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Review

Adaptogens, Performance, and Psychophysiological Responses to Exercise: A Narrative Review

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Abstract

Adaptogens are a group of bioactive substances that are purported to enhance non-specific resistance to stress and promote physiological homeostasis. Adaptogens are typically derived from specific medicinal plants or fungi, with many having been used in folk medicine for centuries for their stress-reducing properties. Emerging evidence has shown that adaptogens modulate various aspects of stress responses through hormonal, neural, and cellular mechanisms, which are highly relevant to performance and responses to exercise. Adaptogens may exert ergogenic effects by modulating fatigue, autonomic balance, neuromuscular function, and metabolic responses during exercise. Collectively, evidence has suggested that adaptogens have the potential to improve responses to exercise and enhance performance during aerobic, sprint, and resistance modes of activity. Despite promising findings, the current body of literature is highly fragmented, heterogeneous in study design, and has largely failed to bridge the gap between mechanisms in preclinical models and applicable exercise performance outcomes in humans. Furthermore, the psychophysiological underpinning of potential improvements to exercise responses remains less described. The purpose of this narrative review is to synthesize current evidence of adaptogens, supplementation, and responses to exercise as it pertains to performance, physiological, and psychological domains. Particularly, adaptogen supplements (i.e., *Rhodiola Rosea*, Ashwagandha, *Cordyceps*, *Panax ginseng*), which are commercially available and prominent in the exercise literature, are highlighted. Information related to dosing, effectiveness, and underlying mechanisms of action are discussed with an emphasis on how this influences psychophysiological responses to exercise. Lastly, future research needs and limitations based on the current literature are discussed. Despite some promising evidence of the ergogenic effects of adaptogens, this review highlights the need for additional well-controlled studies with more emphasis on psychophysiological mechanisms before widespread recommendations for their use can be made.

Keywords: performance; ergogenic aid; supplement; training

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1. Introduction

Adaptogens are a unique class of naturally occurring substances that are primarily derived from organic matter such as plants and fungi [1]. These substances have been purported to enhance non-specific resistance to various types of stressors, including physical, chemical, and biological stressors, ultimately promoting maintenance of homeostasis.

While adaptogens have been thought to be utilized for centuries throughout folk medicine by various cultures, the modern-day description of these substances is thought to have originated in the Soviet Union in the mid-20th century, as described by scientist Lazarev [1,2]. The term "adaptogen" was initially introduced to describe compounds capable of increasing resistance to stress while also maintaining the integrity of normal functioning of biological processes. Later, this was expanded upon to suggest that adaptogens should contain certain key characteristics: (1) improve resistance to a diverse range of stressors, (2) exhibit minimal to no toxicity, and (3) exert a stabilizing or buffering effect on physiological processes irrespective of the direction of homeostatic disruption [3,4]. Despite adaptogens having been utilized throughout history in traditional medicine such as Ayurveda and traditional Chinese medicine, scientific interest and research have increased steadily over the past two decades due to growing recognition of potential therapeutic and performance-enhancing effects in health and human disease [4]. As a consequence, adaptogens have emerged as one of the most widely available and commercially consumed botanical supplements marketed to improve resilience to stress, reduce fatigue, enhance cognitive function, and support physical performance.

The rationale for the use of adaptogens centers around their purported ability to modulate key neuroendocrine and cellular stress-response pathways that improve homeostatic balance. Experimental and clinical evidence suggests that adaptogens exert a wide range of systemic effects, including modulation of activity of the hypothalamic–pituitary–adrenal (HPA) axis, sympathetic-adrenal-medullary system, autonomic nervous system (ANS), inflammatory signaling, and cellular metabolism [5–7]. Through the modulation of these systems, adaptogens may blunt stress responses through mitigation of cortisol increases, improve mitochondrial function, enhance antioxidant activity, and regulate neurotransmitter release responsible for the control of motivation, mood, fatigue, and performance outcomes. Such effects have generated attention and application of adaptogens in the field of athletic and sport performance. Indeed, a number of adaptogenic substances have been shown to impart ergogenic effects through improvements in aerobic endurance capacity, muscular strength/power, fatigue resistance, and exercise recovery under physically demanding conditions [8–10].

Among adaptogenic substances, *Rhodiola Rosea* (RR), *Cordyceps*, Ashwagandha (*Withania somnifera*), and *Panax ginseng* have received the most substantial attention and support in clinical and sports nutrition applications. RR has been traditionally used throughout Eastern Europe and parts of Asia to combat fatigue and improve resilience and has repeatedly demonstrated benefits for endurance performance, fatigue resistance, and perceived exertion during exercise [11]. *Cordyceps*, a medicinal fungus widely utilized in traditional Chinese medicine, has been investigated for its effects on aerobic capacity, oxygen utilization, and tolerance to exercise [12]. Ashwagandha, one of the most prominently featured botanicals in Ayurvedic medicine, has been purported to influence muscular strength, exercise recovery, and sleep quality through modulation of neuroendocrine pathways [13]. Similarly, *Panax ginseng* has a long history of use as a tonic for vitality and physical endurance and has been studied for its effects on fatigue, cognitive function, immune system modulation, and exercise performance [14,15]. Taken together, these particular adaptogens are thought to have ergogenic effects and psychophysiological effects through overlapping mechanisms involving stress regulation, autonomic modulation, energy metabolism, and neurochemical signaling.

Despite previous reviews and empirical evidence surrounding these adaptogens and exercise [8–10], gaps in the literature remain. First, existing studies vary with respect to supplement formulations, dosages, intervention durations, and outcome measures, which need to be more explicitly acknowledged to allow for more direct comparisons across

investigations. Furthermore, while much of the literature has highlighted the ergogenic effects and performance outcomes associated with adaptogen use, less attention has been directed toward linking psychophysiological processes to adaptogen-induced performance enhancement, including perceived exertion, affective responses, motivation, ANS activity, and cognitive function during exercise. Mechanistic pathways through which adaptogens influence both physiological and psychological processes during exercise have also been incompletely described in the context of exercise performance and recovery. As such, an updated evaluation of how adaptogenic supplements influence psychophysiological mediators of exercise performance is warranted to better understand the roles of adaptogens in sport and exercise training. Therefore, the purpose of this narrative review is to examine the current evidence surrounding the most well-studied adaptogens on psychophysiological mediators of exercise performance while linking key mechanistic insights and priorities for future research.

2. Materials and Methods

2.1. Design and Purpose of Review

This review was formed according to methods and guidelines of previously published narrative reviews [16–19]. Overall, this narrative review aimed to summarize and aggregate available evidence on the psychological and physiological effects of adaptogens as it pertains to enhancement of exercise performance. Selected adaptogens for the review included RR, *Cordyceps*, Ashwagandha (*Withania somnifera*), and *Panax ginseng* due to the volume and relevance of existing exercise literature. Evidence was accumulated across various disciplines including exercise physiology, exercise psychology, sports science, neuroscience, and nutrition in a narrative approach to allow for a wide reporting of mechanistic and behavioral findings as it pertains to responses to exercise. Also included are studies which particularly highlight mechanisms of action and ergogenic properties of adaptogens across a variety of populations.

2.2. Literature Search, Inclusion, and Synthesis

The literature search and synthesis were conducted in accordance with previous approaches in narrative reviews [18,19]. Various databases were utilized to synthesize and search for peer-reviewed evidence, including Google Scholar, Scopus, and PubMed/MEDLINE. All evidence had to be published in the past 25 years [2001–2026] for inclusion. Furthermore, the available text had to be published in the English language to be included. A variety of search terms were utilized to capture relevant literature, which included Medical Subject Headings (MeSH) and applicable keywords as shown in Table 1. Throughout the literature search, combinations of search terms were strung together with "AND" or "OR" to narrow search results. While human experimental studies including relevant exercise outcomes were the primary focus of the review, inclusion of studies using animal models was strategically incorporated to aid in supporting psychophysiological mechanisms of action in particular. Meta-analytic and systematic reviews were included to bolster strength of evidence, while case reports, conference proceedings, and non-peer-reviewed sources were omitted from inclusion. Strength of the accumulated evidence was qualitatively determined by authors using the following criteria: (1) inclusion of healthy human subjects, (2) study design and methodological quality, with randomized placebo-controlled trials given greatest weight, (3) clear description of dose, form, and bioactive constituents, (4) type of exercise or physical task, (5) directness of measuring psychophysiological outcomes.

Table 1. Categorical breakdown of medical subject headings (MeSH) and other relevant keywords for the literature search.

Category	MeSH	Other Keywords
Population	Adult, Athletes, Female, Male, Young adult	Athlete, Healthy adults, Physically active, Trained, Untrained
Intervention	Cordyceps, Fungi, Panax, Medicinal plants, Rhodiola, Withania	Ashwagandha, *Cordyceps militaris*, Mushroom, *Panax ginseng*, *Rhodiola rosea*, *Withania somnifera*
Psychological variables	Affect, Anxiety, Coping skills, Depression, Executive function, Emotion, Mental fatigue, Memory, Motivation, Psychological stress	Psychological, Psychological stress, Mood, Emotional regulation, Mental stress, Reward, Effort allocation, Coping, Stress resilience, Reward-seeking, Psychological coping
Physiological variables	Antioxidants, Autonomic Nervous System, Brain, Creatine Kinase, Cortisol, Cytokines, Dopamine, Exercise, Fatigue, Inflammation, Metabolic Equivalent, Metabolism, Muscles, Muscle Fatigue, Norepinephrine, Oxidative Stress, Post-Exercise Recovery, Reactive Oxygen Species, Resistance Training	Aerobic Capacity, Aerobic Exercise, Anaerobic Exercise, Autonomic, Exercise Performance, Force Output, Neural Signaling, Neurotransmitter, Oxygen Uptake, Parasympathetic, Power Output, Muscle Activity, Muscular Strength, Sympathetic, Sympathomimetic, Velocity, VO2max, VO2peak

3. Psychophysiological Effects of Adaptogens

3.1. Overview

Adaptogens encompass a large class of bioactive compounds from various plant and fungal sources, many of which have little to no empirical evidence to support their use or are beyond the scope of this review. As such, the purpose of this section is to provide foundational information by summarizing current physiological and psychological understanding of the most well-studied adaptogens as relevant to the context of exercise or physical stress. Namely, RR, *Cordyceps*, Ashwagandha, and *Panax ginseng* are highlighted (Figure 1). For a more comprehensive review of adaptogens in other contexts, see reviews from Todorova et al. and Panossian et al. [1,20].

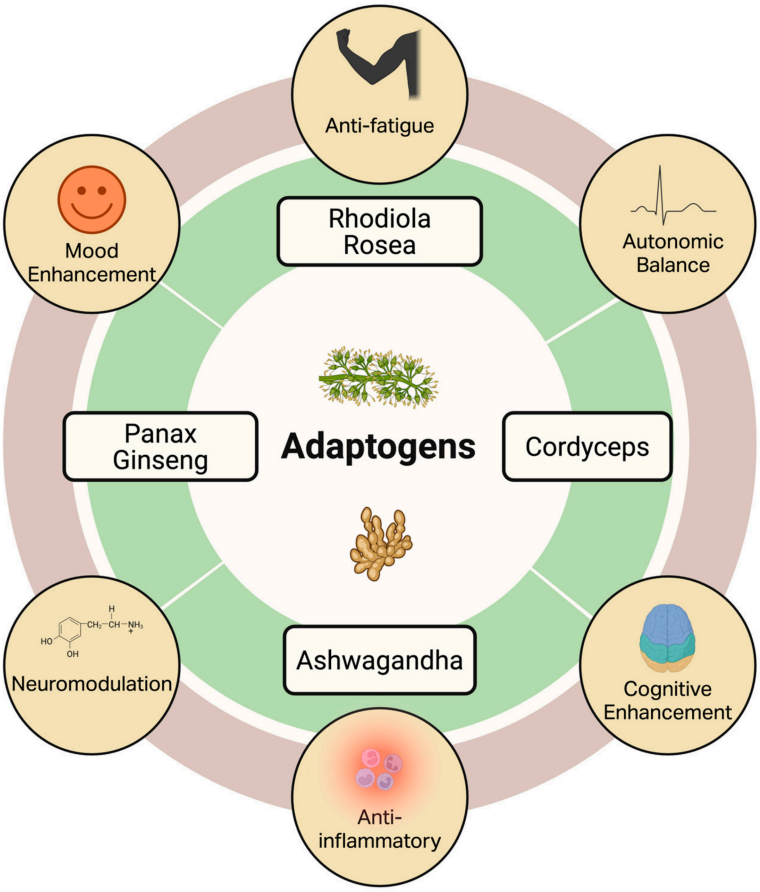


Figure 1. Purported psychophysiological effects of reviewed adaptogens. Created in BioRender. Ballmann, C. (2026) https://BioRender.com/hixt363.

3.2. *Rhodiola Rosea*

RR is a medicinal herb native to Arctic regions of Asia and Europe found in rocky terrains and high altitudes. Known by different names such as *arctic root*, *golden root extract*, *golden root*, and *rosenroot*, this perennial plant is considered a traditional herbal medicine in Tibetan, Russian, and Chinese cultures and has been used for various benefits including preventing altitude sickness, improving vitality, increasing energy levels, and decreasing fatigue [3,21]. The main bioactive constituents of RR include phenylpropanoid glycosides (i.e., rosavin, rosarin) and phenylethanol derivatives such as salidroside. Standardized extracts are most commonly sold in commercial capacities to contain approximately 3% rosavins and 1% salidroside, although considerable variability exists among available products, which likely contributes to inconsistencies of efficacy and action across clinical studies [3,4,21]. Pharmacological effects of RR have been suggested to manifest as anti-inflammatory, antioxidative, neuroprotective, and anxiolytic, via various pathways identified in preclinical and clinical models [22,23].

RR has been widely shown to exert physiological effects and adaptations that improve resilience to stress. Experimental evidence has shown that RR may aid in regulating stress-responsive mediators, including heat shock proteins (i.e., HSP70), nitric oxide signaling, cortisol secretion, and various transcription factors (i.e., c-Jun N-terminal kinase, forkhead box O) responsible for mediating cellular stress responses [3,24]. Furthermore, RR has been suggested to modulate mitochondrial function and cellular energy metabolism. Salidrosides in RR have been shown to enhance mitochondrial biogenesis, increase ATP production, and improve oxidative metabolism efficiency in preclinical models [25,26]. RR has been found to influence inflammatory responses and increase neuroprotection via modulation

of PI3K (Phosphoinositide 3-kinase)/AKT (Protein Kinase B) pathways and by producing antioxidant effects through various mechanisms including reductions in reactive oxygen species, increasing antioxidant capacity, and driving production of endogenous antioxidant enzymes (i.e., superoxide dismutase) [27–29]. RR may further reduce inflammation through reducing production of pro-inflammatory cytokines [4]. Lastly, RR has been suggested to modify activity of monoamines and other pathways such as β-endorphins, which may contribute to reductions in pain perception and improve resilience to fatigue [30,31]. Worth noting, many of these physiological effects have been established in preclinical models, and further studies investigating the translation of these findings to humans are warranted.

Among the reported psychological effects of RR, reductions in perceived fatigue and improved mental performance have been widely reported [30,32]. Several studies have shown that RR decreases stress-related fatigue, improves cognitive processing, and promotes attention [33,34]. Furthermore, RR has been suggested to improve mild to moderate depression, symptoms of anxiety, and enhance factors related to mood [35,36]. Benefits from RR have also been suggested to manifest in improvements in learning and functional memory, although this has largely been established in preclinical models [34]. Psychological benefits of RR have been attributed to potential modulation of neuroplasticity, albeit it appears that RR does not modulate cortical excitability [37]. Lastly, RR has been associated with improvements in reactive performance and decision-making during times of stress and fatigue [38]. These psychological adaptations induced by RR are likely underpinned by complex interactions across various neural pathways involving dopaminergic, cholinergic, and noradrenergic transmission [3]. Furthermore, RR has been suggested to modulate HPA-axis activity and cortisol release, which likely aids in promoting autonomic balance and aspects of emotional regulation [39,40].

3.3. Cordyceps

Cordyceps is a genus of entomopathogenic fungi that has been utilized for centuries in traditional Chinese medicine, thought to be useful in combating fatigue and promoting longevity. Historically, *Cordyceps sinensis* was largely harvested from Tibetan areas and incorporated into medicinal tonics to promote respiratory, renal, and systemic health [41]. Due to the scarcity and expense of naturally occurring *Cordyceps sinensis*, much modern-day consumption of *Cordyceps* is through cultured mycelial products in the form of *Cordyceps militaris*, which provides a scalable alternative while also maintaining similar bioactive constituents, including various polysaccharides, adenosine analogues, ergosterol, and cordycepin [42,43]. Further complicating interpretation of evidence, *Cordyceps* strains are often combined into "medicinal mushroom" blends, making delineation of precise contributions of each form to bioactive effects difficult [44]. Most commonly, *Cordyceps* medicinal applications are targeted to produce immunostimulatory, antioxidant, antiviral, hepatoprotective, mitochondrial, and anti-cancer effects [45–47]. However, recent accumulation of evidence has suggested that *Cordyceps* supplementation may also alter psychological processes related to mood regulation and cognitive health [48,49].

Physiologically, *Cordyceps* is thought to exert various effects through active components including polysaccharides, adenosine, and cordycepin, although this has largely been shown in preclinical models. When ingested, the resultant polysaccharides have antioxidant, anti-inflammatory, antiviral, and antitumor effects [50]. Systematic circulation of isolated *Cordyceps* polysaccharides activates TLR2/4–Dectin-1 on innate cells, stimulating a short burst of cytokine production, such as IL-12 and TNF-α, thereby triggering a pro-inflammatory response [45,50,51]. Because cytokines can cross the blood–brain barrier and influence hypothalamic activity, subsequent IL-10 production dampens this spike through an anti-inflammatory effect [52]. This rapid transition from pro-inflammatory

to anti-inflammatory effects is thought to help regulate HPA axis activity. Therefore, the polysaccharide-induced immune response creates a balancing effect in which stress resilience increases and HPA axis sensitivity decreases. *Cordyceps* supplementation also supplies adenosine and its bioactive compound cordycepin, which have been shown to produce anti-inflammatory effects and activate A1 receptors throughout the body, particularly in the brain, thereby supporting neural activity and sleep regulation, and potentially producing a neuroprotective effect [50]. This signaling cascade may further influence psychological outcomes including mood regulation, arousal, and fatigue. Cordycepin has also been shown to activate AMP-activated protein kinase (AMPK) and promote mitochondrial adaptations through the induction of peroxisome proliferator-activated receptor gamma coactivator-1α (PGC-1α) [53,54]. This may in turn result in adaptive responses to metabolism, glucose transport, antioxidant capacity, and angiogenesis [53].

For psychological outcomes, much less is known about the effects of *Cordyceps* supplementation, especially in humans. Collectively, available evidence suggests that the psychological benefits of *Cordyceps* are likely mediated through improvements in physiological resilience rather than direct modulation of mood or affective processes. As previously noted, high adenosine content in *Cordyceps* may impact arousal levels and sleep, which may ultimately influence psychological outcomes [50]. Furthermore, *Cordyceps* has been shown to protect against cognitive deficits and improve both short-term and long-term memory, likely through anti-inflammatory properties [55]. Polysaccharides in *Cordyceps* have been suggested to exert antidepressant effects through gut–brain axis modulation, although precise mechanisms are still being elucidated [49].

3.4. Ashwaganda

Ashwagandha, or *Withania somnifera*, is an Ayurvedic herb commonly used in traditional medicine in regions near India as an adaptogen, taken whole or mixed into tonics. In traditional medicine, Ashwagandha was prescribed to promote longevity, enhance resilience to stress, support physical function, and enhance cognition [56,57]. The pharmacologic actions of Ashwagandha are primarily attributed to a diverse group of naturally occurring steroidal lactones known as withanolides, particularly withaferin A, withanolide A, and withanone, although other constituents such as alkaloids and phenolic compounds have been suggested to contribute to biological effects [56,57]. These constituents exhibit pleiotropic actions by interacting with numerous intracellular pathways involved in stress adaptation, inflammation, mitochondrial function, and neural signaling. The multi-target pharmacology of Ashwagandha positions supplementation as an integrated approach to induce both physiological and psychological adaptations rather than isolated effects.

The physiological actions of Ashwagandha in stress resilience have been well described and center around anti-inflammatory effects, modulation of the HPA axis, and neuromodulatory actions. Preclinical investigations have demonstrated that withanolides increase antioxidant capacity and inhibit intracellular inflammatory signaling through the inhibition of nuclear factor-κB [58]. Withaferin A has also been shown to inhibit cytokine signaling including TNF-α and various interleukins [58,59]. This attenuation in cytokine release may also dampen HPA axis overactivity and modulate cortisol concentrations [57]. Importantly, numerous human trials have shown that Ashwagandha blunts excessive cortisol secretion while improving resilience to chronic stress [60,61]. Furthermore, withaferin A is thought to modulate neural signaling pathways in preclinical models by altering enzyme interactions and neural signaling cascades and increasing brain-derived neurotrophic factor (BDNF). This upregulation is thought to modulate GABAergic pathways contributing to brain neuroplasticity and decreased stress sensitivity [62]. Investigations utilizing animal and cellular models have also suggested Ashwagandha may reduce neuroinflammation

and preserve mitochondrial integrity within neurons [58,63,64]. Ashwagandha supplementation has also been suggested to produce increases in testosterone versus placebo in human trials [65].

The most consistently reported psychological benefits of Ashwagandha are alleviation of perceived stress and anxiety. Indeed, multiple human trials have shown reductions in perceived stress, anxiety, and overall psychological well-being with chronic supplementation [60,66]. Ashwagandha supplementation has also been implicated in improvements in working memory, executive function, and cognitive processing speed in humans [67–69]. Extracts from Ashwagandha have been shown to improve mood and energy levels in healthy adults [68]. Furthermore, improvements in sleep quality and efficiency have been reported with chronic Ashwagandha supplementation in humans [70]. Lastly, Ashwagandha supplementation may result in reductions in symptoms of fatigue and improve autonomic balance, thereby enhancing recovery from stress [71]. Worth noting, many of the psychological adaptations from Ashwagandha supplementation in humans are likely a result of integrated physiological mechanisms (i.e., hormonal control), further supporting Ashwagandha as a bioactive adaptogen capable of producing psychophysiological benefits, although greater translation from preclinical to human models is needed.

3.5. Panax Ginseng

Panax ginseng has long-standing use in traditional Chinese medicine as an adaptogenic medicinal plant, which has been substantiated by contemporary evidence of both psychophysiological and physiological resilience [72]. Because the genus *Panax ginseng* includes multiple species and scientific literature is inconsistent in nomenclature, the following narrative will use the term "*Panax ginseng*" as an umbrella term but refer to the precise *Panax* species or bioactive constituent when possible. The biological activity of *Panax ginseng* is primarily attributed to a diverse class of steroidal saponins known as ginsenosides, although other components such as polysaccharides, phenolic compounds, and volatile oils have been suggested to contribute to pharmacological effects [73,74]. More than 150 different ginsenosides have been identified, with Rb1, Rb2, Rc, Rd, Re, Rf, Rg1, Rg3, and Rh1 representing the most extensively studied constituents [73]. Together, these compounds have been shown to exert pleiotropic actions in preclinical models by interacting with various molecular targets including glucocorticoid receptors, nitric oxide synthase, ion channels, neurotransmitters, and intracellular signalling involved in cellular metabolism and stress adaptation [75–77]. Rather than acting through a single pathway, ginsenosides are thought to produce integrated physiological responses that are characteristic of adaptogens by enhancing the ability of organisms to maintain homeostasis during environmental, physical, and psychological challenges or stressors [3].

Physiologically, *Panax ginseng* and its constituents have been widely reported to exert antioxidant and anti-inflammatory effects in preclinical models. Ginsenosides in *Panax ginseng* have been shown to enhance endogenous antioxidant enzymes, reduce lipid peroxidation, and reduce reactive oxygen species accumulation [78,79]. Furthermore, *Panax ginseng* has been suggested to suppress activation of intracellular inflammatory signalers (i.e., nuclear factor-κB) and blunt production of proinflammatory cytokines including TNF-α, interleukin-6 (IL-6), and interleukin-1β through the modulation of mitogen-activated protein kinase (MAPK) pathways [80,81]. These properties may further increase stress resilience through neurotrophic effects by dampening cytokine release and suppressing HPA axis hyperactivity [73,82]. *Panax ginseng* has also been implicated in the modulation of cellular energy metabolism. Evidence using preclinical models has shown that several ginsenosides in *Panax ginseng* activate AMPK, resulting in changes in substrate utilization, mitochondrial function, and oxidative capacity [83–85]. Although these

mechanisms have been repeatedly demonstrated in cellular and animal models, it is worth noting that evidence of translation into clinically meaningful improvements in humans is particularly lacking.

Psychological benefits of *Panax ginseng* and ginsenosides have also been reported. Ginsenosides influence multiple neurotransmitter systems, including cholinergic and dopaminergic neurotransmission, and enhance cerebral blood flow, leading to possible enhancements of attention and executive function [3,86]. Ginseng has also been shown to improve aspects of working memory and subjective ratings of calmness in humans [87]. Antidepressant and mood-enhancing effects from ginseng have also been reported in human trials [88,89]. Ginseng may aid in the attenuation of mental fatigue or help to preserve performance during cognitively demanding tasks in humans [90]. Together, these mechanisms and psychological effects position *Panax ginseng* as an effective adaptogen for instances of mental stress or cognitive fatigue. However, these findings should be interpreted cautiously given the substantial heterogeneity across studies in terms of ginseng species, extraction methods, ginsenoside concentrations, dosing regimens, and study populations, which limits the ability to draw definitive conclusions about optimal supplemental protocols [91,92].

4. Adaptogens, Performance, and Responses to Exercise

4.1. Rhodiola Rosea and Exercise

RR is among the most widely investigated adaptogens for enhancing exercise performance, with evidence suggesting that its potential ergogenic effects arise from an interaction of physiological and psychological mechanisms. Unlike many other ergogenic supplements that primarily target peripheral physiological adaptations, RR is thought to impart benefits through an integrated interaction between central nervous system regulation, neuroendocrine function, and cellular energy production, although mechanistic rationale is largely based on preclinical models. As previously mentioned, ergogenic effects are thought to be mediated through multiple bioactive compounds, namely rosavin and salidroside [3,32,93]. Dosing strategies vary considerably, with ranges from 200 to 1500 mg/day most commonly reported. Furthermore, duration of supplementation is highly variable, with most studies utilizing acute/short-term dosing but some reports of supplementation up to 4 weeks. Although findings remain somewhat inconsistent due to differences in extract standardization, supplementation duration, and exercise protocols, current evidence suggests that RR may impart performance enhancement to both aerobic and anaerobic exercise.

The most well-studied purported benefit of RR is on endurance exercise performance, although the magnitude of improvements tends to be modest and conflicting [28,94–97]. Several randomized controlled trials have demonstrated improvements in endurance capacity, exercise tolerance, and time-trial performance following both acute and chronic supplementation [96,97]. De Bock et al. investigated the effects of acute (i.e., single dose) versus chronic (i.e., 4 weeks) RR supplementation protocol with 200 mg/day on time to exhaustion and VO2max during an endurance capacity test in healthy adults [97]. Findings revealed that while 4 weeks of RR supplementation did not provide any ergogenic benefit, a single acute dose of 200 mg ingested 1 h prior to exercise increased time to exhaustion and VO2max during testing [97]. Further supporting the efficacy of acute supplementation, Noreen et al. showed that an acute oral dose of RR at 3 mg/kg resulted in faster times during a 6-mile endurance cycling time trial [96]. Furthermore, this was accompanied by psychophysiological benefits including lower heart rate during warm-up and lower perceived exertion during the time trial [96]. While mechanistic evidence to explain these improvements is scarce in humans, bioactive components of RR have been shown experimentally to influence dopaminergic, serotonergic, and noradrenergic

activity in animal models, which play central roles in motivation, mood regulation, and fatigue perception [98,99]. If these effects do indeed translate to humans, neuromodulation from RR supplementation could improve effort allocation and lower fatigue perception during exercise, thereby enhancing performance. RR-induced changes in cellular energy metabolism have also been suggested, albeit in preclinical or animal models. Elevated mitochondrial ATP content in skeletal muscle has been reported in rodent models following RR administration [100]. Other reports have suggested RR supplementation may impact mitochondrial function and optimize muscle metabolic pathways [11,21]. While such physiological adaptations would plausibly improve endurance exercise performance, it should be noted that this has not been empirically confirmed in humans and thus is largely speculative at the moment. It is also worth noting that disparities in findings exist regarding RR supplementation and endurance performance. Parisi et al. investigated the chronic effects of 4 weeks of RR supplementation at 170 mg/day on aerobic capacity in trained male athletes and showed no benefits to VO2max, time to exhaustion, heart rate, or perceived exertion [95]. Using a similar supplementation period, Jowko et al. showed that a chronic 4-week supplementation protocol with RR at 600 mg/day did not affect endurance exercise capacity or hormonal responses in healthy males, albeit improvements in reactive performance and psychomotor tests were observed [28]. Precise reasons for disparities are not fully clear but may be due to differences in the duration of supplementation, as acute supplementation protocols with RR have more frequently shown ergogenic benefit. However, it is difficult to distinguish the role of supplement duration in ergogenic benefits due to heterogeneity in dosing, extract composition, and population tested. Furthermore, there are likely some confounding effects from differences in supplement composition, dosing, and overall study design approaches. Additional studies investigating standardized dose and supplement duration to RR with endurance exercise are warranted.

Recently, considerable attention has been dedicated to the effects of RR supplementation on anaerobic and resistance exercise. Benefits of RR supplementation have been shown to impart improvements in muscular strength and power in humans [101–104]. Ballmann et al. showed that a short-term 3-day RR supplementation protocol at 1500 mg/day resulted in improved anaerobic performance as evidenced by increased power output, anaerobic capacity, and total work during repeated sprints in trained females [101]. This is further supported by other investigations showing improved power and barbell velocity during resistance exercise with RR supplementation [102,103]. Taken together, this suggests that RR supplementation may be particularly useful in enhancing explosive exercise performance. This may be related to previous suggestions that RR may increase central nervous system and sympathetic activity in preclinical models. In rodent models, RR has been shown to increase exercise capacity and markers of CNS activity, while in humans RR supplementation improves reaction time, which may reflect CNS excitation [28,105]. Furthermore, Williams et al. showed that a short-term 3-day RR supplementation protocol at 1500 mg/day resulted in greater catecholamine concentrations pre-exercise, in particular norepinephrine, with concomitant increases in barbell velocity in humans [102]. Thus, RR may also possess sympathomimetic properties contributing to enhanced force production from muscle [106]. RR supplementation has also been shown to be beneficial to muscular strength and endurance performance in humans. Liu et al. showed that 30 days of 2.4 g/day of RR resulted in superior bench press and back squat maximal strength compared to placebo in untrained individuals undergoing a resistance exercise program [107]. Participants undergoing RR supplementation also saw increases in repetition volume during a muscular endurance test at 60% of maximal strength. Marcos-Frutos et al. also showed short-term 3-day RR supplementation at 600 mg/day resulted in greater bench press repetition volume at 70% of maximal strength in resistance-trained males and females [108]. These performance

improvements were accompanied by lower perceived exertion, suggesting RR may increase dissociation during resistance exercise performed to failure. Overall, available evidence suggests RR may be effective at modulating anaerobic/resistance exercise performance, particularly during explosive activities. However, establishing the optimization of dosage and form will be necessary before general recommendations of efficacy can be made.

4.2. Cordyceps and Exercise

Although many forms of *Cordyceps* exist, the majority of evidence investigating the influence of supplementation on exercise performance has utilized either *Cordyceps sinesis* (CS) or *Cordyceps militaris* (CM). Most studies reporting ergogenic effects employed doses of 3–4 g/day of CS or CM with a duration of 3–12 weeks, with reported benefits occurring with longer duration usage compared to acute protocols. Furthermore, the vast majority of investigations have focused solely on endurance/aerobic based exercise types, and results have yielded conflicting results. Psychophysiological outcomes with CS or CM supplementation are less frequently reported and have also yielded mixed responses. Chen et al. showed increases in metabolic and ventilatory threshold with 12 weeks of CS supplementation in older adults, but VO2max remained unaltered compared to placebo [109]. No changes in heart rate or heart rate recovery were reported. Further supporting this, Nagata et al. showed that 2 weeks of 2.5 g/day of CS supplementation improved aerobic efficiency and ventilatory responses during prolonged exercise in healthy males [110]. Importantly, these improvements were concomitant with increases in plasma catecholamines, namely epinephrine and norepinephrine, suggesting CS may facilitate sympathetic responses needed for attenuating fatigue during prolonged exercise. Increases in catecholamines with CS may also impart psychophysiological benefits during exercise through altered arousal and effort allocation, although the precise contributions of this to performance outcomes are not known. In marathon runners, Savioli et al. showed that 2 g/day of CS ingestion resulted in lower heart rate at submaximal intensities after 8 weeks and improved 5K race performance after 12 weeks of supplementation [111]. This may suggest that potential ergogenic benefits of CS supplementation are dependent on long-term supplementation rather than acute effects. Mechanistically, this is supported by animal studies suggesting that adaptive benefits to exercise with CS are dependent on upregulation of metabolic regulators (i.e., AMPK, PGC1-α), angiogenesis, and improved glucose metabolism, which would be expected to develop endurance adaptations over weeks to months [53]. However, it is worth noting that conflicting results on the ergogenic benefits of CS exist. Tsuk et al. reported that a 30-day low-dose CS (11.25 mL extract) and high-dose (22.5 mL extract) did not result in any benefit to aerobic capacity or psychophysiological responses to exercise in humans [112]. Furthermore, Parcell et al. showed 5 weeks of 3 g/day of CS did not alter aerobic capacity or time trial performance in trained male cyclists [113]. While reasons for disparities are not fully clear, it is likely a consequence of dosing and supplement regimens. Indeed, as previously mentioned, ergogenic and adaptive benefits from CS appear to occur with moderate doses in regimens that last for $\geq$8 weeks. Furthermore, some regimens include other bioactive ingredients or mushrooms which may alter the efficacy. Psychophysiological responses, including perceived exertion, heart rate, and fatigue, appear to be modulated by CS supplementation, especially at submaximal intensities but are less frequently reported, highlighting the need for future trials to include these outcomes.

In recent years, CM has largely replaced CS in commercial supplements due to ease of cultivation in laboratory settings and production standardization. While CM and CS are fundamentally similar, their composition does differ as CM typically contains greater concentrations of cordycepin, a primary bioactive ingredient thought to underlie metabolic and cellular adaptation [46,54]. Despite this, findings on the ergogenic benefits of CM are still

mixed. Hirsch et al. showed that 3 weeks of 4/g day of a CM mushroom blend improved aerobic capacity and time to exhaustion in recreationally active adults [114]. However, no benefits were observed with only 1 week of CM supplementation. Pasha et al. also reported that 3 weeks of 1 g/day of CM resulted in enhanced running performance at 200 m and 5 km in male and female runners [115]. Importantly, this was accompanied by increases in oxygen saturation, suggesting that CM may directly or indirectly mediate adaptations to exercise training that are particularly useful for endurance. However, there have been some reports suggesting CM supplementation may enhance anaerobic performance as well. Wang et al. showed that 7 weeks of 8 g/day of CM improved muscular power and sprint performance during a 30 s maximal effort cycle test in trained swimmers [116]. However, this is not fully supported, as other reports have shown little to no difference in peak power output and anaerobic performance with CM supplementation [117]. Another important aspect that CM may influence in relation to exercise is recovery. It has been previously shown that humoral markers of recovery and inflammation may be modulated by CM and result in lower markers of muscle damage (i.e., creatine kinase) and select cytokines (i.e., interleukin-4) [116]. While biomarkers alone may not be indicative of ergogenic effects, these findings suggest that CM may influence recovery and inflammation during training. This is further supported by Nakamura et al., who showed that 1.8 g/day of CM for 16 weeks lowered white blood cell count and creatine kinase levels in long-distance male runners throughout training, albeit no performance enhancement was reported [118]. These effects are likely reflective of previous investigations showing anti-inflammatory properties of CM [119,120]. Indeed, acute dosing (3 days) of CM has been shown to modulate human immune responses, including decreasing the activity of various cytokines, including TNF-α, IL-12, and MCP-1 [119]. Thus, it is plausible that CM may be useful in improving exercise recovery, although more direct testing in humans is warranted.

A fundamental difficulty in assessing the efficacy of *Cordyceps* on exercise performance is the heterogeneity in form, dosing, sourcing, and regimen duration across studies. *Cordyceps* is often given as CS, CM, or in mushroom blends, which makes comparisons across studies difficult as these forms are functionally distinct. Furthermore, even among the same forms, supplement composition varies considerably, where commercial products may differ in part of the fungus used (i.e., fruiting body vs. mycelium), preparation (i.e., whole mushroom powder vs. extracts), and concentrations of bioactive constituents. Indeed, most studies only report the total dose (e.g., 3–4 g/day) without quantification of bioactive compounds. Psychophysiological effects of *Cordyceps* are also understudied outside of heart rate or perceived exertion. Thus, while CM and CS have some evidence to support its use as an ergogenic aid, particularly in aerobic exercise, our understanding of this remains equivocal due to aforementioned difficulties and shows the need for future trials using standardized methods and homogeneous approaches for further substantiation of previous findings.

4.3. Ashwagandha and Exercise

Considerable attention has emerged in the past two decades surrounding purported ergogenic benefits of Ashwagandha, which are thought to be mediated through both physiological and psychological mechanisms [121,122]. Use of Ashwagandha has been suggested to have implications for enhancement of performance and recovery from exercise primarily through modulating HPA axis activation, autonomic balance, inflammatory signaling, and oxidative stress [13,121,122]. This may in turn affect exercise capacity by improving recovery, reducing fatigue, optimizing endocrine responses, and optimizing training stimuli over time. Although precise mechanisms are still being elucidated, Ashwagandha is rich in bioactive phytochemicals including withanolides and alkaloids, which together exert

pleiotropic effects on biological processes necessary for peak physical performance [123]. While varying dosing strategies have been investigated, the majority of studies typically use between 500 and 600 mg/day with regimen durations of 1–12 weeks in healthy adults. Benefits from Ashwagandha have been primarily reported in endurance and resistance-based exercise with little evidence available in the context of sprint/anaerobic performance. There is evidence for psychophysiological underpinnings of the ergogenic effects of Ashwagandha, including modulation of perceived fatigue, hormonal responses, recovery aspects, and some aspects of mood.

One of the most consistent findings with Ashwagandha supplementation is improvements in muscular strength and other resistance training adaptations. In one of the earliest randomized controlled trials investigating this, Wankehde et al. showed that 8 weeks of Ashwagandha root extract supplementation at 600 mg/day increased upper and lower body strength, promoted greater degrees of muscle hypertrophy, and reduced exercise-induced muscle damage compared with placebo in young males participating in resistance training [124]. These improvements were accompanied by lower circulating creatine kinase levels and modest increases in serum testosterone, suggesting enhanced recovery and greater anabolic signaling for muscle growth [124]. Further supporting this, Verma et al. reported similar findings in resistance-trained males and females, demonstrating that 8 weeks of Ashwagandha root extract supplementation at 600 mg/day increased bench and leg press strength, muscle circumference, and muscular endurance following an 8-week resistance training program [125]. Similar benefits with longer supplementation periods have also been reported. Ziegenfuss et al. showed that 12 weeks of 500 mg/day of aqueous extract of Ashwagandha improved bench press and squat strength while enhancing DEX-derived android/gynoid ratios [126]. Importantly, these performance improvements were accompanied by psychophysiological benefits including increased perceived recovery from exercise and attenuated perceived soreness compared to placebo [126]. This suggests Ashwagandha may possibly influence recovery, as other investigations have also noted improved perceived recovery and sleep quality in athletes [127]. Improvements to recovery of exercise may be due to modulation of the HPA axis, as evidence has reported Ashwagandha-induced reductions in cortisol, which may improve tolerance to intense training [60,128]. Improved autonomic balance and reductions in self-reported stress and fatigue have also been documented [71]. How these psychophysiological changes translate to exercise performance outcomes has not been fully elucidated. Although some conflicting evidence exists [127,129], there is promising evidence to support Ashwagandha supplementation as a driver of adaptation to resistance exercise, with disparities likely due to differences in supplementation regimens, concentrations of bioactive components, and population studied.

Additionally, Ashwagandha supplementation appears to improve responses to aerobic and endurance-based exercise through mechanisms involving cardiorespiratory function and oxygen utilization. Several randomized controlled trials have demonstrated improvements in VO2max and endurance performance following weeks of supplementation [130–132]. Choudhary et al. showed increases in aerobic capacity and VO2max with 8 and 12 weeks of Ashwagandha root extract at a dose of 600 mg/day in healthy adults [130]. Tiwari et al. also showed improvements in VO2max with 600 mg/day of Ashwagandha root extract for 8 weeks in healthy adults with notable psychophysiological benefits including improved fatigue recovery, energy levels, and improved antioxidant status [131]. Interestingly, the benefits of Ashwagandha supplementation may transcend fitness level/training status. Shenoy et al. showed that 1000 mg/day of aqueous roots of Ashwagandha improved VO2max and aerobic capacity in elite competitive cyclists versus a placebo [132]. Thus, benefits from Ashwagandha supplementation may be performance-

enhancing, although future studies will need to directly compare efficacy between varying training statuses to understand ergogenic potential. Collectively, these findings are supported by systematic reviews and meta-analyses demonstrating small-to-moderate but consistent improvements in VO2max across diverse populations, although heterogeneity does exist regarding extract standardization and supplement protocols [133,134].

Beyond its direct physiological effects, the psychological benefits associated with Ashwagandha supplementation likely contribute to improvements in exercise performance and recovery. As an adaptogen, Ashwagandha has consistently demonstrated efficacy in reducing perceived stress, anxiety, and fatigue while improving overall well-being, vigor, and sleep quality [66,135,136]. As previously mentioned, these effects are likely mediated through modulation of the HPA axis and improved neuroendocrine responses. Lopresti et al. showed significant reductions in perceived stress and serum cortisol alongside improvements in vigor and sleep quality following 60 days of 240 mg/day of standardized Ashwagandha extract in adults with high stress [61]. Others have reported dose-dependent reductions in anxiety with improvements in overall well-being [66]. Because exacerbations in psychological stress, mood disturbances, and poor sleep quality are independently associated with impaired recovery, increased fatigue, and decreased willingness to train, these findings suggest that the ergogenic effects of Ashwagandha may be mediated not only through direct physiological adaptations but also through improvements in psychological readiness and resilience. However, evidence for this in the context of exercise training is currently understudied, and future investigations incorporating psychological outcome monitoring in randomized controlled trials are in dire need.

4.4. Panax Ginseng and Exercise

Among the adaptogens investigated for potential improvements in exercise performance, *Panax ginseng* possesses one of the longest histories of purported use for improving physical ability and has been extensively studied pharmacologically. *Panax ginseng* has been proposed as an ergogenic aid capable of improving exercise performance through physiological and psychological mechanisms related to fatigue resistance and stress resilience. However, despite considerable attention and investigation, the human exercise literature remains extremely heterogeneous, with considerable variability in *Panax* species, dosing protocols, supplementation duration, and types of exercise testing [137]. As such, direct evidence supporting an ergogenic effect of ginseng supplementation in humans is less consistent than other adaptogens. However, anti-inflammatory and antioxidant properties of *Panax ginseng* have been repeatedly shown and support possible efficacy in the context of exercise recovery [138–140]. Dosing varies considerably across the literature but is typically in the range of 1–3 g/day, with some investigations using lower dosing ranges of 200–500 mg/day. Acute supplementation protocols are less common, with most investigations using chronic regimens of 4–8 weeks in duration.

Panax ginseng has been extensively studied, especially in the context of endurance exercise performance, and has largely produced equivocal results. Liang et al. showed that 30 days of 1350 mg/day of *Panax ginseng* enhanced time to exhaustion and oxygen uptake during endurance cycling in untrained adults, although improvements were modest [141]. Bhattacharjee et al. also reported that an acute dose of 200 mg of *Panax ginseng* resulted in improved time to exhaustion during a graded treadmill exercise test in healthy adult males [142]. Interestingly, performance improvements were accompanied by psychophysiological changes in that both heart rate and perceived exertion were lower with *Panax ginseng* ingestion. Authors attributed these changes to constituents in *Panax ginseng*, including ginsenosides, that have been suggested to induce bradycardia. Furthermore, other reports using the same acute dosing protocol noted lower heart rate, increased fat utilization, and

reduced blood lactate during submaximal exercise in recreational runners, which may indicate improved metabolic efficiency, albeit the translation to exercise performance is not fully understood [143]. Despite these reports, there are a large number of investigations suggesting that *Panax ginseng* does not provide ergogenic effects to endurance-based exercise. Kulaputana et al. showed that 8 weeks of 3 g/day of ginseng did not affect lactate threshold or time to exhaustion during cycling in physically active military males [144]. Ping et al. reported that an acute 200 mg dose of *Panax ginseng* resulted in no changes in time to exhaustion, oxygen uptake, heart rate, or perceived exertion in males completing treadmill running in the heat [145]. Furthermore, a systematic and meta-analytic review showed that across the *Panax ginseng* and exercise literature, there is insufficient evidence to support potential ergogenic effects of *Panax ginseng* on fatigue and endurance performance [137]. In terms of resistance-based exercise performance, there is relatively little evidence available on how *Panax ginseng* may alter responses in humans. In male athletes, 8 days of 100 mg/day of *Panax ginseng* increased muscle excitation and lowered perceived exertion during lower body resistance exercise after subsequent eccentric overload exercise, although no changes in repetition volume were observed [14]. Furthermore, Azizi et al. reported that 6 weeks of 500 mg/day of *Panax ginseng* concomitant with resistance training resulted in no changes to upper or lower body strength in male bodybuilders [146]. No changes in circulating cortisol or testosterone were noted, and body composition was also unaltered. Overall, direct evidence of the ergogenic effects of *Panax ginseng* in humans is not well supported despite some reports of psychophysiological benefits. Whether differences in bioactive constituents or supplement regimens have contributed to these disparities is not fully clear.

Interestingly, there is mounting evidence that *Panax ginseng* may play a role in recovery from exercise, particularly in the context of muscle damage [140]. Lin et al. showed that 30 days of 1.6 g/day of *Panax ginseng* before eccentric downhill running attenuated markers of muscle damage (i.e., creatine kinase), lipid peroxidation products (i.e., 8-isoprostane), and some inflammatory cytokines including interleukin-4 [138]. Similarly, Jung et al. observed that 7 days of 20 g/day of *Panax ginseng* before high-intensity uphill running resulted in lower creatine kinase and interleukin-6 levels in young adult males compared to placebo [139]. Bolstering this further, Cristina-Souza et al. showed that 8 days of 100 mg of *Panax ginseng* preserved motor unit recruitment and lowered perceived exertion following eccentric muscle damage [14]. Mechanisms underlying these benefits have been incompletely described in humans, but have been attributed to anti-inflammatory and antioxidant properties of constituents of *Panax ginseng* (i.e., ginsenosides) [79,81,147]. For example, preclinical evidence has suggested that *Panax ginseng* supplementation may inhibit immune cell infiltration and oxidative damage to various cellular components [148,149]. Furthermore, *Panax ginseng* has been shown to preserve satellite cell number and glutathione following intense exercise in humans, suggesting preservation of myogenesis following training [150]. However, it is worth noting that low sample sizes in available evidence on *Panax ginseng* and exercise recovery make it difficult to draw broad conclusions, which was recently highlighted in a systematic review suggesting inconclusive findings on efficacy [92]. Furthermore, the consequences of purported recovery enhancement on exercise performance metrics remain unclear. Thus, larger, well-controlled studies in humans are necessary to delineate possible benefits of *Panax ginseng* to recovery following intense exercise.

5. Safety and Practical Considerations

Although RR, *Cordyceps*, Ashwagandha, and *Panax ginseng* have been suggested to be well tolerated at doses typically utilized in exercise literature, evidence on the safety of supplementation is less extensive. Few studies have directly reported adverse effects

with supplementation. However, the absence of adverse effects reported should not be interpreted as evidence for long-term safety. Most exercise studies have investigated supplementation over several weeks, whereas adaptogen supplements that are commercially available may be consumed chronically. Consequently, the safety of prolonged use, particularly at higher doses or with concurrent use of other supplements/medications, remains incompletely characterized. Potential adaptogen–drug interactions and contraindications should be considered when translating findings from controlled trials to practical application. As previously described, the biological activity of adaptogens may influence pathways involved in blood pressure regulation, glucose metabolism, immune function, and nervous system activity, which should be carefully considered before initiating supplementation for exercise performance [3,20].

Other practical considerations such as product quality, purity, and form of commercially available products should be considered. Botanical supplements may differ in plant species, origin, concentration of bioactive constituents, and standardization of processing. While standardization is intended to improve consistency of concentrations of bioactive components, the presence of a standardized quantity of one or more constituents does not necessarily ensure equivalence in the broader phytochemical composition or between commercially available products. Product quality and contamination are also of concern, as unlike pharmaceutical products, commercially available dietary supplements are not tightly regulated, and the actual contents of a product may not always correspond precisely to the quantities listed on product labels. Finally, the doses reported in this review should not be interpreted as universal recommendations. The current literature is quite heterogeneous in the form used and often does not disclose concentrations of bioactive constituents in their totality. Overall, although the adaptogens reviewed appear to have favorable short-term tolerability with exercise in healthy adults, evidence regarding long-term safety, clinically meaningful interactions, and equivalence among commercial preparations remains limited.

6. Limitations and Future Directions

Despite increasing interest in adaptogenic supplementation as a strategy to improve performance and psychophysiological responses to exercise, the current body of evidence remains limited by substantial methodological heterogeneity. Across studies investigating RR, *Cordyceps*, Ashwagandha, and *Panax ginseng*, considerable variability exists in supplement composition, extract standardization, supplementation duration, and exercise testing protocols. Many investigations utilize proprietary or poorly described extracts without reporting concentrations of key bioactive constituents. Consequently, direct comparisons across studies are difficult, and dose–response relationships remain largely underexplored, representing a prominent limitation to establishing efficacy.

Another important limitation appearing from the current review is the relatively limited mechanistic evidence of adaptogens in humans and/or the translation of mechanistic evidence in animals to human participants. Although numerous preclinical studies demonstrate that adaptogens influence mitochondrial function, oxidative stress, inflammatory signaling, neuroendocrine regulation, and neurotransmitter release, thereby altering adaptations to exercise, many proposed pathways linking adaptogen supplementation to enhanced exercise performance remain speculative in humans. Relatively few studies have concomitantly elucidated mechanistic underpinnings of adaptogen-induced adaptations and exercise performance outcomes. Equally important, this review highlights inconsistent assessment of psychophysiological outcomes as a major limitation. Although the defining characteristics of adaptogens manifest in their ability to influence both physiological and psychological responses to stress, most exercise studies continue to prioritize reporting of performance variables while only including limited psychophysiological measures outside

of heart rate and perceived exertion. Comprehensive assessments of mood state, motivation, fatigue perception, cognition, and autonomic responses are infrequently incorporated in study designs despite their likely contribution to exercise performance. This represents a substantial knowledge gap because improvements in exercise performance may arise through enhanced psychological processes or interactions with physiological adaptations.

Future research should prioritize standardized supplementation protocols using chemically characterized extracts with verified concentrations of active constituents to improve reproducibility and comparisons between investigations. Large, adequately powered trials employing rigorous blinding methods are needed to be able to translate findings across diverse populations, including females, older adults, and vary training statuses. Future investigations should also directly compare acute versus chronic supplementation strategies across adaptogens to optimize dosing and supplement protocols. Finally, future research should work to move beyond examining isolated adaptogens and begin investigating comparative efficacy across compounds. Direct head-to-head comparisons or co-ingestion of adaptogens using standardized methodologies would provide valuable insight into the potential realization of the ergogenic potential of adaptogens. The latter of which may be especially relevant as many commercial supplements are amalgamations of various adaptogens.

7. Conclusions

Adaptogenic supplements represent a promising yet still evolving nutritional strategy for enhancing exercise performance through complementary physiological and psychological mechanisms. Collectively, the available evidence suggests that RR, *Cordyceps*, Ashwagandha, and *Panax ginseng* are the most well-studied adaptogens in the context of exercise and that each possesses distinct mechanistic profiles that may influence exercise performance by modulating metabolism, neuroendocrine function, neural activation, inflammation, and perceptions of fatigue and recovery. Despite mixed results, Ashwagandha seems to demonstrate the most consistent evidence supporting improvements in endurance and resistance exercise, whereas RR appears to be particularly effective when administered acutely to enhance high-intensity exercise performance. *Cordyceps* shows potential to improve endurance exercise performance, although methodological heterogeneity limits definitive conclusions. In contrast, despite extensive investigation, evidence supporting the ergogenic benefits of *Panax ginseng* remains inconsistent, with stronger support for its possible role in attenuating exercise-induced muscle damage and promoting recovery rather than direct performance enhancement. Importantly, many of the proposed ergogenic benefits of adaptogens likely arise from integrated psychophysiological responses, underscoring the importance for future research to highlight psychological factors in addition to traditional performance outcomes. As standardized supplementation and more in-depth psychophysiological measurements are incorporated into human trials, a more comprehensive understanding of how adaptogens have the potential to influence exercise performance will emerge and better define their role within evidence-based sports nutrition. Thus, the use of adaptogens to enhance performance and psychophysiological responses to exercise should be viewed with cautious optimism.

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