

Exercise with Green Tea Consumption Improve Sports Performance

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Regular exercise is fundamental for maintaining a healthy lifestyle.

green tea

sport

1. Neutralizing Free Radicals: Green Tea

Natural interventions to reduce the negative effects of exercise and improve body function during exercise has found its place in the athletes' training program. The use of supplements is often promoted to athletes with claims of improving performance, but it may not clearly specify their ergogenic effects. Thus, extensive research is being done on the role of their effectiveness on sports performance ^[1].

Among dietary and natural supplements, tea is popular and widely used due to its antioxidant, anti-inflammatory, and anticarcinogenic properties ^[2]. Among them, black tea is highly consumed (78% popularity), followed by green tea (20% popularity) ^[3]. Green tea is a very potent beverage because of its antioxidant, anti-inflammatory, anticarcinogenic, and antiallergic properties ^[4]. Additionally, green tea decreases the symptoms of metabolic syndrome and diabetes by controlling blood glucose, lowering cholesterol, etc. ^[3].

1.1. Green Tea Chemical Composition and Its Biological Characteristics

The chemical formula of green tea consists of proteins and amino acids (20–25% raw material), such as glutamic acid, tryptophan, glycine, serine, aspartic acid, tyrosine, valine, leucine, threonine, arginine, sinus, and carbohydrates (5–7% raw material; cellulose, glucose, fructose, and sucrose). It also contains lipids (nickel linoleic acid and linoleic acid), vitamins (B, C, and E), caffeine, chlorophylls, and carotenoids. Unstable compounds (aldehydes, alcohols, esters, lactones, and hydrocarbons), minerals, and essential elements (5% dry weight; Ca, Mg, Cr, Mn, Fe, Cu, Zn, Mo, Se, Na, P, Co, Sr, Ni, K, F, and Al) are also included. Green tea has a rich source of polyphenols, such as flavonoids. Flavonoids are phenolic derivatives that differ in their concentration in green tea ^[5]. Catechins are the most important flavonoids in green tea.

The components in green tea have medicinal properties because of the presence of polyphenols, specifically flavonoids. These flavonoids contain a high proportion of catechins (80–90%) compared to other teas. Green tea has four main catechins: epigallocatechin gallate (EGCG; 60%), epigallocatechin (EGC; 20%), epicatechin-3-gallate (ECG; 14%) and epicatechin (EC; 6%). Among them, EGCG has the most health benefits, as it is effective

in maintaining cardiovascular health and metabolism. In green tea, the amount of catechins varies, although a standard extract has been acquired for its use in supplementation [3]. Catechins cannot be completely extracted from fresh green tea leaves; therefore, there are large differences in the extract concentrations obtained. In addition, catechins are relatively unstable and can vary in amount under different conditions. Therefore, it is not possible to estimate the doses of catechins used in animal studies due to their lack of quantification [6][3][7].

The metabolic reactions for all catechins follow the same pathways of phase II detoxification reactions. Animal studies show that catechin uptake occurs in the intestine and liver [8]. Catechins are partially bound to intestinal mucosa, liver, and kidneys, and about 5% of catechins are transported freely (i.e., unbound) through the bloodstream. For optimal biochemical functioning, catechins must attach to certain biochemical components (e.g., glutathione via liver enzymes) to improve their water solubility and facilitate their excretion in bile and urine. Thus, large amounts of catechins (including bile-attached catechins) are not absorbed in the small intestine and are transported to the large intestine, where they are broken down to smaller metabolites by resident microbes and reabsorbed for excretion via the urine as valerolactones [9]. Catechins were initially thought to have low viability of about 8–9% and very high detoxification [10]. However, studies have observed that the bioavailability of catechins increases by about 40% due to antimicrobial activity [11][12], where catechins were present up to 48 h after ingestion in human urinary excretion. This increase in bioavailability of catechins is explained by the conversion of larger compounds (ECGC and ECG) to smaller compounds (such as UDP-glucuronosyltransferases and sulphotransferases) via the phase II detoxification reaction.

1.2. Effectiveness and Life Span of Green Tea Catechins

Pharmacological research demonstrates that green tea catechins have an effectiveness in the range of 2–13% in mice [13]. Some properties that can contribute to the oral bioavailability of green tea include its low solubility in gastrointestinal fluid, low permeability of the membrane, its degradation and metabolism in the gastrointestinal tract, and its transmission through intestinal epithelial membrane. Green tea catechins are stable at pH <6.5, but EGC and ECGC are rapidly degraded at pH >7.4. The concentration of polyphenols is higher in the fasted state than at postprandial [13]. Isbrucker et al. found that 20 mg·kg⁻¹ body mass per day of ECGC had no side effects in animals [14]. Most animal studies have used 0.1% green tea extract, equivalent to 10 mg per 100 mL of dissolved water, because it showed effectiveness with the lower amount [14].

Gallate-type catechins (e.g., ECGC and ECG) have a longer life span than nongalactic catechins (EGC and EC) because they are bound to proteins, which prevent premature excretion. The short half-life of nongalactic catechins occurs when it crosses the intestinal wall. The lasting effect of the maximum serum level of green tea catechins is about one hour in the fasted state and about two hours in the satiated state [15]. Green tea catechins are shown to be more stable at low pH and in the fasted state [16]. Alimentation raises the pH of the gut, a condition that destroys catechins.

1.3. Antioxidant Function Green Tea

Green tea is a rich source of antioxidants. Structural properties of green tea catechins play a role in their antioxidant function. The presence or absence of the galvanic portion and the number and position of the –OH groups on the ring define their structural property. The presence of the carboxyl group enables catechins to interact with the biological substance and gives its antioxidant function by binding to hydrogen or transferring electrons and hydrogen, or both [17]. The antioxidant activity of tea appears to inhibit lipid-inhibiting alkoxyl and peroxy radicals [18]. For example, the antioxidant activity of green tea extract is due to the increase in superoxide dismutase activity and catalase expression. These enzymes protect cells against oxidative stress [19]. The proposed mechanism for this process is the reduction of nitric oxide concentration in the plasma, which directly lowers the activity of oxygen species [20][21]. Malondialdehyde, a marker of oxidative stress, also decreases after consuming green tea [20][21]. Elevated levels of Phase II antioxidant enzymes have been observed after drinking green tea by increasing levels of polyphenols in the small intestine, lungs, and skin of mice [22] and rat prostate [23] and the oral cavity of hamsters [24]. The underlying mechanism of this process can be through the activation of MAPKs by green tea polyphenols [25]. Activation of the Nrf2 signaling pathway is also involved in this process [26]. Stimulation of phase II enzymes not only neutralizes free radicals and oxidative stress but can also have a detoxifying effect on carcinogens, such as aflatoxin B1 [26]. Studies have shown that catechins have a direct (antioxidant) or indirect (increased activity or expression) effect on oxidative stress. The following **Figure 1** shows the effect of green tea catechins on oxidative stress [18].

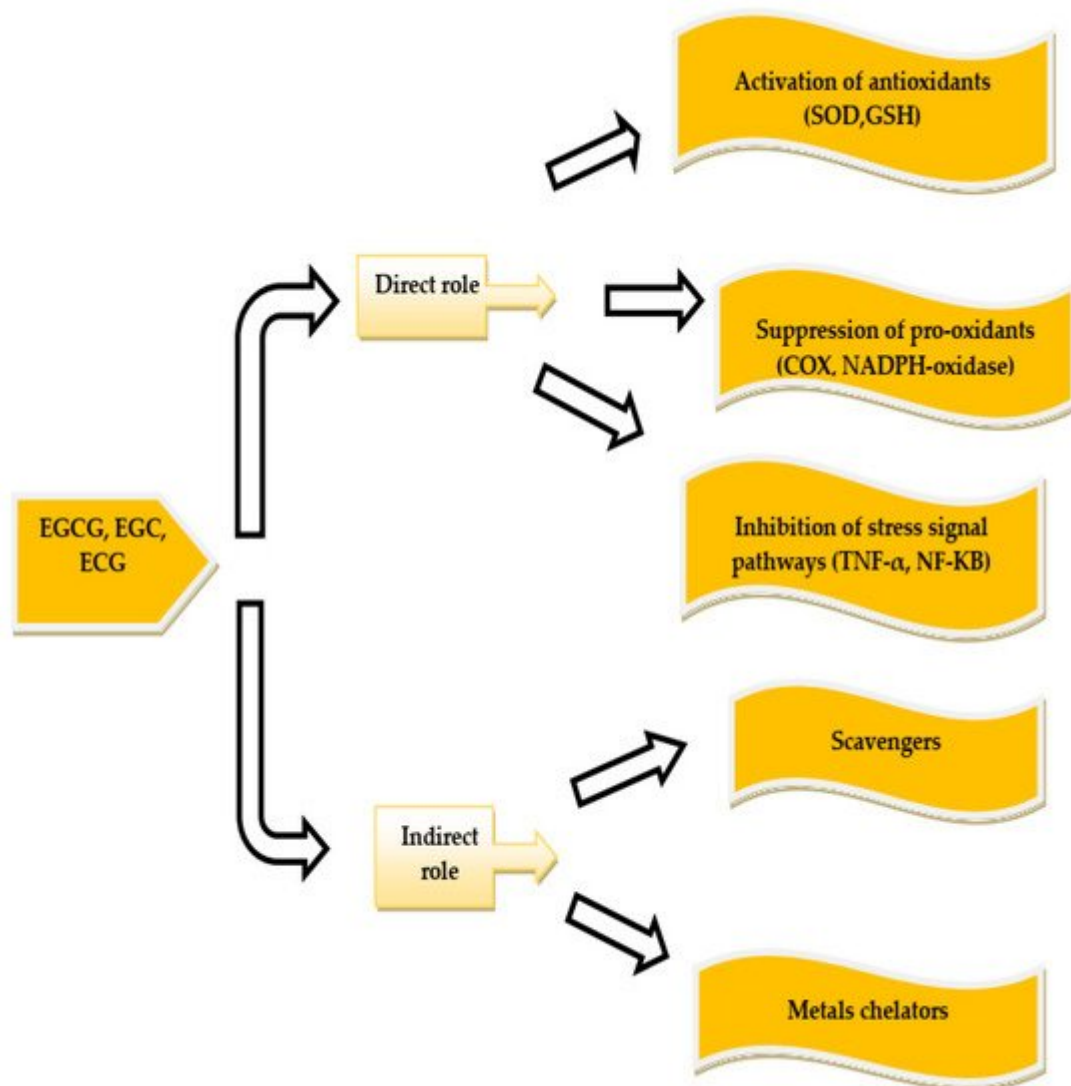


Figure 1. Mechanism regarding the effect of green tea catechins on oxidative stress.

1.4. Green Tea Used as an Ergogenic Aid

Green tea is an ergogenic supplement that optimizes mitochondrial function and increases lipolysis and fatty acid metabolism, thereby reducing fatigue and improving endurance performance. After a Japanese study examined positive effects of catechins in rats [18], there was an increase in investigations regarding the effects of green tea catechins in animal models [18][19]. One study observed that mice who exercised with consumption of green tea extract (GTE; 0.2% and 0.5% supplementation groups) improved exercise performance compared to the exercise only and control groups, suggesting that the presence of catechin EGCG stimulated lipid metabolism [19].

2. Sport Performance and Drinking Green Tea

In recent years, many studies have studied the effect of polyphenols, especially catechins, on athletic performance. Most of these studies have examined the effect of catechins on exercise-induced muscle damage and their biological and physiological role in improving physical function. Until a few years ago, as catechins are

antioxidants, their role in preventing muscle damage was studied [21]. However, in recent years, more studies have significantly examined the effect of polyphenols on athletic performance. Studies on polyphenols and exercise include antioxidant supplements, such as green tea extract (GTE). Although the majority of studies on green tea have been done on animals, lately, a large number of studies have been done on human athletic performance. Green tea extract contains a large amount of catechins that increase daily energy consumption in humans. For example, short-term consumption of green tea extract on healthy untrained men increased the amount of energy available during 30 min of cycling at 60% of the maximum oxygen consumption. However, the chemical process of green tea and green tea extract in the face of oxidative stress remains unknown. It has been reported that the inhibitory capacity of catechins is due to the presence of a hydroxyl group at the 5 prim position, which increases their ability to inhibit free radicals [21].

3. How Can Green Tea Improve Sports Performance?

The use of natural strategies and interventions to improve athletic performance, in addition to overall health, has attracted the attention of athletes at all levels of sport, and green tea consumption has particularly been demonstrated to be effective [27][9]. Meta-analysis studies have shown that green tea consumption improves performance without any side effects [28][7][9]. Further meta-analysis investigations on antioxidant effects and the presence of polyphenols in green tea have shown its beneficial effects on exercise performance [9][15]. There are many mechanisms for the effectiveness of polyphenols. Although it is not possible to address them all here, we will mention some of them [29]. Natural interventions, such as plant extracts and phytochemicals, enhance physical function, improve recovery after exercise, maintain overall health [8], and have minimal side effects [30][31]. In addition, regular green tea consumption (434 mL·day⁻¹) was found to reduce body fat and decrease waist-to-pelvis ratio compared to the control group (i.e., no green tea ingestion). Similar to these findings, rodent models with high fat diet and body fat mass lost weight with green tea catechin consumption [32][33].

Green tea polyphenols and catechins also affect SIRT1, which has a role in increasing the activity of PGC-1α after deacetylation, consequently improving mitochondrial function [34][35]. Another action of green tea polyphenols and catechins is increased endothelial NO synthesis and vasodilation [36][37]. The production of NO improves the perfusion of oxygen to the active muscles and improves athletic performance [38][39]. Thus, GTE supplementation can reduce oxidative stress through its polyphenols [40] and produce NO to improve maximum oxygen uptake, thus delaying fatigue [40]. Additionally, green tea consumption reduces muscle pain caused by improper exercise, bruising, and subsequent injuries. The reduction of exercise-induced fatigue because of GTE supplementation has great practical applications in sports performance in both amateur [41] and professional [26] athletes because it may be the limiting factor in achieving a personal record or successful performance. Oxidative stress not only accumulates during exercise [41] but also does so after exercise; thus, the consumption of green tea during and following exercise can lower oxidative stress (i.e., lipid peroxidation) [42]. Plasma triglyceride levels can indicate the effectiveness of catechins, which has been shown to be reduced with exercise in normal mice [43]. In addition, the consumption of green tea extract lowered triglyceride levels in Zucker mice and mice fed with a sucrose-rich diet.

Studies have demonstrated that green tea flavonoids have an insulin-like activity and increase insulin activity [43]. The **Figure 2** shows the effect of exercise combined with green tea consumption on exercise performance.

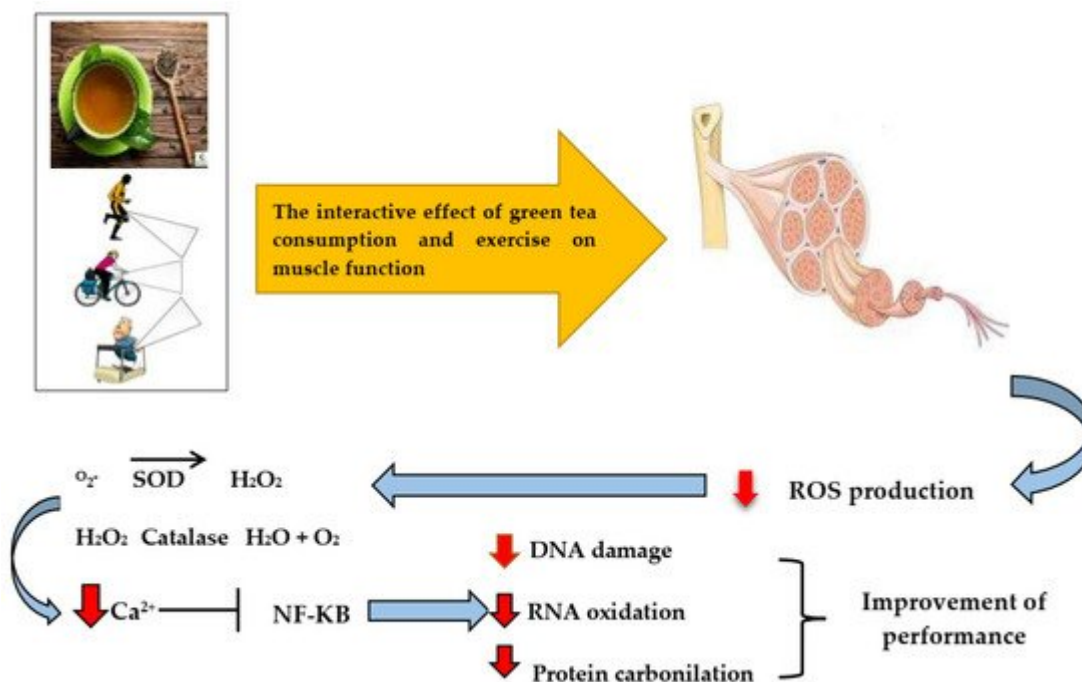


Figure 2. Possible mechanisms related to the effects of green tea catechins and exercise training on performance. Exercise and concomitant consumption of green tea reduce oxidative factors and suppress the activation of inflammatory factors by regulating calcium release, reduce DNA and RNA damage, release caspases due to TRX activation, and ultimately lead to improved performance.

Ichinose et al. examined the effect of drinking green tea with moderate-intensity exercise and found that concomitant use of the two interventions increased metabolism of fat, which was the predominant fuel during exercise [44]. The predominance of the fat energy source reduced VO_2 during exercise. This process resulted in a 10% reduction in post-workout oxygen consumption in both groups, which was consistent with other studies [45][46]. They found that exercise combined with drinking green tea resulted in metabolic adaptation and reduced energy expenditure at the same intensity of exercise. This reduction in energy leads to a decrease in the amount of basal metabolism. They observed this mechanism by measuring the concentration of free fatty acids after exercise and reported that the level of free fatty acids was significantly higher immediately after exercise in trained mice. Beta-oxidation cycle enzymes are important during exercise and fatty acid oxidation [47]. Murase et al. [48] found that drinking tea with exercise improved the activity of beta-oxidation enzymes and improved mitochondrial enzymes. They also found that drinking tea with exercise delayed the onset of fatigue [48]. According to studies and observation of the interaction between exercise and nutritional interventions, new insights can be provided for the use of natural interventions during physical activity to improve athletic performance or maintain health.

One of the limitations of our review is that there is a wide range of oxidative stress factors that could not be addressed. Additionally, this review only mentioned few of the many effects of green tea on performance and

health. The amount of green tea required to obtain the maximum benefits is also unclear. Moreover, it is not clear how much physiological oxidative stress production is beneficial and how much harms the body. Most of the research has been done on healthy and young people, and there have been few investigations examining oxidative stress factors associated with metabolic syndrome and other diseases. Therefore, more studies are needed to answer these questions.

References

1. Medicine, A.C.o.S.; Association, A.D. Joint Position Statement: Nutrition and athletic performance. American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada. *Med. Sci. Sports Exerc.* 2000, 32, 2130–2145.
2. Gleeson, M.; Nieman, D.C.; Pedersen, B.K. Exercise, nutrition and immune function. *J. Sports Sci.* 2004, 22, 115–125.
3. Saedmocheshi, S.; Saghebjo, M.; Vahabzadeh, Z.; Sheikholeslami-Vatani, D. Aerobic Training and Green Tea Extract Protect Against N-methyl-N-nitrosourea-induced Prostate Cancer. *Med. Sci. Sports Exerc.* 2019, 51, 2210–2216.
4. Takahashi, M.; Miyashita, M.; Suzuki, K.; Bae, S.-r.; Kim, H.-K.; Wakisaka, T.; Matsui, Y.; Takeshita, M.; Yasunaga, K. Acute ingestion of catechin-rich green tea improves postprandial glucose status and increases serum thioredoxin concentrations in postmenopausal women. *Br. J. Nutr.* 2014, 112, 1542–1550.
5. Musial, C.; Kuban-Jankowska, A.; Gorska-Ponikowska, M. Beneficial properties of green tea catechins. *Int. J. Mol. Sci.* 2020, 21, 1744.
6. Vahabzadeh, Z.; Molodi, M.; Nikkho, B.; Saghebjo, M.; Saedmocheshi, S.; Zamani, F.; Roshani, Y.; Babanzadeh, S. Aerobic training and hydroalcoholic extracts of green tea improve pro-oxidant-antioxidant balance and histopathological score in the N-methyl-N-nitrosourea-induced prostate cancer model of rat. *EXCLI J.* 2020, 19, 762.
7. Khan, N.; Mukhtar, H. Tea and health: Studies in humans. *Curr. Pharm. Des.* 2013, 19, 6141–6147.
8. Kalogeropoulos, N.; Chiou, A.; Ioannou, M.S.; Karathanos, V.T. Nutritional evaluation and health promoting activities of nuts and seeds cultivated in Greece. *Int. J. Food Sci. Nutr.* 2013, 64, 757–767.
9. Higdon, J.V.; Frei, B. Tea catechins and polyphenols: Health effects, metabolism, and antioxidant functions. *Crit. Rev. Food Sci. Nutr.* 2003, 43, 89–143.
10. Kanwar, J.; Taskeen, M.; Mohammad, I.; Huo, C.; Chan, T.H.; Dou, Q.P. Recent advances on tea polyphenols. *Front. Biosci. (Elite Ed.)* 2012, 4, 111.

11. Del Rio, D.; Calani, L.; Cordero, C.; Salvatore, S.; Pellegrini, N.; Brighenti, F. Bioavailability and catabolism of green tea flavan-3-ols in humans. *Nutrition* 2010, 26, 1110–1116.
12. Calani, L.; Del Rio, D.; Luisa Callegari, M.; Morelli, L.; Brighenti, F. Updated bioavailability and 48 h excretion profile of flavan-3-ols from green tea in humans. *Int. J. Food Sci. Nutr.* 2012, 63, 513–521.
13. Peluso, I.; Serafini, M. Antioxidants from black and green tea: From dietary modulation of oxidative stress to pharmacological mechanisms. *Br. J. Pharmacol.* 2017, 174, 1195–1208.
14. Isbrucker, R.; Edwards, J.; Wolz, E.; Davidovich, A.; Bausch, J. Safety studies on epigallocatechin gallate (EGCG) preparations. Part 2: Dermal, acute and short-term toxicity studies. *Food Chem. Toxicol.* 2006, 44, 636–650.
15. Yang, C.S.; Wang, X. Green tea and cancer prevention. *Nutr. Cancer* 2010, 62, 931–937.
16. Ananingsih, V.K.; Sharma, A.; Zhou, W. Green tea catechins during food processing and storage: A review on stability and detection. *Food Res. Int.* 2013, 50, 469–479.
17. Lambert, J.D.; Elias, R.J. The antioxidant and pro-oxidant activities of green tea polyphenols: A role in cancer prevention. *Arch. Biochem. Biophys.* 2010, 501, 65–72.
18. Ikeda, I.; Kobayashi, M.; Hamada, T.; Tsuda, K.; Goto, H.; Imaizumi, K.; Nozawa, A.; Sugimoto, A.; Kakuda, T. Heat-epimerized tea catechins rich in gallic catechin gallate and catechin gallate are more effective to inhibit cholesterol absorption than tea catechins rich in epigallocatechin gallate and epicatechin gallate. *J. Agric. Food Chem.* 2003, 51, 7303–7307.
19. Murase, T.; Haramizu, S.; Shimotoyodome, A.; Nagasawa, A.; Tokimitsu, I. Green tea extract improves endurance capacity and increases muscle lipid oxidation in mice. *Am. J. Physiol.-Regul. Integr. Comp. Physiol.* 2005, 288, R708–R715.
20. Centner, C.; Zdzieblik, D.; Dressler, P.; Fink, B.; Gollhofer, A.; Koenig, D. Acute effects of blood flow restriction on exercise-induced free radical production in young and healthy subjects. *Free Radic. Res.* 2018, 52, 446–454.
21. Özyurt, H.; Luna, C.; Estévez, M. Redox chemistry of the molecular interactions between tea catechins and human serum proteins under simulated hyperglycemic conditions. *Food Funct.* 2016, 7, 1390–1400.
22. Radak, Z.; Chung, H.Y.; Koltai, E.; Taylor, A.W.; Goto, S. Exercise, oxidative stress and hormesis. *Ageing Res. Rev.* 2008, 7, 34–42.
23. McARDLE, A.; Jackson, M.J. Exercise, oxidative stress and ageing. *J. Anat.* 2000, 197, 539–541.
24. Powers, S.K.; Ji, L.L.; Leeuwenburgh, C. Exercise training-induced alterations in skeletal muscle antioxidant capacity: A brief review. *Med. Sci. Sports Exerc.* 1999, 31, 987–997.

25. Koubaa, A.; Triki, M.; Trabelsi, H.; Baati, H.; Sahnoun, Z.; Hakim, A. The effect of a 12-week moderate intensity interval training program on the antioxidant defense capability and lipid profile in men smoking cigarettes or hookah: A cohort study. *Sci. World J.* 2015, 2015, 639369.
26. Mikkelsen, U.; Couppé, C.; Karlsen, A.; Grosset, J.; Schjerling, P.; Mackey, A.; Klausen, H.; Magnusson, S.; Kjær, M. Life-long endurance exercise in humans: Circulating levels of inflammatory markers and leg muscle size. *Mech. Ageing Dev.* 2013, 134, 531–540.
27. Cabrera, C.; Artacho, R.; Giménez, R. Beneficial effects of green tea—A review. *J. Am. Coll. Nutr.* 2006, 25, 79–99.
28. Zhou, Y.; Huang, L.; Zheng, W.; An, J.; Zhan, Z.; Wang, L.; Chen, Z.; Liu, L. Recurrent nonsevere hypoglycemia exacerbates imbalance of mitochondrial homeostasis leading to synapse injury and cognitive deficit in diabetes. *Am. J. Physiol.-Endocrinol. Metab.* 2018, 315, E973–E986.
29. Shixian, Q.; VanCrey, B.; Shi, J.; Kakuda, Y.; Jiang, Y. Green tea extract thermogenesis-induced weight loss by epigallocatechin gallate inhibition of catechol-O-methyltransferase. *J. Med. Food* 2006, 9, 451–458.
30. Kennedy, D.O.; Wightman, E.L. Herbal extracts and phytochemicals: Plant secondary metabolites and the enhancement of human brain function. *Adv. Nutr.* 2011, 2, 32–50.
31. West, B.J.; Deng, S.; Isami, F.; Uwaya, A.; Jensen, C.J. The potential health benefits of noni juice: A review of human intervention studies. *Foods* 2018, 7, 58.
32. Zhang, Y.; Yu, Y.; Li, X.; Meguro, S.; Hayashi, S.; Katashima, M.; Yasumasu, T.; Wang, J.; Li, K. Effects of catechin-enriched green tea beverage on visceral fat loss in adults with a high proportion of visceral fat: A double-blind, placebo-controlled, randomized trial. *J. Funct. Foods* 2012, 4, 315–322.
33. Rains, T.M.; Agarwal, S.; Maki, K.C. Antiobesity effects of green tea catechins: A mechanistic review. *J. Nutr. Biochem.* 2011, 22, 1–7.
34. Gurd, B.J. Deacetylation of PGC-1 α by SIRT1: Importance for skeletal muscle function and exercise-induced mitochondrial biogenesis. *Appl. Physiol. Nutr. Metab.* 2011, 36, 589–597.
35. Afzalpour, M.; Ghasemi, E.; Zarban, A. Effects of 10 weeks of high intensity interval training and green tea supplementation on serum levels of Sirtuin-1 and peroxisome proliferator-activated receptor gamma co-activator 1-alpha in overweight women. *Sci. Sports* 2017, 32, 82–90.
36. Kim, J.-a.; Formoso, G.; Li, Y.; Potenza, M.A.; Marasciulo, F.L.; Montagnani, M.; Quon, M.J. Epigallocatechin gallate, a green tea polyphenol, mediates NO-dependent vasodilation using signaling pathways in vascular endothelium requiring reactive oxygen species and Fyn. *J. Biol. Chem.* 2007, 282, 13736–13745.

37. Ras, R.T.; Zock, P.L.; Draijer, R. Tea consumption enhances endothelial-dependent vasodilation; a meta-analysis. *PLoS ONE* 2011, 6, e16974.
38. Kingwell, B.A. Nitric oxide-mediated metabolic regulation during exercise: Effects of training in health and cardiovascular disease. *FASEB J.* 2000, 14, 1685–1696.
39. Potenza, M.A.; Marasciulo, F.L.; Tarquinio, M.; Tiravanti, E.; Colantuono, G.; Federici, A.; Kim, J.-a.; Quon, M.J.; Montagnani, M. EGCG, a green tea polyphenol, improves endothelial function and insulin sensitivity, reduces blood pressure, and protects against myocardial I/R injury in SHR. *Am. J. Physiol.-Endocrinol. Metab.* 2007, 292, E1378–E1387.
40. Machado, Á.S.; da Silva, W.; Souza, M.A.; Carpes, F.P. Green tea extract preserves neuromuscular activation and muscle damage markers in athletes under cumulative fatigue. *Front. Physiol.* 2018, 9, 1137.
41. Lin, D.; Nussbaum, M.A.; Seol, H.; Singh, N.B.; Madigan, M.L.; Wojcik, L.A. Acute effects of localized muscle fatigue on postural control and patterns of recovery during upright stance: Influence of fatigue location and age. *Eur. J. Appl. Physiol.* 2009, 106, 425–434.
42. Jówko, E.; Długolecka, B.; Makaruk, B.; Cieśliński, I. The effect of green tea extract supplementation on exercise-induced oxidative stress parameters in male sprinters. *Eur. J. Nutr.* 2015, 54, 783–791.
43. Wekesa, A.; Harrison, M.; Watson, R. Physical activity and its mechanistic effects on prostate cancer. *Prostate Cancer Prostatic Dis.* 2015, 18, 197.
44. Ichinose, T.; Nomura, S.; Someya, Y.; Akimoto, S.; Tachiyashiki, K.; Imaizumi, K. Effect of endurance training supplemented with green tea extract on substrate metabolism during exercise in humans. *Scand. J. Med. Sci. Sports* 2011, 21, 598–605.
45. Carter, S.; Rennie, C.; Tarnopolsky, M. Substrate utilization during endurance exercise in men and women after endurance training. *Am. J. Physiol.-Endocrinol. Metab.* 2001, 280, E898–E907.
46. De Bock, K.; Derave, W.; Eijnde, B.O.; Hesselink, M.; Koninckx, E.; Rose, A.J.; Schrauwen, P.; Bonen, A.; Richter, E.A.; Hespel, P. Effect of training in the fasted state on metabolic responses during exercise with carbohydrate intake. *J. Appl. Physiol.* 2008, 104, 1045–1055.
47. Holloszy, J.O.; Coyle, E.F. Adaptations of skeletal muscle to endurance exercise and their metabolic consequences. *J. Appl. Physiol.* 1984, 56, 831–838.
48. Murase, T.; Haramizu, S.; Shimotoyodome, A.; Tokimitsu, I.; Hase, T. Green tea extract improves running endurance in mice by stimulating lipid utilization during exercise. *Am. J. Physiol.-Regul. Integr. Comp. Physiol.* 2006, 290, R1550–R1556.

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