

Polyphenols in Athletes' Performance

Maricela DRAGOMIR, Cezar Ionuț BICHESCU, Dimitrie STOICA,

Maricica STOICA

“Dunarea de Jos” University of Galati (Romania)

maricela.dragomir@ugal.ro

cezar.bichescu@ugal.ro

dimitrie.stoica@ugal.ro

maricica.stoica@ugal.ro

Abstract

Polyphenols are composed of thousands of compounds characterized by hydroxy groups attached to aromatic rings, being classified into flavonoids, lignans, phenolic acids, and stilbenes. They are frequently associated with different sports disciplines owing to their capability to enhance the body's antioxidant capacity, and their anti-inflammatory properties, which can reduce exercise-induced inflammation, helping athletes to recover more quickly between training sessions. This article examines the most common polyphenols and their role in augmenting the body's antioxidant capacity, essential for athletes across various sports disciplines.

Keywords: polyphenols, sports, antioxidant capacity, anti-inflammatory potential.

1. Introduction

Intense endurance training and competitions may cause athletes to experience exercise-induced fatigue, reduction of muscle performance, and the onset of oxidative stress, potentially affecting their activity levels and performance. In response, both specialists and amateur athletes have increasingly adopted the use of phytochemicals and natural plant extracts to boost athletic performance, maximize recovery after exercise and prepare for the next exercises (Cao *et al.*, 2024; Sánchez Díaz *et al.*, 2022). Among the natural plant extracts, polyphenols have substantial positive influence in the improving athletic performance and recovery (Cao *et al.*, 2024). In addition, polyphenols are frequently associated with different sports disciplines due to their ability to enhance the body's antioxidant capacity, through vascular and antioxidative mechanisms (Bojarczuk and Dzitkowska-Zabielska, 2022; Miyai, 2024; Sánchez Díaz *et al.*, 2022). Polyphenols activate genes, which increase the mitochondrial efficiency and boost blood flow, which facilitates greater oxygen delivery to mitochondria. Notably, polyphenols are involved in the removal of damaged mitochondria and their replacement with newly synthesized ones. Given that mitochondria provide 85–95% of a muscle cell's energy, their enhanced efficiency directly correlates with improved athletic performance (Sears, 2017). This article examines the most prevalent polyphenols, which include flavonoids, lignans, phenolic acids, and stilbenes, exploring their relationship with athletic performance.

2. Methodology

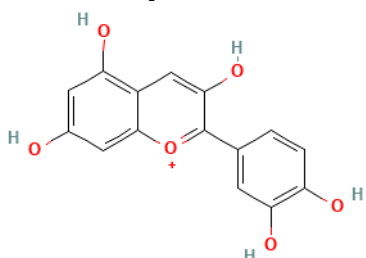
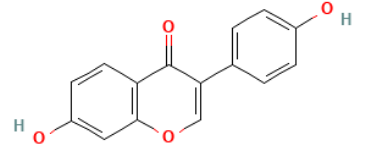
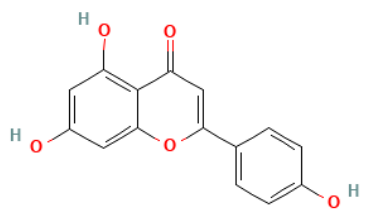
The objective of this paper is to explore a database essential for offering current and significant information regarding the association of polyphenols with athletic performance. Data were gathered from multiple sources, including databases such as Web of Science and Scopus, and encompassed ISI/BDI articles, book chapters, and websites.

3. Results

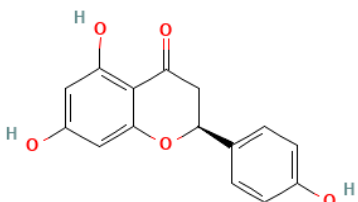
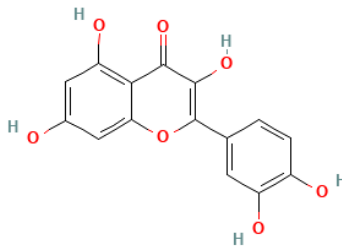
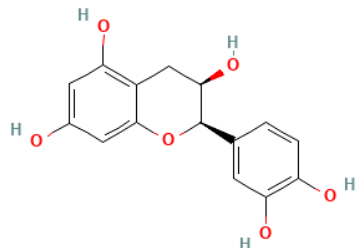
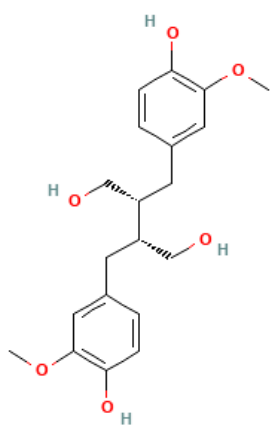
3.1. Classification of polyphenols

Polyphenols, micronutrients found in plants (in glycosylated form) and their derivatives, are composed of thousands of substances identified by hydroxy groups attached to benzene (aromatic) rings. They are classified into four primary categories based on the number of phenolic rings and connecting structural components: flavonoids, lignans, phenolic acids, and stilbenes (Bojarczuk and Dzitkowska-Zabielska, 2022; Cao *et al.*, 2024; Elejalde *et al.*, 2021; Sánchez Díaz *et al.*, 2022; Sorrenti *et al.*, 2020) (Table 1).

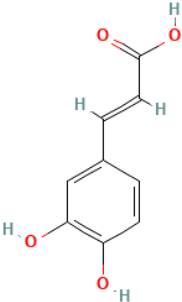
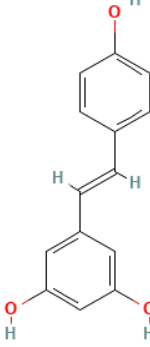
Table 1. Categories of polyphenols: Structures and roles of the most common polyphenols

Class/Subclass	Example/Structure/Role	References
Flavonoids Anthocyanins	<p>Cyanidin</p>  <p>Neuroprotective, antioxidant</p>	(PubChem Compound Summary for CID 128861, Cyanidin, 2024)
Isoflavones	<p>Daidzein</p>  <p>Antioxidant, anti-inflammatory, phytoestrogenic properties</p>	(PubChem Compound Summary for CID 5281708, Daidzein, 2024; Ubaid <i>et al.</i> , 2023)
Flavones	<p>Apigenin</p>  <p>Antioxidant, antiproliferative, anti-inflammatory, antimetastatic</p>	(Chen <i>et al.</i> , 2023; PubChem Compound Summary for CID 5280443, Apigenin, 2024)
Flavonones	<p>Naringenin</p>	(PubChem Compound Summary for CID

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0. International License

	 <chem>O=C1C(=O)C(=C(O)C=C1O)C2=CC=C(O)C=C2</chem>	439246, Naringenin, 2024)
	Expectorant, protects against muscle atrophy	
Flavonols	Quercetin	(PubChem Compound Summary for CID 5280343, Quercetin, 2024; PubChem Compound Summary for CID 72276, Epicatechin, 2024)
	 <chem>O=C1C(=O)C(=C(O)C=C1O)C2=CC(=C(O)C=C2)C3=CC(=C(O)C=C3</chem>	
	Antibacterial, antioxidant, radical scavenger	
	Epicatechin	
	 <chem>O=C1C(=O)C(=C(O)C=C1O)C2=CC=C(O)C=C2[C@@H](O)C3=CC=C(O)C=C3</chem>	
	Antioxidant; used in trials studying the treatment of pre- diabetes	
Lignans	Secoisolariciresinol	(PubChem Compound Summary for CID 65373, Secoisolariciresinol, 2024)
	 <chem>COc1ccc(O)cc1C[C@H](O)C[C@@H](O)C[C@H](O)C2=CC=C(OC)C=C2</chem>	
	Antidepressant; used in trials studying the treatment of breast cancer	

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0. International License

Phenolic acids	Caffeic acid  Antioxidant	(PubChem Compound Summary for CID 689043, Caffeic Acid, 2024)
Stilbenes	Resveratrol  Neuroprotective, antiatherogenic, antithrombotic, antihypercholesterolemic, vasorelaxants, and anticancer	(PubChem Compound Summary for CID 445154, Resveratrol, 2024; Sorrenti <i>et al.</i> , 2020)

Sources of polyphenols include colourful fruits and vegetables, berries, grapes, citrus fruits, green tea, wine, dark chocolate, cereals, etc. (Miyai, 2024; Ubaid *et al.*, 2023).

3.2. Polyphenols associated with sports

Nowadays, polyphenols have gained recognition in sports due to their benefits: antioxidant and anti-inflammatory potential (Bojarczuk and Dzitkowska-Zabielska, 2022; Miyai, 2024). Endurance exercise can induce oxidative damage that restricts blood vessel vasodilation and alters blood rheology, with the ergogenic effects of polyphenols appearing to have noticeable vascular effects (increasing the oxygen difference between arterial and venous blood, enhancement in oxygen transport efficiency, greatly enhancing the capacity of muscle perfusion), which potentially improve athletic performance (Bowtell and Kelly, 2019; Cao *et al.*, 2024; Tofas *et al.*, 2019). Certain polyphenols have been shown to increase NO (nitric oxide) production, which improves blood flow and oxygen delivery to muscles, thereby enhancing endurance and aerobic performance. Polyphenols also have anti-inflammatory properties, which can reduce exercise-induced inflammation and soreness, helping athletes recover more quickly between training sessions. Furthermore, polyphenols have been shown to modulate gut microbiota, which may indirectly influence recovery by supporting gastrointestinal health and nutrient absorption. Incorporating polyphenol-rich foods/beverages

into a diet is a sustainable strategy for athletes to benefit from these bioactive substances. Athletes may also consider supplementing with concentrated polyphenol extracts or functional foods fortified with polyphenols to enhance their intake. It is important to note that polyphenols are most effective when consumed as part of a well-balanced diet rich in diverse plant-based foods (Miyai, 2024). Few studies have explored the epigenetic role of polyphenols in modulating key proteins related to energy balance, antioxidant mechanisms, glucose and lipid homeostasis, and their overall impact on sports performance (Sorrenti *et al.*, 2020). Anthocyanins, nutritional ergogenic aids for delivering meaningful effects for a wide range of athletes and physically active individuals, have demonstrated antioxidant, anti-inflammatory, and vasodilatory effects in multiple human studies, aiding exercise recovery (Willems and Sam, 2022). Cyanidin has been shown to enhance physical performance and protect against post-exercise oxidative stress in both non-athletes and athletes. Numerous studies have emphasized the strong anti-inflammatory and antioxidant properties of anthocyanins, as well as their capacity to boost immunity, improve sleep, aid muscle recovery, and reduce post-exercise pain, particularly in strength sports (Copetti *et al.*, 2022; Sorrenti *et al.*, 2020). Daidzein exhibits a wide range of pharmacological and beneficial properties, such as enhancing cardiovascular health, reducing cholesterol levels, and exerting anticancer, antifibrotic, and antidiabetic effects (Ubaid *et al.*, 2023). Apigenin has promising pharmacological properties as a myocyte-protective agent, mitigating damage and degradation. Apigenin enhances myocyte protection through mechanisms that include promoting cell proliferation, exerting anti-inflammatory and antioxidant effects, preventing muscle atrophy, and increasing overall cell resilience (Huang *et al.*, 2022). Naringenin can enhance the endurance and aerobic metabolic capacity of skeletal muscle and protects against muscle atrophy (Lv *et al.*, 2023). Quercetin has been shown to enhance mental and physical performance and immune function, thereby lowering the risk of infection during intense exercise. In athletes, studies have primarily focused on its effects on sports performance, such as sprint and endurance exercises, resistance training, and competitions like marathons or triathlons. Quercetin has improved the torque-velocity curve of knee extensors and resulted in less reduction in maximum voluntary isometric contraction after resistance exercise, with a higher rate of torque development and neuromuscular efficiency. Overall, quercetin is a valuable sports supplement that regulates multiple pathways related to sports performance and post-race recovery (Rojano-Ortega *et al.*, 2023; Sorrenti *et al.*, 2020). Catechins (from green tea) show promising effects in enhancing exercise recovery due to their antioxidant, anti-inflammatory, and lipid metabolism-regulating properties (Bawono *et al.*, 2023). In the context of sports, resveratrol has been shown to enhance muscle strength, fatigue tolerance, and muscle regeneration following disuse. Both in vivo and human studies indicate that resveratrol possesses numerous ergogenic, hypoglycemic, and anti-obesity properties beneficial for maintaining optimal body composition. Additionally, resveratrol supplementation has significantly improved glucose control and insulin sensitivity in diabetic or pre-diabetic individuals without affecting glycemic measures in non-diabetic subjects (Sorrenti *et al.*, 2020).

4. Conclusions

This article has explored the multiple roles of polyphenols in enhancing athletic performance and recovery. By categorizing them into flavonoids, lignans, phenolic acids, and stilbenes, it has provided an understanding of their biological functions and health benefits. Polyphenols enhance mitochondrial efficiency, increase oxygen delivery to muscles, and support muscle cell

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0. International License

energy production, which are critical in improving athletic performance. Furthermore, the antioxidant and anti-inflammatory properties of polyphenols contribute significantly to reduce exercise-induced fatigue and oxidative stress, while their role in modulating gut microbiota and influence nutrient absorption highlights their potential in health management for athletes. As such, incorporating polyphenol-rich foods and supplements into athletes' diets emerges as a strategy to harnessing these benefits effectively.

References

- Bawono, L. C., Khairinisa, M. A., Jiranusornkul, S., Levita, J. (2023) The role of catechins of *Camellia sinensis* leaves in modulating antioxidant enzymes: A review and case study. *Journal of Applied Pharmaceutical Science*, 13(12), 052–065. <http://doi.org/10.7324/JAPS.2023.143056>.
- Bojarczuk, A., Dzitkowska-Zabielska, M. (2022) Polyphenol supplementation and antioxidant status in athletes: A narrative review. *Nutrients*, 15(1), 158. <https://doi.org/10.3390/nu15010158>.
- Bowtell, J., Kelly, V. (2019) Fruit-derived polyphenol supplementation for athlete recovery and performance. *Sports Medicine*, 49(Suppl. 1), 3–23. <https://doi.org/10.1007/s40279-018-0998-x>.
- Cao, G., Zuo, J., Wu, B., Wu, Y. (2024) Polyphenol supplementation boosts aerobic endurance in athletes: Systematic review. *Frontiers in Physiology*, 15, 1369174. <https://doi.org/10.3389/fphys.2024.1369174>.
- Chen, P., Chen, F., Guo, Z., Lei, J., Zhou, B. (2023) Recent advancement in bioeffect, metabolism, stability, and delivery systems of apigenin, a natural flavonoid compound: Challenges and perspectives. *Frontiers in Nutrition*, 10, 1221227. <https://doi.org/10.3389/fnut.2023.1221227>.
- Copetti, C.L.K., Diefenthaler, F., Hansen, F., Vieira, F.G.K., Di Pietro, P.F. (2022) Fruit-Derived Anthocyanins: Effects on Cycling-Induced Responses and Cycling Performance. *Antioxidants*, 11, 387. <https://doi.org/10.3390/antiox11020387>.
- Elejalde, E., Villarán, M.C., Alonso, R.M. (2021) Grape polyphenols supplementation for exercise-induced oxidative stress. *Journal of the International Society of Sports Nutrition*, 18, 3. <https://doi.org/10.1186/s12970-020-00395-0>.
- Huang, X., Yu, Z., Ning, L., Lei, Y., Zhang, X., Wang, Z. (2022) Apigenin as a promising myocyte protectant against damage and degradation. *Biocell*, 46(2), 383–388. <https://doi.org/10.32604/biocell.2021.015651>.
- Lv, Z., Meng, J., Yao, S., Xiao, F., Li, S., Shi, H., Cui, C., Chen, K., Luo, X., Ye, Y., Chen, C. (2023) Naringenin improves muscle endurance via activation of the Sp1-ERRg transcriptional axis. *Cell Reports*, 42, 113288. <https://doi.org/10.1016/j.celrep.2023.113288>.
- Miyai, M. (2024) Polyphenols in sports nutrition: Enhancing performance and recovery naturally. *Journal of Nutrition Science Research*, 9, 259.
- | | | | | | | | |
|---------|----------|---------|-----|-----|----------|-----------------------|---|
| PubChem | Compound | Summary | for | CID | 128861, | Cyanidin, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Cyanidin , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 439246, | Resveratrol, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Resveratrol , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 5280343, | Quercetin, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Quercetin , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 5280443, | Apigenin, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Apigenin , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 5281708, | Daidzein, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Daidzein , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 65373, | Secoisolariciresinol, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Secoisolariciresinol , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 689043, | Caffeic Acid, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Caffeic-Acid , accessed June 23, 2024. |
| PubChem | Compound | Summary | for | CID | 72276, | Epicatechin, | 2024. |
| | | | | | | | https://pubchem.ncbi.nlm.nih.gov/compound/Epicatechin , accessed June 23, 2024. |
- Rojano-Ortega, Peña-Amaro, J., Berral-Aguilar, A.J., Berral-de la Rosa, F.J. (2023). Quercetin supplementation promotes recovery after exercise-induced muscle damage: A systematic review and meta-analysis of randomized controlled trials. *Biology of Sport*, 40(3), 813–825. <http://doi.10.5114/biolsport.2023.121320>.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0. International License

- Sánchez Díaz, M., Martín-Castellanos, A., Fernández-Elías, V.E., López Torres, O., Lorenzo Calvo, J. (2022) Effects of polyphenol consumption on recovery in team sport athletes of both sexes: A systematic review. *Nutrients*, 14, 4085. <https://doi.org/10.3390/nu14194085>.
- Sears, B. 2017. The Importance of Polyphenols in Athletic Performance. <https://blog.zoneliving.com/drsears/blog/importance-polyphenols-sports-performance>, accessed on June 23, 2024.
- Sorrenti, V., Fortinguerra, S., Caudullo, G., Buriani, A. (2020) Deciphering the role of polyphenols in sports performance: From nutritional genomics to the gut microbiota toward phytonutritional epigenomics. *Nutrients*, 12(5), 1265. <https://doi.org/10.3390/nu12051265>.
- Tofas, T., Draganidis, D., Deli, C.K., Georgakouli, K., Fatouros, I.G., Jamurtas, A.Z. (2019) Exercise-induced regulation of redox status in cardiovascular diseases: The role of exercise training and detraining. *Antioxidants (Basel)*, 9(1), 13. <https://doi.org/10.3390/antiox9010013>.
- Ubaid, M., Salauddin, Shadani, M.A., Kawish, S.M., Albratty, M., Makeen, H.A., Alhazmi, H.A., Najmi, A., Zoghebi, K., Halawi, M.A., Ali, A., Alam, M.S., Iqbal, Z., Mirza, M.A. (2023) Daidzein from dietary supplement to a drug candidate: An evaluation of potential. *ACS Omega*, 8(36), 32271–32293. <https://doi.org/10.1021/acsomega.3c03741>.
- Willems, M.E.T., Blacker, S.D. (2022) Anthocyanin-rich supplementation: Emerging evidence of strong potential for sport and exercise nutrition. *Frontiers in Nutrition*, 9, 864323. <https://doi.org/10.3389/fnut.2022.864323>.