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PROTEIN METABOLISM AND EXERCISE: EVALUATING THE NECESSITY OF AMINO ACID SUPPLEMENTS

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Abstract

The intricate process of protein metabolism is vital to overall health, muscular growth, and repair—especially during physical activity. This study explores the complex interplay between protein metabolism and exercise, emphasizing the roles of dietary supplements, MPS (muscle protein synthesis), and resistance training. The findings demonstrate that resistance exercise significantly raises MPS in many muscle areas, and that deliberate consumption of protein supplements and amino acids amplifies the benefits. According to the study, high-intensity exercise increases protein turnover, with sarcoplasmic and myofibrillar proteins exhibiting different responses. For endurance athletes, leucine and other necessary amino acids should be consumed in a tailored manner to optimize muscle growth and repair. Athletes usually maintain positive nitrogen balances, a sign that they are consuming enough protein to maintain and adapt their muscles. This study highlights how important it is to balance protein intake with the kind and level of exercise to maximize anabolic reactions and support overall muscle health. This study emphasizes the value of customized dietary plans and calls for more research to examine the complex interplay between supplements, activity, and protein metabolism.

Keywords: *Protein, Metabolism, Exercise, Amino Acid, Supplements*

1. INTRODUCTION

Protein synthesis and breakdown occur within the body as part of protein metabolism, a basic biological activity. Amino acid-based proteins are necessary for many physiological processes, such as immune system response, muscle repair, enzyme functioning, and hormone synthesis. The body needs protein during exercise, particularly resistance and endurance training, because it needs it for muscle growth and repair. Important considerations concerning the sufficiency of dietary protein consumption and the possible function of amino acid supplements in promoting the best possible exercise performance and recuperation are brought up by this increased demand.

Athletes and fitness enthusiasts who want to improve their workout results are increasingly turning to amino acid supplements. Supplements that claim to increase muscle protein synthesis, decrease pain in the muscles, and speed up recovery include branched-chain amino acids (BCAAs), whey protein, and essential amino acids. The usefulness and necessity of these supplements are still up for discussion, though. A well-balanced diet that includes a variety of foods high in protein, such as meat, dairy, legumes, and nuts, can help many people satisfy their protein demands.

This study examines the available data on protein metabolism during exercise to determine whether amino acid supplements are necessary. It will examine how various forms of exercise impact the amount of protein required, how dietary protein helps meet these needs, and the possible advantages and disadvantages of supplementing. This research aims to give evidence-based suggestions for people who want to enhance their nutritional strategies for performance and recovery by understanding the relationship between exercise and protein metabolism. The results of this study will add to the current conversation about individualized diet plans and the benefits of supplements for physical activity and overall health.

2. REVIEW OF LITREATURE

Torre-Villalvazo et al. (2019) Examine the effects of protein and amino acid supplements on immunity as well as how they affect workout recovery and performance. The study highlights how taking supplements and eating the correct quantity of protein might alter these signaling pathways, accelerating the synthesis of muscle protein and enhancing post-exercise recovery. The study

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highlights how important it is to tailor protein and amino acid intake to each specific exercise regimen in order to optimize metabolic processes and improve athletic performance.

Master and Macedo (2021), who focus specifically on the amino acids and proteins found in milk. The authors look at the advantages of these supplements in terms of boosting total exercise performance, reducing muscle injury, and improving muscle protein synthesis. The analysis emphasizes the significance of casein and whey proteins, highlighting how their unique amino acid compositions and digestibility contribute to the reason behind their superior supplement performance. The benefits of combining resistance training with milk proteins are also highlighted in the study, with a focus on how athletes and other physically active people can boost their strength and muscle mass.

Li et al. (2024) examines the mechanisms via which amino acids regulate skeletal muscle metabolism and provides guidance on appropriate exercise dosage and potential negative effects. The study examines the different ways that amino acids aid in the synthesis of muscle protein, energy production, and recuperation. It also examines their interactions with mTOR and AMPK signaling pathways. The authors provide evidence-based suggestions for amino acid supplements that account for exercise duration, intensity, and individual variability. By addressing the negative effects of increased amino acid intake, such as gastrointestinal distress and metabolic irregularities, the research also emphasizes the need for customized supplementing solutions.

Williamson et al. (2019) Examine how dietary protein consumption affects protein metabolism and endurance-trained male performance. According to the study, eating more protein can dramatically accelerate the synthesis of new proteins and decrease the breakdown of existing muscle protein, which improves recovery and endurance. The authors stress that sustaining muscle mass and encouraging the metabolic changes required for endurance training depend on consuming the right amount of protein. This study emphasizes how crucial it is for endurance athletes to consume enough protein to meet their high energy requirements and recuperation needs.

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3. HUMAN PROTEIN METABOLISM: A BROAD PERSPECTIVE

Human body protein mass provides structural support, enzymes to catalyze metabolic reactions, signalling intermediates within and between cell tissues, and fuel for extreme survival. Major protein deposits are found in skeletal muscles, accounting for 40% of body weight in young males with 20-22% BMI (kg.m−2) and about 60% of total body protein in humans. Plasma proteins (including albumin, about 50% of liver proteins), immune cells (primarily leucocytes), intestinal tract proteins (digestive enzymes), bone, and dermal collagen are also produced by the liver. Protein balance shows the net protein synthesis and breakdown of any cell or tissue, which varies greatly between tissues, organs, and cell compartments.

Table 1: Averages of human skeletal muscle's fractional synthesis rates (FSR) for particular proteins (fasted state).

Muscle Fraction	**FSR, Mean ± SD (% per day)**
Myosin Heavy Chain	0.92 ± 0.09
Actin	1.803± 0.20
Sarcoplasm	1.31 ± 0.31
Mitochondria	1.95 ± 0.11

Table 1 shows the average fractional synthesis rates (FSR) of several proteins in fasted human skeletal muscle, revealing protein turnover. Myosin heavy chain, a muscular contraction protein, with an FSR of 0.92% per day, showing a lower synthesis rate than other muscle fractions. Actin, another key contractile protein, has a greater FSR of 1.803% each day, suggesting its dynamic role in muscle construction and function. Sarcoplasm, which contains metabolic proteins and enzymes, has a daily FSR of 1.31%. The mitochondria, which produce energy and metabolism, have the greatest FSR at 1.95% each day, indicating active protein turnover to meet muscle cell energy

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needs. These data indicate that all muscle fractions synthesize protein, but mitochondria turnover protein the fastest, possibly due to their vital function in energy metabolism.

4. MUSCLE PROTEIN CONTENT AND THE CONSEQUENCES OF EXERCISE

Several reviews discuss human muscle protein production and breakdown during and after resistance exercise. We must distinguish fasted (post-absorptive) or fed findings during versus after exercise for muscle protein synthesis (MPS) or breakdown (MPB).

Table 2 shows that short-term intensive resistance training enhance mixed skeletal muscle protein at rest. Methodological discrepancies may exist between reports, although the total work production (80–90% of maximum contraction) appears to provide the most benefit. Resistance exercise works better on myofibrillar than sarcoplasmic proteins. Muscle protein synthesis increases appear to last up to 4 hours following exercise. Resistance training appears to have no effect on muscle protein breakdown.

Table 2: Resistance exercise's effects on MPS and MPB in untrained and fasting states.

Exercise Protocol	**FSR (%.h⁻¹) Post Ex/Pre-Ex-Ratio**	**FBR (%.h⁻¹) Post Ex/Pre-Ex-Ratio**
Mixed Muscle Proteins		
5 x 7-13 rep. 80% max	+50%*	-
6 x 11 rep. 100% max	+141%*	-
9 x 8 rep. 80% max	+151%*	+40%*
9 x 130% max	+133%*	+49%*
7 x 9 rep. 80% max	+32%*	-
9 x 11 rep. 75% max	+38%*	NS
11 x 13 rep. 80% max	+52%*	-
5 x 12 rep. 80% max	+139%*	-

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6 x 92% max	+355%*	-
Myofibrillar Proteins		
6 x 92% max	+325%*	-
7 sec at 30% max to exhaus.	+181%*	-
Sarcoplasmic Proteins		
6 x 92% max	+79%*	-
Mitochondrial Proteins		
7 sec at 30% max to exhaus.	+181%*	-

Table 3: Resistance exercise's effects on MPS and MPB in untrained and fasting states.

Exercise Protocol	**Nutritional Protocol**	**FSR (%.h⁻¹) Post Ex/Prix Ratio**	**FBR (%.h⁻¹) Post Ex/Pre-Ex-Ratio**
Mixed Muscle Proteins			
6 x 11 rep. max	11g AA (IV)	+133%*	NS
12 x 10 rep. 80% max	7g EAA (oral)	+425%*	NS
6 x 13 rep. 80% max	11g whey + CHO (oral)	+144%*	-
11 x 20 rep. 70% max	Leu EAA + CHO (oral)	+171%*	-
5 x 11 rep. max	42g egg proteins (oral)	+92%*	-
9 x 12 rep. 70% max	11g whey (oral)	+41%*	-

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Myofibrillar Proteins			
6 x 12 rep. 80% max	1g protein.kg⁻¹ (oral)	+85%*	-
22 x 18 rep. 75% max	6g protein's⁻¹ (oral)	+191%*	NS
stepping ex (+26% bw)	45g EAA + CHO	+228%*	-
6 x 10 rep. max	25g whey (oral)	+231%*	-
9 x 12 rep. max	25g whey (oral)	+199%*	-
11 x 9 rep. 80% max	0.3g.kg⁻¹ LM whey	+95%*	-
5 x 12 rep. 80% max	20g whey protein (oral)	+51%*	-
Sarcoplasmic Proteins			
22 x 12 rep. 75% max	6g protein.h⁻¹ (oral)	+322%*	-
6 x 12 rep. max	25g whey (oral)	+105%*	-

Tables 2 and 3 shed light on how, in untrained and fasting people, resistance exercise and dietary interventions impact muscle protein synthesis (MPS) and muscle protein breakdown (MPB). The effects of resistance training alone on various muscle fractions are the main topic of Table 2. It demonstrates that resistance training dramatically raises the fractional synthesis rates (FSR) of mitochondrial, sarcoplasmic, mixed muscle, and myofibrillar proteins. Exercises such as 6 × 11 reps at 100% max for mixed muscle proteins raise FSR by 141%, highlighting the significant impact of high-intensity resistance training on MPS. Exercises at 130% max result in a 133% increase in FSR and a 49% increase in MPB, suggesting that although there is a significant increase in protein synthesis, there is also an increase in protein breakdown, perhaps as a result of muscle

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injury and remodeling processes. Exercises at 92% max result in a 325% increase in FSR for myofibrillar proteins, demonstrating the significant influence of near-maximal loads on contractile protein synthesis. On the other hand, FSR rises by 181% after intense activity at 30% max, indicating that myofibrillar protein synthesis can be greatly increased even by lower-intensity activities that are completed to exhaustion. Resistance training promotes protein synthesis across different muscle fractions, with the response varied according to exercise intensity and duration. Sarcoplasmic and mitochondrial proteins also respond favorably, with FSR rising by 79% and 181%, respectively.

The combined effects of resistance training and dietary treatments are examined in Table 3. Here, the anabolic effect of exercise is enhanced by the addition of amino acids and protein supplements. Intravenous injection of 11g of amino acids during 6 x 11 reps at maximum intensity causes a 133% rise in FSR for mixed muscle proteins, but does not significantly alter MPB, indicating greater protein synthesis without increased breakdown. A 425% increase in FSR is obtained by oral ingestion of 7g of essential amino acids during 12 x 10 repetitions at 80% max, indicating the synergistic effect of amino acid supplementation with exercise. When exercise and whey protein supplementation are coupled, myofibrillar protein synthesis is also greatly increased. For example, a 231% increase in FSR after 6 x 10 repetitions at maximum intensity with 25g of whey protein suggests that supplementation can maximize the anabolic response of these proteins. When 6g of protein is consumed hourly over a 22 x 12 rep program at 75% max, sarcoplasmic proteins show a 322% increase in FSR. This highlights the significance of continuous protein intake to maintain increased synthesis rates in sarcoplasmic fractions necessary for metabolic adaptations. Overall, these results show that MPS is greatly increased by resistance exercise in different muscle fractions, and that these benefits are further enhanced by nutritional supplements. The incorporation of particular protein sources and amino acids into post-exercise nutrition maximizes the anabolic response, indicating a promising approach to enhance muscle repair and adaptation in persons who are not trained.

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5. SIMPLE DIETARY GUIDELINES FOR CONSISTENT PHYSICAL ACTIVITY

The information provided here encourages athletes and those who exercise regularly to pay attention to sufficient protein consumption in order to maintain or improve their status of skeletal muscle mass. The scientific literature, however, demonstrates a broad range of useful behaviors that support the adaptation of muscle growth through particular dietary applications: how much, when, how, and what kind of protein? We'll make an effort to distinguish the wheat from the chaff.

The World Health Organization (WHO), the USA Institute of Medicine, and the health organizations in France and Belgium have set exact guidelines for the recommended daily allowance (RDA) of 0.83 $g.kg^{-1}$ body weight for young, sedentary adults. Based on the statistical distribution of adult participants, a protein intake alimentary deficit occurs when body weight is less than 0.40–0.50 g/kg.

However, the daily load of ±0.8 $g.kg^{-1}$ body weight seems inadequate for persons engaging in medium- or high-intensity physical activities on a regular basis (sports, leisure, jobs). There is evidence in many publications to support a somewhat regular growth above the "RDA" amount.

There is growing evidence that the amount of muscular growth during recovery is influenced by the time and source of protein consumed. There seems to be a slight differential in the turnover of muscle proteins between young men and women. A balance between the amount of protein consumed daily and the amount used during activity is what's known as adequate protein balance. As previously mentioned, this balance could be estimated using the amount of nitrogen that is taken in through food and released as nitrogen wastes, primarily in urine. Although the nitrogen balance (NBal) has been used for a long time, this approach is not the most precise one. Urine collection is still an indirect way to assess the daily balance between nitrogen released from protein degradation (mostly muscle mass) and protein intake as determined by the daily meal questionnaire. An example of NBal on young athletes is shown in Table 4 (Poortmans unpublished data).

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Table 4: N balance (NBal) of athletes was measured twice a day for seven days using urine nitrogen analysis and a meal questionnaire.

Sport	**Athletes (Number)**	**Gender**	**Age (Years)**	**NBal (Mean ± SE)***	**NBal > Than 0^{**} $(g \cdot protein^{-1} \cdot 24h^{-1})$**
Running	20	M	20-21	1.47 ± 0.08	1.23
Rowing	20	M	16-21	1.30 ± 0.08	1.18
Cycling	20	M	18-22	1.60 ± 0.10	1.39
Swimming	10	M, F	12-19	1.61 ± 0.15	1.52
Gymnastics	10	F	9-13	1.71 ± 0.41	1.40
Gymnastics	15	F	16-17	1.13 ± 0.20	0.87
Basketball	15	M	20-40	1.76 ± 0.15	1.19
Aerobics	10	F	20-34	1.25 ± 0.07	1.18
Orienteering	20	M	23-35	1.39 ± 0.14	1.32

Bodybuilding	10	M	26-37	1.95 ± 0.14	1.35

The nitrogen balance (NBal) of athletes participating in different sports is shown in Table 4, which was calculated over a seven-day period using meal questionnaires and urine nitrogen tests. An essential marker of protein metabolism, nitrogen balance shows the distinction between nitrogen intake and excretion. While a negative nitrogen balance denotes a possible protein shortfall or increased protein requirements, a positive nitrogen balance supports enough protein consumption for growth, recovery, and maintenance of lean body mass.

The table demonstrates that athletes participating in sports like gymnastics, basketball, and bodybuilding have some of the highest mean nitrogen balance values. For example, bodybuilders' NBal of 1.95 ± 0.14 $g \cdot protein^{-1} \cdot 24h^{-1}$ suggests that their high-protein diets complement their rigorous training schedules, which frequently target muscular hypertrophy. A high nitrogen balance (1.76 ± 0.15) is also observed in basketball players, indicating that they consume enough protein to match the demands of their sport, which calls for both power and endurance.

Athletes in strength and power sports have higher nitrogen balances than those in endurance sports, such as rowing and running. The NBal for rowers is 1.30 ± 0.08, and for runners it is 1.47 ± 0.08. Despite being lower, these readings nevertheless show a positive nitrogen balance, indicating that the athletes are getting the protein they need to sustain both recovery and endurance performance. The marginally reduced equilibrium could be attributed to the distinct metabolic requirements of endurance sports, which entail elevated energy expenditure and the utilization of protein for both energy and repair.

The data indicates variations in nitrogen balance between genders, especially in sports such as gymnastics, where female athletes between the ages of 9 and 13 have a mean NBal of 1.71 ± 0.41, which is higher than that of their older counterparts between the ages of 16 and 17, who have an NBal of 1.13 ± 0.20. The observed discrepancy could perhaps be attributed to variances in growth rates, hormonal fluctuations, and training load among junior athletes. This underscores the

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significance of customized nutritional approaches to bolster female athletes over a range of developmental phases.

5.1 Endurance type of training

examined three different protein intakes for endurance athletes (light: 0.8 g.kg.day; medium: 1.8 g.kg.day; high: 3.6 g.kg.day). There was no correlation between protein synthesis and food intake following exercise. However, when examining young, unskilled individuals under fast conditions who practiced for 60 minutes at 30% Wmax or 30 minutes at 60% Wmax on a bicycle, marginally modified this conclusion. In the post-exercise phase, they saw a steady mitochondrial protein fraction in both cases along with a 60% increase in myofibrillar protein in the vastus lateralis muscle. Furthermore, these scientists found that the two muscle compartments' protein synthesis continued for 24 to 48 hours after exercise.

A few studies highlighted the effects of varying protein consumption amongst endurance athletes who had received training (Table 5).

Table 5: Muscle protein synthesis in experienced endurance athletes following varying protein intake ratios during 50–75% VO2max endurance training.

Types of Food	Quantities	Protein Synthesis
Pro	2.6 g·kg⁻¹	Stable
	0.25 g·kg⁻¹	Stable
Whole Milk	5 ml·kg⁻¹	Stable
	0.095 g·kg⁻¹	+101%
EAA	15.5 g	+15%
Leu	51 mg·kg⁻¹	+14%
	7 g	Stable

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Muscle protein synthesis (MPS) in seasoned endurance athletes after consuming different protein sources during training at 50–75% of VO2max is shown in Table 5. The table lists the various food categories, their corresponding amounts, and how they affect the synthesis of proteins.

Pro: Consuming 2.6 $g \cdot kg^{-1}$ and 0.25 $g \cdot kg^{-1}$ of protein each day had a consistent impact on MPS. This implies that although protein consumption is necessary to preserve muscle mass and function, these specific ratios did not, in endurance athletes under the investigated conditions, significantly increase protein synthesis. This stability suggests that basal protein intake levels for seasoned endurance athletes may be adequate to meet the needs of muscle maintenance and repair without the need to increase synthesis rates.

Whole Milk: While protein synthesis was likewise steady when 5 $ml \cdot kg^{-1}$ of whole milk was consumed, there was a notable increase in protein synthesis (+101%) when 0.095 $g \cdot kg^{-1}$ was consumed. This discovery raises the possibility that some whole milk constituents, like casein and whey proteins, may have strong anabolic effects at particular dosages. This is probably because of their balanced amino acid profiles and sluggish digestion rates, which prolong the supply of amino acids needed for muscle growth and repair.

Essential Amino Acids (EAA): 15% more protein was synthesized after consuming 15.5 g of EAAs. Because they include the necessary building blocks that the body is unable to manufacture on its own, EAAs are needed for the synthesis of muscle protein. This increase highlights the significance of consuming enough EAAs to maintain muscle protein synthesis and repair, especially during endurance training when muscle deterioration may occur.

Leucine (Leu): A 14% increase in protein synthesis was observed upon consuming 51 $mg \cdot kg^{-1}$ of leucine, a branched-chain amino acid (BCAA). One important regulator of muscle protein synthesis, the mTOR pathway, is known to be strongly stimulated by leucine. This result emphasizes the significance of leucine as a necessary dietary amino acid for fostering muscle anabolism, especially in endurance athletes who might require extra assistance for muscle growth and repair. Higher intakes of 7 g, however, did not result in any more increases, indicating that there may be a threshold beyond which leucine supplementation does not further improve MPS.

6. CONCLUSION

Muscle protein synthesis (MPS), resistance training, and dietary supplements are closely related to one another, as the research on protein metabolism and exercise highlights. It demonstrates that resistance training raises MPS in all muscle fractions, but that the effects are enhanced when protein supplements and amino acids are strategically consumed. Myofibrillar and sarcoplasmic proteins, for example, show distinct responses to high-intensity training in terms of increased protein turnover. Additionally, a customized protein intake is beneficial for endurance athletes, as certain nutrients such as leucine and vital amino acids enhance muscle growth and repair. It is noteworthy that athletes have positive nitrogen balances, indicating that they consume enough protein to sustain and grow their muscles. In order to optimize anabolic reactions and maintain muscle health, this research emphasizes the significance of matching protein intake with exercise intensity and type.

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