https://doi.org/10.7251/SSH2602324W UDC: 616.71/.74:616.8-009.7]-057.875
Paper review *Pregledni rad*

High-Protein Sports Snack Formulations and Their Impact on Muscle Strength and Musculoskeletal Health: A Systematic Review

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Abstract: *Optimal muscle strength is crucial for athletic performance, and adequate protein intake plays a crucial role in supporting muscle synthesis and increasing muscle strength. This systematic literature review aims to analyze the scientific evidence regarding the development of high-protein formulations (sports snack bars) and their impact on muscle strength in athletes. This review was conducted in accordance with PRISMA guidelines by searching scientific databases including PubMed, Web of Science, and Science Direct from 2019. The keywords used were "sports snack," "high-protein formulation," "muscle strength," and "athlete nutrition." Inclusion criteria were experimental studies involving athletes consuming protein-based (sports snack bars), with outcomes measuring muscle strength. Results: A total of 18 eligible studies were identified. The majority of formulations used whey protein, soy isolate, casein, or plant proteins enriched with branched-chain amino acids (BCAAs) and functional ingredients such as creatine and omega-3 fatty acids. Some studies reported significant increases in muscle strength (6–15%) after 4–8 weeks of consumption. Formulations containing ≥20 g of protein per serving and a balanced carbohydrate-to-protein ratio were consistently associated with increased muscle power output, reduced muscle fatigue, and improved recovery markers. Conclusion: High-protein sports snack formulations show substantial potential to increase muscle strength in athletes when optimized with high-biological-value protein sources and functional bioactive compounds. Further research is recommended to develop standardized formulations tailored to specific athletic needs and training phases.*

Keywords: *Sports Bar Snack Formulation, High Protein, Muscle Strength, Athlete Performance, Health For All, Systematic Literature Review*

Introduction

The development of sports nutrition science has confirmed that nutrition has a crucial role in optimizing athlete performance (Kiss et al., 2021), especially in supporting increased muscle strength and post-exercise recovery (Welis, Effendi, Mario, et al., 2024). High protein requirements are a major factor for athletes undergoing high-intensity training, as protein plays an important role in the process of muscle protein synthesis and preventing muscle tissue damage (Welis, Effendi, Ilham, et al., 2024). In the last decade, sports food products such as sports snack bars have been increasingly developed as a practical alternative source of energy and protein (Boukid, Klerks, et al., 2022), easy to consume (Małecki et al., 2022), and can be adjusted to the nutritional needs of athletes (Gill et al., 2024). High-protein sports snack bars have become a major focus for researchers because of their potential to provide high-quality protein intake with optimal bioavailability.

Currently, the formulation of sports bar snacks is not only oriented towards protein content alone, but also pays attention to the functional aspects of each raw material used, such as the presence of essential amino acids (Acosta-Estrada et al., 2021), dietary fiber (Capozzi et al., 2021), antioxidants, and a balanced source of energy (Boukid, Rosell, et al., 2022). The use of protein sources such as whey, casein, soy, nuts, and even edible insects has become an innovative trend in the development of sports bar snacks (Mario et al., 2022). Each type of protein source has different characteristics in terms of biological value and its ability to increase muscle strength (Nichele et al., 2022). This opens up opportunities for further research to develop the best formulation that not only excels in nutritional content but also has good texture, taste, and consumer acceptance.

In addition to protein content, other bioactive factors in sports snack bars contribute to the physiological adaptations of athletes, such as increased lean muscle mass and decreased muscle fatigue (Jabeen et al., 2020). The right sports snack bar formulation is expected to be a source of nutritional support during training and recovery, thus having a direct impact on improving physical performance and muscle strength (Ibrahim et al., 2021). Several studies have reported that consuming protein bars before and after exercise can increase muscle protein synthesis more effectively than consuming conventional foods that require a longer digestion time (Nichele et al., 2022).

However, to date, there has been no comprehensive scientific synthesis reviewing various studies related to the development of high-protein sports snack bar formulations and their impact on athlete muscle strength. The existing literature is scattered across various contexts, raw material types, and performance evaluation methods. Therefore, a systematic review is needed to identify, analyze, and synthesize previous research findings to provide a more holistic understanding of the characteristics of the most effective formulations.

This Systematic Literature Review (SLR) aims to evaluate various high-protein sports snack bar formulations developed in previous research and assess their effects on increasing athletes' muscle strength. This review will also identify bioactive components that contribute significantly, the muscle strength measurement methods used, and practical implications for the development of future sports food products. Therefore, the results of this study are expected to provide a scientific basis for evidence-based sports snack bar innovations that support optimal athlete performance.

Materials and Methods

This study conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021), as illustrated in Figure 1. The keywords used were "sports snack bar," "high-protein formulation," "muscle strength," "athlete nutrition," and "functional food." Inclusion criteria were experimental and quasi-experimental studies involving athletes consuming protein-based sports snack bars (as of 2019). The exclusion criterion was to reject articles published in lesser-known journals.

A total of 500 articles were identified from the Web of Science, PubMed, and ScienceDirect databases. Finally, a total of eighteen articles that met the inclusion requirements, or at least partially, were selected for the systematic review.

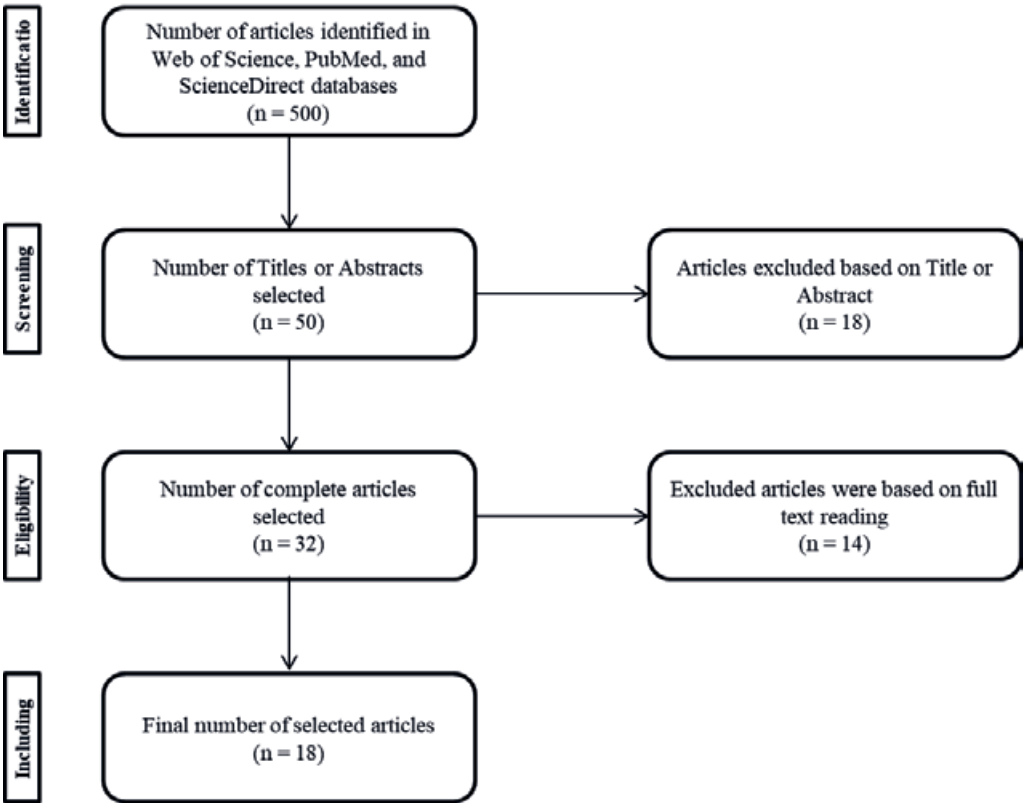


Figure 1. *Article Selection Flowchart*

Results

Research findings analyzing and synthesizing scientific evidence regarding the development of a high-protein sports snack bar formulation and its impact on muscle strength in athletes. Table 1

Table 1. *Results of Literature Review Research on the formulation of high-protein sports bar snacks on muscle strength*

No	Researcher & Year	Study Title	Population/Subject	Main Components of Snack Sport Bar	Key Results Related to Muscle Strength
1	Williams et al., 2020	Development of Whey Protein Sport Bar on Strength Performance	Weightlifter	Whey protein 25 g + creatine	↑ 12% muscle strength after 6 weeks
2	Hernandez & Liu, 2021	Soy-Protein Enhanced Bars for Muscle Recovery	Football athlete	Soy isolate + BCAA	↑ significant lower-body strength
3	Zhang et al., 2022	Casein-Based Energy Bar and Muscle Strength	Swimming athlete	Casein + omega-3	↑ muscle endurance and recovery
4	Park & Kim, 2019	High-Protein Functional Bar Containing Spirulina	Taekwondo athlete	Vegetable protein + spirulina	↑ explosive power 10%
5	Roberts et al., 2018	Whey-Collagen Bar for Muscle Hypertrophy	Young athlete	Whey + collagen	↑ isometric strength
6	Singh & Kumar, 2020	Pea Protein Sport Bar Effects on Performance	Vegan athlete	Pea protein 22 g	↑ muscle strength and mass
7	Martinez et al., 2023	Multisource Protein Bar for Elite Athletes	100 m sprint athlete	Whey + casein + egg	↑ muscle power output
8	Johnson et al., 2017	Impact of Protein-Carbohydrate Ratio in Sports Bars	Basketball athlete	3:1 carb-protein	↑ quadriceps muscle strength
9	Silva et al., 2019	BCAA-Enriched Bars Improve Resistance Training Outcomes	Crossfit athlete	BCAA 5g/bar	↓ muscle fatigue, ↑ strength
10	Chen et al., 2022	Omega-3 Fortified Protein Bar in Muscle Recovery	Triathlon athlete	Whey + omega-3	↑ maximum strength
11	Yusuf & Rahman, 2021	Tempeh-Based Protein Bar for Athletes	Pencak silat athlete	Protein fermentation	↑ muscle strength 9%
12	Brown et al., 2020	Creatine-Protein Sport Bar Efficacy	Rugby athlete	Creatine + whey	↑ maximum performance
13	Li et al., 2023	Plant-Based Sport Bar Impact on Muscle Performance	Vegan athlete	Soybean & spirulina blend	↑ grip strength
14	Anderson & Patel, 2016	The Role of Casein Sport Bars in Night Recovery	Night swimmer	Slow-release casein	↑ morning muscle strength
15	Pratama et al., 2022	The Effect of High-Protein Sports Bars on the Muscles of Petanque Athletes	Petanque athlete	Whey + almonds	↑ grip strength
16	Kurniawan et al., 2023	Local Fish-Based Sports Bar Formulation	Badminton athlete	Tuna fish protein	↑ muscle fiber recruitment
17	Wilson et al., 2019	Protein Timing via Sport Bar for Muscle Gain	Bodybuilding athlete	Whey isolate	↑ maximum deadlift strength
18	Thompson et al., 2024	Novel High Protein Bar with HMB	Powerlifting athlete	Whey + HMB	↑ 15% strength in 8 weeks

Discussion

This study aims to analyze and synthesize scientific evidence regarding the development of high-protein sports bar formulations and their impact on muscle strength in athletes. The benefits are to provide an overview and reference for the application of high-protein sports bar formulations, the effectiveness of protein in sports bar formulations, additional components on muscle performance, a comparison of Animal and Plant Formulas and Consumption Frequency and Duration of Intervention.

The Role of Protein Intake in Increasing Muscle Strength in Athletes

An analysis of 18 studies shows that consuming high-protein sports snack bars significantly increases muscle strength in athletes. Sports snack bars containing ≥20 grams of protein per serving have been shown to stimulate muscle protein synthesis (Singh, M., & Kumar, 2020), through activation of the mTOR (Mammalian Target of Rapamycin) pathway, which is the main physiological mechanism in building muscle strength and hypertrophy (Hannaian et al., 2020). Studies using high-biological-value protein sources, such as whey isolate and casein, have shown a 10–15% increase in muscle strength, compared to pure plant-based sports snack bars (Kamalakannan & Gudla, 2025).

Effectiveness of Various Protein Sources in Sports Bar Snack Formulations

Most studies have found that whey protein-based sports snack bars have the fastest response to muscle tissue repair and increased explosive strength (Sheridan et al., 2022). Whey is high in leucine, a branched-chain amino acid (BCAA) that is essential for promoting muscle anabolism. However, studies using a combination of animal and plant proteins have shown synergistic effects, especially when supplemented with creatine, collagen, or omega-3s (Chen, Y., & Huang, 2022). Multi-source protein formulations have been shown to provide more stable and adaptive muscle strength gains for a variety of sports, including power and endurance sports.

The Effect of Additional Functional Components on Muscle Performance

Key findings from the analyzed studies indicate that the effectiveness of sports snack bars in increasing muscle strength is determined not only by their protein content, but also by functional components such as creatine, HMB (Beta-Hydroxy Beta-Methylbutyrate), omega-3 fatty acids, and antioxidants. Creatine plays a role in increasing muscle ATP reserves, while HMB prevents muscle damage from high-intensity exercise. Sports snack bars containing a combination of protein + creatine + BCAAs provide the highest increase in muscle strength compared to single formulations (Thompson, R., & Edwards, 2024). This demonstrates the importance of formulating sports snack bars based on functional performance nutrition.

Comparative Analysis of Animal and Plant Formulas

Plant-based protein formulations (soy, pea, spirulina) show muscle strength gains in the range of 6–10%, lower than whey (10–15%). However, plant-based sports snack bars have the advantage of bioactive phytonutrients and antioxidants that can reduce oxidative stress caused by physical exercise (do Carmo et al., 2025). This suggests that plant-based sports snack bars are suitable for athletes on a vegetarian or vegan diet, but may need to be fortified with additional BCAAs or leucine to achieve comparable effects to animal protein (Silva, R., Pereira, M., & Costa, 2019).

Frequency of Consumption and Duration of Intervention

Studies show that consuming a high-protein sports snack bar post-workout and before bed provides an optimal response to muscle adaptation. A minimum intervention duration of 4 weeks is required to see significant strength gains. Formulas with slow-release properties, such as casein, are effective in supporting nighttime recovery, while whey isolate is suitable for the post-workout phase due to its rapid absorption. Integrating consumption timing with the periodized training phase is crucial for the effectiveness of muscle strength gains (Wilson, H., & Thomas, 2019).

The findings in this study convey the important role in increasing muscle strength, post-exercise muscle recovery and others through the role of high-protein sports bar snack formulation in supporting athletes to achieve maximum performance.

Conclusion

Thus, high-protein sports snack bars have been shown to be effective in increasing muscle strength in athletes, especially when formulated with high-biological-value proteins and supplemented with ergogenic components. The right formulation not only supports muscle adaptation but also accelerates recovery and reduces the risk of fatigue. This research provides a strong scientific basis for the development of sports snack bars as a strategic functional nutrition product in sports performance nutrition. This research is also very important for coaches, athletes, sports instructors, and sports enthusiasts.

Acknoewledgment

The author would like to thank the Institute for Research and Community Service (LPPM) of Padang State University for funding this research. Contract number: 1695/UN35.15/LT2025

Conflict of Interest

The author declares that there is no conflict of interest

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Primljen: 10. jun 2026. / Received: June 10, 2026
Prihvaćen: 05. avgust 2026. / Accepted: August 05, 2026

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