IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DIETARY PHOSPHATE MANAGEMENT IN DIALYSIS AND CKD PATIENTS -A REVIEW

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ABSTRACT:

Managing phosphorus intake is vital in addressing mineral and bone disorders associated with chronic kidney disease. The phosphorus pyramid seems like a practical and visually informative tool for both patients and healthcare professionals. The emphasis on dietary control, plant-based sources, cooking methods, and awareness of additives aligns with the complexity of addressing phosphorus retention in real-life situations. Education indeed plays a key role in empowering individuals to make informed nutritional choices for integrated CKD-MBD management.

INTRODUCTION:

Phosphorus restriction in treating mineral and bone disorders in chronic kidney disease is one of the crucial roles. (CKD-MBD). CKD-MBD significantly impacts the survival and quality of life of renal patients, posing a considerable burden on healthcare costs[1]. Serum phosphorus elevation serves as a primary trigger for CKD-MBD, highlighting the importance of dietary control. Phosphorus, obtained both naturally and as a food additive, presents absorption variations based on its source[2]. While inorganic phosphorus absorption is influenced by calcitriol levels, plant-origin phytates have lower bioavailability[3]. The challenge of implementing dietary phosphorus control in real-life situations underscores the necessity for information, education, and counselling to integrate dietary interventions effectively into the therapeutic approach for CKD-MBD.

PHOSPHORUS:

Phosphorus is crucial for bone formation, acid–base balance, and energy production in the body[4]. In chronic kidney disease (CKD), the declining renal function impairs the kidneys' ability to excrete excess phosphorus, leading to disrupted phosphorus homeostasis[5]. The 2020 NKF guidelines recommend maintaining serum phosphorus levels within normal ranges (3.4–4.5 mg/dL) and restricting dietary phosphate in cases of hyperphosphatemia[5,6], which can result in serious consequences such as renal osteodystrophy, cardiovascular and soft tissue calcification, secondary hyperthyroidism, cardiac disease, and increased mortality in end-stage renal disease (ESRD) patients[7].

Phosphorus requirements vary based on the stage of renal failure, emphasizing the importance of not restricting phosphorus intake to the point of malnutrition, particularly for hemodialysis (HD) patients[8]. Nephrologists often recommend a phosphorus restriction of 800–1000 mg/d, although studies demonstrating the efficacy and outcomes of this level of restriction in CKD patients are lacking[5].

Dietary phosphorus comes from three sources: organic phosphorus from plant foods (bioavailability 20–40%), organic phosphorus from animal protein (bioavailability 40–60%), and inorganic phosphorus found in additives and processed foods (bioavailability ≈100%)[9]. Phytates in plant foods have lower bioavailability due to the absence of phytase, the enzyme that degrades phytates in humans[9]. Inorganic phosphorus from additives is almost entirely absorbed, contributing significantly to daily phosphorus intake. Choosing foods with lower bioavailability and without phosphate additives is recommended[10]. Studies suggest that vegetarian diets may result in lower phosphate levels compared to animal-based diets in CKD patients[11].

Dairy products, rich in phosphorus, require careful consideration. Higher dietary phosphorus intake and a higher phosphorus to protein ratio have been associated with increased mortality risk in HD patients. Opting for nutrient-dense sources with only organic phosphorus is encouraged, as opposed to processed foods with phosphate additives that are often high in sodium[12].

PHOSPHORUS METABOLISM IN THE BODY:

Daily phosphorus ingestion, primarily absorbed in the gastrointestinal tract, undergoes regulation involving phosphaturic hormones. About 29% of body phosphorus resides in bones, while less than 1% is quantified in clinical blood tests. Intracellularly, 70% of phosphorus is interchangeable[13].

In individuals with normal renal function, phosphorus excretion is facilitated by phosphatonins, such as parathyroid hormone (PTH) and Fibroblast Growth Factor 23 (FGF23). In renal impairment, compensatory mechanisms initially maintain normal serum phosphorus levels through decreased tubular reabsorption[14]. However, as renal function declines, a positive phosphorus balance occurs.

FGF23, a phosphatonin released by bone, plays a crucial role in promoting phosphaturia and inhibiting vitamin D activation. This establishes an osteo-renal axis, challenging traditional paradigms in understanding phosphorus balance control[15]. The intricate interplay of hormones like PTH and FGF23 highlights the complexity of phosphorus regulation in the body, particularly in the context of renal impairment[15].

Which strategies may reduce dietary phosphorus intake?

Dietary protein restriction:

The connection between protein and phosphorus intake is well-established, with an average of 12–14 mg of phosphorus per gram of protein in a mixed diet[16,17]. In non-dialysis chronic kidney disease (CKD) patients, restricting protein intake is linked to a lower phosphorus intake. Protein-restricted diets are commonly employed during the "conservative" management of advanced CKD, aiding in the reduction of dietary phosphorus.

However, achieving phosphorus restriction in dialysis patients is challenging due to their high protein requirements. As a result, alternative strategies are necessary for dialysis patients, as described further below.

Increasing the intake of foods with low phosphorus content and /or low phosphorus bioavailability:

Analysing phosphorus content in various food groups reveals that nuts, hard cheeses, egg yolk, meat, poultry, and fish have the highest phosphorus load (mg/100 g edible part). Expressing phosphorus content as mg per gram of protein (mg/g protein) helps identify foods with a more favourable phosphorus to protein ratio, assuming an upper limit of 12 mg/g[18].

Considering the net intestinal absorption of phosphorus, plant-origin phosphorus generally has lower absorption compared to animal-origin phosphorus from meat, fish, poultry, and dairy products. Notably, added phosphorus, especially in the form of phosphoric acid found in soft drinks like cola, is almost completely absorbed[19]. The variability in phosphorus-containing preservatives adds complexity, with some sodas containing phosphorus-based additives while others do not.

BOILING FOODS:

Boiling food causes demineralization, resulting in reduced phosphorus, sodium, potassium, and calcium content in both plant and animal-derived products. The extent of mineral loss depends on factors such as the amount of boiling water used, piece size, cooking time, and the absence of peels for plant-based items. Jones et al. reported significant phosphorus reduction after boiling, with a 51% decrease for vegetables, 48% for legumes, and 38% for meat[20].

Crucially, boiling achieves phosphorus reduction while causing negligible nitrogen loss[21], leading to a more favourable phosphorus to protein ratio. This underscores the potential of boiling as a cooking method to address phosphorus content, particularly in the context of dietary management for conditions such as chronic kidney disease.

Identifying and avoiding phosphate additives:

Phosphorus is a major component in additives like phosphoric acid, phosphates, and polyphosphates used in industrial food processing for preservation, colour enhancement, flavour improvement, and moisture retention. These additives, added at various stages of food production, processing, and storage, contribute a considerable amount of phosphorus compared to natural sources[22]. Regulations mandate reporting the presence of phosphorus-containing additives on food labels, but specific amounts are often unavailable in most databases[23].

In Europe, these additives may be listed by their full name or an abbreviation (as the "E" series). This extra phosphorus, termed "hidden phosphorus," is not always accounted for in common databases and food composition tables[22,24]. Studies suggest that processed foods may introduce an additional phosphorus burden of 700–800 mg per day[25,26], potentially impacting phosphate binder therapy, which typically removes 200–300 mg of phosphorus daily[27]. Educational interventions on avoiding foods with phosphorus-containing additives have shown a positive impact on reducing serum phosphorus levels[28].

Nutritional counselling:

Patient education is crucial in managing nutritional care, especially for renal patients who may be unaware of hidden phosphorus in food and drinks[29]. Knowledge about phosphorus tends to be lower than that of other nutrients, as observed in both patients and healthcare professionals[30].

Educational strategies, such as the "traffic light" labelling scheme, motivational interviewing, and programs like the "Phosphate Education Program," aim to reduce serum phosphorus[31]. A multidisciplinary approach involving nephrologists, renal dietitians, nurses, and active patient and caregiver involvement is essential[32,33]. Renal dietitians play a pivotal role, not just advising on restrictions but providing solutions and alternatives in dietary planning.

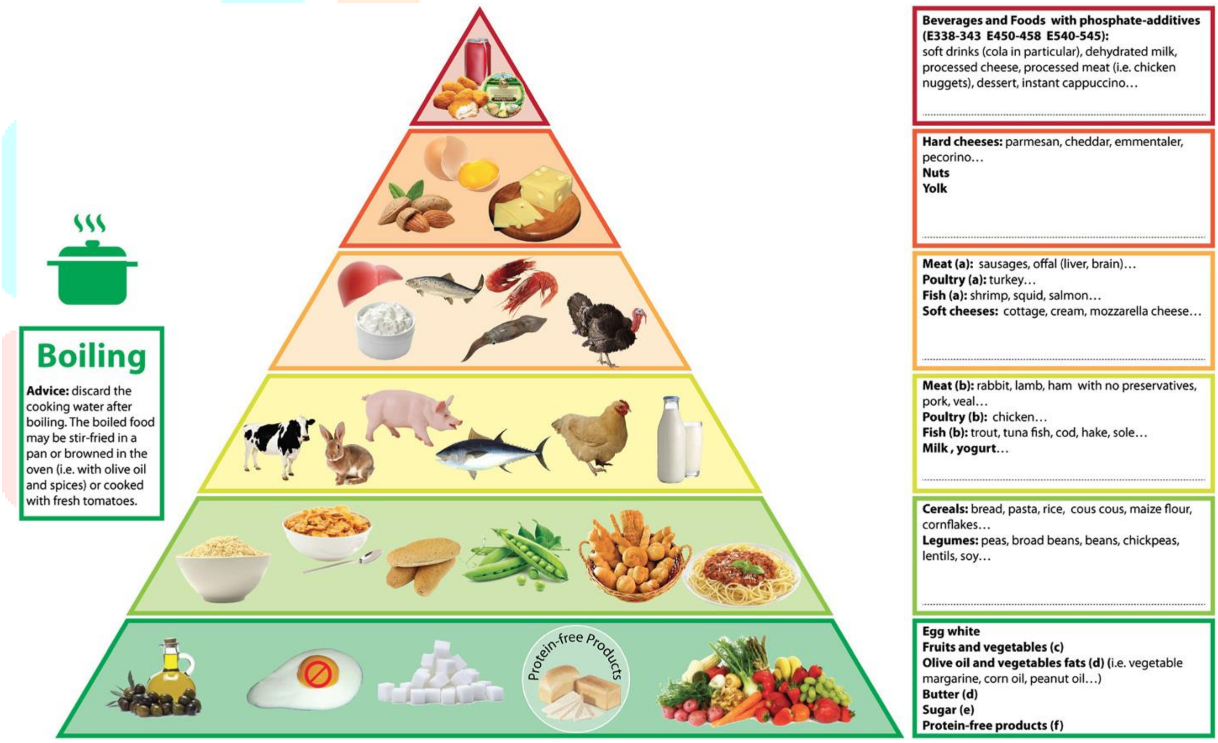
The dietitian's interaction style is crucial for patient adherence, fostering understanding and non-judgmental relationships[34,35]. Accessible resources, including online brochures, support CKD patients in making informed food choices[36,37]. While having a dietitian in every nephrology unit is ideal, simple, and effective tools can be valuable for nurse-led educational programs targeting phosphorus reduction.

Food pyramids:

The food pyramid has been a widely used visual tool in nutritional education strategies[38,40] since the late 70s, with various versions introduced globally[42]. Originally designed to emphasize nutrient adequacy and moderation, it evolved to incorporate over 25 adapted versions from different countries and organizations, becoming more image-based for enhanced clarity[47-53].

Notable examples include the Mediterranean diet pyramid, which visually guides daily, weekly, and less frequent consumption of food groups[54]. The Mediterranean diet pyramid, contributing to the diet's global popularity, has been adapted to reflect dietary changes in the region[55].

In 2013, the Italian Ministry of Health promoted the development of an Italian food pyramid for a healthy lifestyle, featuring both weekly and daily versions. In this context, the "Phosphorus Pyramid" was created, serving as a specialized tool for educating about phosphorus intake in the context of chronic kidney disease and mineral and bone disorders.



The "Phosphorus Pyramid" categorizes foods across six levels based on phosphorus content, phosphorus to protein ratio, and phosphorus bioavailability. Each level is distinguished by a coloured edge, ranging from green (unrestricted intake) to red (avoid as much as possible). The key considerations for different food groups include:

a) Foods with unfavourable phosphorus to protein ratio (>12 mg/g)

b) Foods with favourable phosphorus to protein ratio (<12 mg/g)

c) Caution with fruits and vegetables in dialysis patients to manage potassium intake

d) Limiting fats in overweight/obese patients to control energy intake

e) Avoiding sugar in diabetic or obese patients

f) Protein-free products for non-dialysis patients requiring protein restriction but high energy intake.

This specialized pyramid provides targeted guidance for individuals, especially those with chronic kidney disease, addressing both phosphorus and overall nutritional concerns.

The phosphorus pyramid:

The Phosphorus Pyramid serves as a visual tool based on current nutritional databases and literature, presenting the phosphate load of various foods. It aims to assist viewers in identifying foods with lower or higher effective phosphate loads without requiring memorization[16,20-22,24,50].

The pyramid comprises six levels, categorized by phosphorus content, phosphorus to protein ratio, and phosphorus bioavailability. Each level is color-coded from green to red, indicating recommended intake frequency. Key details for the first three levels include:

Base (Green Edge): Contains foods with very low phosphorus content or bioavailability, including sugar, olive oil, protein-free foods, and fruits/vegetables. Intake is unrestricted, but special warnings are given for specific patient groups.

Second Level: Mainly includes vegetable foods like cereals (white bread, pasta, rice) and legumes (peas, broad beans, soy), with suggested intake of 2–3 servings per day.

Third Level: Includes animal-based foods like lamb, rabbit, ham, and certain fish (trout, tuna fish, cod, hake, sole) with a relatively low phosphorus to protein ratio. Special warnings are given for farmed fish, milk, and yogurt, suggesting no more than 1 serving per day.

This pyramid provides practical guidance for individuals, considering both phosphorus content and nutritional needs, particularly for those managing chronic kidney disease.

The fourth level of the Phosphorus Pyramid includes foods with a higher phosphorus to protein ratio, such as turkey, offal (liver, brain), shrimp, squid, salmon, and soft cheeses. The suggested intake is one serving per week.

The fifth level features foods with very high phosphorus content, including nuts, yolk, and hard cheeses. The recommended intake is no more than 2–3 servings per month.

At the top, the sixth level advises avoiding foods with phosphorus-containing additives (cola beverages, processed meat, processed cheese) as much as possible.

The right-side boxes allow customization based on individual needs, enabling the addition of specific foods during counseling, considering phosphorus content, phosphorus to protein ratio, and bioavailability.

The boiling pot on the left suggests boiling as the preferred cooking method to reduce phosphorus content. Additional suggestions include simmering with olive oil, garlic, and parsley, browning in the oven with olive oil and spices, or cooking with fresh tomatoes to enhance taste and appearance. This comprehensive approach offers practical guidance for individuals managing phosphorus intake, particularly those with chronic kidney disease.

CONCLUSION:

Dietary phosphorus restriction is a consistent theme across various stages of chronic kidney disease (CKD). An effective approach to reduce phosphorus intake without compromising protein needs involves avoiding high-phosphorus foods and those with phosphorus additives. Preferring foods with a lower phosphorus to protein ratio and using boiling as the primary cooking method can contribute to better phosphorus control.

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