. Muscle wasting and malnutrition are associated with an increased risk of hospitalization, infections, cardiovascular events and mortality in this population [29]. Furthermore, PEWS contributes to the vicious cycle of CKD progression by impairing physical function and exacerbating comorbidities, thereby further compromising renal function and overall prognosis [29].

Therefore, protein-energy wasting syndrome represents a significant clinical challenge in the management of CKD patients, necessitating comprehensive nutritional and metabolic interventions to mitigate its deleterious effects. Addressing the underlying mechanisms driving PEWS, including inflammation, hormonal imbalances and metabolic derangements is essential for improving outcomes and quality of life in CKD patients [28, 29].

1.5 Therapeutic strategies targeting protein metabolism

Management of protein metabolism abnormalities in CKD involves a multifaceted approach aimed at mitigating uremic toxicity, inflammation and hormonal imbalances. Dietary protein restriction, especially of high biological value proteins, is recommended to reduce nitrogenous waste production and preserve renal function [30]. Additionally, emphasizing the importance of individualized dietary plans and regular monitoring under medical supervision can optimize therapeutic outcomes for preserving renal function. Protein restriction is a cornerstone of dietary management in patients with CKD. It aims to alleviate the burden on the kidneys by reducing the production of nitrogenous waste products and slowing the progression of renal dysfunction. However, the rationale behind protein restriction in CKD patients is multifaceted and warrants detailed exploration. One of the primary objectives of protein restriction in CKD patients is to mitigate the decline in renal function. High dietary protein intake imposes a substantial workload on the kidneys, leading to glomerular hyperfiltration, increased intraglomerular pressure and subsequent renal injury [30]. By reducing protein intake, especially of high biological value proteins, such as meat and dairy products, proteinuria and glomerular hypertension can be attenuated, thereby preserving renal function and delaying the need for renal replacement therapy [31]. It is essential to acknowledge that protein restriction in CKD patients should be individualized based on several factors, including the stage of CKD, nutritional status, dietary preferences and comorbidities. While moderate protein restriction (0.6-0.8 g/kg/day) is generally recommended for CKD patients without significant proteinuria or malnutrition, more stringent protein restriction (<0.6 g/kg/day) may be warranted in advanced CKD stages or the presence of uremic symptoms [32]. Moreover, close monitoring of nutritional status, serum albumin levels and dietary adherence is imperative to prevent malnutrition and optimize clinical outcomes in CKD patients following a protein-restricted diet.

1.6 Management of CKD

Protein restriction also plays a crucial role in managing uremic toxicity in CKD patients. Uremic toxins, such as urea, creatinine and indoxyl sulfate, accumulate in the bloodstream as renal function declines and contribute to the pathogenesis of uremic symptoms, such as fatigue, anorexia and pruritus. Protein consumption can be decreased to lessen the generation and buildup of uremic toxins, which will relieve uremic symptoms and enhance the quality of life for CKD patients [33].

Another rationale for protein restriction in CKD patients is the prevention and management of metabolic acidosis. Excessive dietary protein intake results in the generation of acidic metabolites, such as sulfuric and phosphoric acids, which must be excreted by the kidneys to maintain acid-base balance [34]. However, in the setting of CKD, impaired renal acid excretion leads to metabolic acidosis, which can exacerbate renal injury, bone demineralization and muscle wasting. Therefore, reducing protein intake can help mitigate metabolic acidosis and its adverse effects on renal and musculoskeletal health [35].

A fundamental aspect of CKD management involves the regulation of dietary protein intake and the modulation of protein metabolism. Proteins play a crucial role in maintaining overall health and are involved in various physiological processes, including tissue repair, immune function and hormone production. However, in the context of CKD, disturbances in protein metabolism can have detrimental effects on kidney function and disease progression [36]. Understanding the role of proteins in CKD is essential for optimizing nutritional therapy and improving clinical outcomes in affected individuals. Moreover, proteinuria, the presence of excess protein in the urine, is a common complication of CKD and is associated with an increased risk of kidney damage and cardiovascular events [37]. Therefore, elucidating the mechanisms underlying proteinuria and its impact on renal function is critical for developing targeted therapeutic interventions aimed at preserving kidney function and mitigating disease progression.

The quality of dietary protein is as crucial as the quantity for CKD patients. High-quality protein sources, such as lean meats, poultry, fish, eggs and dairy products, provide essential amino acids and nutrients without excessive phosphorus and potassium content, which can be detrimental to renal function [38]. Plant-based protein sources, including legumes, tofu and nuts, are also valuable options for CKD patients due to their lower phosphorus and potassium content [39].

1.7 Impact of protein-rich foods on CKD progression

Emerging evidence suggests that the type and source of dietary protein may influence the progression of CKD. A link has been established between consumption of Mediterranean-style diets rich in plant-based proteins, unsaturated fats and fiber and reduced risk of pathogenesis of CKD and cardiovascular events [39]. This elucidates the importance of dietary interventions tailored to CKD patients emphasizing the inclusion of healthy protein and fiber sources to mitigate disease progression and promote cardiovascular health. Conversely, diets high in red and processed meat have been linked to an increased risk of progression to CKD and eventual mortality. Therefore, dietary counseling should pay attention to the importance of choosing protein sources that promote renal health and overall well-being in CKD patients [40].

Dietary protein intake is a critical aspect of managing CKD, as it can impact disease progression and outcomes. Protein restriction is often recommended to slow the decline in kidney function and reduce proteinuria in CKD patients [41]. However, it is essential to ensure an adequate intake of high-quality protein to meet nutritional needs and prevent malnutrition in this population [30]. The quality of dietary protein is equally crucial as its quantity in CKD patients. High-quality protein sources, such as lean meats, poultry, fish, eggs and dairy products, provide essential amino acids while minimizing the intake of phosphorus and potassium, which can accumulate in the bloodstream in CKD [38]. Various researches and studies indicate that plant-based proteins like tempeh and tofu offer high-quality protein low in phosphorus and potassium. These provide essential amino acids necessary for muscle maintenance and repair while offering added fiber benefits and various vitamins and minerals. Lentils and chickpeas both legumes are rich sources of protein and fiber making them excellent choices for individuals with CKD. On the other hand, excessive consumption of red and processed meats, which are high in phosphorus and sodium, may exacerbate renal dysfunction and cardiovascular risk [42]. Therefore, dietary counseling should emphasize the importance of selecting protein sources that are low in phosphorus and potassium to support renal health in CKD patients.

Optimal protein consumption is a cornerstone in the management of CKD patients. Dietary protein intake recommendations are tailored based on the stage of CKD, presence of proteinuria, nutritional status and comorbidities. Guidelines suggest a moderate protein intake ranging from 0.6 to 0.8 grams per kilogram of body weight per day (g/kg/day) for CKD patients with preserved kidney function [32]. However, protein restriction may be warranted in advanced CKD stages or in the presence of significant proteinuria to reduce the risk of uremic complications and slow disease progression [30].

The relationship between protein consumption and CKD progression is complex and multifactorial. While protein restriction may slow the decline in kidney function and reduce proteinuria in CKD patients, inadequate protein intake can lead to malnutrition, muscle wasting and impaired immune function [30]. Moreover, recent evidence from Banerjee et al. (2021) suggests that the type and source of dietary protein may influence renal outcomes, with plant-based proteins associated with a lower risk of CKD progression and cardiovascular events compared to animal-based proteins. Therefore, individualized dietary counseling by registered dietitians or nephrologists is essential to optimize protein intake and minimize adverse outcomes in CKD patients [43].

Muscle mass and strength play pivotal roles in managing health and well-being of individuals with CKD. Progressive loss of muscle mass, termed as sarcopenia, is a prevalent complication in CKD patients and is closely linked to adverse outcomes. A study has demonstrated that reduced muscle mass is significantly associated with faster progression of CKD, emphasizing the importance of maintaining muscle health in individuals with this condition [44]. The study suggested that the loss of muscle mass could be attributed to metabolic disturbances commonly seen in CKD, such as chronic inflammation, insulin resistance and impaired protein metabolism, which collectively contribute to muscle catabolism. Clinical trials conducted as part of their research further confirmed that patients with lower muscle mass exhibited worse renal outcomes and a more rapid decline in kidney function. These findings underscore the need for targeted interventions aimed at preserving muscle mass through tailored nutrition and exercise strategies to mitigate CKD progression [44].

Moreover, diminished muscle strength in CKD patients contributes to impaired functional status, increased risk of falls and reduced quality of life [45]. The mechanisms underlying muscle wasting in CKD are multifaceted, involving inflammation, oxidative stress, hormonal disturbances and protein-energy wasting [27, 46]. Nutritional interventions aimed at preserving muscle mass, particularly adequate protein intake with essential amino acids, are crucial for mitigating muscle loss and optimizing outcomes [18]. Furthermore, exercise, including resistance training, has emerged as a promising strategy to improve muscle mass, strength and functional capacity in CKD patients [47]. Integrating regular assessments of muscle mass and strength into clinical practice is essential for identifying individuals at risk of sarcopenia and implementing targeted interventions to enhance muscle health and overall well-being in CKD.

1.8 Protein supplementation in CKD patients

Protein supplements are commonly used by CKD patients to augment dietary protein intake, especially in cases of malnutrition or inadequate oral intake [30]. However, the use of protein supplements in CKD requires careful consideration, as excessive protein intake can exacerbate renal impairment and metabolic acidosis [18]. Before recommending protein supplements to CKD patients, healthcare providers should assess individual nutritional needs, kidney function and comorbidities to determine the appropriateness and safety of supplementation [30]. Close monitoring of serum creatinine, blood urea nitrogen and electrolyte levels is essential to prevent complications associated with excessive protein intake, such as hyperkalemia and uremia [14].

1.9 Types of protein supplementation

Protein supplements come in various forms (Table 2), including powders, shakes, bars and liquid formulations, with whey, casein, soy and pea protein being the most popular options [38]. Whey protein, in particular, has gained attention for its high biological value and potential benefits for muscle preservation and growth in CKD patients [48].

Table 2 Types of Protein-Rich Food supplements for CKD patients

Category of Food Supplements	Key Features of the Food Supplements	Names of the Food Supplements available in the market	References
Kidney-Specific Nutrition Drinks	Designed to provide high protein while maintaining low potassium, phosphorus, and sodium. Beneficial for patients with poor appetite or increased protein needs. Often fortified with vitamins & minerals for CKD patients.	Nepro, Suplena, NovaSource Renal, Nutren Renal, ReGen	[49, 50]
Protein Isolates	High-quality whey, soy, or casein protein isolates. Provide essential amino acids needed for muscle maintenance. Suitable for customized protein intake without excess electrolytes.	Whey Protein Isolate, Soy Protein Isolate, Casein Protein Isolate	[51, 52]

Renal-Specific Supplements	Specially formulated with higher protein and energy but low potassium and phosphorus. Helps prevent muscle wasting without worsening CKD complications. Some include ketoanalogues to reduce nitrogen load.	Renapro, Aminess N, Ketoanalogues (Ketosteril)	[53, 54]
Essential Amino Acid (EAA) Supplements	Provide essential amino acids without excessive nitrogen load. Help maintain muscle mass while reducing uremic toxin buildup. Often used in low-protein diets (LPD) for CKD patients.	Renapro Shot, AminoRen, Nutramino	[44 , 52]
Keto-Analogues of Essential Amino Acids	Provide precursors of essential amino acids without adding nitrogen load. Help reduce uremic toxins and slow CKD progression. Used in very low-protein diets (VLPD).	Ketosteril, Ketoalfa, Alpha-Ketoanalogue Tablets	[44 , 52]
Collagen Protein Supplements	Easily digestible and supports muscle and joint health. Low in phosphorus & potassium, making it kidney-friendly. Helps with wound healing in CKD patients.	ProT Gold, Renalpro Collagen	[55, 56]
Plant-Based Protein Powders	Alternative to animal protein with a lower acid load on kidneys. Common sources: Pea, rice, hemp, and soy protein. Rich in fiber & phytonutrients beneficial for CKD patients.	Orgain Organic Plant-Based Protein, Garden of Life Raw Protein	[57, 58]

Dosage and duration vary depending on the condition. In case of severe muscle loss, the dosage is changed. These supplements are given to patients on dialysis due to severe proteinuria and muscle loss **[59]**.

2 Conclusion

In conclusion, the management of protein intake in CKD patients is a multifaceted endeavor aimed at preserving renal function, managing uremic toxicity and optimizing overall nutritional status. The intricate balance between protein restriction and adequate nutrition poses a significant challenge for healthcare providers, requiring individualized dietary counseling and close monitoring of the clinical parameters. Through this comprehensive review of literature, it is evident that protein restriction plays a pivotal role in slowing the progression of CKD, minimizing uremic symptoms and preventing complications associated with metabolic acidosis. However, the benefits of protein restriction must be weighed against the risks of malnutrition, muscle wasting and impaired immune function, particularly in CKD patients with advanced disease or significant proteinuria. Furthermore, the type and quality of dietary protein sources are crucial considerations in CKD management, with an emphasis on selecting protein-rich foods that are low in phosphorus and potassium to support renal health. Plant-based proteins, such as legumes, tofu and nuts, offer viable alternatives to animal-based proteins and may confer additional benefits in terms of cardiovascular health and CKD progression.

In conclusion, a holistic approach to protein management in CKD patients, incorporating diet counselling, pharmacological interventions and regular monitoring of nutritional status is essential to optimize clinical outcomes and to improve the overall quality of life in this vulnerable population. Moving forward, further research is needed on target protein intake level, dietary interventions and therapeutic strategies for patients across different stages of CKD. By addressing this complex interplay among protein metabolism, renal function and nutritional status, healthcare providers may become able to make a significant mark in establishing guidelines for patients with CKD, thus reducing the global burden of kidney disease.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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