JPPIPA 10(Special Issue) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Importance of Carbohydrate Intake for Maintaining Glycogen Stores and Physical Performance during Prolonged Exercise : A Literature Review

Ismardi[1], Muhamad Sazeli Rifki[1], Wilda Welis[1], Ardo Okilanda[1] , Dally Rahman[2*], Yovhandra Ockta[1]

[1] Faculty of Sports Sciences, Universitas Negeri Padang, Padang, Indonesia
[2] Department of Medical Surgical Nursing and Emergency Nursing, Universitas Andalas, Indonesia

Received: June 12, 2024
Revised: August 10, 2024
Accepted: August 25, 2024
Published: August 31, 2024

Corresponding Author:
Dally Rahman
dallyrahman@nrs.unand.ac.id

DOI: 10.29303/jppipa.v10iSpecialIssue.8733

Abstract: The study investigates the critical role of carbohydrate intake in maintaining glycogen stores and enhancing physical performance during prolonged exercise. The primary aim is to evaluate how carbohydrate consumption influences glycogen levels and athletic performance, focusing on intake types and timing. Utilizing a qualitative descriptive research model, the study conducts an extensive literature review, involving a thorough search of scientific databases such as Scopus, ScienceDirect, and Google Scholar. Specific keywords like "Carbohydrates," "Glycogen Stores," and "Prolonged Exercise" guide the search for relevant articles. These articles are analyzed to extract and synthesize information on the relationship between carbohydrate intake and glycogen reserves during extended physical activities. The findings highlight that a daily carbohydrate intake of 6-12 g/kg body weight is essential for optimal glycogen levels and performance. Simple carbohydrates and fructose-glucose mixtures are particularly effective in enhancing recovery. Additionally, carbohydrate loading before intense exercise significantly improves glycogen stores and endurance performance. The study concludes that while adequate carbohydrate intake is vital for sustaining performance and facilitating recovery, further research is needed to explore the long-term effects and individual variations in carbohydrate nutrition strategies. This includes examining diverse exercise types, athlete profiles, and the interplay between carbohydrates and other dietary components.

Keywords: Athletic Performance; Carbohydrates; Exercise; Glycogen Stores

Introduction

Human health and physical performance are heavily reliant on various factors, one of which is adequate nutrition (Amin et al., 2023). Among the different macronutrients, carbohydrates play a crucial role in supporting physical activity, especially in the context of prolonged exercise (Bourdas et al., 2021; Noakes, 2022). Carbohydrates, as a primary source of energy, are central to maintaining the body's glycogen stores, which are essential for optimal physical performance during extended periods of training or competition (Al Zaki et al., 2023; Insani et al., 2024; Likardo et al., 2023).

Glycogen is the storage form of glucose in the human body, primarily found in the liver and muscles (Chinta et al., 2024). When we consume carbohydrates, the body converts them into glucose, which is then stored as (Arribalzaga et al., 2021; Beermann et al., 2020; Dobrosielski, 2021; Furber et al., 2021). During physical activity, the stored glycogen is used as the main source of energy. Therefore, maintaining sufficient glycogen stores is critical to ensuring good physical performance, particularly in endurance sports such as long-distance

Ismardi, I., Rahman, D., Rifki, M. S., Welis, W., Okilanda, A., & Ockta, Y. (2024). The Importance of Carbohydrate Intake for Maintaining Glycogen Stores and Physical Performance during Prolonged Exercise : A Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 83–89. https://doi.org/10.29303/jppipa.v10iSpecialIssue.8733

running, cycling, or triathlons (Illahi et al., 2023; Safitri et al., 2023). A decline in glycogen levels during exercise can lead to a significant decrease in physical performance. This is because glycogen is the most efficient energy source for intense and (Fruh et al., 2021; Tanous et al., 2022). When glycogen stores deplete, the body must rely on other energy sources like fat, which, although abundant, requires a more complex and slower metabolic process to be converted into usable energy. This can result in decreased speed, strength, and endurance, negatively affecting an athlete's performance (Haris et al., 2024; Khani et al., 2024; Safitri et al., 2024).

Research indicates that adequate carbohydrate intake before, during, and after exercise can help maximize glycogen stores and facilitate faster recovery. For instance, consuming carbohydrates before exercise can increase the available glycogen stores, while intake during exercise can slow glycogen depletion and maintain performance. After exercise, carbohydrates help replenish depleted glycogen, accelerate recovery, and reduce (García-Sillero et al., 2021; Potisaen & Potisaen, 2022; Priego-Quesada et al., 2020). Furthermore, it is important to understand how the type and timing of carbohydrate consumption affect physical performance. Simple carbohydrates, such as glucose and sucrose, are quickly absorbed and used by the body, while complex carbohydrates, such as starch and fiber, take longer to digest and release energy. Choosing the right type of carbohydrate and timing can help maintain stable blood glucose levels, optimize glycogen use, and support better physical performance.

Additionally, recent research shows that nutritional strategies such as carbohydrate loading before highly intense competitions or workouts can significantly increase glycogen stores. This technique, known as "carbohydrate loading," involves consuming high amounts of carbohydrates over several days before strenuous physical activity to boost muscle glycogen reserves (Burke, 2021; Noakes, 2022). This method has been shown to enhance athletic performance in various endurance sports. However, while carbohydrates are vital for maintaining glycogen stores and physical performance, overall nutritional balance remains important. Excessive carbohydrate consumption without considering protein, fat, and other vitamins and minerals can disrupt nutritional balance and overall health. Therefore, a balanced approach tailored to individual needs is key to designing an optimal diet for athletes and physically active individuals.

Adequate carbohydrate intake plays a crucial role in maintaining the body's glycogen stores and maximizing physical performance during prolonged exercise. Understanding how carbohydrates function in the body, when, and which types are most effective can provide significant advantages in training and competition. Therefore, further research and a deeper understanding of carbohydrate nutrition will continue to contribute to the development of better nutritional strategies to enhance athletic performance and overall health. Based on this background, researchers need to conduct a comprehensive literature review on the management of asthma triggered by physical exercise in athletes.

Method

This study employs a qualitative descriptive research model, guided by an extensive literature review, to explore the role of carbohydrate intake in maintaining glycogen stores and enhancing physical performance during prolonged exercise. The methodology begins with a comprehensive search of reputable scientific databases, including Scopus, ScienceDirect, and Google Scholar. The search utilizes specific keywords such as "Carbohydrates," "Glycogen Stores," and "Prolonged Exercise" to identify relevant literature.

Subsequent to the literature search, relevant articles are reviewed to extract essential information concerning the relationship between carbohydrate intake and glycogen stores during extended physical activity. The review process focuses on identifying key elements such as author names, publication years, study designs, research objectives, sample characteristics, methodologies, and summaries of findings. Articles that meet the inclusion criteria are selected for in-depth analysis.

Data collection is performed through a systematic documentation method, wherein pertinent information is gathered and organized from the selected literature. This data is then synthesized into a cohesive document that addresses the research questions related to carbohydrate intake, glycogen maintenance, and physical performance during prolonged exercise. Content analysis is utilized to evaluate the relevance and contributions of each study, providing insights into how carbohydrate intake influences glycogen stores and performance outcomes in extended exercise contexts.

Result and Discussion

The analysis aims to provide evidence-based insights into how carbohydrate intake affects glycogen stores and physical performance during prolonged exercise.This literature review includes a detailed analysis of seven key studies, with further specifics presented in Table 1.

Table 1. Summary of data descriptions

Author	Topic	Results
(Gonzalez & Betts, 2019)	Dietary sugars, exercise and hepatic carbohydrate metabolism	The study highlights that carbohydrate intake is crucial for maintaining glycogen reserves and enhancing performance during prolonged exercise. Key points include the need for about 1 g/kg body mass per hour of carbohydrates, the benefits of fructose-glucose mixtures for faster recovery and reduced gut discomfort, and improved endurance with optimized carbohydrate types.
(Alghannam et al., 2021)	Regulation of energy substrate metabolism in endurance exercise	The study underscores the critical role of carbohydrate intake in endurance exercise, revealing its ergogenic effects by maintaining blood sugar and reducing fatigue. Carbohydrates help spare muscle glycogen, enhance performance by supporting euglycemia, and may vary in effectiveness by sex. Extra-muscular sources also aid in energy metabolism.
(Knuiman et al., 2015)	Glycogen availability and skeletal muscle adaptations with endurance and resistance exercise	The study reveals that glycogen depletion impairs endurance performance, while post-exercise carbohydrate intake aids recovery by replenishing glycogen. Training with low glycogen may enhance muscle adaptations, though effects on resistance exercise are less clear. Adequate carbohydrate intake before and after exercise is crucial for performance and recovery.
(Alghannam et al., 2018)	Restoration of muscle glycogen and functional capacity: Role of post-exercise carbohydrate and protein co-ingestion	The study highlights that high carbohydrate intake (1.2 g/kg BM/h) during recovery significantly restores muscle glycogen and improves exercise capacity. Co-ingesting protein further enhances glycogen resynthesis, especially with lower carbohydrate intake. These findings underscore the importance of adequate carbohydrate and protein intake for optimal recovery and performance.
(König et al., 2019)	Carbohydrates in sports nutrition	The study emphasizes that high carbohydrate intake is vital for performance during prolonged exercise, providing greater energy yield than fats or proteins. Recommended intake is 6-12 g/kg body weight per day to replenish glycogen and prevent hypoglycemia. Post-exercise carbohydrate intake accelerates recovery, and the form of carbohydrate is less critical than total intake.
(Williams & Rollo, 2015)	Carbohydrate Nutrition and Team Sport Performance	The study underscores the importance of carbohydrate intake for team sport performance. Key findings include that ingesting 1.2 g/kg body mass of carbohydrates post-exercise maximizes glycogen storage, while protein addition has minimal impact. Carbohydrate gels improve endurance during exercise, and high glycemic index foods before exercise enhance energy levels and performance.
(Namma-Motonaga et al., 2022)	Effect of Different Carbohydrate Intakes within 24 Hours after Glycogen Depletion on Muscle Glycogen Recovery in Japanese Endurance Athletes	The research shows that higher carbohydrate intake (7-10 g/kg BM/d) significantly improves muscle glycogen recovery in Japanese endurance athletes, compared to 5 g/kg BM/d. Adequate intake is crucial for maintaining performance in subsequent training sessions. The study supports guidelines recommending 6-10 g/kg BM/d for optimal recovery and performance.

This discussion synthesizes findings from the reviewed literature on the role of carbohydrate intake in maintaining glycogen stores and enhancing physical performance during prolonged exercise. The evidence highlights the crucial role of carbohydrates in optimizing athletic performance, particularly in endurance sports. Key themes emerging from the studies include the importance of adequate carbohydrate intake, the impact of carbohydrate type and timing, the benefits of carbohydrate loading strategies, and the necessity of overall nutritional balance. Glycogen, the stored form of glucose in the liver and muscles, is essential for sustained physical activity. Carbohydrates are the primary source of glucose, and their consumption directly influences glycogen levels. Gonzalez & Betts (2019) emphasize that ingesting approximately 1 g/kg body mass per hour of carbohydrates is necessary for maintaining adequate glycogen reserves during prolonged exercise. This aligns with König et al. (2019), who recommend a daily carbohydrate intake of 6-12 g/kg body weight to effectively replenish glycogen stores and prevent hypoglycemia. This consensus underscores the importance of ensuring sufficient carbohydrate intake, particularly during extended physical exertion. Studies demonstrate that low glycogen levels can lead to

decreased performance, as glycogen is the most efficient energy source for high-intensity and prolonged activities (Knuiman et al., 2015; Alghannam et al., 2021). Therefore, athletes should carefully monitor their carbohydrate consumption to maintain optimal glycogen levels and support their performance needs. The type of carbohydrate consumed can impact performance and recovery. Simple carbohydrates, such as glucose and sucrose, are rapidly absorbed and utilized, while complex carbohydrates, like starch and fiber, provide a slower release of energy (Williams & Rollo, 2015). Gonzalez & Betts (2019) highlight the benefits of fructose-glucose mixtures, which are shown to enhance recovery and reduce gastrointestinal discomfort compared to other carbohydrate sources. This suggests that the choice of carbohydrate type may influence the efficiency of glycogen replenishment and overall recovery.

The timing of carbohydrate intake is also critical. Consuming carbohydrates before exercise can elevate glycogen stores, as demonstrated by Alghannam et al. (2018), who found that high carbohydrate intake during recovery significantly restores muscle glycogen. This pre-exercise consumption strategy helps ensure that athletes have adequate glycogen reserves for optimal performance. During exercise, carbohydrate intake can slow glycogen depletion, helping maintain performance levels (Gonzalez & Betts, 2019). Post-exercise carbohydrate intake is crucial for glycogen resynthesis, which is essential for recovery and preparation for subsequent activities (König et al., 2019). Several studies reinforce the significance of carbohydrates for endurance and recovery. Alghannam et al. (2021) note that carbohydrates are essential for maintaining blood sugar levels and reducing fatigue, which helps spare muscle glycogen and enhance performance. Knuiman et al. (2015) support this by showing that glycogen depletion impairs endurance performance, and post-exercise carbohydrate intake aids in glycogen replenishment. This recovery process is vital for athletes, particularly those engaging in frequent or intense training sessions.

The importance of carbohydrate intake for recovery is further supported by Alghannam et al. (2018), who found that combining carbohydrates with protein during recovery improves glycogen resynthesis and exercise capacity. This suggests that while carbohydrates are critical for replenishing glycogen, the inclusion of protein may enhance the recovery process, especially when carbohydrate intake is limited. The findings emphasize the need for a strategic approach to carbohydrate and protein consumption to optimize recovery and performance. Carbohydrate loading, or "carb-loading," is a well-established method for enhancing performance in endurance sports. This technique involves increasing carbohydrate intake several days before an intense exercise or competition to maximize glycogen stores (Burke, 2021). Alghannam et al. (2018) and Namma-Motonaga et al. (2022) provide evidence that higher carbohydrate intake before intense exercise significantly boosts glycogen stores and improves performance. Namma-Motonaga et al. (2022) specifically demonstrate that consuming 7-10 g/kg body mass/day of carbohydrates significantly enhances muscle glycogen recovery compared to lower intakes.

Carbohydrate loading is particularly beneficial for events requiring sustained endurance, as it helps ensure that athletes have ample glycogen reserves to support prolonged exertion. This strategy allows athletes to perform at their best and delay the onset of fatigue, which is crucial for competitive success in endurance sports.While carbohydrates are vital, maintaining a balanced diet is essential for overall health and optimal performance. Excessive carbohydrate intake without adequate consumption of proteins, fats, and micronutrients can disrupt nutritional balance and impact overall health (König et al., 2019). The reviewed studies emphasize the importance of a holistic approach to nutrition, where carbohydrates play a critical role but should be complemented by other nutrients to support overall athletic performance and health.

For instance, protein is essential for muscle repair and recovery, and fats are crucial for long-term energy and overall health. Vitamins and minerals also play roles in energy metabolism and recovery. Therefore, athletes should focus on a well-rounded diet that supports their carbohydrate needs while also addressing other nutritional requirements. The insights from this literature review have practical implications for athletes seeking to optimize their performance through nutritional strategies. Understanding the role of carbohydrates in maintaining glycogen stores and enhancing performance allows athletes to make informed decisions about their dietary intake.

Conclusion

The review of the role of carbohydrate intake in maintaining glycogen stores and enhancing physical performance during prolonged exercise provides substantial insights into how this macronutrient affects athletic performance. Carbohydrates are essential for replenishing glycogen reserves, which are critical for sustaining energy during extended physical activities. Findings consistently highlight that maintaining a carbohydrate intake of 6-12 g/kg body weight per day is crucial for optimal glycogen levels and performance. This intake helps to prevent fatigue and supports endurance, particularly in endurance sports where

glycogen depletion can significantly impair performance. The type and timing of carbohydrate consumption are also pivotal in optimizing performance and recovery. Simple carbohydrates like glucose and sucrose offer quick energy, while complex carbohydrates provide a more sustained release. Research shows that fructose-glucose mixtures can enhance recovery and reduce gastrointestinal issues, emphasizing the need for appropriate carbohydrate selection. Consuming carbohydrates before, during, and after exercise helps boost glycogen stores, maintain performance, and accelerate recovery. These strategies are essential for athletes to maximize their performance and recovery.

Carbohydrate loading, which involves increasing carbohydrate intake before intense exercise, has been shown to significantly improve glycogen stores and enhance performance in endurance events. This approach allows athletes to perform at peak levels and delay fatigue. Evidence suggests that consuming 7-10 g/kg body mass/day of carbohydrates can be particularly effective in muscle glycogen recovery, supporting the strategy's utility for prolonged or high-intensity activities. Despite the valuable insights provided, there are limitations in the current research. Many studies have focused on specific types of exercise or athlete populations, which may not be generalizable to all types of physical activities or different demographics. Additionally, the long-term effects of various carbohydrate intake strategies on overall health and performance are not fully understood. The variability in individual responses to carbohydrate intake suggests that personalized nutrition plans may be more effective than one-size-fits-all recommendations.

Future research should address these limitations by exploring the effects of carbohydrate intake across diverse types of exercise and athlete profiles. Longitudinal studies examining the long-term health implications of different carbohydrate strategies are also needed. Additionally, investigating the interaction between carbohydrate intake and other dietary components, such as proteins and fats, will provide a more comprehensive understanding of optimal nutrition for athletic performance. Personalized nutrition approaches, considering individual metabolic responses and specific needs, should also be explored to develop more effective dietary strategies for athletes.

Acknowledgements
In the course of this research, I would like to express my deepest gratitude to my beloved family for their unwavering support, love, and encouragement. I am also profoundly thankful to the esteemed lecturers at the Faculty of Sports Science for their exceptional guidance, knowledge, and inspiration. Additionally, I wish to acknowledge my fellow students in the Master of Sports Education Program, whose camaraderie has been a continual source of inspiration and motivation.

Author Contributions
This article was written by seven contributors, Ismardi contributed to the writing of the introduction, methodology, literature review, results, and conclusions. Muhamad Sazeli Rifki, Wilda Welis, Ardo Okilanda contributed to the process of conceptualization, methodology, review, and finalization of articles. Yovhandra Ockta contributed to the finalization and improvement of the content of the article and reviews in different thought sections.

Funding
This research was not funded by any party. The funding comes from the author of this article.

Conflict of Interest
The content of this article does not create a conflict of interest.

References

Al Zaki, M., Umar, U., Yenes, R., Rasyid, W., Ockta, Y., & Budiwanto, A. (2023). The Impact of Regular Physical Activity on Lipid Profile and Cardiovaskular Health in Adolescents : A Literature Review. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 213–221. https://doi.org/10.29303/jppipa.v9ispecialissue.7811

Alghannam, A. F., Ghaith, M. M., & Alhussain, M. H. (2021). Regulation of energy substrate metabolism in endurance exercise. *International Journal of Environmental Research and Public Health*, *18*(9). https://doi.org/10.3390/ijerph18094963

Alghannam, A. F., Gonzalez, J. T., & Betts, J. A. (2018). Restoration of muscle glycogen and functional capacity: Role of post-exercise carbohydrate and protein co-ingestion. *Nutrients*, *10*(2). https://doi.org/10.3390/nu10020253

Amin, D. I., Wahyuri, A. S., Irawan, R., Welis, W., Gusni, F., Rahman, D., Budiwanto, A., & Ockta, Y. (2023). Dietary Adherence and Physical Activity : Unraveling the Threads Impacting Dietary Adherence and Physical Activity : Unraveling the Threads Impacting Blood Pressure in Hypertensive Patients. *Jurnal Penelitian Pendidikan IPA*, *9*(December), 1363–1371. https://doi.org/10.29303/jppipa.v9iSpecialIssue.7388

Arribalzaga, S., Viribay, A., Calleja-González, J., Fernández-Lázaro, D., Castañeda-Babarro, A., & Mielgo-Ayuso, J. (2021). Relationship of carbohydrate intake during a single-stage one-day ultra-trail race with fatigue outcomes and gastrointestinal problems: A systematic review.

International Journal of Environmental Research and Public Health, *18*(11), 1–21. https://doi.org/10.3390/ijerph18115737

Beermann, B. L., Lee, D. G., Almstedt, H. C., & McCormack, W. P. (2020). Nutritional Intake and Energy Availability of Collegiate Distance Runners. *Journal of the American College of Nutrition*, *39*(8), 747–755. https://doi.org/10.1080/07315724.2020.1735570

Bourdas, D. I., Souglis, A., Zacharakis, E. D., Geladas, N. D., & Travlos, A. K. (2021). Meta-analysis of carbohydrate solution intake during prolonged exercise in adults: From the last 45+ years' perspective. *Nutrients*, *13*(12). https://doi.org/10.3390/nu13124223

Burke, L. M. (2021). Nutritional approaches to counter performance constraints in high-level sports competition. *Experimental Physiology*, *106*(12), 2304–2323. https://doi.org/10.1113/EP088188

Chinta, I., Ihsan, N., Handayani, S. G., & Ockta, Y. (2024). The Effect of Aerobic Exercise and Vinyasa Yoga on Body Fat Reduction among Women Gym Members at G Sports Center in Padang City Department Sport Education , Universitas Negeri Padang , Indonesia (Correspondence author ' s email , nurulihsan465@gmail.com . *Poltekita: Jurnal Ilmu Kesehatan*, *17*(4), 1232–1238.

Dobrosielski, D. A. (2021). How can exercise reduce cardiovascular disease risk? A primer for the clinician. *Polish Archives of Internal Medicine*, *131*(10), 1–9. https://doi.org/10.20452/pamw.16122

Fruh, S., Williams, S., Hayes, K., Hauff, C., Hudson, G. M., Sittig, S., Graves, R. J., Hall, H., & Barinas, J. (2021). A practical approach to obesity prevention: Healthy home habits. *Journal of the American Association of Nurse Practitioners*, *33*(11), 1055–1065. https://doi.org/10.1097/JXX.0000000000000556

Furber, M., Pyle, S., Roberts, M., & Roberts, J. (2021). Comparing acute, high dietary protein and carbohydrate intake on transcriptional biomarkers, fuel utilisation and exercise performance in trained male runners. *Nutrients*, *13*(12), 1–15. https://doi.org/10.3390/nu13124391

García-Sillero, M., Benítez-Porres, J., García-Romero, J., Bonilla, D. A., Petro, J. L., & Vargas-Molina, S. (2021). Comparison of interventional strategies to improve recovery after eccentric exercise-induced muscle fatigue. *International Journal of Environmental Research and Public Health*, *18*(2), 1–11. https://doi.org/10.3390/ijerph18020647

Gonzalez, J. T., & Betts, J. A. (2019). Dietary sugars, exercise and hepatic carbohydrate metabolism. *Proceedings of the Nutrition Society*, *78*(2), 246–256. https://doi.org/10.1017/S0029665118002604

Haris, F., Fauziah, V., Ockta, Y., Zarya, F., Pranoto, N. W., Rahman, D., Adrian, V., Orhan, B. E., & Karaçam, A. (2024). Observation of stunting status with the motor skills of toddler children Observación del estado de retraso en el crecimiento con las habilidades motoras de niños pequeños Introduction Indonesia faces nutritional problems that have a serious impact on huma. *Retos*, *2041*, 103–111.

Illahi, R. R., Rasyid, W., Neldi, H., Padli, P., Ockta, Y., & Cahyani, F. I. (2023). The Crucial Role of Carbohydrate Intake for Female Long-Distance Runners : A Literature Review. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 206–212. https://doi.org/10.29303/jppipa.v9ispecialissue.7723

Insani, K., Welis, W., Bahtra, R., Putra, A. N., Ockta, Y., Hasan, H., & Orhan, B. E. (2024). The Impact of Training Methods and Endurance on Developing Basic Football Technical Skills in Extracurricular Football Programs. *Community Practitioner*, *21*(5), 1103–1112. https://doi.org/10.5281/zenodo.11239182

Khani, I. R., Simatupang, N., Harahap, N. S., & Ockta, Y. (2024). Stepping Into Vitality: How Brisk Walking Elevates Fitness Among the Elderly in Medan City. *Journal of Physical Education, Sport, Health and Recreations*, *13*(2), 357–362.

Knuiman, P., Hopman, M. T. E., & Mensink, M. (2015). Glycogen availability and skeletal muscle adaptations with endurance and resistance exercise. *Nutrition and Metabolism*, *12*(1), 1–11. https://doi.org/10.1186/s12986-015-0055-9

König, D., Braun, H., Carlsohn, A., Großhauser, M., Lampen, A., Mosler, S., Nieß, A., Oberritter, H., Schäbethal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Heseker, H. (2019). Carbohydrates in sports nutrition. *Ernahrungs Umschau*, *66*(11), 228–235. https://doi.org/10.4455/eu.2019.044

Likardo, R., Neldi, H., Irawan, R., Rasyid, W., Rahman, D., Ockta, Y., & Cahyani, F. I. (2023). Insights into Meniscal Injuries Among Young Football Athletes: A Scoping Review. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 198–205. https://doi.org/10.29303/jppipa.v9ispecialissue.7761

Namma-Motonaga, K., Kondo, E., Osawa, T., Shiose, K., Kamei, A., Taguchi, M., & Takahashi, H. (2022). Effect of Different Carbohydrate Intakes within 24 Hours after Glycogen Depletion on Muscle Glycogen Recovery in Japanese Endurance Athletes. *Nutrients*, *14*(7). https://doi.org/10.3390/nu14071320

Noakes, T. D. (2022). What Is the Evidence That Dietary

Macronutrient Composition Influences Exercise Performance? A Narrative Review. *Nutrients*, *14*(4). https://doi.org/10.3390/nu14040862

Potisaen, J., & Potisaen, T. (2022). The Influence of Cold-Water Immersion on Heart Rate and Fatigue Levels in Sepak Takraw Athletes. *Journal of Exercise Physiology Online*, *25*(1).

Priego-Quesada, J. I., De la Fuente, C., Kunzler, M. R., Perez-Soriano, P., Hervás-Marín, D., & Carpes, F. P. (2020). Relationship between skin temperature, electrical manifestations of muscle fatigue, and exercise-induced delayed onset muscle soreness for dynamic contractions: A preliminary study. *International Journal of Environmental Research and Public Health*, *17*(18), 1–13. https://doi.org/10.3390/ijerph17186817

Safitri, R., Alnedral, A., Gusril, G., Wahyuri, A. S., & Ockta, Y. (2023). Pengaruh Model Pembelajaran Project Based Learning dan Problem Based Learning dengan Self Confidence Terhadap Hasil Belajar Atletik Lari Jarak Pendek. *Gelanggang Olahraga: Jurnal Pendidikan Jasmani Dan Olahraga (JPJO)*, *7*(1), 20–29. https://doi.org/10.31539/jpjo.v7i1.7292

Safitri, R., Alnedral, Wahyuri, A. S., Gusril, Wahyuri, A. S., & Ockta, Y. (2024). The Impacts of the Project-Based Learning and Problem-Based Learning Models with Self- Confidence on Students ' Learning Outcomes. *IRJE (Indonesian Research Journal in Education)*, *8*(1), 269–283.

Tanous, D., Wagner, K. H., Leitzmann, C., Motevalli, M., Wirnitzer, G., Rosemann, T., Knechtle, B., & Wirnitzer, K. (2022). Dietary Intake of Recreational Endurance Runners Associated with Race Distance—Results from the NURMI Study (Step 2). *Nutrients*, *14*(18), 1–18. https://doi.org/10.3390/nu14183698

Williams, C., & Rollo, I. (2015). Carbohydrate Nutrition and Team Sport Performance. *Sports Medicine*, *45*(1), 13–22. https://doi.org/10.1007/s40279-015-0399-3