

**RESISTANCE TRAINING, WHEY PROTEIN, AND NANDROLONE DECANOATE:
EFFECTS ON RENAL FUNCTION**

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ABSTRACT

Objective: To analyze, through a narrative literature review, the effects of whey protein, nandrolone decanoate, and resistance training on renal function and physiological parameters related to muscle health. **Materials and methods:** This is a narrative literature review based on the analysis of scientific articles, books, and documents indexed in national and international databases. Publications addressing the metabolic and physiological effects of protein supplementation, resistance training, and the use of anabolic steroids were prioritized, with an emphasis on renal function. **Results:** Whey protein proved effective in promoting protein synthesis and muscle recovery, but excessive intake was associated with renal overload and increased urea levels. Resistance training demonstrated beneficial effects on hypertrophy, strength, and quality of life, including in populations with clinical conditions. Nandrolone decanoate showed relevant anabolic effects but presented renal and cardiovascular risks, particularly when administered in high doses or over prolonged periods. **Conclusion:** The integration of resistance training with adequate protein supplementation may represent a safe strategy to optimize muscle performance. However, the indiscriminate use of anabolic steroids, such as nandrolone decanoate, poses serious risks to renal function and overall health. Clinical monitoring and health education are essential to guide safe practices and prevent associated complications.

Key words: Whey proteins. Resistance training. Nandrolone decanoate. Renal function markers.

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RESUMO

Treinamento resistido, whey protein e decanoato de nandrolona: efeitos sobre a função renal

Objetivo: Analisar, por meio de uma revisão narrativa da literatura, os efeitos do whey protein, do decanoato de nandrolona e do treinamento resistido sobre a função renal e parâmetros fisiológicos relacionados à saúde muscular. **Materiais e métodos:** Trata-se de uma revisão narrativa da literatura realizada a partir da análise de artigos científicos, livros e documentos indexados em bases de dados nacionais e internacionais. Foram priorizadas publicações que abordam os efeitos metabólicos e fisiológicos da suplementação proteica, do treinamento resistido e do uso de esteroides anabolizantes, com ênfase na função renal. **Resultados:** O whey protein mostrou eficácia na promoção da síntese proteica e recuperação muscular, mas o consumo excessivo esteve associado a sobrecarga renal e aumento da ureia. O treinamento resistido revelou efeitos benéficos sobre hipertrofia, força e qualidade de vida, inclusive em populações com condições clínicas. Já o decanoato de nandrolona apresentou efeitos anabólicos relevantes, porém com riscos renais e cardiovasculares, sobretudo quando administrado em doses elevadas e por períodos prolongados. **Conclusão:** A integração do treinamento resistido com suplementação adequada de proteínas pode ser uma estratégia segura para otimizar o desempenho muscular. Contudo, o uso indiscriminado de esteroides anabolizantes, como o decanoato de nandrolona, representa riscos graves à função renal e à saúde geral. O monitoramento clínico e a educação em saúde tornam-se fundamentais para orientar práticas seguras e prevenir complicações associadas.

Palavras-chave: Whey proteins. Treinamento resistido. Decanoato de nandrolona. Marcadores renais.

INTRODUCTION

Whey protein, a high-biological-value protein supplement, is widely used by athletes and individuals seeking muscle mass gain due to its rapid digestion, essential amino acid content, and ergogenic and immunomodulatory properties (Marshall, 2004; Krissansen, 2007; Haraguchi et al., 2009).

When combined with resistance training, this supplement enhances protein synthesis, promotes muscle recovery, and contributes to morphofunctional and neuromuscular adaptations, leading to hypertrophy, increased strength, and functional endurance (Lemos, Viana, 2002; Fleck, 2006; Wilkinson et al., 2008).

The use of anabolic-androgenic steroids (AAS), such as nandrolone decanoate, has expanded in both sports and aesthetic contexts due to their potential for rapid muscle mass gain and physical performance improvement (Shahidi, 2001; Silva et al., 2007).

However, improper use, particularly at high doses or for prolonged periods, carries significant risks, including hormonal, behavioral, cardiovascular, and renal alterations, and is frequently associated with proteinuria, glomerulosclerosis, and tubular necrosis (Fernandez, 2011; Pope et al., 2013; Araújo et al., 2002).

Renal function, central to body homeostasis, is commonly assessed through biomarkers such as glomerular filtration rate, creatinine, proteinuria, and urea, which allow for early detection of changes and monitoring of renal dysfunction progression (Andrassy, 2003; Sodr e et al., 2007).

Integrating these indicators is essential to evaluate the effects of protein supplementation and AAS use on kidney health, especially given the growing popularity of these practices.

Considering the increased use of whey protein and AAS for ergogenic and aesthetic purposes, and the potential adverse effects on renal function, it is necessary to compile and critically analyze the available literature to guide safe practices and provide reliable scientific evidence.

This narrative review aims to analyze studies on the effects of whey protein and nandrolone decanoate on renal function, highlighting physiological mechanisms, potential risks, and strategies for preventing renal dysfunction.

MATERIALS AND METHODS

This is a narrative literature review based on the analysis of scientific articles, books, and documents indexed in national and international databases. Publications focusing on the metabolic and physiological effects of protein supplementation, resistance training, and anabolic steroid use, with an emphasis on renal function, were prioritized.

Whey proteins

Whey protein is a dietary supplement widely used by individuals engaged in physical activity and those seeking muscle mass gain. This food presents functional characteristics and several health benefits, including immunomodulatory, antimicrobial, and antioxidant properties, in addition to contributing to improved muscle strength and vitality (Marshall, 2004).

Supplementation with whey protein is often employed as a strategy to reduce the effects of exercise-induced oxidative stress, favoring physical performance and muscle recovery.

In addition to being considered an affordable supplement, its use is justified by the numerous benefits attributed to whey protein (Krissansen, 2007; Farup et al., 2013).

Among its main advantages, the high nutritional value stands out, characterized by both the balanced composition of essential amino acids and its rapid digestion and absorption. These factors make this protein highly effective in promoting protein synthesis and muscle recovery (Lemon, 1998; Champe, Harvey, 2000; Tipton et al., 2004).

However, it is important to emphasize that diets with high doses of whey protein may trigger harmful changes to renal function. Studies suggest that excessive protein intake may increase the glomerular filtration rate and renal acid load (Palatini, 2012; Goraya, Wesson, 2012), progressively leading to increased intraglomerular pressure and impaired renal function (Terada et al., 2009).

This concern is reinforced by analyses discussing the balance between ergogenic benefits and metabolic risks (Santesso et al., 2012; Martin et al., 2013).

According to Kersey et al. (2012), the growth in the consumption of nutritional supplements, alongside the use of anabolic-

androgenic steroids, has already become a worldwide phenomenon, despite the strict control applied by regulatory agencies. In this context, understanding the safe limits of whey protein intake becomes essential.

Milk, the main source of this protein, is composed essentially of two fractions: caseins

and whey, the latter being the aqueous portion where the proteins of greatest nutritional interest are found. The composition of whey is illustrated in Figure 1 (Marques, 2018; Macedo, 2018), highlighting its relevance not only in the sports context but also in metabolic and clinical health.



Figure 1 - Percentage composition of milk proteins (Marques, 2018).

Whey protein, popularly known as milk serum protein, is obtained from the extraction of whey, the liquid and translucent fraction resulting from the cheese-making process. This fraction contains approximately 15% to 20% of the total milk proteins, concentrating a large amount of nutrients of biological interest. Whey stands out mainly for its high content of essential amino acids, particularly branched-chain amino acids (BCAA) such as leucine, isoleucine, and valine, in addition to bioactive peptide sequences that exhibit important physiological and functional properties in the human body (Haraguchi et al., 2009; Haraguchi, Abreu, Paula, 2006; Sgarbieri, 2004; Marques, 2018).

Currently, whey protein is considered the most widely consumed dietary supplement worldwide due to its high purity, rapid

absorption, and proven effectiveness when compared to other protein sources. Proteins, both animal- and plant-based, may be classified according to their composition, digestibility, texture, and absorption parameters, with whey surpassing many of them in these aspects (Haraguchi, Abreu, Paula, 2006).

This protein is regarded as one of excellent quality, with high bioavailability, a complete profile of essential amino acids (lysine, leucine, tryptophan, cysteine, isoleucine, and valine), as well as minerals such as calcium, phosphorus, magnesium, potassium, and sodium, in addition to vitamins A, C, D, E, and B complex (Sgarbieri, 2004).

Such nutritional characteristics justify the expressive growth of its consumption in recent years, making it one of the most relevant

and widely used supplements in the global market (Sgarbieri, 2004; Rolim, 2007).

Beyond its nutritional value, several studies have highlighted its health benefits. Whey protein supplementation has been associated with multiple functions: it stimulates post-exercise protein synthesis, promotes gains in strength and muscle mass, helps prevent sarcopenia, contributes to tissue recovery, reduces the worsening of hepatic steatosis,

enhances physical performance, favors body fat loss, assists in glycemic control, and strengthens the immune system (Pitkänen et al., 2003; Chaves et al., 2018; Al-Dhuayan, 2018). These effects emphasize the importance of whey protein not only in sports contexts but also in clinical health, demonstrating its versatility as both an ergogenic and nutritional resource. Figure 2 schematically illustrates the main effects of whey protein on the body.



Figure 2 - Effects of whey proteins (Laboratory of Physiology and Exercise Prescription of Maranhão – LAFIPEMA).

In addition, whey protein has the advantage of being a protein with high biological and nutritional value, widely recognized for its ability to stimulate the synthesis of blood and tissue proteins. It is also notable for its rapid metabolism and protein replenishment, especially in situations of metabolic stress induced by physical exercise, when the demand

for amino acids becomes greater (Gurgen et al., 2015; Haraguchi, Abreu, Paula, 2006; Sgarbieri, 2004).

According to Sgarbieri (2004), whey protein consumption may also play a role in appetite regulation, as it is associated with the hormonal modulation of insulin, ghrelin, and leptin, all of which are directly involved in

hunger and satiety control. This effect is further reinforced by the delayed gastric emptying that occurs after protein ingestion, resulting in a longer satiety effect, which may contribute positively to strategies for body weight management.

Individuals engaged in physical activity, particularly those exposed to high-intensity or high-volume training, present an increased need for protein intake. During exercise, amino acids may be oxidized as an alternative energy source, especially when glycogen stores are depleted. A significant reduction in amino acid availability can impair insulin's stimulatory effect on tissue protein synthesis, thereby compromising recovery and muscle hypertrophy processes (Rolim, 2007).

However, excessive protein intake must be approached with caution, as it may lead to serious health risks. Surplus protein increases the workload on organs such as the kidneys and liver, since part of the ingested protein is catabolized and converted into ammonia, which is subsequently transformed into urea for renal excretion. When exacerbated, this process can compromise renal and hepatic function in the long term (Sgarbieri, 2004; Pereira et al., 2003).

Beyond its metabolic implications, different biochemical pathways demonstrate how whey protein contributes to muscle hypertrophy and strength gains. Protein synthesis can be modulated by factors such as exercise intensity, duration, and frequency, as well as dietary quality.

Alterations in protein metabolism may lead either to anabolic responses, favoring muscle growth, or to catabolic states, when protein degradation predominates. An imbalance in protein turnover, often associated with intense training and inadequate diets, may compromise the expected results, emphasizing the importance of proper protein supplementation (Rolim, 2007; Oliveira et al., 2012).

Resistance Training

Physical exercise, particularly resistance training with weights, plays a fundamental role in preventing muscle atrophy and promoting muscle mass gain, a process known as hypertrophy (Lemos, Viana, 2002). Skeletal muscle hypertrophy can be achieved through structured resistance training programs, typically involving repeated exercise sessions combined with adequate nutritional

support, such as balanced diets rich in whey protein (Wilkinson et al., 2008; Kersey et al., 2012).

Skeletal muscle adaptation to resistance exercise results in neuromuscular and morphofunctional changes, including increased muscle strength, enhanced lean body mass, and improved functional endurance (Lemos, Viana, 2002).

According to Johansen (2007), the benefits of resistance training observed in the general population also extend to individuals with renal disease, with interventions such as aerobic training, resistance training, and functional training programs demonstrating positive effects on health and well-being.

Wagner (1989) notes that physical training may be performed with specific objectives, such as competition preparation or aesthetic enhancement, rather than solely for health purposes. This perspective helps explain why some anabolic steroid users perceive the risk-benefit ratio of this practice as favorable.

Carpinelli (2011) highlights that strength training, also known as resistance training, has become widely practiced over the past decades and is recognized for its benefits, including increased strength, lean body mass gain, reduced body fat percentage, improved physical conditioning, and enhanced quality of life. Additionally, resistance training stimulates muscle protein turnover, promoting both protein synthesis and degradation, which supports hypertrophic adaptations and functional improvements in skeletal muscles (Hoffman, Ratamess, 2006).

According to Lemos and Viana (2002), resistance training induces fundamental physiological responses that promote structural and functional alterations in muscle fibers, resulting in hypertrophy and chronic adaptations from strength training. Certain training protocols can modify the proportion of slow-twitch (type I) and fast-twitch (type II) muscle fibers (Fleck, 2006), while changes in fiber morphology, associated with an approximate 25% increase in protein content and greater motor unit recruitment, contribute to strength gains and muscle hypertrophy, enhancing adaptive capacity to resistance exercise (Fleck, 2006; Harris et al., 2004).

During resistance training, progressive overload above normal training levels is applied according to the overload principle, aiming to stimulate adaptive physiological responses (McArdle, 2008). This type of exercise, used in

both humans and animal models, promotes increases in muscle fiber cross-sectional area, sarcomere number, and protein synthesis, generating morphofunctional and neuromuscular adaptations. The magnitude of these responses depends on exercise duration, frequency, intensity, and type, activating hypertrophic mechanisms in the musculature (Fleck, 2006; McArdle, 2008; Hornberger, Farrar, 2004).

The resistance used is commonly provided by free weights, but also includes hydraulic, electromagnetic, elastic, or spring-based resistance. Resistance training not only strengthens muscles, tendons, and ligaments but also improves cardiovascular health, increases aerobic capacity, reduces resting heart rate, lowers body fat percentage, and enhances musculoskeletal safety (Viana, Novaes, 2009; Polito, Farinatti, 2003; Queiroz et al., 2010; McArdle, 2008).

Additionally, systematic resistance exercise stimulates muscle protein metabolism, balancing synthesis and degradation, which is fundamental for the maintenance of lean mass and optimization of physiological responses to training.

Nandrolone Decanoate

Hormones are chemical substances secreted by endocrine glands and released into the bloodstream, exerting their action on target cells located at a distance from the site of secretion.

Their function is essential for homeostasis and the regulation of fundamental physiological processes, including growth, reproduction, and metabolism. Moreover, hormones exhibit structural diversity, being derived from proteins and peptides, or from steroids and amines, which directly influences their mode of action and affinity for cellular receptors (Boff, 2008; Graceli et al., 2010).

Nandrolone decanoate is among the most widely used anabolic-androgenic steroids (AAS) in sports and aesthetic contexts. Its broad acceptance stems from the ease of administration, primarily via the intramuscular route, which is considered the most effective form. In usage protocols, commonly known as "cycles," the duration typically ranges from 6 to 12 weeks, with doses that can be adjusted progressively in a pyramidal pattern, aiming to optimize adaptive response and increase androgen receptor density (Shahidi, 2001).

However, the use of anabolic-androgenic steroids is not without risks. Adverse effects can impact multiple systems, including the endocrine, cardiovascular, hematologic, renal, and psychiatric systems, altering regulatory functions and compromising overall balance (Fernandez, 2011).

These negative effects become more evident with indiscriminate or prolonged use, potentially resulting in severe complications such as hormonal dysfunctions, elevated blood pressure, emotional disturbances, and renal overload.

Therefore, while anabolic steroids have significant anabolic potential for muscle growth and performance enhancement, they represent high-risk substances when improperly administered. The scientific literature warns that incorrect use may lead to multiple side effects, affecting the individual's overall health and producing lasting or irreversible consequences (Pope et al., 2013; Basaria, 2010).

According to Pope et al., (2013), several renal pathologies are associated with the abusive use of dietary supplements and anabolic steroids, and the improper use of these substances can cause significant kidney damage, including a reduction in glomerular filtration rate and, in more severe cases, acute renal failure.

Despite these risks, anabolic steroids have demonstrated the ability to produce rapid results in muscle mass development and physical performance improvement. This efficacy explains the high demand for these substances among athletes, bodybuilders, and individuals interested in body aesthetics.

In addition to recreational and sports use, anabolic steroids have recognized therapeutic applications and are indicated for the treatment of conditions such as chronic debility, various types of trauma, extensive burns, post-major surgery recovery, partial androgen deficiency in men and the elderly, secondary androgen deficiency due to chronic diseases, male hormonal contraception, osteoporosis, and sarcopenia (Hoberman, Yesalis, 1995; Kennedy, 2000; Sader et al., 2001).

Most commercially available steroid hormones are synthetic derivatives of male sex hormones, such as testosterone, which is primarily secreted by Leydig cells in the testes (approximately 95%) and, to a lesser extent (5%), by the cortical zone of the adrenal glands located above the kidneys. Female sex

hormones, including estrogen, progesterone, and estradiol, are derived from cholesterol. Due to their low molecular weight, these hormones can easily cross the plasma membrane, binding to cytoplasmic receptors specific for estrogens or androgens to form the steroid-receptor complex. This complex migrates to the cell nucleus, where it interacts with DNA, modulating gene transcription and promoting the synthesis of target proteins, thereby determining the anabolic, androgenic, and physiological effects characteristic of these hormones.

Messenger RNA (mRNA) plays a central role in cellular protein synthesis, serving as the crucial intermediary between the genetic information encoded in DNA and the production of functional proteins. In this context, anabolic steroids, such as nandrolone decanoate, are particularly relevant, as they are rapidly absorbed by muscle tissues, enhancing endurance and significantly contributing to increases in muscle volume (Wichstrom, 2006; Silva et al., 2007; Leshner, 2000; Kennedy, 2000).

Muscles exhibit remarkable adaptive capacity to various stimuli, especially those induced by resistance training. Experimental studies in animals have demonstrated that the effects of anabolic-androgenic steroids (AAS) on muscle mass gain are closely associated with the activation of androgen receptors, resulting in specific metabolic and morphological adaptations (Silva et al., 2002; Munn et al., 2005).

Experimental protocols using sub-physiological or supra-physiological doses reveal variable impacts on the organism, even with concurrent resistance training. It is important to note that, at physiological doses, the affinity of the AAS/receptor complex for glucocorticoid receptors is minimal.

The biological androgenic actions are diverse and appear to be mediated by multiple androgen receptors, each acting through the activation of responsive elements in distinct target genes. In animal models, nandrolone decanoate also exhibits a stimulatory effect on erythropoiesis, likely via direct activation of hematopoietic stem cells in the bone marrow and by increasing erythropoietin release. Furthermore, it provides protection against bone marrow suppression induced by cytotoxic agents, highlighting its role in promoting hematological homeostasis (Vingren et al., 2010; Munn et al., 2005; Graceli et al., 2010).

Nandrolone decanoate, an anabolic steroid, was initially developed for the treatment of immunological disorders, including severe anemia and HIV-positive patients, due to its ability to promote muscle mass gain and physical endurance in debilitated individuals. Although it is naturally produced by the human body, its endogenous synthesis occurs in limited quantities. Structurally, nandrolone decanoate is similar to testosterone, the male hormone responsible for muscle mass increase, highlighting its anabolic potential. However, improper administration can lead to adverse effects, such as increased body hair and behavioral changes, including aggression (Araújo et al., 2002; Bisschop et al., 1997; Cunha et al., 2004; Graceli et al., 2010).

Commercially known as Decadurabolin®, its use—particularly among young bodybuilders, athletes, and individuals seeking muscle hypertrophy—has risen alarmingly in various regions. Studies have documented that irregular use at high doses, often 10 to 100 times above therapeutic recommendations, can cause severe health consequences (Araújo, 2002; Bisschop et al., 1997; Cunha et al., 2004; Boff, 2008; Graceli et al., 2010).

According to Shahidi (2001), the intramuscular route is the most commonly used, typically administered in cycles of 6 to 12 weeks, with progressive increases in a pyramidal pattern depending on the user's goals. Anabolic steroids exhibit numerous adverse effects, and their implications for renal function remain incompletely understood.

Excessive use has been associated with various renal pathologies, including nephrolithiasis, acute tubular necrosis, proteinuria, focal segmental glomerulosclerosis, renal cell carcinoma, and Wilms' tumor, although many patients also present concomitant nephrotoxic factors, such as nonsteroidal anti-inflammatory drugs, nutritional supplements, high-protein diets, and dehydration (Pope et al., 2013; Basaria, 2010; Kennedy, 2000; Venâncio et al., 2010; Tamaki et al., 2001).

Renal Biomarkers

The kidneys are paired organs, each weighing approximately 125 to 140 g, with dimensions of 10 to 12 cm in length, 4 to 6.5 cm in width, and 2 to 3 cm in thickness. They are located along the vertebral column, generally at

the level of the third lumbar vertebra, with the left kidney positioned slightly higher than the right. Each kidney has a medial indentation called the renal hilum, through which blood vessels, nerves, and the renal pelvis pass. Blood supply occurs via the renal arteries, which originate from the abdominal aorta, while venous drainage is carried out by the renal veins, returning blood to the inferior vena cava (Guyton and Hall, 2008; Gartner, 2007; Silverthorn, 2017).

Chronic kidney disease (CKD) is an increasing public health problem, characterized by renal damage leading to progressive and irreversible loss of kidney function, affecting glomerular, tubular, and endocrine structures. In Brazil, there is a progressive increase in the prevalence of patients requiring dialysis, highlighting the need for continuous monitoring of renal function. Changes in the glomerular filtration rate may indicate impaired kidney function and help anticipate the diagnosis of CKD (Bareiss et al., 2014).

The kidneys perform multiple vital functions, including waste filtration, nutrient reabsorption, homeostasis regulation, water and electrolyte balance, blood pressure control, maintenance of osmolarity, pH, and glycemia, as well as endocrine functions such as erythropoietin secretion and vitamin D activation (Sodré et al., 2007; Silverthorn, 2017).

Several clinical and laboratory biomarkers are used to assess kidney function. The main ones include:

Glomerular filtration rate (GFR), considered the gold standard for evaluating renal function.

Serum and urinary creatinine, classic indicators of renal excretory function.

24-hour urine output, which allows assessment of kidney excretion capacity throughout the day.

Proteinuria, measured by urinary protein excretion, evaluated via 24-hour microalbuminuria, total 24-hour proteinuria (PT 24h), or by the protein/creatinine (rP/C) or albumin/creatinine ratio in a single urine sample (Andrassy, 2003; Dantas et al., 2006).

Monitoring these biomarkers is essential for early detection of kidney alterations and prevention of CKD progression, enabling more effective therapeutic interventions and long-term preservation of renal function. Thus, the kidneys not only eliminate waste but also play a central role in metabolic regulation and maintenance of body homeostasis (Sodré et al., 2007).

Renal biomarkers and the functional importance of the kidneys

Renal function biomarkers are essential tools for assessing kidney performance, allowing early diagnosis and monitoring of functional alterations. Among the main parameters used in clinical and experimental practice are the glomerular filtration rate (GFR), serum and urinary creatinine, 24-hour urine output, and proteinuria, each with specific evaluation methods and distinct clinical relevance (Andrassy, 2003; Dantas et al., 2006).

In addition to their excretory function, the kidneys play central roles in maintaining body homeostasis, regulating water balance, osmolarity, blood pH, blood pressure, and glycemia during prolonged fasting. They also perform important endocrine and metabolic functions, including the secretion of erythropoietin, responsible for red blood cell production, and the activation of vitamin D, essential for calcium and phosphorus metabolism.

Table 1 - Main Renal Biomarkers, Evaluation Methods, and Clinical Significance.

Biomarker	Evaluation Method	Clinical Significance
Glomerular Filtration Rate (GFR)	Calculated from serum creatinine or inulin; CKD-EPI or MDRD formulas	Assesses glomerular filtration capacity; detects early reduction in kidney function
Serum Creatinine	Blood test	Traditional indicator of renal function; increases with significant loss of function
Urinary Creatinine	24-hour urine collection	Estimates daily renal excretion and allows GFR calculation
24-hour Urine Output	Total urine collection over 24 hours	Evaluates urinary volume and renal excretion capacity

Proteinuria	24-hour microalbuminuria, 24-hour total proteinuria, rP/C or albumin/creatinine	Detects glomerular or tubular injury; monitors progression of chronic kidney disease (CKD)
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Thus, the kidneys' primary function is the regulation of the internal environment, ensuring chemical and physiological balance through selective reabsorption of substances and ions (Sodré et al., 2007; Silverthorn, 2017).

Continuous monitoring of these biomarkers allows early detection of renal alterations, guides therapeutic interventions, and preserves kidney function, preventing systemic complications and promoting the maintenance of body homeostasis.

Structure and function of the nephron and the renal collecting system

The adrenal gland is located at the superior pole of each kidney and is responsible for producing vital hormones such as adrenaline, noradrenaline, and corticosteroids. The functional unit of the kidney is the nephron, which is tasked with filtering the blood and forming urine. Each kidney contains approximately 1,200,000 nephrons, totaling about 2,400,000 in both kidneys, which ensures an efficient capacity to excrete waste and maintain the body's fluid and electrolytic balance.

The nephron consists of two main structures: the glomerulus and the renal tubules. The glomerulus is formed by microscopic arterial capillaries originating from afferent arterioles and is surrounded by Bowman's capsule, a double-walled structure that collects the initial blood filtrate. The filtered fluid travels through the proximal tubule, then through the loop of Henle, and subsequently through the distal tubule, which performs the selective reabsorption of water, ions, and essential nutrients.

The tubules empty into the collecting ducts, which run through the renal cortex and medulla until they converge in the renal pelvis. The formed urine is then conducted by the ureter, a long muscular tube that connects each kidney to the bladder, functioning as a conduit for transporting urine for temporary storage.

The specific function of the glomerulus is to filter water and solutes from the blood, while the renal tubules transform this filtrate into urine, adjusting its concentration and composition according to the body's needs. This process ensures the maintenance of

homeostasis, including fluid, electrolytic, and acid-base balance (Guyton and Hall, 2008; Gartner, 2007; Silverthorn, 2017).

Two main factors can influence urine formation: variation in blood volume, since urine is derived from blood, and changes in blood pressure, which interfere with the propulsion of blood through the renal capillaries and the pressure difference between the arterial capillaries and Bowman's capsule (Kirsztajn, 2007; Levey et al., 2014). Alterations in these parameters can directly impact glomerular filtration and, consequently, urine production.

In a study conducted by Brenner et al., (1998), Wistar rats were subjected to protein restriction, being fed a diet reduced in proteins. The objective was to provoke alterations in nephrogenesis, reduce the number of nephrons, and induce hypertension in the animals, demonstrating how nutritional and structural factors can affect renal function.

To evaluate renal function, several clinical and laboratory biomarkers are used, the most common being: creatinine, proteinuria, albuminuria, glomerular filtration rate (GFR), and cystatin C (Kirsztajn, 2007; Cirillo, 2010; Levey et al., 2014).

These markers are essential for the early detection of renal dysfunction, allowing for more effective therapeutic interventions and preventing the progression of chronic kidney disease (CKD).

Creatinine is one of the most widely used biomarkers because its production is relatively constant and directly related to the individual's muscle mass (Abensur, 2011).

It is freely filtered by the glomeruli and partially secreted by the renal tubules. Although it is widely used to estimate GFR, its serum levels only become significantly indicative of renal dysfunction in more advanced stages of CKD (Bostom et al., 2002; Pereira et al., 2006; Kirsztajn, 2007).

Proteinuria and albuminuria are sensitive biomarkers of glomerular injury, capable of detecting early changes in renal function even before alterations in serum creatinine occur. On the other hand, cystatin C offers advantages over creatinine, as its serum concentration is not influenced by muscle mass, providing a more precise estimate of GFR

across different populations (Kirsztajn, 2007; Cirillo, 2010).

Therefore, the combination of these biomarkers allows for a more comprehensive assessment of renal function, which is fundamental for the early diagnosis of anomalies, monitoring the progression of CKD, and guiding individualized therapeutic strategies.

Evaluation of renal function and biomarkers

A significant increase in serum creatinine usually occurs only when there is a reduction of more than 50% in the glomerular filtration rate (GFR). To overcome the limitations of plasma creatinine, the calculation of creatinine clearance, corrected for body surface area, can be used. This provides a more precise estimate of GFR and correlates better with actual renal function (Abensur, 2011; Bastos et al., 2007; Feitosa et al., 2005).

Creatinine clearance requires a 24-hour urine collection. Ensuring collection precision and proper storage are essential elements to guarantee the reliability of the results (Bostom et al., 2002; Pereira et al., 2006; Kirsztajn, 2007).

According to Kirsztajn (2007), GFR is the most widely used marker to evaluate renal function and can be estimated from serum

creatinine, urinary creatinine, and 24-hour urinary flow, in addition to methods using specific drugs to measure renal excretion directly.

Proteinuria is another relevant marker. Small amounts of protein in the urine are normal, as proteins are large and generally do not cross the glomerulus. The presence of elevated levels indicates glomerular or tubular alteration, serving as an early indicator of kidney injury (Abensur, 2011).

The integration of these biomarkers allows for a comprehensive assessment of renal function, detecting early changes, monitoring the progression of chronic kidney disease, and guiding individualized therapeutic interventions.

The presence of proteins in the urine, known as proteinuria, can indicate damage to the glomeruli, which are responsible for filtering blood in the kidneys. Healthy glomeruli perform a selective function, separating substances that should be eliminated in the urine from those that need to be preserved in the blood, maintaining the body's metabolic balance. The detection of proteins in the urine is generally performed through laboratory urine tests, which allow for the identification of both the presence and the quantity of excreted proteins (Bastos et al., 2007; Feitosa et al., 2005; Berne and Levy, 1998).

Table 2 - Main biomarkers of renal function.

Serum Creatinine	Blood test	Widely available; simple to measure	Sensitive only in advanced stages of CKD; influenced by muscle mass
Creatinine Clearance	24h urine collection and serum creatinine, corrected for body surface area	Estimates GFR more accurately than isolated creatinine	Requires proper urine collection; susceptible to storage errors
Glomerular Filtration Rate (GFR)	Calculations based on creatinine or specific drugs	Direct indicator of renal function; detects early changes	Complexity of calculation; may require drug-specific measurement
Proteinuria / Albuminuria	24h microalbuminuria, 24h total proteinuria, P/C ratio, or albumin/creatinine ratio	Sensitive to early glomerular injury	Can be influenced by physical exertion, infection, or fever
24h Urinary Flow	Total 24h urine collection	Evaluates excretion capacity and fluid balance	Depends on patient cooperation; collection errors can alter results

The main cause of proteinuria is diabetes mellitus, which is why diabetic patients must undergo routine urine tests. The early detection of proteinuria in these patients is an initial marker of diabetic nephropathy, a significant kidney disease resulting from chronic excess glucose in the body, which can lead to progressive glomerular injury (Murussi et al., 2008; Alves, 2004; Cirillo, 2010).

Another widely used marker to evaluate renal function is urea, the end product of protein metabolism, synthesized by the liver. Circulating urea is filtered by the kidneys and eliminated in the urine, playing an important role in the body's nitrogen balance. Changes in urea levels can occur in cases of renal dysfunction, hepatic alterations, or high-protein diets, characterizing uremia—a potentially toxic condition for the body (Abensur, 2011; Vidigal, 2009).

The evaluation of urea is frequently requested alongside creatinine, allowing for a more precise analysis of renal function and glomerular filtration rate. It is important to highlight that urea is partially reabsorbed in the renal tubules; therefore, the calculation of its clearance may underestimate the actual GFR (Abensur, 2011; Vidigal, 2009; Bastos et al., 2007).

Tubular reabsorption of urea can vary according to the patient's clinical state, increasing in situations of higher extracellular volume. Normal blood urea levels generally range between 20 and 40 mg/dL (Brenner et al., 1988; Regina et al., 2001).

CONCLUSION

This study demonstrated that whey protein combined with resistance training promotes hypertrophy and muscle recovery, reinforcing its ergogenic and nutritional role. However, excessive consumption may pose potential risks to renal function, especially in predisposed individuals or those without professional supervision.

Anabolic-androgenic steroids, particularly nandrolone decanoate, have shown high efficacy in increasing muscle mass and strength. Nevertheless, indiscriminate use is associated with severe adverse effects, including cardiovascular, hormonal, and renal alterations, making it a concerning factor in both sports and recreational contexts.

The analysis of renal biomarkers confirms their relevance as tools for early

monitoring of potential dysfunctions resulting from supplementation and AAS use. Detecting changes in proteinuria, creatinine, and glomerular filtration rate is essential to prevent chronic complications.

Given the increasing use of supplements and anabolic steroids, it is crucial to expand research investigating their long-term effects, particularly on renal function. Health education strategies, professional guidance, and proper regulation can contribute to safer use, balancing sports performance with health preservation.

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