Original Article

Access this article online
Quick Response Code:
Website:
www.jehp.net
DOI:
10.4103/jehp.jehp_538_24

Effect of increased protein intake before pre-event on muscle fatigue development and recovery in female athletes

Taghread Ahmed Elsayed Ahmed, Heba Ali Ibrahim Seleem, Ghada Mohamed Youssef Elsayed, Marwa Ahmed Fadl Kholif, Rania Mohammed Abduljawad, Nour Taha Ebrahem Housen[1], Naglaa Mohamed Roby Sofy[2], Hager Abdel Hady[3]

Department of Sport and Exercise Science, College of Science and Humanities - Jubail, Imam Abdulrahman Bin Faisal University, Dammam, KSA, [1]Department of Self Development, Deanship of Preparatory Year, Imam Abdulrahman Bin Faisal University, Dammam, KSA, [2]Kindergarten Department, College of Education, Imam Abdulrahman Bin Faisal University, Dammam, KSA, [3]Department of Assistant and Supportive Subjects, College of Science and Humanities - Jubail, Imam Abdulrahman Bin Faisal University, Dammam, KSA

Address for correspondence:
Prof. Taghread Ahmed Elsayed Ahmed, Department of Sports Science and Physical Activity, College of Science and Human Studies in Jubail, Imam Abdulrahman Bin Faisal University, Dammam, KSA.
E-mail: taelsayed@iau.edu.sa

Received: 23-03-2024
Accepted: 14-05-2024
Published: 31-01-2025

Abstract:

BACKGROUND: Protein plays a vital role in facilitating muscle growth and also plays an important part in the optimal repair and recovery of the muscle after exercise. These benefits are achieved by consuming higher-protein diets. Therefore, this study aimed to investigate the effects of increased protein intake before the pre-event on muscle fatigue (MF) and ascertain if the increased protein intake before the pre-event contributes to improving recovery in female athletes.

MATERIALS AND METHODS: The experimental study was conducted at the Sports Academy for Basketball in Zagazig, Egypt, from July 2 to August 12, 2023. The study was conducted on 20 female basketball players (age: 16.65 ± 0.47 years; body height: 165.42 ± 3.09 cm; body mass: 59.68 ± 3.63 kg; training age: 2.44 ± 0.56 years). They were divided into two equally sized groups: The group with higher protein intake before the pre-event (HPP) and the group with normal protein intake before the pre-event (NPP) group. Both groups consumed the same dosage of protein (1.2 g/kg/day) as instructed (American College of Sports Medicine (ACSM) recommendation). Both groups performed the same training protocol, three times a week, over 6 weeks. All variables were assessed one week before the experimental program and after the 6-week training period. Data were collected using the Running-Based Anaerobic Sprint Test (RAST) to assess fatigue index (FI) and peak power (PP), and the Anaerobic Power Step Test to assess anaerobic capacity (AC). Moreover, changes in heart rate (HRC) to assess the recovery. The collected data were analyzed using SPSS version 22 software with the descriptive statistical test. The level of significance was set at $P \leq 0.05$.

RESULTS: The results showed that both groups made significant improvements in all variables (FI-PP-AC-HRC), but the HPP group had significantly greater improvements than the NPP group. The percentage of improvement ranged from 7% to 27% for the HPP group, versus 3% to 15% for the NPP group.

CONCLUSION: The major conclusion drawn from this study was that increased protein intake before the pre-event has a positive impact on reducing MF development and enhancing recovery in female athletes.

Keywords:

Anaerobic capacity, fatigue index, muscle fatigue, peak power, recovery

Introduction

Protein is a key nutrient responsible for several biological functions, including

How to cite this article: Ahmed TA, Seleem HA, Elsayed GM, Kholif MA, Abduljawad RM, Housen NT, *et al*. Effect of increased protein intake before pre-event on muscle fatigue development and recovery in female athletes. J Edu Health Promot 2025;14:6.

the repair and growth of many cellular structures like skeletal muscle. Dietary protein supplies the amino acids necessary for gene activity, transport of biological molecules, energy production, and the synthesis of hormones, enzymes, and neurotransmitters. For growth, repair, and synthesis of biologically active proteins, a positive protein balance must be attained and the rate of protein synthesis must exceed the rate of degradation. As you are learning, protein is vital to support the unique demands of growth, development, and normal physiological function during adolescence.[1-3] Consuming adequate dietary protein is critical for maintaining optimal health, growth, development, and function throughout life. Dietary protein requirements in athletes are dictated largely by body mass and lean body mass, as well as net energy balance and the requirement of physical activity.[4] The estimated average requirement (EAR) for protein is 0.8 g per kg body mass per day (g/kg/d) for sedentary adults and reflects the minimum amount of dietary protein required to meet indispensable amino acid requirements, establish nitrogen balance, and prevent muscle mass loss.[5,6] This Recommended Dietary Allowance (RDA) is similar to international adult protein recommendations established by the World Health Organization (0.83 g/kg/d).[7] The potential muscle-related benefits achieved by consuming high-protein diets, which are greater than RDA but within the acceptable macronutrient distribution range, have become increasingly clear. Increased protein intake contributes to greater strength, allows for greater muscle mass preservation when consumed during periods of negative energy balance, and provides a greater muscle protein synthetic response when evenly distributed across meals.[8,9]

Muscle fatigue (MF) can be defined as an exercise-induced decrease in the ability to produce force. Fatigue can also be defined as a decrease in maximal force or power production in response to contractile activity.[10] It can originate at different levels of the motor pathway and is usually divided into central and peripheral components. Peripheral fatigue is produced by changes at or distal to the neuromuscular junction. Central fatigue originates in the central nervous system (CNS), which decreases the neural drive to the muscle.[11] MF is a commonly experienced phenomenon that limits athletic performance and other strenuous or prolonged activities. Some factors affect muscle contraction and fatigue. The production of skeletal muscle force depends on contractile mechanisms, and failure at any of the sites upstream of the cross-bridges can contribute to the development of MF, including nervous, vascular, and energy systems; specifically, metabolic factors and fatigue reactants during the process of contraction.[12] Central neurotransmitters, especially acetylcholine, play an important role during whole-body exercise and fatigue and produce a positive effect on exercise performance. The so-called central fatigue hypothesis states that exercise induces changes in the concentrations of these neurotransmitters, and fatigue arises from changes within the CNS or proximal to the neuromuscular junction.[13] Muscle protein synthesis (MPS) is a very complex process that requires sufficient calories and protein, along with two key hormones produced in the body: human growth hormone and testosterone. Furthermore, MPS requires mechanical tension, muscle damage, and metabolic stress. To further enhance MPS,[14] protein plays a vital role in facilitating muscle growth while also playing an important part in the optimal repair and recovery of the muscle after exercise. Each time after exercise the muscle is damaged to some extent depending on the intensity and duration of exercise. This is an important part of adapting to the training session as it allows the muscle to remodel into a leaner, faster, stronger, and fitter muscle fiber. Protein which is broken down into amino acids in the body plays an important role in providing essential building blocks to the damaged muscle allowing it to repair and rebuild after each training session. As the body does not store protein, consuming high-quality protein around exercise is central to providing the muscle with the key elements it needs to optimize recovery.[15,16]

It is well established that athletes require a higher daily protein intake of between 1.2 and 2.3 g/kg of protein compared to non-exercising individuals to facilitate recovery and training adaptations.[4] ACSM has also published position statements on the protein requirements of athletes. They note recommended protein intakes ranging from 1.2 to 1.7 g/kg.[17,18] Recent studies have highlighted the increased protein requirements for elite endurance athletes and found that the recommended protein intake for endurance-trained adults is 1.83 g/kg/d, higher than the current recommendations.[19] This was supported by Bandegan *et al*. (2019),[20] who reported that the EAR for protein in endurance-trained men 24 h post-exercise is 2.1 g/kg/d, exceeding current guidelines. As with endurance athletes, multiple factors impact protein balance and protein requirements for strength/power athletes; however, training history and training status appear to significantly impact the efficiency with which the body processes protein.

It is now recognized that endurance and team sports athletes need an increased level of protein intake to support their training and performance goals. In fact, athletes who exercise intensely for more than 60 min three times weekly should increase their intake of protein to support their body's ability to recover after the training session. Consuming high-quality protein around exercise is a great solution to ensure the delivery of protein to the muscle and support athletes' recovery goals and training adaptations. It also contributes to recovery by feeding the muscle with amino acids. Consequently, intake of high-quality protein before pre-event is a good way to hit the ability to recover after the training session.[21]

Despite greater awareness of how high-protein diets might be advantageous for muscle mass, actual dietary patterns, particularly as they pertain to protein, have remained relatively unchanged in athletes. The current protein RDA, however, is often incorrectly applied when used as the definition of recommended intake, rather than its true designation as the required minimum intake. This misapplication is problematic for athletes and would necessitate higher protein needs. Thus, based on performance and recovery effects, it appears that the prudent approach would be to have athletes consume protein pre-training and pre-competition. Understanding the impact of protein intake on MF and recovery can provide valuable insights for coaches and researchers in the sports field. Hence, we decided to conduct this research that studies the effect of increased protein intake before pre-event on MF development and recovery in female athletes. Consequently, the two main aims of this study were[11] to investigate the effects of increased protein intake before pre-event on MF and[17] to ascertain if the increased protein intake before pre-event contributes to improving recovery in female athletes.

Materials and Methods

Study design and setting

This study adopted an experimental research approach and was conducted at the Sports Academy for Basketball in Zagazig, Egypt. The study was carried out from July 2 to August 12, 2023. The sample was selected through convenient sampling for this study, and pre and post-measurements were used for two experimental groups.

Study participants and sampling

An experimental study was conducted on 20 female basketball athletes who were selected from the Sports Academy for Basketball in Zagazig, Egypt (age: 16.65 ± 0.47 years; body height: 165.42 ± 3.09 cm; body mass: 59.68 ± 3.63 kg; training age: 2.44 ± 0.56 years). They were divided into two equal-sized experimental groups: high-protein pre-event (HPP) group (n = 10) and normal protein pre-event (NPP) group (n = 10). Before the commencement of the experimental program, a comparison was made between the two groups in a pretest for all study variables. No significant differences between the two groups were observed. It was ensured that the two groups were equivalent in terms of chronological age, training age, and all physiological variables before conducting the study.

Data collection tool and technique

To examine the change of MF and recovery following a competitive match, fatigue index (FI) and peak power (PP) were measured using the Running-Based Anaerobic Sprint Test (RAST), while the anaerobic capacity (AC) was measured using the Anaerobic Power Step Test. The recovery was examined by measuring changes in heart rate (HRC). Heart rate (HR) was taken at rest pre-match (basketball), immediately post-match, and after 3 min of post-match. The tests used in the study were carried out.

Running-Based Anaerobic Sprint Test (RAST)

The test involves six sprints over 35 m with a 10 s recovery between each sprint, providing measurements of peak power and FI. The test procedures are explained to the subject, followed by a warm-up. Cones are set up at each end of the 35 m running track. Two testers may be required, with one person timing each 35 m sprint and the other timing the 10 s recovery period. The subject stands at one end of the track and starts a maximal sprint upon the command "go." It is important to ensure that the subject sprints maximally through the line each time. After 10 s, the next sprint starts from the opposite end of the 35 m track. This procedure is repeated until six sprints are completed. The time taken for each sprint is recorded to the nearest hundredth of a second. The sprint times, along with body weight, are used to calculate maximal, minimal, and average power outputs, as well as the FI. Calculation of the result has been done as follows:

*Fatigue Index = (maximum power – minimum power) ÷ total time for the 6 sprints

*Peak Power = the highest power measurement.

The test-retest reliability for the RAST was r = 0.86.

Anaerobic Power Step Test

The performance of the Anaerobic Power Step Test is primarily dependent on the glycolytic pathway of metabolism, and secondarily on the phosphagen system. The test procedures are explained to the subject, followed by a warm-up. The subject stands alongside the bench with the dominant leg resting on top of the bench, the subject performs as many steps as possible in 60 s, by raising the body to the top of the step with the test leg. The legs and back were straightened with each step. The free leg dangles in a straight position during the ascent and supports and pushes off when the foot contacts the floor during the descent. A step was counted each time the subject's support leg was straightened and then returned to the starting position. The number of steps was recorded at 60 s. Calculation of the result has been done as follows: Anaerobic capacity (kg m/s) = $(+w/t) \times 1.33$

(+w = positive work), (t = 60 s for An Cap), (1.33 = factor to convert +w to total work)

The test–retest reliability for the Anaerobic Power Step Test was $r = 0.88$.

Experimental procedure

Before the study commenced, anthropometric parameters, such as body composition, FI, PP, AC, and recovery (HRC), were assessed. The evaluation of these analyses was performed one week before the intervention. Diet interventions were performed during 6 weeks. At the end of the study, the FI, PP, AC, and HRC were re-evaluated. Following the randomization of participants into two experimental groups, personalized dietary plans, including food substitution options, were provided to all participants. The distribution of protein throughout the day was assessed for both the HPP and NPP groups based on self-reported meal descriptions, which consisted of breakfast, lunch, and dinner. Fixed meal times were established. Protein intake before the pre-event was also evaluated for both groups. The United States Department of Agriculture (USDA) food composition table was utilized. To achieve the targeted protein intake in each group, high-quality protein sources such as meat, fish, eggs, milk, and other dairy products were recommended for both groups. Furthermore, both groups were advised to consume comparable amounts of protein. All prescribed diets were normocaloric and equicaloric, providing approximately 1.2 g of protein per kilogram of body weight per day (g/kg/day) in the dietary plans. The HPP group consumed the proposed amount of protein, which accounted for 60% of their daily dietary plan (1.2 g/kg/day) 2 h pre-match (basketball) during lunch, while the remaining 40% of the daily protein intake was evenly distributed across the other meals. The protein intake for the HPP group was divided as follows: 0.24 g/kg at breakfast, 0.72 g/kg at lunch, and 0.24 g/kg at dinner. On the other hand, the NPP group consumed similar protein amounts divided evenly into three meals per day as follows: 0.4 g/kg at breakfast, 0.4 g/kg at lunch, and 0.4 g/kg at dinner. They consumed the proposed amount of protein, which accounted for 33% of their daily dietary plan (1.2 g/kg/day) 2 h pre-match (basketball) during lunch. Both groups performed the same training protocol, three times a week. The intervention lasted for 6 weeks.

Ethical considerations

The study received ethical approval from the Institutional Human Ethics Committee (EC No: 22/2023), and participants were included only after providing informed written consent. Both groups of participants were informed about the study's purpose and the methods used for data collection. Clear explanations were given regarding all testing and study procedures; participants were informed about the potential risks and benefits associated with the study. Ethical considerations, such as confidentiality and the participant's right to withdraw at any time, were ensured. Participation in the study was voluntary, and permission was obtained from an authority figure before collecting data in the research field.

Results

No subject sustained an injury as a result of the experimental program. All subjects completed at least 15 of the 18 training sessions. Both groups demonstrated statistically significant improvement between the pre-test and post-test in MF, which was indicated by the FI, PP, and anaerobic power (AP) ($P < 0.05$), as shown in Tables 1 and 2. There were no intergroup differences in all variables before the program, but after the experimental program, there were significant differences between groups, as shown in Table 3. The HPP group demonstrated a significant improvement better than the NPP group in MF (FI, PP, and AP) and recovery (HRC). Figure 1 shows the percentage of improvement in FI, PP, AP, and HRC (HR resting, HR after effort, and HR after 3 min of effort) for the two experimental groups, which ranged from 7% to 27% for the HPP group versus 3% to 15% for the NPP group. These results indicate that increasing protein intake before the event had a greater effect on improving MF and recovery for the HPP group compared to taking the normal dose of protein before the event in the NPP group. In addition, the results suggest that consuming 60% of the recommended daily protein intake 2 h before the event has a more positive effect than evenly dividing the daily recommended protein levels throughout the day.

Discussion

The main purpose of this study was to investigate the impact of increased protein intake before the event on MF development and recovery in female athletes. The results of the study showed significant differences ($P < 0.05$) in MF (FI, PP, and AP) and recovery (HRC) between the pre-test and post-test for the experimental group (HPP), which consumed 60% of the recommended daily protein

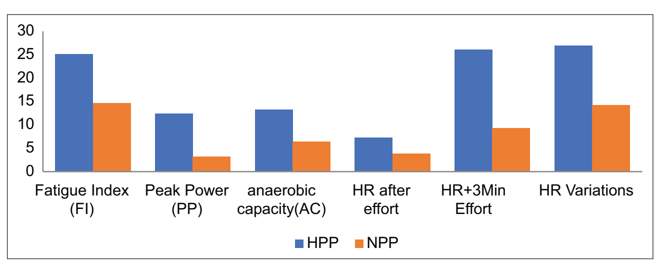

Figure 1: The percentage of improvement in muscle fatigue and recovery between the HPP and the NPP

Table 1: Means, standard deviations (SD), and significant differences between pre and post-measurement for the experimental group (HPP)

Variables	Pre-test		Post-test		*t*	*P*
	Mean	±SD	Mean	±SD		
Fatigue index (W/s)	9.87	0.15	7.39	0.37	15.22	0.00*
Peak power (Watts)	654.34	22.69	735.24	21.63	5.69	0.00*
anaerobic capacity (kg m/s)	3348.09	181.39	3790.73	100.53	7.20	0.00*
HR after effort	161.51	1.51	149.70	1.83	32.87	0.00*
HR after 3 min of effort	147.80	3.16	109.30	6.24	16.46	0.00*
HR after effort & after 3 min	149.70	1.83	109.30	6.24	22.26	0.00*

Table 2: Means, standard deviations (SD), and significant differences between pre and post-measurement for the experimental group (NPP)

Variables	Pre-test		Post-test		*t*	*P*
	Mean	±SD	Mean	±SD		
Fatigue Index (W/s)	9.73	0.51	8.31	0.29	6.18	0.00*
Peak Power (Watts)	649.32	16.90	670.04	23.22	3.36	0.02*
anaerobic capacity (kg m/s)	3276.91	138.61	3485.69	180.05	7.34	0.00*
HR after effort (bpm)	162.20	1.75	156.10	3.21	5.22	0.00*
HR after 3 min of effort	147.60	2.22	133.90	3.84	8.88	0.00*
HR after effort & after 3 min	156.10	3.21	133.90	3.84	12.64	0.00*

Table 3: Means, standard deviations (SD), and significant differences in the post-measurement between the two experimental groups HPP and NPP

Variables	HPP		NPP		*t*	*P*
	Mean	±SD	Mean	±SD		
Fatigue Index (W/s)	7.39	0.37	8.31	0.29	4.34	0.00*
Peak Power (Watts)	735.24	21.63	670.04	23.22	4.59	0.01*
anaerobic capacity (kg m/s)	3790.73	100.53	3485.69	180.05	3.31	0.02*
HR after effort (bpm)	149.70	1.83	156.10	3.21	5.48	0.00*
HR after 3 min of effort	109.30	6.24	133.90	3.84	10.62	0.00*
HR difference after effort vs. 3 minutes. HR after effort–HR after 3 min	40.40	5.73	22.20	5.55	7.21	0.00*

HPP: The higher protein pre-event group; NPP: the normal protein pre-event group; **P*<0.05

intake 2 h before the event. This can be attributed to the fact that protein intake before an event has the potential to inhibit muscle protein breakdown, stimulate protein synthesis, and maintain a positive amino acid balance. Increased protein intake before an event may enhance muscle protein synthesis, leading to improved repair and growth capacity, which could potentially reduce MF during exercise. Furthermore, protein can contribute to energy production, helping to delay the onset of fatigue during exercise. Increased protein intake before an event may also help in reducing muscle damage. This can lead to faster recovery post-exercise by providing essential amino acids needed for muscle repair and growth. This might aid in reducing post-event muscle soreness and fatigue.

The results also showed significant differences ($P < 0.05$) in MF (FI, PP, AP) and recovery (HRC) between the pre-test and post-test for the experimental group (NPP), which consumed 33% of the recommended daily protein intake 2 h before the event. This is due to their regular training, which lasted for 6 weeks, three times a week. These results are supported by Shakerian *et al*. (2016), who reported that regular exercise activities have a preventive role in affecting musculoskeletal disorders.[22] As explained by Ikenna *et al*. (2022), musculoskeletal disorders are injuries that affect the muscles, tendons, ligaments, joints, nerves, and all structures involved in movement support.[23] Therefore, the regular training for the experimental group (NPP) contributed to improving MF. In addition, taking a dose of high-quality protein sources before the event also contributed to improving MF and recovery. These findings are further supported by Mitchell *et al*. (2017), who examined the effects of dietary protein intake on appendicular lean mass and muscle function and found that consuming a diet providing the RDA for protein intake has beneficial effects on lean body mass and leg power.[24]

The analysis of MF development in female athletes reveals interesting findings. First, when comparing athletes who were provided with increased protein intake before their event to those who did not have this intervention, it was observed that the HPP group experienced a slower onset of MF. This indicates that a higher protein intake before physical exertion can delay the development of fatigue, allowing athletes to perform at a higher intensity for a longer period. These results are supported by Joanisse *et al*. (2021), who reported that protein plays an important role in providing essential building blocks to the damaged muscle allowing it to repair and rebuild after each training session support.[15] As the body does not store protein, consuming high-quality protein around exercise is central to providing the muscle with the key elements it needs to optimize recovery. The results also showed that there were statistically significant differences between the post-measurements of the two groups and in favor of the experimental group HPP, which consumed 60% of the recommended daily protein dose 2 h before the event. Additionally, the comparison of recovery rates showed that female athletes who consumed more protein experienced a faster recovery time after strenuous exercise compared to those with lower protein intake. This suggests that increased protein intake promotes quicker recovery, enabling athletes to engage in subsequent training or competitions with reduced downtime. These results are supported by Kerksick *et al*. (2017), who reported that consuming high-quality protein during exercise is a great solution to ensure the delivery of protein to the muscle and support athletes' recovery goals and training adaptations.[21] It also contributes to recovery by feeding the muscle with amino acids support. Consequently, intake of high-quality protein before pre-event is a good way to hit the ability to recover after the training session. The results indicate that the HPP group demonstrated a significant improvement better than the NPP group in muscle fatigue (FI, PP, AP) and recovery (HRC). Overall, these results highlight the beneficial effects of increased protein intake on MF development and recovery in female athletes.

Findings from the study revealed that increased protein intake before an event resulted in a significantly faster recovery rate for female athletes compared to those with normal protein intake. This suggests that higher protein intake may have a protective effect against MF. The comparison of recovery rates showed that athletes who consumed a higher protein diet experienced reduced MF and quicker restoration of muscle function. These results highlight the potential benefits of increased protein intake for female athletes in terms of both MF prevention and recovery. These findings have important implications for female athletes, as they suggest that modifying protein intake can potentially enhance performance and reduce the risk of MF-related injuries.

Limitation and Recommendation

Investigating the effects of increased protein intake before the pre-event on MF development and recovery in female athletes was one of the strengths of this study. One limitation is the sample size, as the study only included a small number of basketball player participants at the Sports Academy in Zagazig. Another limitation is the duration of the study, as it was conducted over a relatively short period. In addition, the study focused only on female athletes. Lastly, the study did not explore the impact of different types or sources of protein on MF, which could be an important factor to consider in future research.

Conclusion

The study investigated the effect of increased protein intake before a pre-event on MF development and recovery in female athletes. The findings showed that higher protein consumption before the event led to a significant decrease in MF during physical activity. In addition, the recovery rates for the athletes who consumed more protein before the event were faster compared to those with a regular protein intake. This suggests that increasing protein intake before a pre-event can enhance muscle performance and reduce fatigue in female athletes may have a protective effect against MF. These results have important implications for female athletes, as they can optimize their protein intake to improve their overall athletic performance.

Acknowledgments

The authors express their gratitude to the Sports Academy for Basketball in Zagazig, Egypt for their support, both in terms of resources and encouragement, in conducting this study. They are also appreciative of colleagues for their technical assistance. The authors would like to extend their thanks to all the junior basketball players who took part in this study, as their dedication to following instructions and attending throughout the study period was crucial. This research would not have been possible without the enthusiastic involvement of wonderful athletes.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Carbone JW, Pasiakos SM. Dietary protein and muscle mass: Translating science to application and health benefit. Nutrients 2019;11:1136.
2. Brestensky Mm, Nitrayova S, Patras P, Nitray J. Dietary requirements for proteins and amino acids in human nutrition. Curr Nutr Food Sci 2019;15:638–45.
3. Joint WHO/FAO/UNU Expert Consultation. Protein and amino acid requirements in human nutrition. World Health Organ Tech Rep Ser 2007;935:1-265.
4. Jager R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, *et al*. International Society of Sports Nutrition Position Stand: Protein and exercise. J Int Soc Sports Nutr 2017;14:20.

5. Wolfe RR. Branched-chain amino acids and muscle protein synthesis in humans: Myth or reality.J Int Soc Sports Nutr 2017;14:30.
6. Wolfe RR, Cifelli AM, Kostas G, Kim IY. Optimizing protein intake in adults: Interpretation and application of the recommended dietary allowance compared with the acceptable macronutrient distribution range. Adv Nutr 2017;8:266-75.
7. Weiler M, Hertzler SR, Dvoretskiy S. Is it time to reconsider the U.S. recommendations for dietary protein and amino acid intake? Nutrients 2023; 5:838.
8. Carbone JW, McClung JP, Pasiakos SM. Recent advances in the characterization of skeletal muscle and whole-body protein responses to dietary protein and exercise during negative energy balance. Adv Nutr 2019;10:70–9.
9. Stokes T, Hector AJ, Morton RW, McGlory C, Phillips SM. Recent perspectives regarding the role of dietary protein for the promotion of muscle hypertrophy with resistance exercise training Nutrients 2018;10:180.
10. Pethick J, Tallent J. The Neuromuscular fatigue-induced loss of muscle force control. Sports 2022;10:184.
11. Aguilera JF, Morcillo JJ, Zarapuz AR, Suárez VJ. Central and peripheral fatigue in physical exercise explained: A narrative review. Int J Environ Res Public Health 2022;19:3909.
12. Theofilidis G, Bogdanis GC, Koutedakis Y, Karatzaferi C. Monitoring exercise-induced muscle fatigue and adaptations: Making sense of popular or emerging indices and biomarkers. Sports 2018;6:153.
13. Wan JJ, Qin Z, Wang PY, Sun Y, Liu X. Muscle fatigue: General understanding and treatment. Exp Mol Med 2017;49:e384.
14. Gwin JA, Church DD, Wolfe RR, Ferrando AA, Pasiakos SM. Muscle protein synthesis and whole-body protein turnover responses to ingesting essential amino acids, intact protein, and protein-containing mixed meals with considerations for energy deficit. Nutrients 2020;12:2457.
15. Joanisse S, McKendry J, Lim C, Nunes E, Stokes T, Mcleod J, *et al*. Understanding the effects of nutrition and post-exercise nutrition on skeletal muscle protein turnover: Insights from stable isotope studies. Clin Nutr Open Sci 2021;36:56-77.
16. Shivakumar N, Minocha S, Kurpad A. Protein quality and amino acid requirements in relation to needs in India. Indian J Med Res 2018;148:557-68.
17. American College of Sports Medicine (ACSM), American Dietetic Association, and Dietitians of Canada. Nutrition and Athletic Performance. Med Sci Sports Exerc 2009;41:709–31.
18. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and athletic performance. Med Sci Sports Exerc 2016;48:543-68.
19. Kato H, Suzuki K, Bannai M, Moore DR. Protein requirements are elevated in endurance athletes after exercise as determined by the indicator amino acid oxidation method. PLoS One 2016;11:e0157406**.**
20. Bandegan A, Martin G, Rafii M, Pencharz P, Lemon P. Indicator amino acid oxidation protein requirement estimate in endurance-trained men 24 h postexercise exceeds both the EAR and current athleteguidelines. Am J Physiol Endocrinol Metab 2019;316:E741–8.
21. Kerksick CM, Arent S, Schoenfeld BJ, Stout JR, Campbell B, Wilborn CD, *et al*. International society of sports nutrition position stand: Nutrient timing. J Int Soc Sports Nutr 2017;29:14-33.
22. Shakerian M, Rismanchian M, Khalili P. Effect of physical activity on musculoskeletal discomforts among handicraft workers. J Edu Health Promot 2016;5:8.
23. Ikenna UC, Nwobodo LN, Ezeukwu AO, Ilo IJ, Ede SS, Okemuo AJ, *et al*. Relationship between the development of musculoskeletal disorders, physical activity level, and academic stress among undergraduates students of University of Nigeria. J Edu Health Promot 2022;11:399.
24. Mitchell CJ, Milan AM, Mitchell SM, Zeng N, Ramzan F, Sharma P, *et al*. The effects of dietary protein intake on appendicular lean mass and muscle function in elderly men: A 10-wk randomized controlled trial. Am J Clin Nutr 2017;106:1375–83.