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Systematic Review

Astragalus membranaceus (Huangqi) Supplementation in Sports Training: A Systematic Review

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Abstract: The aim of this systematic review is to study the effects of *Astragalus membranaceus* (Huangqi) supplementation for sports activity and physical performance. PubMed, EMBASE, Web of Science, Cochrane Library, and Google Scholar were systematically searched for relevant studies from inception up until October 2023. Eleven clinical studies were considered eligible for inclusion (six of them involved the administration of Huangqi alone, while, in the remaining trials, this herb was supplemented in combination with other remedies). On average, the number of study participants ranged from 8 to 120, and the sports activities practiced by the subjects included martial arts, mountain hiking, basketball, rowing, running, aerobic exercises, and strength training. When a dried extract was used, Astragalus was taken at a daily dose of 1 to 4 g for several weeks. Huangqi supplementation was associated with improvements in aerobic performance, oxidative status, reticulocytes percentage, and response to acclimatization, without a specific effect on the athletes' strength. Better post-exercise immune functions were also observed, especially with regard to NK cell activity, IL-2 levels, CD4+/CD8+ ratio, and lymphocyte turnover. No adverse effects were described. In conclusion, Astragalus supplementation has the potential to decrease fatigue, enhance aerobic performance, and mitigate post-exercise immune suppression in athletes. It is advisable to conduct additional research on the subject to enhance the robustness of the existing evidence through larger-scale controlled trials.

Keywords: *Astragalus membranaceus*; Huangqi; dietary supplementation; sports medicine; review

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1. Introduction

1.1. Background

Astragalus membranaceus, commonly known as Huangqi, milkvetch, or Astragalus, is a well-regarded medicinal plant with a rich history in Traditional Chinese Medicine and other traditional healing systems (this plant is native to the northern and eastern regions of China, as well as Mongolia) [1]. For over two millennia, the dried root of *Astragalus membranaceus*, originally recorded in Shennong Bencao Jing (Shennong's Classic of Materia Medica, 200–300 AD), has been a widely favored herbal remedy in China, cherished for its health-enhancing properties; in contemporary Chinese medicine, it finds application in Fu zheng therapy, serving as an immune stimulant, and it is esteemed for its capacity to fortify the body's fundamental vitality encompassing the immune system, metabolic processes, respiratory functions, and waste elimination [2]. Astragalus is a perennial herb of the Fabaceae family, typically growing to a height of 60 to 150 cm, and it is characterized by its upright, hairy stems; pinnately compound leaves; and clusters of small, yellow flowers [3]. The roots of this plant (*Radix astragali*) are the most commonly used part in traditional medicine and are harvested for their medicinal properties, as they are known to possess immunomodulatory, anti-inflammatory, adaptogenic, and antioxidant properties [4,5]. For this reason, Astragalus supplementation has gained interest in sports medicine due to its potential to enhance athletic performance and support the overall well-being of

athletes, for example by potentially boosting physical performance, expediting post-activity recovery and preventing the exercise-induced immunodepression in endurance sports [6]. However, to the best of our knowledge, no previous study has systematically synthesized the existing evidence concerning the impact of *Astragalus membranaceus* supplementation on the augmentation of sports activities.

1.2. Research Objectives

The primary objective of this systematic review is to thoroughly investigate the potential benefits associated with the supplementation of *Astragalus membranaceus* in the context of sports activity and physical performance. In this examination, we aim to discern the specific effects of *Astragalus membranaceus* supplementation on various aspects of sports performance, including endurance, strength, recovery, and overall physiological adaptations. By critically reviewing a diverse range of studies, we seek to provide an evidence-based understanding of the potential mechanisms through which *Astragalus membranaceus* may influence athletic performance.

2. Methods

2.1. Eligibility Criteria

This research was designed as a systematic literature review, and its results are reported in accordance with the PRISMA statement [7]. The review protocol was registered in the Open Science Framework (OSF) under the following: https://osf.io/tc6p5, accessed on 28 October 2023.

Relevant clinical studies assessing the efficacy and safety of *Astragalus membranaceus* supplementation in subjects performing any type of sports training and physical activity were considered for inclusion in this review. No publication date restrictions were posed. For the purpose of ensuring robust and reliable inclusion, the studies had to be available in the English language or, at the very least, feature an English abstract or summary. Furthermore, the selected studies had to be published in peer-reviewed journals as original research articles.

The following PICOS criteria were applied for article inclusion in this review:

- **P (population)**: athletes or healthy subjects performing any type of physical training. To place greater emphasis on the physiological impacts of *Astragalus membranaceus* supplementation rather than its therapeutic benefits, individuals with any preexisting medical conditions were intentionally excluded from the primary search.
- **I (intervention)**: *Astragalus membranaceus* supplementation, administered orally at any dose for any period of time. Moreover, studies where Astragalus was administered in conjunction with other supplements were also included in this review to provide a comprehensive understanding of its potential impact when used in combination with other substances.
- **C (comparison)**: any type, including no control. However, the focus was mainly placed on placebo-controlled studies in order to scrutinize the effects of *Astragalus membranaceus* in a context where the placebo group served as a valuable reference point, facilitating a more robust assessment of its potential benefits.
- **O (outcomes)**: all physiological outcomes, including strength, self-reported vigor, time to exhaustion, physical performance, body mass composition, and hematological parameters.
- **S (study design)**: clinical investigations, including both controlled trials and studies with a pre-post design. In vitro and in vivo laboratory experiments with animal or cell models were excluded from the main search.

2.2. Information Sources

In order to achieve a methodologically optimal combination of scientific databases [8], PubMed, EMBASE, Web of Science, Cochrane Library, and Google Scholar were systematically screened for relevant studies from inception up until October 2023.

2.3. Search Strategy

These were the search strategies used for each scientific database:

PubMed: (Astragalus[Title/Abstract] OR "Radix astragali"[Title/Abstract] OR Huangqi [Title/Abstract] OR "Huang Qi"[Title/Abstract] OR Milkvetch[Title/Abstract]) AND (sport*[Title/Abstract] OR physical[Title/Abstract] OR training[Title/Abstract] OR athlete*[Title/Abstract]).

EMBASE: (astragalus:ti,ab,kw OR 'radix astragali':ti,ab,kw OR huangqi:ti,ab,kw OR 'huang qi':ti,ab,kw OR milkvetch:ti,ab,kw) AND (sport*:ti,ab,kw OR physical:ti,ab,kw OR training:ti,ab,kw OR athlete*:ti,ab,kw).

Web of Science: (TS = (Astragalus) OR TS = (Radix astragali) OR TS = (Huangqi) OR TS = "Huang Qi" OR TS = (Milkvetch)) AND (TS = (sport*) OR TS = (physical) OR TS = (training) OR TS = (athlete*)).

Cochrane Library: ("*Astragalus membranaceus*" OR "radix astragali" OR "Huangqi" OR "milkvetch") AND ("sport*" OR "physical" OR "training" OR "athlete*") in Title Abstract Keyword—(word variations were searched).

Google Scholar: "*Astragalus membranaceus*" AND "sport" AND "trial".

2.4. Selection Process

A single researcher (M.A.) initially evaluated all the materials obtained following a database search, focusing on their titles and abstracts. Subsequently, a second investigator (D.D.) conducted a thorough examination of the articles that met the criteria for a full-text review. This two-tiered evaluation process was designed to ensure a proper selection of relevant studies for further consideration and analysis.

2.5. Data Collection Process

An investigator (M.A.) manually gathered information from the studies meeting the inclusion criteria using an Excel spreadsheet. Meanwhile, the second researcher (D.D.) conducted a random verification process to ensure the accuracy and completeness of the collected data.

2.6. Data Items and Effect Measures

The key data elements retrieved from the studies incorporated into the review encompassed the participants' demographics, the particular research methodology, pertinent information regarding the intervention and its comparison, as well as the recorded outcomes.

2.7. Study Risk of Bias Assessment

Every eligible controlled trial underwent assessment using the Jadad score [9], which involved assigning an overall score on a scale of −1 to 5 to gauge its methodological quality. Studies scoring 3 or higher were categorized as high-quality, while those with lower scores were deemed to be of lower quality [10]. The risk-of-bias evaluation played a role in shaping the review's analysis.

2.8. Synthesis Methods

The data were qualitatively synthesized and subjected to critical discussion. A clear distinction was made between the results of studies in which *Astragalus membranaceus* was supplemented alone and those in which it was administered in combination with other herbal remedies or compounds to address potential confounding factors. No preplanned meta-analysis was undertaken, as an initial literature search indicated substantial heterogeneity among the available studies, impeding a comprehensive quantitative synthesis.

3. Results

3.1. Literature Search and Study Selection

Overall, 529 articles (PubMed: 59; EMBASE: 111; Web of Science: 117; Cochrane Library: 26; Google Scholar: 216) were screened, and 11 of them were considered eligible for inclusion in this systematic review [11–21]. The most important characteristics of these studies are summarized in Table 1. The article screening and selection process is described in a flow-diagram (Figure 1).

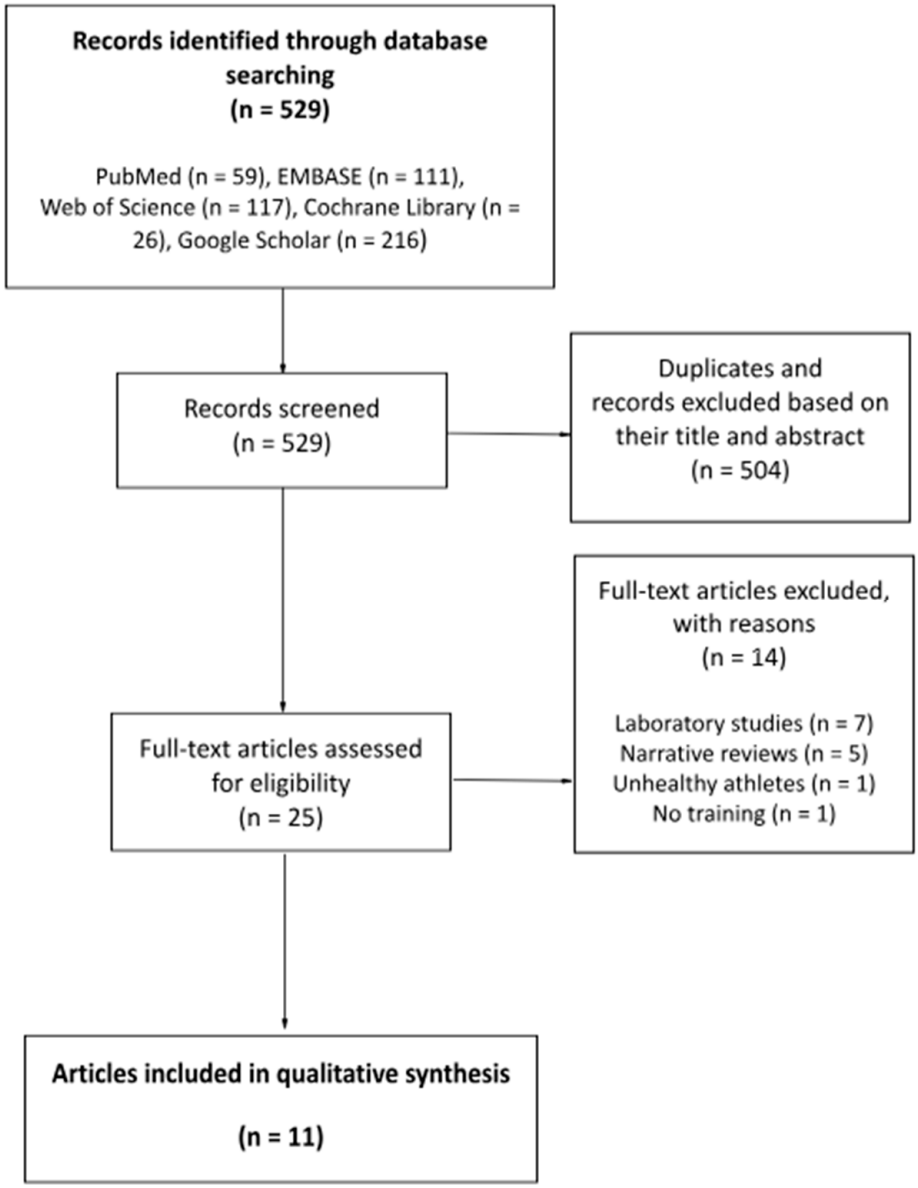

Figure 1. Flow diagram representing the article selection process.

Table 1. Summary of clinical studies about the effects of Astragalus supplementation in sports activities.

Population		Intervention (n)	Comparison (n)	Outcomes (Intervention Versus Comparison/s)	Study Type	Jadad Scale *	Reference
120 older adults Age (range): 60–75 yo Gender: all females Sport: Taiji boxing	AM	0.5 lt of AM decoction (30 g of AM boiled in 1.5–2 lt of water) every training day for 12 months (n = 60)	No supplementation (n = 60)	↑ IgA, IgG, and IgM levels ↓ Lymphocyte apoptosis	RCT	3	[11]
20 young adults Age (mean): 20–21 yo Gender: all males Sport: mountain hiking		2 g of AM extract b.i.d. for 15 days (n = 20)	Placebo (n = 20)	↑ PWC-170 test, VO2 max, and post-exercise SOD ↓ Post-training heart rate, BLA, BUN, and MDA ↓ Fatigue caused by altitude acclimatization (3700 mt)	RCT	3	[12]
20 athletes Age (range): 18–24 yo Gender: all males Sport: middle-distance running		0.5 lt of AM decoction every day for 4 weeks (n = 10)	0.5 lt of water (n = 10)	↑ Post-exercise NK cell activity and CD4+/CD8+ ratio = IgA, IgG, and IgM	RCT	?	[18]
18 athletes Age (mean): 20.4–21.4 yo Gender: all males Sport: rowing		500 mg of AM extract b.i.d. for 6 weeks (n = 10)	Placebo (n = 8)	= Athletes' strength = Lactate acid production ↑ Post-exercise IL-2 levels and NK cells	RCT	3	[13]
15 athletes Age: 24.0 ± 1.0 yo Gender: all females Sport: aerobic training		15 g of AM diluted in a sport drink and taken during the post-exercise recovery phase (n = 15)	-	↑ Aerobic performance ↑ Physical condition ↑ Muscular morphology	Pre-post study	-	[14]
8 young adults Age (mean): 25.0–25.3 yo Gender: 4 M + 4 F Sport: unspecified, but the participants are described as physically active		1.8 g of AM extract b.i.d. for 2 weeks (n = 8)	-	↑ Reticulocytes percentage ↓ OFF-hr Score = RBC, Hct, WBC, and PLT	Pre-post study	-	[21]

Table 1. *Cont.*

Population	Intervention (n)	Comparison (n)	Outcomes (Intervention Versus Comparison/s)	Study Type	Jadad Scale *	Reference
44 older adults Age (range): 55–84 yo Gender: 21 M + 23 F Sport: strength training	1.5 g of AM, *Panax ginseng* and *Panax quinquefolius* extracts + 3 g of creatine a day for 12 weeks (n = 14)	Creatine (n = 15) Placebo (n = 15)	↑ Strength and lean mass (similar to that observed with creatine only) ↓ Blood lipids ↑ Self-reported vigor ↓ Body fat	RCT	4	[15]
36 athletes Age (range): 20–30 yo Gender: all males Sport: running	7.5 g of DBT every day for 11 days (n = 18)	Placebo (n = 18)	↑ Running performance ↓ Exercise-induced rise in hepcidin levels = TNF-α and IL-6 = GOT, GPT, LDH, and BUN	RCT	3	[20]
20 athletes Age (mean): 16.6–16.8 yo Gender: 16 M + 8 F Sport: judo	HJT q.d. for 5 weeks (n = 9)	Placebo (n = 11)	= No significant changes in hematological parameters (RBC, Hb, Hct, GOT, GPT, BUN, and CK) attributed to HJT = No adverse events	RCT	3	[16]
16 athletes Age (range): ? Gender: all males Sport: rowing	15 g of AM and *Ganoderma lucidum* extracts before training sessions for 30 days (n = 8)	Placebo (n = 8)	↑ Total lymphocytes, CD4+ cell count, and CD4 + /CD8+ ratio after the exercises = Post-training testosterone and cortisol levels	RCT	?	[19]
12 athletes Age: 20.1 ± 1.1 yo Gender: all males Sport: basketball	HJT q.d. for 8 weeks (n = 6)	Placebo (n = 6)	↑ Anaerobic threshold ↓ Fatigue (increased time to exhaustion)	RCT	3	[17]

AM + other compounds

Table description: This table describes the most relevant characteristics of the included studies, grouped on the basis of their intervention type (Astragalus supplementation or Astragalus administered in combination with other herbs) and ordered by sample size (number of participants). * The section labeled "Jadad Scale" delineates the comprehensive quality score allocated to each trial. Pre-post studies were deemed ineligible for evaluation using this scale (symbol "-"). Similarly, trials lacking an accessible full-text were exempted from assessment (symbol "?"). Outcomes (=/↑/↓): non-significant difference/Significantly higher/Significantly lower ($p < 0.05$).

3.2. Description of the Included Studies

Among the studies included in this review, all but two [14,21] were controlled trials.

Overall, the number of study subjects ranged from 8 to 120 (median: 20), and most of them were young adults of the same gender, either males or females; the sports activities performed by the subjects included martial arts (Taiji or judo), mountain hiking, basketball, rowing, running, aerobic exercises, and strength training (see Table 1).

The interventions in the studies exhibited variation, with six of them exclusively involving *Astragalus membranaceus* supplementation, albeit in different formulations (encapsulated dried extract, fluid extract diluted in a sport drink, and decoction); the other trials, as detailed in Table 1, featured a combination of *Astragalus membranaceus* and other compounds, such as creatine, ginseng [15], or reishi extract [19].

The study participants took the supplement for a duration that ranged from as short as 11 days to as long as 12 months; when Astragalus was administered as a standalone dried extract, the daily dosage typically varied from 1 to 4 g, and it was usually divided into two separate administrations (see Table 1).

Two studies investigated the effects of Huangqi Jianzhong Tang (HJT) [16,17,20], a traditional Chinese remedy with the following herbs: Radix Astragali, Radix Paeoniae Alba, Ramulus Cinnamomi, Fructus Jujubae, Glycyrrhizae Radix Et Rhizoma Praeparata Cum Melle, Rhizoma Zingiberis Recens, and Saccharum Granorum [22]. In one trial, another Chinese formula, called Dang-Gui Bu-Xue Tang (DBT) and composed of Radix Angelicae sinensis and Radix Astragali, was administered to the study participants [20].

Astragalus membranaceus supplementation was found to improve the subjects' aerobic performance, oxidative status, reticulocytes percentage, and response to acclimatization [12,14,21] without a specific effect on the athletes' strength [11]. The results of studies in which Astragalus was co-administered with other remedies showed similar results (see Table 1). The Chinese formulations DBT and HJT were associated with better aerobic performance of the athletes [16,17,20]. If compared with creatine alone, Astragalus, ginseng, and creatine supplementation did not improve the strength and lean mass of the study participants [15]. The utilization of a combination of Astragalus and reishi (Ganoderma lucidum) appeared to exhibit an enhancement in post-training immune system functions, and it also seemed to potentially mitigate the post-exercise cortisol surge, even though no statistically significant disparities were evident when comparing the intervention group with the control group in the post-test results [19].

Astragalus membranaceus supplementation was associated with better post-exercise immune functions, especially with regard to NK cell activity, IL-2 levels, CD4+/CD8+ ratio, and lymphocyte turnover [11,13,18]. Inconsistent findings emerged regarding immunoglobulin (IgA, IgG, and IgM) levels: in particular, one study reported higher levels in the intervention group [11], while another trial did not reveal a significant difference between the intervention and control groups [18].

The included studies revealed an absence of adverse effects associated with *Astragalus membranaceus* supplementation. Moreover, laboratory blood examinations conducted on the participating athletes yielded no indications of any detrimental impacts on liver or kidney functions [16,20].

The studies described in Table 1 were generally characterized by an acceptable quality (mostly 3 out of 5 points in the Jadad scale): while they met the criteria for methodological quality, some exhibited a deficiency in providing comprehensive descriptions of their randomization and blinding procedures. Despite the overall quality being satisfactory, these specific aspects were observed to be somewhat lacking in detail within the reviewed studies.

4. Discussion

4.1. A Critical Overview of the Available Evidence

In this comprehensive overview of the available evidence, *Astragalus membranaceus* supplementation appears to be connected with augmenting the aerobic performance of athletes. This observation underscores the potential of Astragalus to contribute positively

to endurance, thereby bolstering the athlete's ability to excel in activities that demand sustained aerobic effort. However, it is crucial to recognize that this effect on aerobic performance is not mirrored in the realm of strength levels: in fact, the body of research suggests that Astragalus supplementation does not yield significant improvements in muscular strength. Consequently, athletes who primarily engage in activities requiring bursts of power and force may not find Astragalus to be a key factor in enhancing their performance in this particular aspect. Furthermore, the scientific investigations indicate that the administration of Huangqi can lead to notable enhancements in the immune system's resilience and function following physical exertion. This heightened post-exercise immune response may be particularly advantageous for athletes seeking to maintain their well-being and perform at their best, even in the face of the physiological stressors induced by strenuous training regimens. It is important to note that these positive outcomes are generally associated with the consumption of a daily dose of Astragalus extract ranging from 1 to 4 g, which is often consumed over several weeks. The choice of Astragalus extract is preferable due to the standardized quantity of the plant's offered active compounds, ensuring a more consistent and reliable intake. In contrast, decoctions of Astragalus, while traditional, tend to be less favored in contemporary contexts due to the inherent challenges in maintaining a consistent level of the plant's bioactive components, which can vary with each preparation.

In a study involving mountain hikers, the influence of Astragalus on aerobic performance was evident, as it was linked to substantial enhancements in average VO2 max, with an increase from 40.85 to 44.25 mL/kg/min after 15 days of daily 4 g Astragalus supplementation, alongside a decrease in heart rate after strenuous exercise from around 161 to 147 bpm, while no significant alterations were observed in the control group receiving placebo pills [12]. In another study with basketball players, the group taking HJT had an improved exhaustion time (820 $\pm$ 31 s), which significantly exceeded that of the control group (780 $\pm$ 28 s) [17].

The research involving Astragalus in combination with other herbal remedies does not definitively attribute the findings solely to Astragalus; however, the results are consistent with other studies and suggest that Huangqi may have played a role in these observed effects (see Table 1). The ergogenic action and immune function-related modifications appear to be synergistic with that of other supplements with similar pharmacodynamics, such as myco-therapeutic [19] or ginseng [15] extracts. Huangqi was also associated with a potential increase in the production of red blood cell precursors and a significant systemic antioxidant effect [12,21].

The existing research does not provide a definitive timeframe for the duration of the observed effects resulting from Astragalus supplementation, leaving uncertainty regarding how long the benefits persist. Similarly, the extent to which Astragalus enhances aerobic performance remains unclear, and there is limited information on whether the post-exercise immune stimulation, which mitigates the exercise-induced transient immune suppression [23], effectively aids athletes in preventing infections when they are exposed to pathogens following training. Further investigation is needed to address these questions comprehensively and to elucidate whether there are gender differences in the effects of Huangqi supplementation for sports training.

4.2. Purported Mechanism of Action

So far, Astragalus species have yielded more than 200 distinct compounds, comprising a diverse array of chemical constituents, including flavonoids, triterpenoids, polysaccharides, amino acids, alkaloids, ß-sitosterol, metalloids, and anthraquinones [3]. Among this extensive repertoire, flavonoids and triterpenoids emerge as the most prevalent constituents. Notably, polysaccharides, isoflavonoids, and triterpenoid saponins, which encompass astragalosides (as depicted in Figure 2), play a pivotal role as the primary bioactive components of Huangqi, given their significant contribution to the diverse pharmacological properties of Astragalus, with specific regard to its immunomodulatory properties [24,25]. In

particular, research has demonstrated that Astragalus polysaccharides can enhance the functioning of macrophages, NK cells, T and B lymphocytes, dendritic cells, and microglia, while also triggering the production of numerous cytokines [25] and improving the gut microbiota composition [26]. Additionally, astragalosides can modulate T cell activation through different molecular pathways, offering a potential explanation for the immune stimulation caused by *Astragalus membranaceus* [27,28].

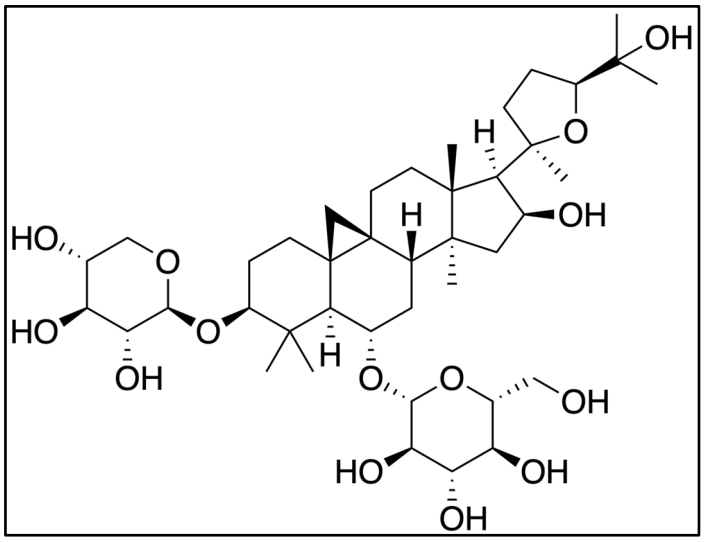

Figure 2. Biochemical structure of astragaloside IV, an active principle of Astragalus extracts. Image freely distributed under the Public Domain license and available at: https://en.wikipedia.org/wiki/Astragaloside#/media/File:Astragaloside_IV_Structure.svg (accessed on 16 October 2023).

When we examine the ergogenic and anti-fatigue effects of Astragalus, which contribute to enhancing athletes' aerobic performance, it is postulated that these effects may be partly attributed to a potential combination of antioxidative actions, including stimulating antioxidant enzymes and reducing the generation of oxygen free radicals [29,30]. Additionally, there may be an effect on the production of red blood cells, leading to improved tissue oxygenation [12,21]. Other mechanisms could encompass the expedited removal of byproducts from muscle metabolism, the anti-inflammatory effect, and the regulation of stress hormone levels [31–33], which may favor quicker post-exercise recovery and better physical performance.

In the context of post-activity, and even following sports-related trauma or muscle injuries, it has been suggested that Astragalus supplementation might potentially expedite athletes' recuperation [34]. In a trial with eleven male participants receiving astragalosides supplementation (4 mg per day for a week) or placebo pills, the intervention effectively reduced biomarkers associated with muscle damage and inhibited the secretion of pro-inflammatory cytokines (IL-6 and TNF-α), while simultaneously increasing the release of the muscle regenerative factor IGF-1 during the initial phases of the recovery process [35]. Additionally, the astragalosides group exhibited a quicker return to baseline muscular strength in comparison to the placebo group, indicating that astragalosides supplementation expedites the resolution of inflammation, bolsters muscle regeneration, and accelerates the restoration of strength following exercise-induced injury [35]. Another study with 600 aerobics athletes with muscle injuries indicated that the Radix astragali and Salvia miltiorrhiza injection significantly improved overall treatment efficiency, increased serum antioxidant levels, and reduced muscle damage markers, suggesting its potential for promoting efficient skeletal muscle injury repair [36]. This evidence indicates that Huangqi may have a role in accelerating muscle microdamage after eccentric exercise and recovering from delayed-onset muscle soreness, which is likely caused by a combination of muscle damage and inflammation [37].

4.3. Safety and Tolerability of Intervention

No adverse effects (neither severe, nor mild) were reported in the trials analyzed in this review, and Astragalus administration was well tolerated by the study participants. Nevertheless, it has been reported that supplementing it with Huangqi may occasionally result in symptoms such as malaise, headaches, and a temporary reduction in blood pressure; these side effects are generally mild and transient, typically resolving on their own within 24 h following Astragalus administration [38].

Hepatotoxicity has been suggested as a possible adverse outcome of Huangqi usage; however, researchers propose that this effect could be more related to impurities found in complex herbal mixtures rather than being directly attributed to Astragalus itself [39]. In line with this hypothesis, no alterations in liver function parameters were reported in the studies included in this review [16,20]. Nonetheless, a case report highlighted the enlargement of liver and kidney cysts, along with elevated CA19.9 levels, following Astragalus administration, and these conditions tended to ameliorate upon discontinuation of the supplement [40].

Additionally, Huangqi can potentially interfere with other supplements and medicines, as it has been found to alter the concentration of liver-metabolized drugs like tacrolimus, inhibit P-glycoprotein efflux pumps, and have a synergistic effect with natriuretic agents [41–43]. Generally, there is a dearth of information regarding the potential interactions between Astragalus and other medications; for this reason, as a precaution, it is advisable to seek medical guidance before using this supplement, particularly for athletes managing specific medical conditions and undergoing long-term medication regimens.

Lastly, Huangqi, when supplemented at a daily dose of at least 3.6 g for two weeks, has the capacity to influence reticulocyte counts, leading to a significant increase in the reticulocyte percentage from 0.69% on day 1 to 1.53% on day 22 ($p < 0.05$ compared to day 1), with a further increase to 1.85% on day 29 ($p < 0.05$ compared to day 1) [21]. As demonstrated in mechanistic research, it is suggested that the impact of Radix Astragali on hematological parameters is linked to the dosage [44], with higher doses potentially associated with more pronounced effects. However, the alterations in reticulocyte count were not accompanied by significant modifications in the overall concentration of mature red blood cells, hematocrit, or hemoglobin levels [16,21]. All the same, professional athletes should openly disclose its usage when subjected to anti-doping tests.

4.4. Study Limitations

Overall, the majority of the existing studies tended to encompass relatively modest participant numbers, thus potentially limiting the generalizability of the findings to a broader population. Furthermore, some of these studies exhibited a lack of comprehensive methodological descriptions, which can raise questions about the robustness of the research design and the quality of the data. The observed interventions across these studies exhibited a notable degree of heterogeneity: this variance extended to aspects such as the dosages and formulations of *Astragalus membranaceus* supplementation, rendering it challenging to establish precise and universally applicable recommendations for athletes seeking to leverage the potential benefits of this herbal remedy in their training and performance routines. Additionally, the possibility of publication bias cannot be entirely ruled out.

5. Conclusions

In summary, the utilization of *Astragalus membranaceus* supplementation appears to exhibit a positive correlation with an improvement in aerobic performance among athletes, especially those practicing endurance sports. For example, a daily dose of 4 g of this supplement for 15 days resulted in notable improvements in VO2 max (40.85 to 44.25 mL/kg/min) and post-exercise heart rate (161 to 147 bpm) compared to the placebo group; furthermore, athletes taking Huangqi-containing supplement exhibited a significantly prolonged exhaustion time (820 $\pm$ 31 s) compared to the control group (780 $\pm$ 28 s). However, this supplementation did not yield any noticeable impact on the

strength levels of the athletes. Additionally, the enhancement of some immune functions was observed, which might be useful to compensate for transient immune deficiency after strenuous physical exercise.

A few bullet points can summarize the most relevant results of this systematic review:

- *Astragalus membranaceus* supplementation demonstrated a positive impact on aerobic performance in athletes across various sports activities.
- Individuals supplemented with Huangqi showed enhanced post-exercise immune functions.
- No adverse effects were reported in association with Astragalus supplementation, indicating its relatively safe profile for use in sports performance.

To bolster the validity of these findings, further research is necessary, particularly in studies involving larger and more diverse participant samples. Additionally, to mitigate the influence of potential confounding variables, it is advisable to employ a standardized herbal extract when assessing the effects of *Astragalus membranaceus*, while also refraining from the concurrent use of Astragalus with other supplementary agents. These measures will contribute to a more comprehensive and accurate understanding of the supplement's impact on the study outcomes.

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Abbreviations

AM	Astragalus Membranaceus
BUN	Blood Urea Nitrogen
CK	Creatine Kinase
DBT	Dang-Gui Bu-Xue Tang
Gender (M/F)	Males/Females
GOT	Glutamic Oxaloacetic Transaminase
GPT	Glutamic Pyruvic Transaminase
Hb	Hemoglobin
Hct	Hematocrit
HJT	Huangqi Jianzhong Tang
IL-2	Interleukin 2
IL-6	Interleukin 6
LDH	Lactate Dehydrogenase
MDA	Malondialdehyde
NK cells	Natural Killer cells
Outcomes (=/↑/↓)	Non-significant difference/Significantly higher/Significantly lower ($p < 0.05$)
PLT	Platelets
PWC	Physical Working Capacity
RBC	Red Blood Cells
RCT	Randomized Controlled Trial
TNF	Tumor Necrosis Factor
WBC	White Blood Cells
yo	years old

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