Human Performance Enhancement in Sports and Exercise: Nutritional Factors – Protein

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Resumen: For years there has been tremendous debate by sports nutritionist over the question – "Do men and women who are athletes need more protein in their daily diet than non-athletic individuals?" Research over the last few decades has provided evidence to answer that question with a "yes". The protein needs of both strength and endurance athletes can be approximately 1.5 to 2.0 times higher than the present adult recommended dietary allowance (0.8 grams dietary protein per kilogram of body mass per day). The exact amount is depended upon a variety factors; such as, type-mode of exercise, intensity-duration of exercise, gender, whether someone is a vegetarian, age, and health. This article discusses the recommendations for the daily protein needs of athletes and those factors that need to be considered by athletes and their coaches with respect to amino acid - protein consumption in an attempt to improve exercise performance.

Key words: Diet. Exercise Training. Adaptation. Anabolism. Myoplasticity.

Performance humana, suplementación en deportes y ejercicio: factores nutricionales – proteínas

Abstract: Por años se ha dado un acalorado debate entre los nutricionistas deportivos sobre la pregunta "¿Los hombres y mujeres que son atletas necesitan más proteína en su dieta diaria que los individuos no-atletas?" Las investigaciones de las últimas décadas han dado evidencia de que la respuesta a esa pregunta es "si". Los requerimientos de proteína tanto en los atletas de fuerza como en los de resistencia puede ser aproximadamente de 1.5 a 2.0 veces mayor que lo recomendado para un adulto (0.8 gramos de proteína alimenticia por quilogramo de masa corporal por día). La cantidad exacta dependerá de una variedad de factores, tales como el tipo y modalidad del ejercicio, la intensidad y duración del ejercicio, el sexo, si la persona es vegetariana, su edad y su salud. Este artículo trata las recomendaciones para losa requisitos diarios de proteína de los atletas y aquellos factores que deben ser considerados por los atletas y sus entrenadores respecto al consumo de aminoácidos-proteína en la tentativa de perfeccionar el desempeño del ejercicio.

Palabras clave: Dieta. Entrenamiento. Adaptación. Anabolismo. Mioplasticidad.

INTRODUCTION

Protein forms a wide and diverse set of structures in the human body and is critical in a number of physiological functions (MANORE; THOMPSON, 2000; MESSINA; MESSINA, 1996). Regrettably, from a nutritional perspective, protein is one of the most abused and misunderstood of the dietary nutrients that are essential to human health and performance. Many fraudulent claims have been made and reported in the popular literature on the use of dietary protein consumption by athletes and person who exercise train. This occurrence is unfortunate because abuse of protein intake in the diet can result in the opposite of the desired effect of improved health and performance. Severe medical complications can occur with inappropriate protein intake that not only impacts general health, but can actually threaten an individual's life (LEMON, 1996; MANORE; THOMPSON, 2000).

The discussion of the nutritional and physiological aspects of dietary protein intake is a complex and complicated topic. Many excellent books, book chapters and research articles have been devoted to dealing with this issue in depth. The purpose of this brief article is to focus on the fundamental aspects of this topic in order to provide the reader with basic background knowledge. The intent is to provide pertinent information, relative to adult (18-70 years age) athletes and individuals involved in exercise training, on correct dietary practices for protein consumption which can lead to human performance enhancement.

Typically protein accounts for approximately 15-20% of our total body mass (SKOLNIK; CHERNUS, 2010). Skeletal muscle is one of the primarily protein containing tissues in the body. However, protein is not as large a muscle constituent in amount as most individuals tend to believe. On average the protein composition of muscle is only somewhere between 15-20% its total mass (MANORE; THOMPSON, 2000; SKOLNIK; CHERNUS, 2010). This means one kilogram of skeletal muscle contains roughly 150 to 200 grams of protein which are associated with the contractile process, structural integrity, and metabolic activity of the tissue. In addition to skeletal muscle, protein is found in many other bodily tissues such as cardiac-smooth muscle, tendons, ligaments, collagen, eyes, bone, brain, skin, nails and hair. Furthermore, it is important to emphasize that the physiological roles of protein are highly varied, being involved with the metabolic, hormonal, immune and the transport systems within the body (MANORE; THOMPSON, 2000).

All proteins are made up of chemical constituents called amino acids. These molecules are in turn comprised of carbon, hydrogen, oxygen, nitrogen and in select cases, sulfur. The name "amino acid" is derived from that fact that each molecule consists of nitrogen containing amine moiety and an acidic carboxyl group. In human nutrition amino acids are categorized into essential and non-essential status. The essential amino acids, also called indispensable, are ones we must consume in our dietary food because our body can not make then. Conversely, non-essential (dispensable) amino acids can be made within the body and can be, but do not have to be completely, consumed in our food (MANORE; THOMPSON, 2000; MESSINA; MESSINA, 1996; SKOLNIK; CHERNUS, 2010). Many foods are comprised of both non-essential and essential amino acids within their protein constituent. Table 1 lists the essential versus non-essential amino acids.

Essential (Indispensable) Amino Acids	Non-Essential (Dispensable) Amino Acids
Isoleucine	
Leucine	Alanine
Lysine	Arginine
Methionine	Aspartate
Phenylalanine	Asparagine
Threonine	Glutamate
Tryptophan	Glutamine
Valine	Glycine
Histidine†	Proline
Cysteine†	Serine
Tyrosine†	

Table 1. Essential and non-essential amino acids found in protein of the human diet. The † symbol denotes conditionally essential amino acids. See Manore and Thompson (2000) for greater detail concerning essentiality of certain amino acids.

RECOMMENDED PROTEIN INTAKE

There are several means by which the amount of daily protein intake can be quantified. Perhaps historically the method most people are familiar with is the Recommended Dietary Allowance (RDA). The RDA represents the daily dietary intake level of a nutrient considered sufficient by the Food and Nutrition Board (part of the Institute of Medicine of the United States National Academy of Sciences) to meet the requirements of nearly all (97–98%) healthy individuals in each life-stage and gender group (DRI-FOOD; NUTRITION BOARD, 2009; MANORE; THOMPSON, 2000). The RDA is calculated based on the estimated average requirement (EAR) and is usually approximately 20% higher than the EAR. The EAR is the amount of a nutrient expected to satisfy the needs of 50% of the people in a select age group based on the scientific literature (DRI-FOOD; NUTRITION BOARD, 2009). The Dietary Reference Intake (DRI) is a more contemporary system of nutrition recommendations from the Institute of Medicine for the amount of daily protein intake (DRI-FOOD; NUTRITION BOARD, 2009). THE DRI for protein is recommended at between 10-35% of total daily caloric intake or approximately 56 grams a day for adults (~70 kilograms body mass). The DRI system is now used by both the United States and Canada and is intended for use by the general public as well as health professionals. The DRI was introduced in 1997 in order to broaden the existing RDA guidelines. However, the RDA is still one of the most common and familiar means by which nutrient recommendations are expressed throughout the world and in much of the available research literature, and will be used in this article.

The RDA for adults over the age of 18 years is 0.8 grams per kilogram of body mass per day (g/kg/d) (FOOD; NUTRITION BOARD, 2009). This means a 65 kilogram person should consume a total of 52 grams of protein in a single day. The World Health Organization places this value for adults at 0.83 g/kg/d (WHO TECHNICAL REPORT, 2007). For younger individuals who are in rapid growth phases the RDA requirements are higher; 4-13 years of age = 0.95 g/kg/d, 14-18 years of age = 0.85 g/kg/d (FOOD; NUTRITION BOARD, 2009; MANORE; THOMPSON, 2000).

RECOMMEND PROTEIN INTAKE - ATHLETES

It has always been a hotly debated subject concerning how much protein is needed in the diet of athletes and individuals involved in exercise training. As noted, the RDA recommendations are for the maintenance of general health and do not necessarily represent the optimal dietary intake for individuals involved in exercise training. It is well established that exercise training results in muscle damage and additional dietary protein is needed for the repair of damaged skeletal muscle (LEMON, 1996; MANORE; THOMPSON, 2000). Furthermore, many athletes are attempting to not just repair and maintain their skeletal muscle mass status, but actually increase their mass via hypertrophy of the muscle in response to their exercise training. These increases in the amount of muscular size (growth) would also result in the need for greater dietary protein intake. Key research studies by Gontzea *et al*. (1975), Lemon *et al*. (1992), and Todd *et al*. (1984) incorporating the nitrogen balance procedure has demonstrated the need of protein intakes in physical active individuals to be greater than the RDA.

Muscular growth and hypertrophy are not the only reasons for increased protein requirements within physically active individuals. Research studies incorporating isotopic tracer techniques (specific research methodologies allowing the detection of amino acid and protein utilization and turnover at the cellular level) have yielded findings that indicate protein contributes to energy production during and following exercise (BABIJ *et al*., 1983; EVANS *et al*., 1983; HAGG *et al*., 1982). The following points summarize the key aspects of this research:

- select amino acids can become substrates for gluconeogenesis (i.e., conversion to glucose) to prevent hypoglycemia from occurring,
- select amino acids can be converted to Krebs cycle intermediates and used in the oxidation of Acetyl-CoA for ATP production,
- select amino acids can be oxidized for direct ATP production in the muscle.

Thus, taken collectively, the above information substantiates that while the RDA is more than adequate in many adults, it is sub-optimal for athletes and individuals involved in exercise training. There is, however, no formally recognized RDA value for physically active persons approved by a government or supervising organization. Nevertheless, the following protein recommendations based upon current research studies have been made by leading scientists in the field of sports nutrition (LEMON, 1996; MANORE; THOMPSON, 2000):

- Persons involved in endurance exercise activities (e.g., distance running, long course triathlons) should consume a daily dietary intake of 1.2 to 1.4 g/kg/d protein.

- Persons involved in resistance exercise activities (e.g., weight-lifting, power-lifting) should consume a daily dietary intake of 1.6 to 1.7 g/kg/d protein.

Regrettably, the amount of research looking at team sports such as football, volleyball, handball and so forth, is limited and too incomplete at this time for specific recommendations to be made. Even so, without a doubt, the type of exercise training and physical activity necessary to participate in these teams sports obviously supports that daily protein intake needs to be in the range of those listed above and greater than the 0.8 g/kg/d RDA value.

It is important to recognize that many factors can influence protein metabolism (synthesis vs. degradation) in the body during and following exercise, and thus affect the exact amount of protein needing to be consumed in the diet. Factors such as the intensity and duration of an exercise session, type-mode of exercise performed, carbohydrate availability, total energy intake, overall energy balance, gender, exercise training level, age and health have all been shown to influence protein metabolism (LEMON, 1996). A thorough discussion of these factors is beyond the scope of this brief article and the reader is directed to the work of Lemon (LEMON, 1996) for more details as well as the earlier articles in this nutritional series within *Revista Universitaria de la Educación Física y el Deporte* (HACKNEY, 2008, 2009).

EXCESSIVE PROTEIN INTAKE

The need for an elevated dietary protein intake in athletes is well established and has been trumpeted in the popular press and on the internet for a number of years. Unfortunately, the reporting by popular magazines and press on the science behind this recommendation has been lacking in clarity and understanding. These short-comings has led to the false inference, by some athletes and coaches, that "more is better" when it comes to protein intake. This has led to many athletes consuming protein at far higher intakes than those recommended above, and the development of many popular high protein diet regimes for athletes; such as, "The Zone Diet" or the "40-30-30 Diet". Many nutrition professionals are concerned by this trend because excessively high protein intakes by individuals can lead to some adverse health effects. It is known medically that if persistently high amino acid or protein consumption occurs it can lead to increased risk for; renal damage, urinary calcium losses – affecting bone, elevate serum lipoprotein levels – affecting heart disease risk, dehydration, and possible amino acid toxicity effects (LEMON, 1996; MANORE; THOMPSON, 2000; MESSINA; MESSINA, 1996). Obviously, several of these occurrences are major medical health concerns. It is also important for athletes and coaches to recognize that there is a physiological limit to which amino acids from dietary protein can be incorporated into the human body for protein synthesis. In normal, healthy adult individuals (i.e., not consuming illegal substances for doping purposes) research points to this limit being at approximately 2.0 g/kg/d of intake (LEMON, 1996; MANORE; THOMPSON, 2000). If consumptions exceed this upper limit, then the risk of health problems from over consumption increases. Furthermore, with over consumption some of the excessive calories consumed in the form of protein can be stored as adipose (fat) on the body. In many cases, this last point, that protein can be converted to fat and stored as adipose on the body, seems to not be recognized or understood by many athletes. Put simply, just because you consume a protein substance is no guarantee that it will be incorporated into the body as protein.

PROTEIN QUALITY

Protein quality is a term that refers to the amino acid composition (i.e., with respect to the essential amino acids) and the digestibility of a specific protein. Different systems have been established that rate how well proteins from various sources are evaluated on these factors. One of the most universal rating systems used is the one adopted by the Food and Agriculture Organization of the World Health Organization (FAO/WHO), referred to as the Protein Digestibility Corrected Amino Acid Score (WHO TECHNICAL REPORT, 2007). The rating system ranks cow's milk and egg protein highest with beef and soy protein following closely afterward (WHO TECHNICAL REPORT, 2007). Another means of assessing protein quality involves looking at the biological value of a food, which estimates how the food contributes to the overall nitrogen balance - that is, it serves as an indication of how well the body uses the food. A positive nitrogen balance means you are consuming adequate amounts of dietary protein and you are creating a physiological environment to facilitate protein synthesis in the body (MANORE; THOMPSON, 2000). Examples of foods high in biological value include eggs, milk, soy, beef, pork, poultry and fish (SKOLNIK; CHERNUS, 2010).

A further term associated with protein quality is "complete protein". Complete protein typically refers to whether protein sources contain all the essential amino acids when consumed at the recommended levels of intake (MANORE; THOMPSON, 2000). Plant proteins are generally classified as incomplete and animal proteins as complete. However, all of the amino acids can appear in plants proteins, but in relatively low amounts as compared to animal-based proteins. This means an individual needs to eat more of a plant protein source in order to obtain adequate amounts of the essential amino acids (i.e., it is currently recommended that individuals who eat no meat or dairy products consume approximately 10% more protein daily [~0.9 g/kg/d]) (MANORE; THOMPSON, 2000). Also, in some case an individual must consume more than one source of plant protein in order to obtain all the essential amino acids in one meal – this is referred to as mutual supplementation. That is, mutual supplementation involves consuming plant protein sources which have complementary amino acid combinations at each meal (such as soybeans and rice, wheat bread and peanut butter, pinto beans and corn tortillas) in order to obtain sufficient amounts of all of the essential amino acids (MESSINA; MESSINA, 1996). Contrary to what was once thought, recent studies show that it is not absolutely necessary to consume these foods together at the same meal as the endogenous protein levels in the gastrointestinal tract are maintained adequately enough between meals to support appropriate levels of protein synthesis (MESSINA; MESSINA, 1996).

VEGETARIAN ATHLETES

Research supports that vegetarian athletes are quite capable of meeting their daily protein needs and maintaining high levels of exercise training (MESSINA; MESSINA, 1996). Lacto-ovo vegetarians, who eat animal by-products as well as plants, can easily consume beans, nuts, soy, eggs and dairy products to obtain all the complete protein they need on a daily basis. Vegan vegetarians, who eat no animal products of any kind, can also obtain adequate protein amounts from beans, nuts, soy and other plant sources of protein. Physically active vegetarians who are at risk for inadequate protein intakes are generally those who are not consuming a sufficient overall energy intake, as opposed to inadequate sources of protein (MANORE; THOMPSON, 2000; MESSINA; MESSINA, 1996). This means they are on too low of a calorie intake in their daily food consumption, creating a negative energy balance. It is also important that vegetarians consume a wide variety of foods, and if this is not possible, then they may need to consider supplementation for select micro-nutrients such as vitamin B_{12}, zinc and iron (MESSINA; MESSINA, 1996).

AMINO ACID – PROTEIN SUPPLEMENTATION

Amino acid and, or protein supplementation use is very popular among athletes, especially those involved primarily with strength, resistance exercise activities. Many of the companies who make and sell such supplements make compelling claims as to the effectiveness and efficiency of their supplements for "building muscle". Research on this topic is conflicting and some times ambiguous due to poor research design or the lack of adequate scientific controls in the research. Although some well executed studies have shown exceptional results with certain supplementation use, replication and substantiation of these findings are necessary before definitive conclusions can be made about supplementation usage versus proteins found in daily foods (TIPTON *et al.*, 1999; WILSON *et al.*, 2008).

There are aspects of supplementation usage, however, that can be highly helpful to the athlete in training. For example, it is extremely convenient at times for the athlete to use amino acid or protein supplements rather than purchasing and preparation some sources of protein found normally in foods. This is especially true if the athlete is attempting to consume the supplement within a prescribed timing protocol to maximize effects (see later discussion). There is a trade-off for this convenience, however, in that there is a high financial cost. Supplements that fall into the category of complete proteins, which should be the most effective, can be very expensive to purchase (MANORE; THOMPSON, 2000).

Supplement	Source	Characteristics	Comments
Whey	Milk based protein	Rapidly digested and absorption protein	Source of Leucine a key BCAA
Casein	Milk based protein	Slowly digested and absorption protein	Whey and casein are typically consumed together
Soy	Plant based protein	Relative rapidly digested and absorption protein	Typically has a high fiber component leading to risk of stomach discomfort
Albumen	Egg based protein	High degree of digestibility	Considered a complete protein, also high in Leucine BCAA

Table 2. Select aspects of key amino acid – protein supplements. CAA = Branch-chained amino acid (essential amino acid).

Protein supplements are usually in the form of whey, casein, soy, or albumen based proteins. They are usually prepared and sold as powders, mixes or within bars. Some key aspects of each of these supplements are listed in Table 2.

Nutrient timing

During the last decade, one of the most novel aspects of sports nutrition research has been in the study of "nutrient timing" – i.e., when to consume nutrients in order to maximize their physiological effect. Much

Title	Period		Time Line	Aim	Practice
Energy Phase	Workout	24 Hour Period ↓	~1-2 Hours	•Increase nutrient delivery •Spare muscle glycogen •Limit immune system suppression •Minimize muscle damage •Faster recovery	Consume: 1) CHO before/during exercise -Liquid, 6-8% (e.g., maltose-dextrin) 2) Small amount Pro^{-} before/during -Essential AA (e.g., whey)
Anabolic Phase	Post-Exercise		~1 Hour	•Shift catabolic to anabolic state •Speed waste elimination •Replenish muscle glycogen •Initiate muscle repair and growth •Reduce muscle damage •Bolster immune system	Consume: 1) CHO post-exercise, immediate -Liquid, 6-8% (e.g., maltose-dextrin) -1.0 to 1.5 g/kg 2) Pro^{-} post-exercise -3:1 or 4:1 CHO to Pro^{-} ratio -Essential AA (e.g., whey)
Growth Phase – Rapid	Recovery - Short		~5-6 Hours	•Maintain: - Insulin sensitivity - Positive anabolic State	Consume: 1) Small CHO / Pro^{-}feedings -Every 1 to 2 hours post-exercise -3:1 or 4:1 CHO to Pro^{-} ratio -Essential AA (e.g., whey, casein) 2) Eat typical food / meals (mixed diet)
Growth Phase - Sustained	Recovery - Long		~16-17 Hours	•Maintain positive nitrogen balance •Stimulate protein synthesis •Promote: - Protein turnover - Muscle development	Consume: 1) Energy intake -Neutral balance -Positive nitrogen balance -Pro^{-} intake (1.2 –1.7 g/kg/d) 2) CHO to repletion glycogen 3) Eat food / meals (mixed diet)

Table 3: Overview of the "nutrient timing" procedure. CHO = carbohydrate; Pro- = protein; AA = amino acids (see IVY; PORTMAN [2004] for details of the procedure).

of this research on this topic has focused on athletes involved in strength, and resistance exercise training. The key principle behind this concept is that skeletal muscle is uniquely sensitive as a tissue to particular nutrients within a 24 hour cycle of time, and that improved muscular growth, strength and power can occur if the right combinations of nutrients are delivered to the muscle in the right amount, at the correct moment (SKOLNIK & CHERNUS, 2010).

Table 3 presents a schematic outline of the practical aspects of this concept as put forward by the researchers Ivy and Portman (2004). For more details about this concept and procedure, the reader is referred to references Ivy and Portman (2004) and Skolnik and Chernus (2010).

CONCLUSION

In summary, for many years in sports nutrition research there has been tremendous debate over the question – "Do men and women who are athletes need more protein in their daily diet than non-athletic individuals?" Research over the last few decades has provided evidence to answer that question with a "yes". The protein needs of both strength and endurance athletes can be approximately 1.5 to 2.0 times higher than the present adult RDA (LEMON, 1996). The exact amount is depended upon a variety factors; such as, type-mode of exercise, intensity-duration of exercise, gender, whether someone is a vegetarian, age, and health.

The consumption of adequate dietary protein is critical to the maintenance of health and to optimize the adaptation process of skeletal muscle to exercise training. Research supports that the above recommendations will help facilitate this adaptation process in the athlete. However, it is important to recognize that "more is not better". It is possible to over-consume protein and have negative consequences from over consumption. Also, the athlete and coach need to recognize that protein is only one constituent in the well-balanced diet that an athlete should consume. Appropriate amounts of carbohydrate, essential fats, micro-nutrients and fluids are also critical and part of the proper nutritional profile that an athlete needs, regardless of their type of sport and exercise training regime. Careful assessment of the total nutritional profile of an athlete by a trained professional is essential to facilitate the maximal and optimal physiological adaptive responses to exercise training.

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