Mini review on how ashwagandha (*Withania somnifera*) supports post-exercise recovery

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Abstract. Ashwagandha is known to have many health benefits such as anti-inflammatory, cardioprotective, anti-stress, antioxidant, and revitalizing properties. In the field of sport, Ashwagandha can maintain endurance and reduce post-exercise stress response. However, the mechanism of action remains uncertain. The purpose of this review is to discuss the role of Ashwagandha in sports endurance and recovery. The method used is a literature review which focuses on research publications related to the topic at least from 2015 onwards. Consumption of ashwagandha may reduce cortisol, lactic acid, and urea nitrogen levels and improve Vo2max that may prevent the damaging effects of stress and restore normal physiological functioning during and after exercise. These studies also found ashwagandha may induce muscle cell differentiation. Therefore, ashwagandha extract has a potential effect on endurance and post-exercise recovery.

1 Introduction

Nowadays, individuals are selecting various methods of physical exercise to improve body health. However, excessive or inappropriate physical exercise may lead to several complaints such as muscle fatigue. Fatigue and muscle soreness can be caused by the build-up of lactic acid in the muscles [1]. Additionally, the energy metabolism also plays an important role in endurance according to the intensity of exercise. To address this situation, numerous strategies have been utilized, one of them is the use of supplementation. It is believed that supplementation may prevent post-exercise symptoms and improve most components of exercise. Furthermore, adequate nutrition plays a crucial role in sustaining exercise duration and improving overall ability. One such supplementation is Ashwagandha, which is known for its various benefits such as anti-inflammatory, cardioprotective, anti-stress, antioxidant, and revitalizing properties [2] [3]. Ashwagandha (*Withania somnifera*), commonly referred to as an Indian ginseng, is found throughout Asia, Southern Europe, and North Africa.

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Ashwagandha plants have 0.5m to 2.0 m of heights with green colors. The leaves have a sharp apex and the flowers yellow with little pedicled. Its fruits are orange-red color and the seeds are small, flat, and yellow. Ashwagandha has been utilized for a long period as a traditional medicine in India. This plant provides a lot of health benefits for the human body. Study about Ashwagandha effect has been conducted over the years either *in vitro* or *in vivo.* Studies found that each part of this plant offers various health effects with its bioactive compound [4]. Ashwagandha is known to contain bioactive compounds that can increase exercise and muscle endurance [3]. Prior research has shown that ashwagandha play a role in the post-exercise recovery process [3]. Based on this, this study aims to review more specifically the role of ashwagandha on endurance during exercise and post-exercise recovery.

2 Materials and methods

The study is a mini review. The selection criteria for this review include 1) research on the topic of Ashwagandha in the form of reviews and clinical trials (randomized or not); 2) articles published at least in 2015 onwards and book references published between 2010 and 2023. The search keywords include "Effect of Ashwagandha on Health", "Ashwagandha on Sport Endurance", "Ashwagandha effects on recovery", "*Withania somnifera* on sport and exercise", "Health benefit of *Withania somnifera* supplementation", "Antioxidants on Sport", "Physiology of exercise" "Nutrition of exercise", and "Ashwagandha extract on health".

Sources of information were obtained from free-access articles in various journals such as PubMed, ScienceDirect, and Google Scholar. Articles that fulfilled the criteria were collected and analyzed to answer the effects of ashwagandha on sport endurance and recovery.

3 Results and discussion

3.1 Physiological and biochemical aspects of physical exercise

Exercise endurance and recovery are influenced by the duration and intensity of exercise which also affects adenosine triphosphate (ATP) consumption as an energy source. Exercise requires extra energy to the muscle to sustain muscle contraction and achieve homeostasis. Contraction of the muscle involves actin and myosin proteins that are arranged to form microfilaments. The microfilaments will slide each other, allowing the muscle to shorten or contract and relax. The muscle contraction process acquires energy from ATP [1].

In the context of exercise, certain muscle groups are activated, and the initial ATP requirements are primarily met through ATP hydrolysis by actomyosin ATPase. However, long period or high-intensity exercise will require more energy through metabolism of a combination of substrate, creatinine phosphate (PCr), and muscle glycogen. Repeated high-intensity exercise will limit PCr stored within the muscle, thus increasing the risk of muscle fatigue. In prolonged or endurance exercise, ATP synthesis derives from muscle glycogen, blood glucose, and stored fat within the muscle. Increased duration of exercise reduced the stores and ATP re-synthesis confined to anaerobic glycogenolysis process. The process produces pyruvate which will be metabolized into ATP or converted into lactate [1]. The limitation of anaerobic glycogen metabolism will impact endurance and post-exercise muscle fatigue and soreness [1] [3]. Therefore, maintaining cellular ATP concentration is crucial to prevent muscle fatigue. Different kinds of activity require various metabolite substrates that supply the energy as shown in Table 1.

Table 1. Requirement of ATP re-synthesis based on length and intensity of activity [1]

Activity/ exercise	Duration/ intensity	Metabolic substrate supply
Sprinting	6–60 s/supramaximal	ATP/PCr, glycogen
Endurance	>5 min to 5 hours/ submaximal (60–85% max.)	Glycogen, blood glucose, IMTG, plasma fatty acids, amino acids
Ultra-endurance	>5 hours/submaximal (40–60% max.)	Glycogen, blood glucose, IMTG, plasma fatty acids, amino acid

Table 1 shows that endurance and ultra-endurance exercise require more energy sources to meet the demand. The optimal exercise performance can be influenced by several factors such as diet habits, training status, environment, genetics, and gender. Thus, the diet factor is crucial to maintain the energy source [1].

The other crucial element of exercise performance (endurance and recovery) is an individual's maximum oxygen intake (VO2max). VO2max serves as the highest aerobic energy production rate that can be achieved. A large fraction of VO2max indicates the sustainability for prolonged periods of exercise. Generally, it can be achieved with appropriate training methods. The VO2max also significantly correlates with the cardiovascular system, particularly stroke volume and cardiac output, which is important to deliver the oxygen into systemic circulation. Long duration or over-training can lead to lactic acid buildup in the muscle, and it will increase the risk of muscle fatigue and soreness. Nutrition from diet and supplement is the crucial part to supply the energy source [2,3].

3.2 The effects of Ashwagandha supplementation

In natural medicine in India, known as Ayurveda, Ashwagandha has been utilized as traditional medicine. Research shows that the bioactive components in ashwagandha have various benefits for the body. This plant is recognized for its antioxidant, anti-inflammatory, anti-cancer, anti-stress, cardioprotective, neuroprotection, and exercise endurance [2,3]. Table 2 contains the effects of ashwagandha in previous research studies.

Table 2. Effects of Ashwagandha supplementation

Effects	Study Population/ design/ sample	Intervention/ investigation	Outcome	Reference
Antioxidant	Root of W. somnifera	Total antioxidant capacity ascorbic acid standard curve	ToAC (83.354 +- 1.828)	[6]
	Leaves of W. somnifera	Total antioxidant capacity ascorbic acid standard curve	ToAC 45.41±0.018	[7]
	Root of W.somnifera	Phytochemical	alkaloids, flavonoids, carbohydrate, Steroids and Saponin Glycoside.	[26]
Anti-inflammatory	Rats, n=22	200mg Ashwagandha supplementation	Anti-inflammatory activity against aluminum trichloride	[30]
	W. somnifera extract		inhibit inflammatory markers such as cytokines (IL-6 and TNF-a), ROS, and nitric oxide	[9]

Effects	Study Population/ design/ sample	Intervention/ investigation	Outcome	Reference
Cardioprotective	Mice, n= 36	Withaferin-A low dose (1 mg/kg)	improved cardiac function and reduced infarct size	[15]
Improve cardiorespiratory endurance	Athletes, n=50	300 mg of root Ashwagandha extract	improves cardiorespiratory endurance, VO2max and quality of life	[16]
	Humans, n=50	300 mg Ashwagandha supplementation	Decrease Creatinine Kinase level ($p<0.0001$)	[19]
	Humans, n=80	300mg Ashwagandha capsule	Improve VO2max ($p<0.0001$)	[23]
Anti-stress	Humans, n=130	300 mg of root Ashwagandha extract	Better score of OHQ and PSQI	[17]

3.2.1. Antioxidant effect

The antioxidant effect of Ashwagandha is demonstrated by its high content of alkaloids, flavonoids, and withanolides [4]. This antioxidant activity has different levels in various parts. The study by B. Ganguly et al. [5] [6] found that the root of Ashwagandha exhibits a high level of antioxidant compound, with alkaloid and flavonoid being the most significant contributors. In this study, total antioxidant capacity (ToAC) was determined from an ascorbic acid standard curve, with methanolic extract being the highest (83.354 ± 1.828). Similarly, study by Tebeka et al. [7] stated that Ashwagandha has strong antioxidant activity, especially with methanolic methods of extraction of the leaves. The total antioxidant capacity (ascorbic acid standard curve) is highest in methanolic extraction compared to another method extraction with the value 45.41±0.018. Another research [8] [9] [10] [11] has also found that Ashwagandha possesses strong antioxidant-properties with various extraction methods and various parts of the plant.

Antioxidants have a potential effect on exercise. As oxygen demand increase, the production of free radicals also increases as a response. Antioxidants can counter free radicals with various mechanisms. A study showed that antioxidants significantly reduced lipid peroxidation and improved superoxide dismutase and catalase enzyme activities [12]. Physical activity produces reactive oxygen species (ROS) that influence exercise performance. Furthermore, micronutrients and antioxidants play a significant role in counteracting the ROS [11] [12].

3.2.2. Anti-inflammatory, anti-cholinesterase, immunomodulator

Ashwagandha's anti-inflammatory effects are attributed to its antioxidant effects. A study by Khadrawy et al. [I] reported that the extract of ashwagandha shows antioxidant and anti-inflammatory activity against aluminum neurotoxicity. In that study, inflammatory conditions were induced by aluminum trichloride, and the treatment group was protected by daily Ashwagandha (200 mg/kg, orally). The effects of aluminum were increased peroxidation of lipid and nitric oxide levels in the cortex, hippocampus, and striatum and reduced glutathione level in the hippocampus. Although changes in lipid peroxidation and nitric oxide levels were not significant, the treatment group showed the potential effect of

Ashwagandha on maintaining acetylcholinesterase activity. Similar findings also stated by Reddy et al. [9] and Mikulska et al. [11] that Ashwagandha has been studied for the treatment of many inflammation-associated disease and demonstrated effects of reducing inflammation and apoptosis as well as regulate mitochondrial function preclinically. Ashwagandha extract can inhibit markers of inflammation such as cytokines (IL-6 and TNF-a), ROS, and nitric oxide. This extract also has an inhibiting effect of COX-2 with 86.4% inhibition compared to celecoxib as a positive control [9].

Other research showed that extract of Ashwagandha root was found to decrease the secretion of proinflammatory cytokines, such as interleukin (IL)-8, IL-6, tumor necrosis factor (TNF-α), IL-1β, and IL-12, and increase the secretion of anti-inflammatory cytokines that inhibit the NF-κB and MAPK (mitogen-activated protein kinase) pathways [13]. Ashwagandha also improved the immune profile of the health subjects significantly when given 60mg of extract in the treatment group. The mechanism is through modulating the innate and adaptive immune systems, such as increased natural killer (NK) cell activity and cytokine levels [11] [14].

3.2.3 Cardioprotective, anti-stress, and neuroprotective

The Ashwagandha contains withaferin-A (WFA) that has a cardioprotective effect by regulation of the anti- apoptotic mitochondrial pathway. Guo R et al [15] found that WFA (low-dose) improved cardiac function and decreased infarct size in mice with myocardial infarction. Research by Choudhary et al [16] found that the root extract of Ashwagandha improves cardiorespiratory endurance, VO2max, and quality of life of athletic adults. Cardiorespiratory endurance is widely acknowledged as a significant aspect of physical fitness [16]. Research found this plant extract has a stress-relieving effect and improves psychological well-being [17] [18] . Questionnaires such as Oxford Happiness Questionnaire (OHQ) and *Pittsburgh Sleep Quality Index (PSQI)* were used to assess subjects with Ashwagandha supplementation (300mg root extract capsule) [17). The Hamilton Anxiety Rating Scale (HAM-A), Depression, Anxiety, Stress Scale-21 (DASS-21), and cortisol level were also used to investigate the effects of 240 mg ashwagandha extract supplementation in further study [18]. The result found that there was a significant reduction in the HAM-A ($P=0.40$), DASS-21 ($P=0.096$), and greater reduction in morning cortisol level ($P < 0.001$) [18]. This stress relieving effect may occur through its moderating impact on the hypothalamus-pituitary-adrenal axis.

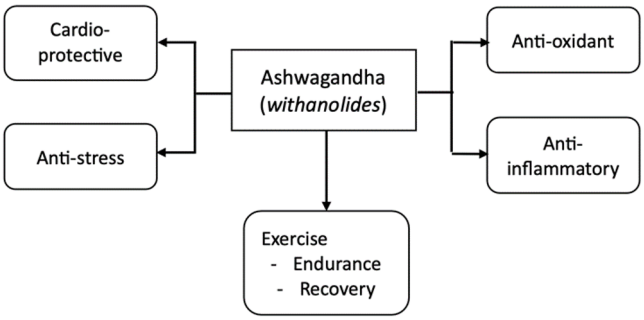

Fig. 1. Diagram of the Ashwagandha effect on exercise: improve endurance and recovery. Ashwagandha has several effects on health, including anti-oxidant, anti-inflammatory, anti-stress, and cardio-protective and has a role in endurance and recovery after exercise [2] [3] [6] [7] [11] [15] [30].

In the field of sport or exercise, several studies have investigated the effects of Ashwagandha supplementation, including its effects on other health parameters such as antioxidant, anti-inflammatory, and cardioprotective. These effects correlate one to another that supports the improvement of exercise endurance and recovery. The mechanisms include reducing cortisol, urea nitrogen, and lactic acid levels in the blood as well as dopamine receptors in the brain to improve the body's response to stress [2] [3] [18].

Similar findings reported by Wankhede et al., [19] reported that Ashwagandha supplementation has a significant effect in increasing muscle mass and strength. In this study, creatine kinase level was used to measure the exercise-induced muscle damage and the experimental group (300 mg root extract) had greater reduction of creatine kinase level compared to placebo (P=0.03) in the resistance training-experienced subjects. Exercise frequently damages the muscle tissue and may impact muscle force and performance [1] [19]. These issues can influence endurance, adaptation, gains, and recovery from exercise, especially resistance training. The study also provides results of Ashwagandha supplementation on muscle strength and size, percentage of body fat, testosterone level, and muscle recovery have a significantly greater value compared to placebo [19]. The muscle recovery effect could be due to some mechanisms or synergistic effects, mediated by the different extract bioactive components. The mechanisms consist of antioxidant activity both at the muscle and central nervous system levels, anti-inflammatory, lactic acid, and urea nitrogen reduction in the blood. Another study of this plant's effects on muscle strength and endurance was reported by Ziegenfuss et al. [20] and Długołęcka et al. [21]. The studies found a beneficial effect of supplementation. For athletes and active people, this supplement offers ergogenic advantages. [21]. There was an improvement in body mass distribution and composition, upper and lower body strength, and also endurance [2] [20] [22].

Further research found Ashwagandha supplementation has an improvement effect on cardiovascular and sports endurance [2], [3], [12], [16], [20], [22], [23]. Tiwari et al [24] in a study with a randomized, placebo-controlled trial showed Ashwagandha root extract improves VO2 max and quality of life in young athletes. Similar findings with research carried out by Perez et al and Sukumar et al. These findings stated improved cardiorespiratory endurance among healthy subjects with supplementation because of its ability to increase VO2max and haemoglobin [25] [26].

Based on the research above, the previous effects of Ashwagandha have a combination of effects that support endurance in exercise. Antioxidants play an important role in combating the ROS effect after exercise. The anti-inflammatory effect of this plant can regulate pro-inflammatory mediators that also can be found during and post-exercise conditions [9]. The improvement of VO2max will improve cardiovascular endurance and VO2max is significant to maintain the capacity to take in, transport, and utilize oxygen. When oxygen demand meets the availability, it will increase endurance [16]. Several factors influence VO2max values such as genetic preposition, enzyme, muscle fibre type, and training. It is also found that nutritional supplementation enhances the training effects and performance [27].

One of the post-exercise effects is muscle recovery. It is important and affects exercise performance. Studies showed antioxidant capacity of Ashwagandha contributes to the recovery rate [12],[24]. Recent studies have shown that Exercise-induced ROS can regulate the body's enzymatic and non-enzymatic antioxidants, therefore it can protect against cellular oxidative damage and induce muscle adaptation [28]. Wang Jia et al. [25] found Ashwagandha extracts and their major withanolides (withaferin A and withanone) have different effects on the differentiation of muscle cells (using C2C12 myoblasts). This study states the extract caused stronger differentiation of myoblasts to myotubes, de-aggregation of heat-induced aggregated proteins, and activated the hypoxia and autophagy pathways [25]. Ashwagandha extract in C2C12 myoblasts was observed to prove the muscle differentiation

potential and stress tolerance. Skeletal muscle differentiation requires the activation of satellite cells that are normally resident in hypoxic areas of the tissue to maintain them in an undifferentiated state. HIF-1α activation has been described as beneficial for the cell during hypoxic stress and promotes myogenesis. As the result of this study, ashwagandha extract promotes elevated levels of HIF-1α and LC3B-II during myoblasts differentiation. Therefore, withanolides in Ashwagandha have a promoting effect on muscle cell differentiation [25]. These results will support muscle repair as a result of muscle damage-induced exercise [12] [25]. Similar findings were found that supplementation of ashwagandha extract (600mg/day) for 8 weeks has a potential effect to enhance muscle tissue regeneration (21).

Besides muscle recovery, this herbal extract was also found to have total body recovery effects [24]. Research states Total Quality Recovery Scores (TQR) and Daily Analysis of Life Demands for Athletes (DALDA) questionnaires were significantly higher in subjects with ashwagandha supplementation. Similarly, the study using Recovery-Stress Questionnaire for Athletes (RESTQ) evaluation also showed a better result in subjects with supplementation (24). The study also stated that the extract improved cardiovascular endurance so it can impact the recovery process. The improvement of VO2max as an endurance parameter affects the oxygen utilization during the exercise and after exercise [16] [27]. Moreover, antioxidant components in ashwagandha play a significant part in an athlete's recovery after training [12]. Several studies have also shown that Ashwagandha supplementation did not cause adverse effects (vital signs, haematological parameters, and biochemistry) up to a dose of 1000 mg/day [29].

4 Conclusion

Ashwagandha has a potential combination of effects that support endurance during exercise, such as antioxidants, anti-inflammatory, improvement of VO2max, neuroprotective, cardioprotective, and anti-stress. These effects may also improve post-exercise recovery, especially in muscle recovery. The bioactive compound that has a role in effects above is withanolides in ashwagandha. Based on the results, further research studies such as randomized control trials on specific populations should be carried out to evaluate more precisely the effects of ashwagandha on exercise performance.

References

1. SusanLanham-New, SA. Sport and Exercise Nutrition. (West Sussex, UK: Wiley-Blackwell, 2011).
2. Bonilla DA, Moreno Y, Gho C, Petro JL, Odriozola-Martínez A, Kreider RB. Effects of ashwagandha (Withania somnifera) on physical performance: systematic review and bayesian meta-analysis. J Funct Morphol Kinesiol.**6**,1 (2021).
3. Pedro Jose Gonzalez-Matarin. Benefits of Ashwagandha Supplementation on Strength and Endurance Exercise: A Narrative Review. Arch Life Sci Nutr Res [Internet].;**7**(1):1–4 (2023).
4. Sharifi-Rad J, Quispe C, Ayatollahi SA, Kobarfard F, Staniak M, Stępień A, et al. Chemical Composition, Biological Activity, and Health-Promoting Effects of Withania somnifera for Pharma-Food Industry Applications. J Food Qual. (2021)
5. Wankhede, S., D. Langade, K. Joshi, SR. Sinha, and S. Bhattacharyya. Examining the effect of Withania somnifera supplementation on muscle strength and recovery: a randomized controlled trial. Journal of the International Society of Sport Nutrition.**12**:43 (2015). DOI 10.1186/s12970-015-0104-9

6. Ganguly B, Kumar N, Ahmad AH, Rastogi SK. Influence of phytochemical composition on in vitro antioxidant and reducing activities of Indian ginseng [Withania somnifera (L.) Dunal] root extracts. J Ginseng Res [Internet].**42**(4):463–9(2018). Available from: https://doi.org/10.1016/j.jgr.2017.05.002
7. Simur TT. Phytochemical investigation and antioxidant activity of leaf extract of withania somnifera from Konso, South Ethiopia. Orient J Chem.**34**(4):1824–31 (2018).
8. Puteri HS, Dewi YLR, Mulyani S. Relationship Between Sedentary Lifestyle and Fiber Intake Primary Dysmenorrhoea in Overweight Adolescent Girls. J Penelit Pendidik IPA.**9**(11):9454–60 (2023).
9. Devaraj Reddy KN, Aluri S, Shetty P, Udaya S, Prasad S, Sudhanva MS, et al. Assessing the Efficacy and Biological Benefits of Withanolide-rich Withania somnifera Root Extract. Annu Res Rev Biol.**39**(5):54–64 (2024).
10. Munir N, Mahmood Z, Shahid M, Afzal MN, Jahangir M, Ali Shah SM, et al. Withania somnifera Chemical Constituents' In Vitro Antioxidant Potential and Their Response on Spermatozoa Parameters. Dose-Response.**20**,1(2022).
11. Mikulska P, Malinowska M, Ignacyk M, Szustowski P, Nowak J, Pesta K, et al. Ashwagandha (Withania somnifera)—Current Research on the Health-Promoting Activities: A Narrative Review. Pharmaceutics.15,4 (2023).
12. Clemente-Suárez VJ, Bustamante-Sanchez Á, Mielgo-Ayuso J, Martínez-Guardado I, Martín-Rodríguez A, Tornero-Aguilera JF. Antioxidants and Sports Performance. Nutrients.**15**(10):1–35 (2023).
13. Sikandan A, Shinomiya T, Nagahara Y. Ashwagandha root extract exerts anti-inflammatory effects in HaCaT cells by inhibiting the MAPK/NF-κB pathways and by regulating cytokines. Int J Mol Med.**42**(1):425–34 (2018).
14. Tharakan A, Shukla H, Benny IR, Tharakan M, George L, Koshy S. Immunomodulatory effect of withania somnifera (Ashwagandha) extract—A randomized, double-blind, placebo controlled trial with an open label extension on healthy participants. J Clin Med.**10**,16 (2021).
15. Guo R, Gan L, Lau WB, Yan Z, Xie D, Gao E, et al. Withaferin a prevents myocardial ischemia/reperfusion injury by upregulating AMP-activated protein kinase-dependent B-cell lymphoma2 signaling. Circ J.**83**(8):1726–36 (2019).
16. Choudhary B, Shetty A, Langade D. Efficacy of Ashwagandha (Withania somnifera [L.] Dunal) in improving cardiorespiratory endurance in healthy athletic adults. AYU (An Int Q J Res Ayurveda).**36**(1):63 (2015).
17. Gopukumar K, Thanawala S, Somepalli V, Rao TSS, Thamatam VB, Chauhan S. Efficacy and Safety of Ashwagandha Root Extract on Cognitive Functions in Healthy, Stressed Adults: A Randomized, Double-Blind, Placebo-Controlled Study. Evidence-based Complement Altern Med. (2021)
18. Lopresti AL, Smith SJ, Malvi H, Kodgule R, Wane D. An investigation into the stress-relieving and pharmacological actions of an ashwagandha (Withania somnifera) extract: A randomized, double-blind, placebo-controlled study. Med (United States).**98**,37 (2019)
19. Wankhede S, Langade D, Joshi K, Sinha SR, Bhattacharyya S. Examining the effect of Withania somnifera supplementation on muscle strength and recovery: A randomized controlled trial. J Int Soc Sports Nutr [Internet].**12**(1):1–11(2015) http://dx.doi.org/10.1186/s12970-015-0104-9
20. Ziegenfuss TN, Kedia AW, Sandrock JE, Raub BJ, Kerksick CM, Lopez HL. Effects of an aqueous extract of withania somnifera on strength training adaptations and recovery:

The STAR trial. Nutrients.**10**(11):1–18 (2018)

21. Długołęcka B, Jówko E, Kotowska J, Gierczuk D. Effects of Ashwagandha (Withania Somnifera) Supplementation on Body Composition and Blood Health Indices in Professional Wrestlers. Polish J Sport Tour.**30**(4):26–32 (2023)
22. Unlocking A, The S, Impact P, Bródnowski MS, Kondratowicza L, Malinowski P, et al. Unlocking Strength : The Powerful Impact of Ashwagandha (Withania somnifera) Supplementation on Resistance Training.1, (2024)
23. Verma N, Gupta SK, Patil S, Tiwari S, Mishra AK. Effects of Ashwagandha (Withania somnifera) standardized root extract on physical endurance and VO2max in healthy adults preforming resistance training: An eight-week, prospective, randomized, double-blind, placebo-controlled study. F1000Research.12,335 (2023)
24. Guo S, Rezaei MJ. The benefits of ashwagandha (Withania somnifera) supplements on brain function and sports performance. Front Nutr.**11**:1–10 (2024)
25. Wang J, Zhang H, Kaul A, Li K, Priyandoko D, Kaul SC, et al. Effect of ashwagandha withanolides on muscle cell differentiation. Biomolecules. **11**,10(2021)
26. Sukumar BS, T. B. T, H.K. S. Phyto physico-chemical profile of Ashwagandha (Withania somnifera Dunal). J Ayurveda Integr Med Sci.**5**(06):120–9 (2020)
27. Gomez JP, Villafaina S, Adsuar JC. nutrients E ff ects of Ashwagandha (Withania somnifera) on. J Nutr.**12**(1119):1–11 (2020)
28. Torre MF, Martinez-Ferran M, Vallecillo N, Jiménez SL, Romero-Morales C, Pareja-Galeano H. Supplementation with vitamins c and e and exercise-induced delayed-onset muscle soreness: A systematic review. Antioxidants.**10**(2):1–17 (2021)
29. Langade D, Kanchi S, Salve J, Debnath K, Ambegaokar D. Efficacy and Safety of Ashwagandha (Withania somnifera) Root Extract in Insomnia and Anxiety: A Double-blind, Randomized, Placebo-controlled Study. Cureus.**9** (2019)
30. Elhadidy M, Sawie H, Meguid N, Khadrawy Y. Protective effect of ashwagandha (Withania somnifera) against neurotoxicity induced by aluminum chloride in rats. Asian Pac J Trop Biomed.**7**(1):59–66 (2018)