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Health Benefits of *Ganoderma lucidum* (Reishi) Supplementation for Athletes: A Narrative Review

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Abstract

Ganoderma lucidum supplementation has gained increasing popularity over recent decades, with a growing number of health benefits, and therapeutic applications being attributed to this medicinal mushroom. Owing to its rich content of antioxidant, immunomodulatory, and anti-inflammatory compounds, *G. lucidum* has attracted considerable scientific interest,

particularly in the context of cancer prevention and management, as well as cardiovascular health. More recently, these properties have prompted interest in the potential application of *G. lucidum* supplementation in sport, and exercise settings. The aim of this narrative review is to evaluate the effects of *G. lucidum* on athletic performance, overall health, and antioxidant status in athletes. The available scientific evidence suggests, that this supplement may possess ergogenic, and health-promoting potential. Several *in vitro* studies, together with a limited number of human investigations, have reported favourable outcomes, including improvements in maximal oxygen uptake (VO_2max), and muscle strength, indicating a potentially beneficial effect of Reishi supplementation. However, the current body of evidence remains limited. Most human studies have relatively small sample sizes, and the available findings are insufficient to support definitive supplementation recommendations. Consequently, further well-designed studies are required before specific guidelines can be established regarding the use of *G. lucidum* in athletes, or its application within particular sporting disciplines.

Keywords Ganoderma lucidum; Reishi; athletic performance; endurance; sport; antioxidant;

1. Introduction

Ganoderma lucidum, commonly known as Reishi, is one of the most widely recognised medicinal mushrooms, and has been used in traditional Chinese, Japanese, Korean, and Vietnamese medicine for approximately 4,000 years [1] . Belonging to the Basidiomycota phylum, *G. lucidum* occurs in six colour variants, each with distinct names across different languages, and different medicinal properties attributed to them [1], [2] . Owing to its long-lasting popularity in East Asian cultures, *G. lucidum* has attracted considerable scientific interest. To date, more than 600 active compounds have been isolated, and identified from this species. Consequently, the market for Reishi-based dietary supplements continues to expand, accompanied by growing public interest in products containing this mushroom. Many studies have reported a wide range of biological activities associated with *G. lucidum*, including anti-atherosclerotic, anti-inflammatory, analgesic, anti-aging, antidiabetic, antioxidant, hepatoprotective, hypolipidemic, and endocrine-modulating effects [3] . The pharmacological activity of Reishi is believed to be largely attributable to its

immunomodulatory properties, which support, and enhance the overall immune function [4]. Despite the extensive body of research investigating its health-related effects, relatively little attention has been given to the potential application of *G. lucidum* supplementation among athletes. Consequently, the extent to which Reishi may exert beneficial or adverse effects on sports performance remains unclear. Therefore, the aim of this narrative review is to evaluate the potential effects of *G. lucidum* on athletes, and to examine the biological properties of its active compounds in order to determine the potential benefits of this increasingly popular dietary supplement.

2. Methods

This narrative review aims to summarise the most recent evidence regarding *G. lucidum*, its extracts, bioactive compounds, and the whole mushroom in the context of athletic performance, and factors that may influence its potential applications in sport. A narrative literature search was conducted using the PubMed, Google Scholar, and Web of Science databases. The following terms were used: “Ganoderma lucidum”, “Lingzhi”, ”Reishi”, “training”, “athletic”, “athletic performance”, “sports performance”, and “sports”. The search identified a total of 3,203 publications. Following the assessment of revelance to the objectives of this narrative review, the most pertinent articles were selected for inclusion. In addition, the reference lists of the included studies were manually screened to identify further relevant publications that may not have been captured during the initial database search.

3. Discussion

3.1 Characteristics and historical applications

Reishi is widely distributed throughout the tropical, and temperate regions of Asia, Europe and North America. *G. lucidum* is an annual wood-decaying fungus that primarily exhibits a saprophytic lifestyle, although it may also act as a parasite on living trees, causing wood rot. The fruiting body typically develops as a pileus measuring approximately 40–200 mm in diameter, with considerable variation in shape, and colour [5], [6] . Among the different varieties of Reishi, the red form is the most popular in Japan, whereas the black form is most commonly used in China [1] . Traditionally, *G. lucidum* has been associated with the promotion of longevity, overall well-being, and resistance to disease, including anticancer effects. These attributes contributed to its inclusion in one of the earliest Chinese pharmacopoeias nearly 2,000 years ago. Since then, it has occupied a prominent position in traditional Chinese medicine, and has often been referred to as the “elixir of eternal youth” [1], [3], [4]. Historically, Reishi has been used in the management of a wide range of conditions, including hepatitis, arthritis, neurasthenia, nephritis, insomnia, asthma, and bronchitis. In

addition, it has traditionally been believed to improve visual function, and support muscles, and joints [2]. Despite its esteemed status, Reishi remained a rare and costly commodity, accessible primarily to the Chinese elite until the twentieth century. Its wider availability was made possible by the development of artificial cultivation methods using sawdust substrates, or natural logs in controlled environment. As a result, the accessibility, and affordability of Reishi increased substantially, contributing to its growing popularity among the general population, and facilitating its widespread use as a medicinal mushroom, and dietary supplement [5].

3.2 Active substances in Reishi, and their properties

G. lucidum contains a wide range of bioactive constituents, including water-soluble proteins, lipids, polysaccharides, and dietary fibre. It is also a rich source of various micronutrients and trace elements, such as manganese, copper, niacin, riboflavin, and thiamine. Notably, the mushroom contains a relatively high protein content, providing approximately 19.5 g of protein per 100 g of dry matter [7]. To date, more than 600 chemical compounds have been isolated and identified from *G. lucidum*, including alkaloids, nucleosides, polysaccharides, proteins, steroids and triterpenes. More than 100 types of triterpenes have been isolated from *G. lucidum*, with nearly half of them appearing to be unique to this species. These compounds are mostly derivatives of lanosterol, and are largely responsible for the characteristic bitter taste of Reishi [7], [8]. The major triterpenoids isolated from Reishi include ganoderic acid, lucidenic acid, as well as ganolucidic acid, ganosporeric acid, ganoderates, lucidal, ganoderiol, or lucildaldehyde [8], [9]. Several of these compounds have been shown to possess biological activities relevant to athletic performance. For example, Liu et al. reported, that ganoderic acid DM, ganoderiol F, ganodermatriol, as well as other compounds are competitive inhibitors of 5-α reductase, the enzyme responsible for the conversion of testosterone into more potent dihydrotestosterone. Although this mechanism may theoretically impede muscle growth, and strength development, its physiological significance in athletes remains unclear [10], [11]. Conversely, 7-oxoganoderic acid Z, and ganoderic acid Jb have been reported to inhibit 3-hydroxy-3-methylguaryl-coenzyme A (HMG-CoA) reductase, a key enzyme involved in the cholesterol biosynthesis. However the majority of triterpenoids identified in G. lucidum have been studied primarily for their anticancer, antibacterial, immunomodulatory, and anti-HIV potential [9]. Consequently, evidence regarding their potential effects on exercise performance, training adaptations, or athletic health remains limited.

Another important class of pharmacologically active compounds are polysaccharides, which exhibit considerable structural diversity, composition, and possess various biological

activities. The majority of these compounds are heteropolysaccharide α- and β-glucans, with molecular weights ranging between several thousands to several millions Daltons. Apart from their hypoglycaemic, and hypolipidemic properties, *G. lucidum* have demonstrated substantial antioxidant activity, including the scavenging of reactive oxygen species, as well as inhibition of lipid peroxidation, and suppression of superoxide anions, and hydroxyl radicals [12]. In a study by Cai et al., polysaccharide extracts were analysed for their antifatigue potential in rats. The animals were divided into 3 groups, each receiving extracts of different molecular weight, and were compared after 28 days of administration in a forced swimming test. It was found, that all three significantly reduced creatine kinase levels, and improved swimming time. Regarding swimming performance, the results were better in the group receiving the highest molecular weight extract. Moreover, the rats receiving the extract had significantly higher glycogen levels in the liver, which could be helpful as energy storage for athletes. Levels of malondialdehyde and lactic acid, which are indicators of oxidative stress, also significantly decreased, with the best results achieved in the group receiving the highest molecular weight. Additionally, serum activities of glutathione peroxidase, superoxide dismutase, and lactate dehydrogenase increased significantly, which could play a beneficial role for athletes by reducing oxidative stress during exercises [13]. Similarly, a study by Zhonghui et al. showed anti-fatigue properties of a polysaccharide extract, which improved performance in the forced swimming time test after 28 days of supplementation in mice. Moreover, a significant increase in liver glycogen, a crucial glucose reserve during periods of increased energy demand, such as during exercise, and in the activities of superoxide dismutase, and GSH-peroxidase was noted [14]. Another study performed on rats observed the effects of polysaccharide extract supplementation. After 6 weeks, a significant reduction in malondialdehyde levels, and an increase in superoxide dismutase, and glutathione peroxidase was observed compared to control, which further suggests that polysaccharides enhance antioxidant activity. It is worth noting, that a significant decrease of plasma total cholesterol, LDL-cholesterol, and triglycerides was observed, while a significant increase in plasma HDL-cholesterol was noted as well. This could be a result of an observed increase in faecal fat and cholesterol content [15]. In a double-blind, crossover study performed on humans, a non-significant trend was observed towards an increase in plasma HDL-cholesterol, and a decrease in plasma triglycerides, which could potentially suggest some positive effect of Reishi on the hyperlipidaemia [16]. The hypolipidemic effect of polysaccharides, and triterpenoids possessing HMG-CoA reductase inhibitory effects, could potentially be beneficial for athletes health, as according to the recent studies, dyslipidaemia remains the most prevalent

cardiovascular risk factor even among the elite athletes [17]. Additionally, a meta-analysis of changes in lipid profiles after the supplementation of *G. lucidum in vivo* showed a significant improvement in total cholesterol, and LDL-cholesterol in healthy animal models. No significant positive changes were noted in triglyceride, HDL-cholesterol, and VLDL-cholesterol levels in these groups [18]. Another study regarding polysaccharide extract also showed significantly improved forced-swimming times in mice, with a dose-dependent trend. Additionally, survival time in an anoxic environment increased significantly, showing improved resilience to hypoxic conditions, which could be beneficial for athletes. Interestingly, an increase in muscle, and liver glycogen was noted, which had a decreasing tendency with rising dose in the liver, while muscle glycogen remained quite constant. Blood lactic acid also showed a significant decrease [19]. Polysaccharide extract also showed cardioprotective effects after supplementation. Similarly, it also improved performance in the forced swimming test, muscle glycogen levels, antioxidant enzymes activities, and reduced blood lactic acid levels [20]. Another study reported only the activities of superoxide dismutase, catalase, and glutathione peroxidase after a forced swimming test. Their activities were improved in mice skeletal muscles after 28 days of supplementation, supporting the claim of antioxidant stimulation of *G. lucidum* polysaccharides. Malondialdehyde levels also decreased after supplementation in this study [21]. Another interesting study analysed the protective effects of Reishi aqueous extract on endurance in rats exposed to a hypoxic environment. This extract was found to improve acclimatisation to a hypoxic environment, stimulate the expression of proteins responsible for protection against oxidative stress, and inflammation in a hypoxic environment, which is artificially created during exercises by the athletes. Moreover, this extract was found to improve ATP and NAD/NADH levels, even surpassing the control levels, thus improving the cellular energy metabolism on a molecular level, which could be potentially useful for athletes during exercise. Another practical effect of this extract was the improvement of spatial reference memory, which is put under pressure in athletes, especially in a stressful environment of competition, where physical endurance must cooperate with mental awareness to achieve victory [22].

The next group of compounds that could potentially benefit athletes are polyphenols, which are abundant in this mushroom, with around 13,991.1 milligrams per 100 grams of dry weight of Reishi. The most abundant types were found to be resveratrol, and apigenin, while phenolic acids, such as caffeic acid derivatives, or flavonols, such as quercetin, were found to be at lower concentrations in this fungus [23]. These compounds have been shown to possess antioxidant, and pro-regenerative properties, and to enhance muscle regeneration. Moreover,

these compounds have been found to improve endothelial function by stimulating nitric oxide production, thus improving vascular function, and blood flow [24], [25]. Some studies have shown, that supplementation with these compounds could potentially improve exercise performance after a period of supplementation; however, due to the substantial heterogeneity of studies, different analysed populations, and different methods used to assess the physical performance, it is hard to conclude, whether these compounds have a real impact on performance, based on evidence from meta-analyses [26].

Other active chemical compounds in Reishi include meroterpenoids, which are hybrid compounds, having a partial terpenoid structure, and a phenolic structure. They also have been found to possess antioxidant, anti-inflammatory, and inhibitory effects against HMG-CoA reductase [3], [27].

Spores of Reishi also show anti-fatigue properties. In an experiment performed on mice, a spore oil was administered at low, medium, and high doses. It was found, that it improved forced swimming capacity in mice, and improved the activity of superoxide dismutase, and ATPase. Moreover, muscle and liver glycogen levels improved, and a muscle-protective effect was established by lowering the creatine kinase levels [28]. Conversely, a study comparing various supplements on mice observed a decrease in forced swimming capacity in mice after 4 weeks of Reishi supplementation compared to placebo [29].

A comparative study was conducted on mice, where two different mixes were used- the first one having a 0.6% concentration of triterpenes, while the second one contained 1% triterpenes, and 12.5% polysaccharides, both administered at low and high doses. Interestingly, it was found, that only the first group exhibited improved forced swimming time in a dose-dependent manner, while the second group did not show any improvement compared to placebo. The same group showed a significant reduction in serum lactic acid, and improvement in liver, and muscle glycogen levels at the higher dose compared to placebo [30]. Another study mixed *G. lucidum* with a “chicken essence”, in a ratio of 1:9, and administered it to 3 groups of mice in different concentrations. After 28 days, it was found that this mix improved overall athletic performance during the forced swimming test (with an almost 3-fold difference between the placebo group, and the highest dose group), and in the grip strength test, with a dose-dependent improvement. Hepatic, and muscular glycogen levels also showed dose-dependent improvement, while creatine kinase levels decreased significantly, indicating muscle-protective effects of this mixture [31].

3.3 *Ganoderma lucidum* - benefits for athletes

A clinical study investigating the efficacy of *G. lucidum* supplementation demonstrated that supplementation with 1000 mg of Reishi for 30 days significantly improves both physical fitness (enhancing cardiovascular endurance) and psychological well-being in sedentary female college students. In particular, administration of a daily dose of 1,000 mg significantly improved maximal oxygen uptake (VO_2max) and Physical Working Capacity (PWC170) both compared to placebo, and to the baseline values. Participants taking 1,000 mg showed a significant increase in right-hand grip strength compared to the placebo group, confirming an improvement in muscle strength. Subjective well-being, and anxiety were also analysed, and showed significant improvement in the 1,000 mg group. Nevertheless, this finding should be interpreted with caution, due to the high risk of bias in such measurements [32]. Li et al. included 60 male and female university cyclists, who received 10 ml of *G. lucidum* polysaccharide extract 6 days a week for 90 days. It was found, that the study group improved endurance, aerobic capacity, endurance threshold, as well as blood haemoglobin levels. Reduced blood lactate, and improved antioxidant capacity of superoxide dismutase, and catalase were noted. Interestingly, an increase in IgM, IgA, and IgG was also noted, suggesting an immunostimulatory effect [33]. Another study analysing cyclists was performed by Rossi et al. on 7 endurance cyclists, who received a mix of *Cordyceps sinensis*, and *G. lucidum* for 3 months. The authors concluded, that this mix has a protective effect against overtraining syndrome, which is described as a 30% decrease in testosterone to cortisol ratio. Nevertheless, due to the very small sample, this study should be repeated on a larger cohort [34]. Li et al. also analysed 40 cyclists of both genders, in a similar study to the aforementioned one. After supplementation, total work output, maximal heart rate, and load duration all significantly improved, while body fat percentage and exercise heart rate decreased. Similarly, a rise in antioxidant enzymes, and immunoglobulins was noted [35]. Liu et al. divided 60 athletes into two groups- control, and a group receiving 75 g of Reishi extract capsules twice daily. After 8 weeks, VO_2max, and grip strength improved significantly. No significant differences were noted in blood tests [36]. Another interesting study included 32 male athletes divided into 3 study groups receiving different doses of *G. lucidum* polysaccharide tablets, and a placebo group. After 30 days, a statistically significant increase in work output, and duration was measured in the study groups. Moreover, antioxidant activity of serum enzymes increased, as well as haemoglobin levels [37]. On the other hand, Zhang et al. studied the immunomodulatory effect of *G. lucidum* on soccer players. They were divided into four groups- control, placebo with hypoxia, and two Reishi with hypoxia. The ratio between $CD4^+$ and $CD8^+$ lymphocytes was measured during the study. It was found,

that Reishi at the highest dose ameliorated the decrease in this ratio caused by hypoxia with training, thus potentially improving immune functions [38] . A clinical study published in 2015, a clinical study on the effects of Reishi in women with fibromyalgia showed that this mushroom improves the functional capacity of patients and may serve as a useful dietary supplement to enhance physical performance in individuals suffering from this condition [39].

3.4 Safety of *Ganoderma lucidum*

The chemical composition of Reishi is highly diverse. Extensive literature demonstrates that these constituents exhibit no demonstrable toxicity or safety concerns. However, despite a few reports linking higher dosages to minor hematological and immune alterations, suitable doses of *G. lucidum* taken under specialist advice, remain safe and free from apparent toxicity or side effects, apart from mild symptoms, such as dry mouth, sore throat, nausea, or flu-like symptoms. Despite its overall safety, *G. lucidum* exhibits strong biological activity, which may potentiate the effects of certain medications. Because *G. lucidum* possesses inherent blood glucose lowering properties, concurrent use with prescription medications for diabetes can synergistically induce hypoglycaemia. Furthermore, the mushroom actively inhibits blood clotting and elevates the risk of haemorrhage, which makes its consumption unsafe for patients with active gastrointestinal bleeding, gastric ulcers, or individuals preparing for scheduled surgical procedures. Due to its natural blood pressure lowering capabilities, *G. lucidum* can also amplify the effects of prescription antihypertensives, potentially leading to severe hypotension. Moreover, some precautions should be taken, when administering this supplement to children, and pregnant women [1], [3], [40].

4. Conclusion

G. lucidum is a mushroom with various supplementation-related applications, which include potential use in sports, and exercise performance. Various active compounds seem to have a crucial role in enhancing overall endurance, especially polysaccharides derived from this mushroom. Moreover, in vivo studies on animals showed, that the concept of supplementing with this mushroom has some scientific basis. Nevertheless, there is a significant lack of studies regarding in-depth analysis of potential anti-fatigue properties of specific chemical substances. Moreover, the studies performed on humans analyse only a limited range of sport disciplines, and sometimes encompass small samples of participants. Therefore, no particular recommendations can currently be made regarding the use of this supplement among athletes.

Disclosures

Author contribution

Conceptualization, K.S.-B. and K.O.; methodology, K.S.-B. and K.O.; software, K.S.-B. and K.O.; validation, K.S.-B. and K.O.; formal analysis, K.S.-B. and K.O.; investigation, K.S.-B. and K.O.; resources, K.S.-B. and K.O.; data curation, K.S.-B. and K.O.; writing—original draft preparation, K.S.-B. and K.O.; writing—review and editing, K.S.-B. and K.O.; visualization, K.S.-B. and K.O.; supervision, K.S.-B.; project administration, K.S.-B.;

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Conflicts of interest

The authors declare no conflict of interest.

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