Proteins in sports nutrition

Position of the working group sports nutrition of the German Nutrition Society (DGE)

Daniel König, Anja Carlsohn, Hans Braun, Mareike Großhauser, Alfonso Lampen, Stephanie Mosler, Andreas Nieß, Klaus Schäbethal, Alexandra Schek, Kiran Virmani, Rainer Ziegenhagen, Helmut Heseker

Abstract

Adequate intake of high quality proteins and amino acids is essential for the body in order to synthesize structures such as muscle, tendons, ligaments, and bone. Protein intake also regulates and affects various metabolic processes, including hormonal regulation. Accordingly, proteins and amino acids are, to varying extents, able to stimulate or inhibit anabolic signal transduction pathways and the synthesis and secretion of various hormones such as insulin, growth hormone, and insulin-like growth factor 1 (IGF-1).

This means that tailoring protein intake to an athlete's specific type of sport and exercise intensity can be helpful in supporting the training process and improving performance. The aims of adjusting intake in this way may include maintaining or building muscle mass or muscle strength, preventing a catabolic state, and improving recovery following exercise.

Even though the importance of protein intake in the field of sport is increasingly well-known, there is still much controversy regarding intake levels, types of protein sources, optimal amino acid composition, and ideal timing of intake. The lay press and commercial websites in particular often give biased or incorrect recommendations without any supporting scientific evidence.

This position paper sets out the current state of knowledge regarding the physiological effects of protein intake in sports, paying particular attention to the aspects of intake level and the dose-response relationship.

Keywords: proteins, sports nutrition, recommended intake, muscle mass, regeneration

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In Ernährungs Umschau, as in many other journals, position papers are not required to undergo the peer review process because they are texts that have already been evaluated and discussed by many experts (peers), and on which there is already a broad-based consensus.

Corresponding author
Klaus Schäbethal
schaebethal@dge.de

Introduction

For the human body, adequate protein intake is crucial. Proteins are essential building blocks for the structure and metabolism of muscle, bone, and connective tissue. Proteins and amino acids also play key roles in cell metabolism, hormonal balance, the immune system, the coagulation system and energy metabolism [1–3]. With regard to possible effects in the field of sport, proteins are frequently reported to have positive effects on muscle protein synthesis, muscle mass, muscle strength, improvement in body composition, prevention of a catabolic state, immunocompetence and ensuring optimal regeneration in the post-exertion phase [1, 4–6].

To achieve these aims, not only is an adequate quantity of protein required, but also an adequately high quality of protein [3, 7]. Although various meta-analyses have been published on this topic, not all questions regarding quantity and quality of protein sources and amino acid composition have been definitively answered. In addition, it is increasingly being discussed whether it is a protein's composition in terms of individual amino acids that determines effectiveness, or whether di-, tri- or oligopeptides with specific signalling effects on cellular regulation also play a role in the muscular adaptation process [3, 8–10].

What is clear and undisputed is that measurable results can only be obtained through a combination of training and protein intake [11, 12]. Simply increasing protein intake without changing training activities will not result in any structural or metabolic adaptations.

Furthermore, there is a broad consensus among scientists that a balanced diet rich in high-quality proteins should always be the priority when it comes to protein intake [1, 3, 7, 12]. Although there have been many studies that reported positive results for protein intake with supplements in the field of sport, the primacy is that a change in protein intake is best achieved through optimization of the diet. As yet, there is no scientific evidence from controlled studies showing that physiological training adaptations can only be achieved through the use of supplements with a specific amino acid compositions [13]. The reason studies use supplements is in fact a methodological one: food items or complete meals are difficult to administer with standardized amounts of protein and a standardized amino acid composition and they also make it more difficult to conduct a randomized, double-blind study. It is, however, accepted that using protein supplements makes sense in certain specific cases [3, 9–11].

First, this position paper will describe the protein requirements of athletes. It will then go into more detail on the topics of types of proteins, increase in muscle mass and strength, regeneration, and timing of protein intake.

Protein requirements in athletes

The D-A-CH reference value for recommended protein intake for healthy adults aged 19 to 64 is 0.8 g/kg body weight per day [14]. As part of the revision of the D-A-CH reference values in 2017, the estimated value for protein intake for people aged 65 or over was set at 1.0 g/kg body weight per day, since it is assumed that older adults have higher protein requirements than younger adults due to a variety of influencing factors [14]. This approach can also be applied to the field of sport: many (though not all) studies have shown that increased protein intake can promote structural and metabolic adaptations during the training process [3, 7, 11, 15, 16]. Due to the dynamic nature of the training-induced adaptational process, it does not necessarily make sense to set protein requirements in training only with the aim of balancing nitrogen intake with nitrogen loss because the athlete in training is not in a state of equilibrium – they are in a process of anabolic adaptation. This principle applies to endurance training as well as it does to all forms of strength training [12, 17, 18].

However, it should be noted that this only applies to training volumes of at least five hours per week. Any physical activity of less than five hours per week should be considered to be only compensating for a sedentary lifestyle [19].

Currently, the International Society of Sports Nutrition and the American College of Sports Medicine recommend that protein intake in ambitious sports should be approx. 1.2–2.0 g/kg body weight per day, depending on the person's training condition and their training goals [3, 7]. In contrast to previous recommendations, protein intake is now no longer considered as a fixed value in athletes' everyday diets. Rather, it should be adapted to training goals, training intensity and the scope of training in a flexible manner [1, 7]. Therefore, depending on the type of sports, for example in sports where there are periodic phases focused on increasing strength or muscle mass, or in cases where fat loss is the aim, it may be helpful to increase the proportion of protein in the diet. In fact, athletes at the start of a new training cycle or those who have had less training may even have higher protein requirements than athletes who are already in the adapted state [3]. However, a recent meta-analysis by Morton et al. pointed out that in studies in which protein supplements were used to attempt to increase fat-free mass (FFM), there was no evidence of additional increases with dosages higher than 1.6 g/kg body weight [9, 10]. Therefore, based on current scientific knowledge, it should be assumed that higher dosages are only helpful and advisable in very specific training situations and only for a limited period of time [3]. The EFSA has not set any upper tolerable intake level for protein, but they do consider double the reference value for adults to be safe [19]. Nevertheless, the possibility that a diet with protein intake of ≥ 2 g/kg body weight per day over a long period of time could have a harmful effect on kidney function cannot be ruled out [20].

Some individual study results suggest that athletes who do sports involving extreme levels of exertion, either strength or endurance exercise, could benefit from even higher protein dosages than this (up to 3 g/kg body weight) [3]. However, there is not yet sufficient data to recommend these extremely high amounts of protein. In addition, unlike carbohydrates and fats which are completely broken down into water and carbon dioxide, in proteins the amino groups of the amino acids are detoxified by being converted into urea and are then excreted in the urine. This means that it is essential to ensure an adequate fluid intake. Although studies have thus far been unable to prove that a healthy kidney can be damaged by such high levels of protein intake, several publications have demonstrated that a kidney that has already been damaged (e.g. through diabetes) can sustain more long-term damage from such high loads of protein [21, 22]. Since only few studies have been conducted under the particular conditions of intense physical exercise (dehydration, reduced renal plasma flow, monocytolysis, proteinuria, etc. [23]) and since even in those few studies, the sample sizes were small, such high dosages should only be taken in the long-term if medical supervision is provided. This is further illustrated by an assessment from the Federal Institute for Risk Assessment (*Bundesinstitut für Risikobewertung*, BfR), in which, for health reasons, guidance values for tolerable supplemental (= additional) daily intakes of isolated branched-chain amino acids were derived (adults: 4.0 g leucine/day, 2.2 g isoleucine/day and 2.0 g valine/day or 8.2 g/day for the sum of supplemental intake of isolated branched-chain amino acids, respectively) [24].

Protein sources

Proteins have a variety of effects on the body. The best researched area regarding the effects of proteins and amino acids in sports is their influence on increasing muscle protein synthesis after strength training. This area has also yielded the most study data on different protein sources and different amino acid compositions [10, 11, 16, 25]. With regard to physiological mechanism, studies to date have shown that particularly when combined with an insulin release triggered by carbohydrate intake, branched-chain amino acids can stimulate muscular protein synthesis via the mTOR signaling cascade (mTOR = mechanistic target of rapamycin) [26]. Apart from questions about intakes of isolated amino acids or different combinations, another matter of great interest is the question of whether intake of proteins from different sources (such as casein, milk, whey, soy, eggs or peas) has any specific benefits.

From a biochemical and physiological point of view, it appears logical that an increased intake of amino acids can increase exercise-induced anabolic stimulation of muscle protein synthesis and the building of muscle mass and muscle strength. However, not all randomized controlled trials have been able to show this training effect [9, 16]. Even though many meta-analyses have ultimately shown that training and protein intake combined have a significant effect in terms of increases in fat-free mass and muscle mass (see below), even these studies were unable to give a definitive answer to which protein sources are most effective because the positive results have been shown by various protein sources and amino acid sources [9, 10, 16, 25, 27].
Regardless of the differences in bioavailability and therefore the differences in timing for the intake of different proteins ("Timing of protein intake"), at present, no protein source can be considered superior to any other in terms of increasing muscle protein synthesis [26, 28]. This also applies to other fields of athletic performance, although there is less supporting data in other areas. Based on the fact that amino acid compositions differ in the protein sources, it is reasonable to postulate that proteins can modulate exercise-induced adaptation processes through pathways other than the mTOR signaling cascade [29, 30]. Furthermore, it is recommended that athletes incorporate various protein sources into their meals, since this is the surest way to achieve a varied and balanced diet.

Regarding recommendations about protein quality, athletes should focus on complete proteins with a high proportion of indispensable amino acids wherever possible [3, 7, 29]. If sources of incomplete protein are used, care should be taken to achieve a complete amino acid spectrum through appropriate food combinations. The foods that need to be combined can be spread over the day – it is not necessary to combine them in a single meal. In addition, there is no evidence that animal proteins would provide a clear advantage over plant proteins [31–33]. Furthermore, a higher proportion of plant proteins in the diet should be considered positive since they provide more dietary fibre and vitamins, as well as higher levels of carbohydrate, and they have lower levels of saturated fatty acids. Although plant proteins often have a lower percentage of indispensable amino acids or branched-chain amino acids, this at least did not lead to any detrimental difference in study findings [28].

In summary, in terms of protein intake, attention should be paid not only to the composition of amino acids, but also to the energy content and the proportion of fat, carbohydrates, micronutrients, bioactive peptides and secondary plant substances, as well as the bioavailability of the food consumed. Based on current knowledge, a mix of different protein sources with different compositions and different absorption kinetics is likely the best choice for athletes [3, 7, 28].
There is no physiological reason why athletes would require protein in the form of supplements as part of their everyday diet. Even recommended pre-workout and post-workout protein intakes can be achieved through the proper combination of foods. Supplementation can only be considered helpful in the case of food intolerances, if energy restriction is required, or in the case of particularly intensive training (see above). As is shown in the chapters that follow, there is no rationale for giving preference to any particular protein or amino acid.

Athletes could be at increased risk of an inadequate supply of proteins and indispensable amino acids in the following cases:

- If they have been on a long-term, low-calorie diet in order to lose body weight (e.g. in sports where weight is critical, such as ski jumping, gymnastics or dance).
- If they have been eliminating important protein-rich food groups from their diet for a long period of time (e.g. due to food intolerances or aversions).
- If they have been eating an unvaried diet with a low nutrient density.
- If they have been eating a vegan diet without paying attention to how plant protein sources need to be combined in order to be effective protein sources.

Maintaining or altering body composition

Maintaining or altering body composition is an important key to maintain or improve performance in many different sports. Altering body composition can involve increasing

Food or dish (g)	Protein content per portion
oven-baked potatoes (250 g) with quark (150 g)	25 g
fried potatoes (200 g) with egg (60 g)	19 g
fruit-flavored quark or skyr (200 g)	16 g–19 g
buttermilk (500 g)	17 g
low-fat milk (500 g)	17 g
oats (50 g) with milk (250 ml)	15 g
wholegrain bread (2 x 55 g) with semi-hard cheese (30 g)[1]	15 g
wholegrain bread (2 x 55 g) with quark (50 g)[1]	14 g
plain yogurt (250 g) with almonds (25 g)	14 g
vegan/dairy-free variants	
wholegrain bread (2 x 55 g) with peanut butter (25 g)	15 g
soy yogurt (300 g)	12 g
wholegrain bread (2 x 55 g) with pureed chick peas (50 g)[1]	11 g
oats (50 g) with almond drink (300 g)	10 g

Tab. 1: **Example foods and portion sizes with approx. 10–25 g protein**
Here, mainly protein sources with high biological value are taken into account, see [47].
[1] Bread with toppings can also be additionally topped with vegetables (e.g. cucumber or tomato).

muscle mass while maintaining or decreasing fat mass, or it can involve mainly reducing fat mass while maintaining muscle mass or allowing muscle mass to be only slightly reduced.

As mentioned before, the additive effect of strength training and protein intake in terms of increasing muscle mass and muscle strength has been demonstrated in some meta-analyses. There is currently no scientific evidence which protein sources have the greatest effects in terms of exercise-induced increases in protein biosynthesis [7, 28]. In addition, it should be noted that the effect on muscle mass is relatively small. In the meta-analysis by Morton et al., which included 49 randomized, controlled studies, the average increase in muscle mass after 13 ± 8 weeks of training was only 0.3 kg [9].

Based on the available studies on strength training, it can be concluded that an additional approx. 0.25–0.3 g/kg body weight, corresponding to an extra 15–25 g of protein per day should be supplied in order to increase muscle protein synthesis (MPS) (◆ Table 1). This extra protein should also supply approx. 10 g of indispensable amino acids; furthermore, the intake should be tailored to match how long the training unit lasts (▶ "Endurance training and protein intake"). The meta-analysis by Morton et al. states that there is little supporting evidence from controlled studies on protein supplementation that total protein quantities of more than 1.6 g/kg body weight per day result in any additional effects at least regarding increases in fat free mass. This should be taken into account when configuring the individual protein balance with the aim of increasing muscular protein synthesis [34].

A short-term increase in protein intake can sometimes be useful: for instance, as part of planned weight loss (reduction of fat mass) through energy reduction that aims to keep loss of muscle mass to a minimum. For example when there is pressure to "make weight" in a competitive sport or in the case of long periods of endurance-type exertion, the body uses its own protein as an energy source. Here, the breakdown of protein and the body's recourse to free amino acids as an energy source leads to a catabolic state, which is not desirable as it leads to reduction in muscle mass. In such cases, it can be helpful to increase the proportion of protein in the diet even when reducing energy intake in order to ensure that the body favours using fat reserves over using protein reserves despite its catabolic state [3].

Protein intake and physical activity have a synergistic effect on the initiation of protein synthesis, on increasing energy metabolism and on fat burning, both in the context of weight reduction and in the context of improving body composition while maintaining a constant weight [7].

Endurance training and protein intake

Proteins are not primary sources of energy or primary energy reserves. Nevertheless, protein is sometimes used as an energy source through the oxidation of amino acids. This happens especially in endurance sports after carbohydrate stores have been exhausted [35]. This can be verified in the form of an increase in urea concentration in the serum following training. For example, in a marathon, about 20 g of amino acids are metabolized for energy. Marathon-specific training consumes similar amounts [36]. Protein requirements among competitive athletes are therefore par-

ticularly high in the context of endurance sports. Some authors have suggested that athletes who do ultra-long distances in particular may require a protein intake that is much higher than 1.2–2.0 g/kg body weight [37]. As mentioned before, today, there is not yet sufficient scientific evidence to recommend such high protein quantities.
When elaborating individual nutrition plans, the fact that endurance athletes usually have a significantly lower body weight than strength athletes should be taken into account – i.e. it should be ensured that the absolute amount of protein for endurance athletes is often significantly lower than that of strength athletes.
There is no doubt that replacing carbohydrates with proteins during physical endurance activity does not improve performance. Rather, many studies have even shown that this results in a reduction in performance, e.g. during a time trial. This affirms the role of carbohydrates as the most important and fastest source of energy during physical exercise. Therefore, replacing carbohydrates with an isocaloric amount of proteins does not improve acute endurance performance [38].

There have also been repeated studies on whether the administration of additional protein increases glycogen resynthesis in the muscles in the immediate post-exertion phase (which lasts until 2 hours after exertion) [3, 7]. There is a broad consensus that this is only the case if less than 1.2 g of carbohydrate per kg of body weight per hour are administered in the post-exercise phase [3, 7]. If for training and physiological reasons it makes sense to reduce the proportion of carbohydrates consumed in the post-exercise phase, then a higher level of glycogen resynthesis can still be achieved through an isocaloric increase in the proportion of protein consumed.

Timing of protein intake

It has been demonstrated that the timing of protein intake can play an important role in terms of improving training effects. For this reason, many current recommendations about protein intake place great emphasis on the timing of protein intake [1, 3, 7].
It has been hypothesized that the beneficial effect of protein intake on muscle protein synthesis should be greatest when administration takes place in a time window of up to 2 hours after exercise [39]. However, not all studies could support this hypothesis [3, 40, 41] and the existence of a relatively short, "anabolic" window in the post-exertion phase (approx. 120 minutes) – as is described for carbohydrates, for instance – is no longer considered relevant by all authors [15, 42]. In the post-exercise phase, muscle protein synthesis is increased for up to 24 hours or even longer. It has not yet been conclusively determined whether muscular protein synthesis or other adaptation effects are actually accelerated more when protein intake takes place in the immediate post-exercise phase (up to 120 minutes after workout), or when intake first takes place 3 or 4 hours thereafter [15, 42]. Furthermore, the question of whether protein is best taken after physical exercise or whether it is better to take part of it before exercise has not yet been sufficiently investigated [3, 15, 42]. Some studies favour administration after exercise and others describe greater effectiveness when protein is administered before or even during exercise [42].
The authors of a recent summary came to the conclusion that the timing of intake should not be viewed too dogmatically [42]. According to them, it is undisputed that protein intake must be tailored to the duration of physical activity in order to increase muscle protein synthesis. Whether this takes place before or after exercise, 1–2 hours, or 2–3 hours after exercise would likely be of little consequence with regard to the net effect in terms of training-induced improvement in performance, which is what matters for the athlete [42]. However, further studies will be required to prove that this view is correct.

There is a consensus that easily digestible proteins should be favoured in the post-exercise phase and proteins that take longer to digest (e.g. casein) are better reserved for the later phase – e.g. as "overnight" proteins. The intention behind the use of such slowly-absorbed proteins is to ensure that even many hours after physical activity, amino acids are available for muscle protein synthesis. However, not all of the studies were able to demonstrate that such overnight proteins had verifiable beneficial effects on physiology in vivo [1, 43].

In consequence, since the metabolic window for protein biosynthesis remains open for a relatively long time, proteins should be supplied several times a day (3–4 x/day) in dosages of up to 2 g/kg body weight per day. In the case of certain training requirements (e.g. at the beginning of a strength training phase, during extreme training units or during planned weight reduction while maintaining muscle mass), supply can be set higher temporarily. However, if supply is to be set higher, kidney function should be checked beforehand and sufficient fluid intake has to be ensured. In addition, consideration should always be given to the composition of the proteins, to the protein sources, to the additional nutrients supplied along with the protein sources and to the digestibility of the proteins.

The influence of protein intake on muscular regeneration

Regeneration following physical exercise to exhaustion is crucial for athletes as part of the training process and during competition periods. Improved "regeneration" is often cited as an argument for increasing the proportion of protein consumed in the post-exercise phase. The term "regeneration", which is difficult to define in physiological terms, can be equated to a lower muscular or immunological response to physical activity on the one hand, or to improved performance during subsequent physical activities on the other hand. Inadequate protein supply during the regeneration phase can lead to a negative nitrogen balance due to the increased muscle protein metabolism caused by the exercise, whereas an adequately high protein supply leads to a positive nitrogen balance. Therefore, protein intake in the post-exercise phase could support the repair of exercise-induced muscle damage and could thus theoretically have a positive effect on regeneration [44]. In some studies, faster recovery of muscle strength following eccentric training was observed after ingestion of very high protein doses of 50–100 g [7]. However, many studies found no increase in performance during subsequent exercise following prior protein intake in the post-exercise phase [7].
Study findings are also inconsistent with regard to a decreased stress response of the muscles and of the whole body. Although one meta-analysis found a small but significant positive effect following protein administration [45], other authors did not come to the same conclusions [44].
A detailed analysis of the available studies shows that in endurance sports such as cycling and long-distance running, the supply of protein or amino acids could possibly reduce exercise-induced muscle damage and/or muscle pain and promote a faster return to the original level of performance, however, after eccentric endurance training, the supply of additional protein did not influence parameters of muscle damage, muscle pain, or performance in the regeneration phase. Targeted protein administration after strength training (whether this training focuses on eccentric exercises or not) has not shown to reduce indicators of muscular damage or muscle pain [46].

In summary, the role of proteins in regeneration following physical exercise remains scientifically controversial. Although there have been various studies investigating the effect of proteins on markers of regeneration after exercise, the exercise protocols, the parameters recorded, the protocols used to check performance, and the type, dosage, and composition of the supplements administered used in those studies differed making the results difficult to compare [46].

Summary

Tailoring protein intake to an athlete's specific type of sport and exercise can be helpful in terms of supporting the training process and improving performance.

Currently, the recommendation is that protein intake in the context of sport should be approx. 1.2–2.0 g/kg body weight per day, depending on the person's training condition and their training goals. Protein intake should not be considered a fixed value for athletes' everyday diet. Rather, it should be adapted to training goals, training intensity, and the scope of training in a flexible manner.
Since the metabolic window for protein biosynthesis remains open longer compared to carbohydrates, proteins should be supplied several times a day (3–4 x/day) in dosages of up to 2 g/kg body weight per day.
As yet, there is no definitive answer to the question of whether there is an "optimal" source of protein or amino acids because positive study effects have been observed with various protein and amino acid sources. However, if sources of incomplete protein are used, care should be taken to achieve a complete amino acid spectrum through appropriate nutrient combinations. In terms of protein intake, attention should be paid not only to the composition of amino acids, but also to the energy content and the proportion of fat, carbohydrates, micronutrients, bioactive peptides and secondary plant substances of the food consumed as protein sources. Based on current knowledge, a mix of different protein sources with different compositions and different absorption kinetics is likely to be the best choice for athletes.

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Conflict of Interest
The authors declare no conflict of interest.

Corresponding author
Klaus Schäbethal
schaebethal@dge.de

Prof. Dr. Daniel König[1]
Prof. Dr. Anja Carlsohn[2]
Hans Braun[3]
Dr. Mareike Großhauser[4]
Prof. Dr. Dr. Alfonso Lampen[5]
Dr. Stephanie Mosler[6]
Prof. Dr. Andreas Nieß[7]
Klaus Schäbethal[8]
Dr. Alexandra Schek[9]
Dr. Kiran Virmani[8]
Dr. Rainer Ziegenhagen[10]
Prof. Dr. Helmut Heseker[11]

[1] Institut für Sport und Sportwissenschaft
Arbeitsbereich Ernährung
Albert-Ludwigs-Universität Freiburg
[2] Fakultät Life Sciences/Department Ökotrophologie
Hochschule für Angewandte Wissenschaften Hamburg
[3] Institut für Biochemie
Deutsches Forschungszentrum für Leistungssport – momentum; Deutsche Sporthochschule Köln
[4] Olympiastützpunkt Rheinland-Pfalz/Saarland
[5] Bundesinstitut für Risikobewertung (BfR)
[6] Institut für Gesundheitswissenschaften
Abteilung Ernährung, Konsum und Mode
Pädagogische Hochschule Schwäbisch Gmünd
Olympiastützpunkt Stuttgart
[7] Abteilung Sportmedizin
Medizinische Klinik
Universitätsklinikum Tübingen
[8] Deutsche Gesellschaft für Ernährung e. V. (DGE)
[9] Redaktion Leistungssport (DOSB)
[10] Abteilung Lebensmittelsicherheit (Abt. 5)
Bundesinstitut für Risikobewertung (BfR)
[11] Institut für Ernährung, Konsum und Gesundheit
Fakultät für Naturwissenschaften
Universität Paderborn

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