JOURNAL OF EDUCATION, HEALTH AND SPORT

eISSN 2391-8306 · Open Access · Peer-reviewed

apcz.umk.pl/JEHS · Nicolaus Copernicus University in Toruń

Cite as: PAJAK, Julia, KAMOSIŃSKA, Anna, SŁAWATYNIEC, Olga, SOBIERAJ, Wiktoria, ŁUNIEWSKA, Wiktoria, MODRZYK, Marta and MAJDA, Antoni. The effect of honey consumption on muscle glycogen resynthesis following exercise: a review of the literature. Journal of Education, Health and Sport. 2026;94:72717. https://doi.org/10.12775/JEHS.2026.94.72717

ARTICLE TIMELINE

Received: 27.05.2026 Revised: 25.06.2026
Accepted: 02.07.2026 Published: 09.07.2026

INDEXING & EVALUATION

MEiN points: 40 Unique ID: 201159
Disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

The journal has been awarded 40 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32318). Unique Journal Identifier: 201159. Scientific disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

Punkty Ministerialne z 2019 – aktualny rok 40 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).

The effect of honey consumption on muscle glycogen resynthesis following exercise: a review of the literature

Julia Pająk, Anna Kamosińska, Olga Sławatyniec, Wiktoria Sobieraj, Wiktoria Łuniewska, Marta Modrzyk, Antoni Majda

Julia Pająk

4th Military Clinical Hospital with Polyclinic SP ZOZ, ul. Rudolfa Weigla 5, 50-981 Wrocław, Poland

julia.pajak@onet.eu

https://orcid.org/0009-0007-0882-9365

Anna Kamosińska

4th Military Clinical Hospital with Polyclinic SP ZOZ, ul. Rudolfa Weigla 5, 50-981 Wrocław, Poland

anna.kamosinska@interia.pl

https://orcid.org/0009-0005-0718-2112

Olga Sławatyniec

4th Military Clinical Hospital with Polyclinic SP ZOZ, ul. Rudolfa Weigla 5, 50-981 Wrocław, Poland

olgaslaw2@gmail.com

https://orcid.org/0009-0007-0373-1588

Wiktoria Sobieraj

Lower Silesian Oncology, Pulmonology and Hematology Center, 12 Ludwika Hirszfelda Square, 53-413 Wrocław, Poland

w.s.sobieraj@gmail.com

https://orcid.org/0009-0007-5412-6302

Wiktoria Łuniewska

Lower Silesian Oncology, Pulmonology and Hematology Center, 12 Ludwika Hirszfelda Square, 53-413 Wrocław, Poland

wiktoria.lun@gmail.com

https://orcid.org/0009-0009-5398-422X

Marta Modrzyk

Institute of Medical Sciences: Opole, Poland

modrzykmarta@gmail.com

https://orcid.org/0009-0003-9590-5602

Antoni Majda

Regional Specialist Hospital in Wrocław, 73a H. M. Kamieńskiego Street, 51-124 Wrocław, Poland

https://orcid.org/0009-0006-4357-513X

antekmajda99@gmail.com

Corresponding Author:
Anna Kamosińska

4th Military Clinical Hospital with Polyclinic SP ZOZ, ul. Rudolfa Weigla 5, 50-981 Wrocław, Poland

anna.kamosinska@interia.pl

Abstract

Glycogen is the primary form of carbohydrate storage in the human body and a key energy substrate during exercise. Its depletion contributes to fatigue and reduced exercise performance; therefore, effective post-exercise glycogen resynthesis is essential for recovery in athletes. Honey, due to its unique composition of glucose and fructose, may support the restoration of both muscle and liver glycogen stores while providing a more stable glycaemic response than pure glucose. Moreover, honey contains antioxidant and anti-inflammatory compounds that may reduce oxidative stress and support immune function after intense physical activity. Available studies indicate that honey demonstrates similar effectiveness to commercial carbohydrate supplements such as glucose, sucrose, and maltodextrin in supporting glycogen replenishment and post-exercise recovery. Some evidence also suggests beneficial effects on delayed-onset muscle soreness (DOMS) and exercise performance. Despite promising findings, further studies are required to establish optimal dosing strategies and evaluate the long-term effects of honey supplementation in sports nutrition.

Background: Muscle glycogen depletion during exercise impairs physical performance and accelerates fatigue. Effective glycogen resynthesis is therefore a crucial element of post-exercise recovery.

Aim: The aim of this study was to review the effects of honey consumption on muscle glycogen resynthesis and post-exercise recovery.

Materials and methods: A review of the available literature concerning glycogen metabolism, recovery, and honey supplementation in physically active individuals was conducted.

Summary: Honey may effectively support glycogen replenishment and recovery due to its carbohydrate composition and antioxidant properties.

Conclusions: Honey appears to be a promising natural alternative to commercial sports supplements used during post-exercise recovery.

Key words: honey; glycogen; recovery; sports nutrition; exercise; athletes

1. Introduction

One of the key factors determining the body's capacity for physical exercise, particularly of moderate and high intensity, is the availability of muscle glycogen, which constitutes the primary form of carbohydrate storage in the human body [1, 2]. During physical activity, its stores become significantly depleted, which is directly associated with a decline in exercise performance and the development of fatigue resulting from both reduced availability of energy substrates and impaired muscle contraction [2]. Therefore, the process of glycogen resynthesis during the post-exercise period constitutes a fundamental component of recovery strategies, while its rate and efficiency largely depend on carbohydrate availability and the timing of carbohydrate intake [3]. In recent years, increasing attention has been directed toward natural sources of carbohydrates, including honey, which may support the restoration of both muscle and liver glycogen, constituting an alternative to commercial peri-exercise supplements for athletes, primarily due to its specific composition and absorption characteristics [4, 5]. The aim of this article is to analyze the available literature regarding the effects of honey consumption on muscle glycogen resynthesis and post-exercise recovery processes.

2. Glycogen - Structure, Storage, and Physiological Significance

Glycogen constitutes the primary form of carbohydrate storage in humans and animals, playing a key role as an energy substrate during physical exercise [1, 6]. Structurally, it consists of α-D-glucose residues linked by $\alpha(1\rightarrow4)$ glycosidic bonds, with $\alpha(1\rightarrow6)$ linkages occurring at branch points approximately every 8-12 residues [6]. This highly branched structure increases glycogen solubility and provides high accessibility of the so-called non-reducing ends to enzymes, primarily glycogen phosphorylase, responsible for its degradation [1, 6]. This enables rapid glycogen mobilization and the release of large amounts of glucose during conditions of increased energy demand, such as physical exercise [1, 6]. The largest glycogen stores are located in the liver and skeletal muscles, whereas smaller amounts are present in tissues such as the kidneys, heart, brain, adipose tissue, and erythrocytes [7]. Liver glycogen is primarily responsible for maintaining normal blood glucose concentrations between meals and during prolonged physical exercise, whereas muscle glycogen is utilized locally as an energy source for working muscles [1, 6]. The physiological significance of glycogen present in other tissues has not yet been fully elucidated [7].

As an energy substrate, glycogen plays a fundamental role in exercise metabolism, and its availability directly influences the body’s capacity for physical performance, particularly during moderate- and high-intensity exercise. During physical activity, glycogenolysis is intensified in order to ensure adequate ATP production for working muscles [1]. It should be emphasized that the rate of glycogen utilization largely depends on the nature of the performed exercise: during short-term, high-intensity activity, glycogen breakdown remains high and relatively constant, whereas during prolonged exercise of moderate intensity, a high initial rate of glycogen depletion is observed, which gradually decreases as exercise duration increases [1].

As exercise continues, glycogen stores become progressively depleted, which is closely correlated with impaired exercise capacity and the onset of muscular fatigue [1, 2]. This is associated not only with reduced availability of energy substrates for ATP production, but also with disturbances in the processes responsible for muscle contraction [8]. One of the key mechanisms linking low glycogen availability with the development of fatigue involves disruptions in calcium homeostasis. It has been demonstrated that low glycogen levels may impair the release of calcium ions (Ca^{2+}) from the sarcoplasmic reticulum, resulting in weakened activation of the muscle contractile apparatus and consequently preventing effective muscle contraction [2, 8]. Furthermore, low muscle glycogen levels are associated with a marked reduction in the capacity to generate maximal power, resulting in impaired muscular performance and increased cellular metabolic stress [1, 2]. The importance of glycogen is particularly evident during endurance exercise performed at an intensity corresponding to 60-80% of VO_2max (maximal oxygen uptake), where its availability determines the ability to sustain exercise. For this reason, athletes often employ glycogen supercompensation strategies, commonly referred to as "carbohydrate loading," in order to maximize muscle glycogen stores and thereby prolong the time required for their depletion [1].

In summary, glycogen plays a fundamental role in maintaining proper skeletal muscle function during physical exercise, and the depletion of its stores constitutes one of the major factors limiting the ability to continue physical activity. Therefore, effective glycogen resynthesis is of key importance for post-exercise recovery, as it enables the restoration of metabolic homeostasis and prepares the body for subsequent exercise.

3. Muscle Glycogen Resynthesis During the Post-Exercise Period

After physical exercise, glycogen replenishment is a key component of post-exercise recovery. The rate of its resynthesis is primarily determined by carbohydrate availability; therefore, adequate intake of carbohydrates following exercise is considered a fundamental element of athletes' nutritional strategies [3, 9]. The process of muscle glycogen resynthesis after intense exercise is biphasic and consists of an early phase that is insulin-independent and a later phase that is insulin-dependent [10, 11].

The first phase begins immediately after the end of exercise and lasts approximately 30-60 minutes; during this time, there is an increased transport of glucose into muscle cells due to the translocation of GLUT4 transporters to the sarcolemma - the muscle cell membrane [10, 11]. This mechanism is a result of muscle contractions occurring during training [10]. During this period, the rate of glycogen resynthesis is highest, particularly when substantial depletion of energy stores has occurred beforehand and when the body receives an adequate amount of carbohydrates [10, 11].

In this context, it is worth noting that the timing of carbohydrate intake after exercise is of considerable importance, particularly in situations where the recovery period before the next bout of exercise is limited [3]. Of particular relevance is the time window lasting up to 2 hours, during which the body exhibits the greatest capacity to replenish glycogen stores from ingested carbohydrates [12, 13]. It has been shown that carbohydrate intake immediately after exercise enables a glycogen resynthesis rate of approximately 25 mmol/kg dw/h, whereas delaying intake by as little as 2 hours may reduce this rate by nearly 50%, which is associated with the gradual decline of the early phase of glycogen resynthesis characterized by rapid and insulin-independent glucose uptake by muscle tissue [14]. In the later phase, typically occurring about one hour after exercise cessation, glycogen resynthesis slows down and becomes more dependent on insulin action [14]. This phase may last from several hours up to 24-48 hours in cases of significant physiological fatigue [10]. During this period, the efficiency of the process depends on the continuous availability of substrates; therefore, regular carbohydrate intake at short intervals is of considerable importance, as it helps maintain relatively stable blood glucose and insulin levels and supports the activation of GLUT4 transporters and glycogen synthase [3, 14]. Analyses indicate that carbohydrate administration at least once per hour (or more frequently) induces a significantly higher rate of glycogen resynthesis compared with less frequent intake [3]. An intake of 1.2 g per kilogram of body mass per hour is considered optimal for maximizing this process [3].

4. The Role of Honey in Post-Exercise Recovery in Athletes

Honey represents an interesting natural alternative to commercial peri-exercise carbohydrate supplements in athletes [4]. Its role in post-exercise recovery and glycogen replenishment is primarily based on its specific composition and absorption mechanisms [4, 5]. Honey is a carbohydrate-rich product, consisting of approximately 80% monosaccharides, namely glucose (30-35%) and fructose (approximately 35-40%), as well as about 19% water [4]. In much smaller amounts, honey contains di- and trisaccharides, including sucrose, which account for approximately 5-10% of its composition. In addition to sugars, honey contains numerous bioactive compounds such as polyphenols and flavonoids with antioxidant properties, enzymes (e.g., catalase, invertase), as well as small amounts of vitamins (B6, niacin), minerals (calcium, magnesium, iron), and amino acids [4, 5, 15, 16]. Additionally, an important characteristic of honey is its variable glycemic index (GI), which can range from 32 to 85 depending on its botanical origin. In this context, honey types rich in slowly absorbed fructose, such as acacia honey, are particularly noteworthy; their low to moderate GI promotes a more stable release of glucose into the bloodstream and helps prevent sharp fluctuations in glycaemia [4].

Due to its specific composition, honey may play a significant role in post-exercise recovery; as a mixture of sugars, it effectively supports glycogen replenishment and provides energy in a more stable manner than glucose alone [4, 14]. Owing to the presence of glucose and fructose, which are metabolized via different pathways, post-exercise honey intake may enable optimal restoration of both muscle and liver glycogen stores. This is based on the fact that glucose is preferentially taken up by skeletal muscles, whereas fructose metabolism occurs primarily in the liver, thereby accelerating the replenishment of hepatic glycogen stores [14]. It is also worth mentioning the phenomenon known as the "fructose paradox." Fructose alone is not particularly effective in restoring muscle glycogen, however, when combined with glucose (as in honey), it may enhance intestinal absorption of water and glucose. As a result, it supports faster post-exercise recovery while also being better tolerated by the gastrointestinal system [17, 18, 19].

Additionally, glucose and fructose utilize different intestinal transporters (SGLT1 and GLUT5, respectively) which increases the total amount of carbohydrates that can be absorbed and utilized per unit of time by the body. This mechanism, by enhancing the availability of these macronutrients, may contribute to the acceleration of post-exercise recovery processes [4, 14]. Available data also suggest that post-exercise honey consumption, particularly when combined with whey protein, helps maintain elevated blood glucose and insulin concentrations for a longer period compared with sucrose, which may support anabolic processes and glycogen resynthesis [4]. In studies on post-resistance exercise recovery, a dose of 120g of powdered honey combined with 40g of whey protein was used, and it was observed that such a combination may not only support the restoration of energy stores but also influence muscle tissue repair and growth in athletes [12, 20]. Honey also exhibits a range of other health-promoting properties that are highly valued among athletes, such as antioxidant and anti-inflammatory potential [4, 21]. Regular honey consumption during periods of intense training may reduce the inflammatory response by lowering pro-inflammatory cytokines such as IL-1β, IL-6, and TNF-α, as well as by reducing markers of oxidative stress, including malondialdehyde and reactive oxygen species [4, 22]. It has been shown that regular honey supplementation at a dose of approximately 20 g per day may positively affect the immune system by increasing T-lymphocyte counts and reducing oxidative stress [20]. This not only supports post-exercise recovery but may also help alleviate immune disturbances induced by intense physical activity [21].

From the perspective of sports disciplines, honey has particular applications in endurance sports such as long-distance running and cycling. Its natural combination of glucose and fructose enables more efficient carbohydrate oxidation, allowing the maintenance of performance during prolonged exercise [13]. In team sports, honey consumption may help prevent hypoglycaemia and maintain concentration during gameplay. Beneficial effects have also been observed in resistance training and bodybuilding, where honey contributed to a reduction in delayed-onset muscle soreness (DOMS) and faster recovery of full muscle function after intense exercise [20]. Additionally, it has been suggested that honey consumption combined with physical activity, such as aerobic training or jumping exercises, may support bone health to a greater extent than exercise alone [13, 20].

Despite its numerous benefits, there are certain limitations and contraindications associated with honey consumption. In athletes with diabetes or insulin resistance, its high content of simple sugars may lead to rapid fluctuations in blood glucose levels; therefore, its intake should be appropriately controlled [12, 23]. Additionally, excessive honey consumption may cause gastrointestinal discomfort, such as bloating, diarrhoea, or abdominal cramps, while inadequate oral hygiene after consumption may promote the development of dental caries and enamel damage [12, 13, 23]. It should also be noted that allergic reactions may occur in individuals sensitive to plant pollen or bee-derived proteins. In therapeutic applications, the use of high-quality honey free from contaminants such as pesticides or heavy metals is particularly important [24].

5. Impact of Honey Consumption on Muscle Glycogen Resynthesis - Analysis of the Literature

In a systematic review conducted by Hills et al. (2019), the available scientific evidence regarding the effects of honey on physically active individuals was analysed. Nine articles involving a total of 186 participants (125 men and 61 women) were included in the analysis. The studies covered various forms of physical activity, such as football, running, cycling, rowing, resistance training, and dance. The authors demonstrated that honey supplementation may have a beneficial effect on both physical performance and post-exercise recovery. The effects of honey were comparable to those of other carbohydrate sources, and additional attention was drawn to its potential to support the immune system and reduce inflammation [4].

Potential regenerative benefits of honey are also supported by more recent studies. Hemmati et al. (2024) evaluated the effects of honey consumption on recovery following exercise-induced muscle damage in resistance-trained women. The study involved 16 women who received either 70 g of honey dissolved in 250 ml of water or a placebo (stevia in the same volume of water) 90 minutes before exercise. In the honey-supplemented group, a significant reduction in delayed-onset muscle soreness (DOMS), improved performance in a muscular endurance test during the recovery period, and an increase in maximal strength were observed [25].

Benefits of honey consumption have also been observed under conditions of high temperature and humidity. Ahmad et al. (2015) investigated the effects of a honey-based beverage on recovery in 10 recreational runners performing exercise in heat stress conditions. The authors demonstrated that rehydration with a honey-containing drink was more effective than water alone. Honey intake helped maintain higher blood glucose concentrations and stimulated an insulin response, which translated into improved recovery and enhanced performance during subsequent exercise bouts. Consequently, the authors recommended honey-based beverages as a natural ergogenic aid for athletes training in hot and humid environments [26].

Comparing honey with other carbohydrate sources, studies indicate its high effectiveness relative to glucose, dextrose, sucrose, or maltodextrin [4]. The beneficial effects of honey are primarily associated with its ability to induce a strong insulin response, which is essential for efficient muscle glycogen resynthesis [4]. Additionally, it has been shown that honey exhibits similar efficacy to carbohydrate gels and isotonic beverages [27]. In the post-exercise phase, honey induces a comparable insulin response to maltodextrin, and after resistance exercise it produces a higher and more sustained increase in glycaemia than sucrose, which may support prolonged anabolic and recovery processes in the body [4].

Despite promising findings, the available literature on the effects of honey on post-exercise recovery has several limitations. Many studies involve small sample sizes, which reduces the reliability of generalizations. In addition, different types of honey vary in composition and glycaemic index, and the lack of precise characterization makes it difficult to compare results across studies. The use of heterogeneous exercise protocols and a focus mainly on short-term outcomes further limit the ability to draw definitive conclusions. In some studies, differences in energy intake between groups may have additionally influenced the results. Consequently, the authors emphasize the need for further, more rigorous research in this area [4].

Table 1. Comparison of selected carbohydrate sources in post-exercise glycogen resynthesis [4, 10, 18, 19, 27].

Carbohydrate source	Main sugars	Glycaemic response	Effect on glycogen resynthesis	Additional effects
Glucose	Glucose	High	Rapid muscle glycogen restoration	Stronf insulin response
Fructose	Fructose	Moderate	Better liver glycogen restoration	Lower GI
Glucose + Fructose	Mixed	Stable/High	Enhanced total carbohydrate utilization	Better intestinal absorption
Maltodextrin	Glucose polymers	High	Effective glycogen restoration	Common in sports nutrition

Honey	Glucose + Fructose + Polyphenols	Variable	Comparable to commercial supplements	Antioxidant and anti-inflammatory effects

6. Conclusions

Available data suggest that honey may effectively support post-exercise recovery, representing a promising natural alternative to commercial peri-exercise carbohydrate supplements. Due to the presence of both glucose and fructose, it enables efficient muscle glycogen replenishment while providing a more stable glycaemic response compared with pure glucose. Its effectiveness is comparable to that of maltodextrin or isotonic gels; however, honey additionally provides antioxidant and anti-inflammatory compounds. Despite these promising findings, a precise determination of its effects on glycogen resynthesis and exercise performance requires further research involving larger cohorts of athletes and standardization of the botanical types of honey used.

Disclosure

Authors do not report any disclosures.

Authors' contributions

Conceptualization: Julia Pająk, Anna Kamosińska

Methodology: Olga Sławatyniec, Wiktoria Sobieraj;

Software: n/a; check: Antoni Majda;

Formal analysis: Julia Pająk, Anna Kamosińska, Wiktoria Łuniewska, Marta Modrzyk;

Investigation: Antoni Majda;

Resources: Olga Sławatyniec, Wiktoria Sobieraj;

Data curation: Marta Modrzyk;

Writing - rough preparation: Anna Kamosińska

Writing - review and editing: Julia Pajak, Wiktoria Łuniewska;

Visualization: Olga Sławatyniec, Wiktoria Sobieraj;

Supervision: Antoni Majda, Wiktoria Łuniewska;

Project administration: Julia Pająk;

Receiving funding: n/a.

All authors have read and agreed with the published version of the manuscript.

Funding statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data availability statement

Not applicable.

Acknowledgments

The authors declare that there are no acknowledgments for this study.

Conflict of Interest Statement

The authors declare no conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing process.

In preparing this work, the author(s) used Gemini for the purpose of refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI was used for additional linguistic refinement of the research manuscript, including improvements in grammar, style, and clarity of the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. After using this tool, the author(s) reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References

1. Katz A. Eur J Appl Physiol. 2022;122:1751-1772. doi:10.1007/s00421-022-04935-1
2. Knuiman P, Hopman MTE, Mensink M. Nutr Metab (Lond). 2015;12:59. doi:10.1186/s12986-015-0055-9
3. Craven J, Desbrow B, Sabapathy S, et al. Sports Med Open. 2021;7:9. doi:10.1186/s40798-020-00297-0
4. Hills SP, Mitchell P, Wells C, Russell M. Nutrients. 2019;11(7):1586. doi:10.3390/nu11071586
5. Yusof A, Ahmad NS, Hamid MSA, Khong TK. Sci Sports. 2018;33(5). doi:10.1016/j.scispo.2018.02.007
6. Daghlas SA, Rahimi N. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2026.
7. Adeva-Andany MM, González-Lucán M, Donapetry-García C, Fernández-Fernández C, Ameneiros-Rodríguez E. BBA Clin. 2016;5:85-100. doi:10.1016/j.bbacli.2016.02.001
8. Ørtenblad N, Westerblad H, Nielsen J. J Physiol. 2013;591(18):4405-4413. doi:10.1113/jphysiol.2013.251629
9. Jensen TE, Richter EA. J Physiol. 2012;590:1069-1076. doi:10.1113/jphysiol.2011.224972
10. Burke LM, van Loon LJC, Hawley JA. J Appl Physiol. 2017;122(5):1055-1067. doi:10.1152/japplphysiol.00860.2016

11. Murray B, Rosenbloom C. Nutr Rev. 2018;76(4):243-259. doi:10.1093/nutrit/nuy001
12. Faltus A, Pawłuszkiewicz K, Mikołajczak M, Korgiel M, Gaweł-Dąbrowska D. Qual Sport. 2025;40:59354. doi:10.12775/QS.2025.40.59354
13. Safitri N, Pitriani P, Mulyana M, Simbolon M. Effect of honey on measurable sport. In: Proc 4th Int Conf Sport Sci Health Phys Educ (ICSSHPE 2019). 2020. doi:10.2991/ahsr.k.200214.094
14. Alghannam AF, Fuchsez JT, Betts JA. Nutrients. 2018;10(2):253. doi:10.3390/nu10020253
15. Żak K, Madyniak K, Jucha H, Kluz A, Pliszka A, Mazur M, Jarych W, Zukierski K, Michalak K. Qual Sport. 2025;40:59776. doi:10.12775/QS.2025.40.59776
16. Muciek A, Mocarska M, Orłowska A, Strakowska K, Opalska L, Maryńczak A, Mencel J, Nitschke N. Qual Sport. 2024;25:56542. doi:10.12775/QS.2024.25.56542
17. Sievenpiper JL, Chiavaroli L, de Souza RJ, Mirrahimi A, Cozma AI, Ha V, Wang DD, Yu ME, Carleton AJ, Beyene J, Di Buono M, Jenkins AL, Leiter LA, Wolever TMS, Kendall CWC, Jenkins DJA. Br J Nutr. 2012;108(3):418-423. doi:10.1017/S000711451200013X
18. Fuchs CJ, Gonzalez JT, van Loon LJC. J Physiol. 2019;597(14):3549-3560. doi:10.1113/JP277116
19. Gonzalez JT, Fuchs CJ, Betts JA, van Loon LJC. Nutrients. 2017;9(4):344. doi:10.3390/nu9040344
20. Mitchell PI. The physiological and performance effects of honey consumption in sport and exercise: a systematic review. MSc by research thesis. University of Leeds; 2019
21. Salehian O, Rashidi M, Sedaghat M. Oral supplementation of natural honey and levels of inflammatory and anti-inflammatory plasma cytokines during 10-week of intensive treadmill training in endurance-trained athletes. Biomed Res. 2014;25(4).
22. Tartibian B, Maleki BH. J Androl. 2012;33(3):449-461. doi:10.2164/jandrol.110.012815
23. Kusuma DA, Naharudin MNB, Callixte C, Aljunaid M, Firmansyah A, Mario DT, Ilham, Komaini A, Ayubi N. Phys Educ Theory Methodol. 2023;23(6):954-962. doi:10.17309/tmfv.2023.6.19
24. Verma G, Kaur A, Kaur G, Sodetou M, Kashyap P, Farooq Q, Sharma B. IP J Nutr Metab Health Sci. 2025;8(3):104-115. doi:10.18231/j.ijnmhs.12374.1760001562
25. Hemmati H, Alkasasbeh WJ, Hemmatinafar M, Salesi M, Pirmohammadi S, Imanian B, Rezaei R. Front Physiol. 2024;15:1426872. doi:10.3389/fphys.2024.1426872

26. Ahmad NS, Ooi FK, Saat Ismail M, Mohamed M. Asian J Sports Med. 2015;6(3):e24044. doi:10.5812/asjsm.24044
27. Naderi A, Gobbi N, Ali A, Berjisian E, Hamidvand A, Forbes SC, Koozehchian MS, Karayigit R, Saunders B. Nutrients. 2023;15(6):1367. doi:10.3390/nu15061367