

Effects of ashwagandha (*withania somnifera*) supplementation on strength and anaerobic capacity of upper and lower limbs of elite wrestlers

Dariusz Gierczuk ^{1ADE}, Ewa Jówko ^{2ABCD}, Tomasz Sacewicz ^{3BD}, Barbara Długołęcka ^{2B}, Wiktoria Gierczuk ^{4BD}, Jerzy Sadowski ^{5AE}

Authors' Contribution:

- A Study Design
- B Data Collection
- C Statistical Analysis
- D Manuscript Preparation
- E Funds Collection

Received: date: 22.03.2026

Accepted: date 02.05.2026

Published: date 06.05.2026

¹ Department of Combat Sports, University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biala Podlaska, Poland

² Department of Physiology and Biochemistry, University of Physical Education in Warsaw, Poland; Faculty of Physical Education and Health in Biala Podlaska, Poland

³ Department of Biomechanics, University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biala Podlaska, Poland

⁴ University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biala Podlaska, Poland

⁵ Department of Sport and Training Sciences, University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biala Podlaska, Poland

* **Corresponding author:** Dariusz Gierczuk Department of Combat Sports, University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biala Podlaska, Poland, email address: dariusz.gierczuk@awf.edu.pl

Dictionary:

Greco-Roman wrestling – a sport in which competitors wrestle using only grips above the waist, without using their lower limbs during attacks or defense.

Nutritional supplementation – the use of appropriately selected nutrients or supplements to complement the diet and support the body's proper functioning.

Muscle strength – the body's ability to overcome or resist external forces through muscular effort.

Anaerobic exercise – intense physical exertion performed without oxygen, lasting a short time and based on anaerobic energy metabolism.

Personal safety – a justified sense of survival ability in various emergency situations, either of external nature (e.g. violence, aggression, unintended fall, fire, tsunami) or internal nature (e.g. stress, disease, fear).

Abstract:

Background and study Aim: Wrestling is a strength and endurance sport. Understanding the methods and means that support the development and enhancement of muscle strength and anaerobic capacity can provide valuable insights and facilitate the design of appropriate training programs in competitive wrestling. The aim of this study was the effect of supplementation with ashwagandha on changes in muscle strength and endurance of the upper and lower limbs in highly skilled wrestlers during an 8-week training program.

Material and Methods: The study included 26 elite wrestlers. All participants were enrolled in a structured sports training program. During the 8-week training period, the athletes received either a placebo or an ashwagandha supplement (2×300 mg/day). Before and after the 8-week supplementation period, selected indicators of muscle strength and anaerobic capacity of the upper and lower limb muscles were assessed.

Results: No differences in muscle strength were observed in wrestlers after the placebo and ashwagandha supplementation periods. The rate of decline in maximum upper and lower limb muscle power and the time to maintain maximum lower limb muscle power worsened in the placebo group, which may be a result of the intensive 8-week preparation period. This effect was not observed in the ashwagandha group.

Conclusions: Ashwagandha does not improve muscle strength in elite wrestlers; however, it may enhance athletes' tolerance to fatigue resulting from an intensive training period, as evidenced by measures of anaerobic capacity in the upper and lower limbs. To identify measures and methods for optimizing the training process, further research should be conducted by extending the duration of supplementation or increasing the dose of ashwagandha or other supplements while developing various motor skills in wrestlers, taking into account their athletic level, gender, and fighting style.

Keywords: Greco-Roman wrestling, motor ability, muscle strength, personal safety

1. Introduction

Motor ability constitutes one of the key determinants of athletic excellence across sports disciplines. It assumes particular importance in disciplines that require the highest level of development of multiple motor abilities. Wrestling exemplifies such a sport, as it necessitates a comprehensive manifestation of motor abilities [1-4], with athletic success largely dependent on their interrelationships [5-7]. Failure to adequately develop any component of physical conditioning reduces the likelihood of achieving competitive success. The literature identifies several factors as determinants of performance in wrestling, including upper and lower limb strength, speed, agility, motor coordination, sport-specific endurance, flexibility, and balance; however, there is no full consensus on their relative importance [5-9, 4]. Among these factors, strength and anaerobic endurance are considered particularly significant [8, 10, 11]. Consequently, wrestling is commonly classified as a strength–endurance sport [12, 13, 8, 1].

Dynamic, short-duration movements, as well as active resistance against an opponent, require a high level of muscular strength and anaerobic capacity in both the upper and lower limbs. When combined with appropriate somatic characteristics and other components of wrestling preparation (technical and tactical), these factors may determine an athlete's competitive success [12, 14-16]. Strength and strength endurance, particularly of the arm and trunk muscles, differentiate wrestlers across styles and distinguish successful athletes from their less successful counterparts [17, 10]. For instance, Greco-Roman wrestlers are characterized by greater upper limb strength, including that of the biceps brachii muscle [18, 8]. Moreover, maximum muscular power in both the upper and lower limbs has been shown to be higher in successful wrestlers compared with unsuccessful ones [14, 19, 20, 8].

The development of muscular power is widely recognized as a fundamental prerequisite for achieving success in wrestling [14, 19, 21, 8]. Wrestling bouts are characterized by fluctuating levels of physical exertion, resulting from the frequent execution of explosive movements in both offensive and defensive actions. Such activity leads to a rapid increase in blood lactate concentration, which may reach values of up to 20 mmol/L [22, 23]. An efficient anaerobic energy system is therefore essential for the execution of rapid technical actions, during which additional energy is supplied through the breakdown of phosphocreatine and glycogen. Actions such as lifting, throwing, or resisting an opponent require a high level of strength and anaerobic endurance in both upper and lower limb muscles. This reflects the efficiency and kinetics of phosphagen metabolism (ATP and phosphocreatine), which underpin a high level of speed–strength capacity. Only an adequate development of these motor abilities enables the effective execution of technical skills and may ultimately determine competitive success or failure [23, 12, 14, 15, 24, 16].

The exploration of novel methods for developing motor abilities that may influence the course and effectiveness of wrestling performance constitutes a potential approach to optimizing the training process in contemporary competitive wrestling. One of the strategies employed to optimize the training process is dietary supplementation. Ashwagandha (*Withania somnifera*) is widely recognized as an herb with properties that enhance the body's resistance to both physical and psychological stress. These effects are primarily attributed to bioactive compounds present in ashwagandha root extract, including steroidal lactones (withanolides) and saponins, which are considered responsible for its adaptogenic properties. The mechanisms underlying

these effects are thought to involve the modulation of adrenal and gonadal function [25, 26]. Consequently, ashwagandha supplementation is commonly used with the aim of improving both mental and physical performance [26].

Indeed, a systematic review and meta-analysis conducted by Bonilla et al. [26] indicated that ashwagandha supplementation (at doses ranging from 240 to 600 mg per day) may enhance strength- and power-related outcomes following resistance training programs. However, these findings primarily pertain to untrained individuals and recreationally active men who do not regularly engage in structured training and conditioning programs. In these studies, muscle strength was most often assessed under training conditions using the one-repetition maximum (1-RM) test. Moreover, scientific evidence regarding the efficacy of ashwagandha supplementation in professional sport remains limited and is largely derived from studies conducted in the Indian population [27]. A more recent investigation by Coope et al. [28] examined the effects of 28 days of supplementation with ashwagandha root extract (600 mg per day) on post-exercise recovery and muscle strength in professional Spanish female football players. Compared with placebo, ashwagandha significantly improved perceived recovery. Additionally, analysis of variance revealed a significant group $\times$ time interaction, suggesting a potential increase in handgrip strength (both right and left) in the ashwagandha group; however, post hoc comparisons did not reach statistical significance.

Undoubtedly, there is still a lack of research in the scientific literature assessing the effects of ashwagandha on exercise performance in athletes (including wrestlers), particularly using standardized laboratory methods to evaluate muscle strength (e.g., maximal muscle torque under isokinetic conditions) or anaerobic capacity (e.g., the Wingate test). We recently published the results of our studies examining the effects of ashwagandha supplementation on blood biochemical indicators, including markers related to post-exercise recovery (muscle damage), as well as body composition, special endurance, and reaction time in highly qualified Greco-Roman wrestlers [29, 30]. However, there is still a clear lack of information in the literature on the wrestling training process regarding the effects of dietary supplementation on key motor abilities, such as muscle strength and anaerobic capacity. Supplementing the data on available dietary supplements—including ashwagandha—regarding their effects on the motor skills of wrestlers at the highest levels of training can provide valuable insights for coaching.

It is also important to emphasize the broader scope and significance of this line of research. Skills acquired through hand-to-hand combat training contribute to the development of self-esteem and psychological resilience, while also enhancing self-defence capabilities. These benefits extend beyond the physical dimension associated with sport and combat disciplines, encompassing a wider capacity for personal protection, including the safeguarding of both the individual and their property [31,33]. Accordingly, a more comprehensive approach to interpreting research findings in athletes with diverse motor profiles may provide a new perspective, enabling the formulation of recommendations that extend beyond the narrow relationship between performance outcomes and their direct application in sport.

The aim of the present study was the effects of ashwagandha supplementation on changes in muscle strength and anaerobic capacity of the upper and lower limbs in highly trained wrestlers during an 8-week training period.

2. Materials and Methods

Experimental Approach to the Problem

During 8 weeks, the athletes followed a structured training program in preparation for a major sporting event. Muscle strength and anaerobic capacity were assessed before (term I) and after the supplementation period (term II). The experiment was designed to provide insight into the effectiveness and potential application of ashwagandha supplementation for improving wrestlers' performance.

Participants

The study involved professional, highly qualified Greco-Roman wrestlers (juniors) of the Polish national team. The exclusion criteria were as follows: chronic diseases, orthopaedic injuries or surgeries in the past six months, taking drugs or steroids to increase physical performance, intake of sleep or anti-anxiety medications, as well as taking herbal or other dietary supplements with antioxidant and anti-inflammatory effects in the last three months before the study.

Twenty-six wrestlers were recruited for the experiment and randomly allocated, in a double-blind manner, to 2 groups: ashwagandha (A, $n = 12$) or placebo (P, $n = 14$). Five wrestlers withdrew from the study, including four participants (1 from group A and 3 from group P) for personal reasons, and one participant (from group A) due to intolerance to the ashwagandha preparation (diarrhoea). Finally, 21 wrestlers (10 from group A and 11 from group P) completed the study and their results were analysed. Study participants were asked to maintain their current eating habits and avoid dietary modifications throughout the study period.

The age of the wrestlers in group P was 19.1 ± 1.8 years, with a training experience of 11.0 ± 3.0 years, while the wrestlers in group A had an average age of 20.8 ± 1.9 years and a training experience of 11.6 ± 3.5 years. The body height and weight of the athletes in group P were 178.7 ± 7.3 cm and 78.2 ± 10.8 kg, respectively, while these indicators in group A were 177.4 ± 7.8 cm and 81.9 ± 19.6 kg. Prior to the study, written consent was obtained from the participants, along with a current medical certificate confirming their good health. For those under 18 years of age, the written consent of parents/legal guardians has been obtained. The athletes were also informed of the risks and benefits of the study prior to any data collection. Participation in the study was voluntary and preceded by a detailed explanation of the measurement procedure.

Study design

The eight-week experiment was part of a planned training program (the second and third phases of the preparatory period) aimed at optimally preparing the athletes for the Polish Senior Greco-Roman Wrestling Championships, in accordance with the specific characteristics of this sport [34-36]. The preparatory period lasted a total of 14 weeks. Ten training sessions were conducted each week (in the morning and afternoon), each lasting 120 minutes. The average training volume (identified in this project only with 'time' among many elements specified in the professional language of training theory) and intensity were similar for all participants. The total training time was 280 hours, with varying specifics, intensity, and complexity to prevent overtraining [37]. In accordance with recommendations in the literature, the first 6-week portion of the preparatory period (prior to the experiment) focused on developing general endurance [38]. The main activities included: refining wrestling technique, cross-country athletics (walking-running, running, running games), team sports

(simplified basketball, soccer), and coordination exercises with acrobatic elements. The effort during this part of the preparatory period was aerobic in nature. The average intensity of the athletes' work was moderate. The second part of the preparatory period (5 weeks) focused on improving technical skills through task-based sparring (35%), strength endurance (25%), strength (dynamic 15% and static 5%), as well as speed (15%) and sport-specific fitness (5%). The training methods used during this period were tailored to the specific nature of wrestling (turning around the head, bridge exercises, dummy throws). The training was of a mixed nature, and the athletes' average intensity ranged between high intensity and submaximal intensity. In turn, training in the third part of the preparatory period (3 weeks), according to modern periodization concepts [39], was focused on improving specific endurance (40%), technical and tactical skills (30%), speed (20%), and specific fitness (10%). During this phase of the preparatory period, specialized exercises and sparring matches were primarily used. The effort was of a mixed and anaerobic nature, and the average intensity of the athletes' work ranged from submaximal to maximal intensity. Performance intensity was determined based on heart rate (HR) measured immediately after physical exertion, where HR <125 bpm – low intensity, 126–145 bpm – moderate intensity, 146–175 bpm – high intensity, 176–195 bpm – submaximal intensity, >195 bpm – maximal intensity [40]. The Polar M400 watch was used to record HR.

During the 8-week training period, participants ingested two capsules per day containing either an ashwagandha preparation or a placebo. Each ashwagandha capsule contained 300 mg of ashwagandha root extract (KSM-66), standardized to 5% withanolides as determined by HPLC. The dosage of ashwagandha extract (2 × 300 mg daily) was consistent with the manufacturer's recommendations for physically active individuals [26].

The placebo capsules were produced by the same manufacturer as the ashwagandha supplement and were identical in appearance (size, shape, and colour) to the ashwagandha capsules. Participants were instructed to take the capsules twice daily after meals (1–2 hours after breakfast and dinner). Each week, athletes were provided with capsules in dark, non-transparent bottles and were asked to report the number of missed capsules. Three wrestlers in the placebo group (P) and two wrestlers in the ashwagandha group (A) reported missing single doses, not exceeding 10% of the total number of capsules. Participants were also asked weekly about their mood and any potential side effects of supplementation (e.g., abdominal pain, diarrhoea, vomiting, headaches, dizziness, or drowsiness). Overall, participants in both groups reported good tolerance of the capsules, and no adverse events were observed. As mentioned above, only one participant from group A withdrew from the study due to intolerance to the ashwagandha capsules.

Measurements of muscle strength and anaerobic endurance in the upper and lower limbs were performed twice during the preparatory period, before and after 8 weeks of supplementation. The measurements were conducted in accordance with the principles of sports metrology.

Muscle strength testing was performed on a Biodex System 4 Pro isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA). During each measurement session, two tests were performed in the following order: Test 1—muscles of the knee extensors and flexors at angular velocities of 60°/s and 180°/s (first 'strength' trial, second 'endurance' trial) and Test 2—internal and external rotators of

the shoulder joint at angular velocities of 60°/s and 180°/s (first ‘strength’ trial, second ‘endurance’ trial).

Prior to the test, participants underwent a standardized five-minute warm-up consisting of cycling on an ergometer at a light intensity, as well as mobility and stretching exercises for the upper and lower limbs. Participants were then familiarized with the device and performed 2–3 submaximal trials for each type of movement to minimize the learning effect. Before each measurement series, participants were instructed to exert maximum, strongest possible effort throughout the full range of motion, both during the concentric extension and flexion phases (external and internal rotation in the shoulder joint, respectively).

The subject performed Test 1 (knee extensors and flexors) while seated in the dynamometer chair. The trunk was positioned at a slight angle (85°); the pelvis and trunk were stabilized with hip and chest straps; the tested lower limb was positioned so that the dynamometer’s axis of rotation coincided with the axis of rotation of the knee joint (lateral femoral condyle); the lever arm was attached to the lower leg approximately 2–3 cm above the medial malleolus using a soft strap; the contralateral limb was stabilized with a belt. The range of motion in the knee joint was determined individually, typically between approximately 90° of flexion and near full extension, excluding the final few degrees if the patient reported discomfort. This range was recorded in the device’s software. Prior to the test, gravitational correction was performed according to the manufacturer’s instructions: the gravitational moment of the limb and the lever arm were recorded during passive knee extension and then incorporated into the calculations by the Biodex software. For each joint, the test was conducted in concentric mode (flexion–extension): 60°/s – low speed, assessing maximum force moment, 5 maximum repetitions; 180°/s – medium speed, assessing the ability to generate force at a higher speed, 10 maximum repetitions. A 30-second rest was taken between sets for different speeds. Order of limbs tested (right/left) – the examination always began with the dominant limb. The torque of the knee extensors and flexors (Nm) was measured.

The subject performed Test 2 (internal and external rotators of the shoulder joint) in a seated position, with the trunk stabilized by straps, the shoulder abducted to 90°, and the elbow flexed to 90°. The hand of the tested limb gripped the handle of the dynamometer lever, ensuring a proper grip and stability of the distal segment during the rotational movement. The forearm was positioned in a neutral position. The dynamometer’s axis of rotation was aligned with the axis of rotation in the shoulder joint according to the manufacturer’s procedure. The range of internal and external rotation was determined individually, most commonly within approximately 45–60° of external rotation and 45–60° of internal rotation relative to the neutral position, excluding the extreme ranges if they caused pain. Prior to the actual test, gravitational correction was performed for the upper limb in the initial position, in accordance with the manufacturer’s procedure. The test was conducted in concentric mode for external and internal rotation: 60°/s – low speed, 5 maximal repetitions; 180°/s – medium speed, 10 maximal repetitions. A 30-second rest period was observed between sets. The order of testing the upper limbs (dominant/non-dominant) was maintained in accordance with the procedure used for the knee joints. External and internal rotators of the left and right upper limbs were assessed (Nm).

The anaerobic capacity of the upper and lower limb muscles was also measured twice (before and after the supplementation period) using the 30-second Wingate test [41].

The test itself was preceded by a five-minute warm-up at a load of 50 W. The test began 5 minutes after the warm-up ended. The load depended on the individual body weight of the subject. For the upper limbs, it was 55 g/kg, and for the lower limbs, 75 g/kg of the subject's body weight. The following parameters characterizing anaerobic capacity were determined: maximum power ($\text{W} \cdot \text{kg}^{-1}$); total work ($\text{J} \cdot \text{kg}^{-1}$); mean power ($\text{W} \cdot \text{kg}^{-1}$); time to reach maximum power (s); time to maintain maximum power (s); maximum power decline rate (%).

Statistical analysis

Statistical analyses were performed using Statistica version 13.3 (StatSoft, Kraków, Poland). The normality of the data distribution was assessed using the Shapiro–Wilk test and visual inspection of quantile distribution plots. Homogeneity of variance was verified using Levene's test. All results are presented as mean standard deviation (SD or $\pm$). The level of statistical significance was set at $p < 0.05$.

Intergroup differences (A vs. P) in anthropometric characteristics (age and height) were evaluated using an independent samples Student's t-test. Variables related to physical performance were analysed using a two-way repeated-measures ANOVA with two factors: group (P vs. A) and time (term I vs. term II). Tukey's post hoc test was applied for multiple comparisons. In addition, the effect size for the ANOVA was calculated using eta squared (η^2).

3. Result

The maximal torque of the knee joint flexors and extensors, assessed at an angular velocity of $60^\circ/\text{s}$ under isokinetic conditions in highly trained wrestlers, was found to be independent of the preparatory phase of the training process (Table 1). Repeated-measures analysis of variance revealed no significant main effects ($p > 0.05$). Furthermore, Tukey's post hoc test indicated no significant differences between the first and second measurement sessions ($p > 0.05$). No significant differences were also observed between groups A and P ($p > 0.05$). A comparable pattern was identified in the assessment of maximal torque of the knee joint flexors and extensors at an angular velocity of $180^\circ/\text{s}$, corresponding to the endurance test.

Table 1. Maximum muscle torque of the lower limbs (knee joint) during an isokinetic test 1, before (term I) and after (term II) an 8-week wrestling training program combined with ashwagandha (A) or placebo (P) supplementation (M & SD).

Knee joint (Nm)	Group P		Group A		Main effects: p-values; effect size η^2		
	term I	term II	term I	term II	term	group	term x group interaction
Tensile test (60 deg/s)							
torque of the extensor muscles of the left knee joint	238.2 ± 42.06	232.0 ± 34.98	219.6 ± 52.74	221.6 ± 58.12	$p = 0.71$ $\eta^2 = 0.008$	$p = 0.49$ $\eta^2 = 0.03$	$p = 0.48$ $\eta^2 = 0.03$
torque of the flexor muscles of the left knee joint	116.4 ± 26.11	120.5 ± 23.32	115.2 ± 14.04	114.0 ± 20.20	$p = 0.65$ $\eta^2 = 0.01$	$p = 0.69$ $\eta^2 = 0.009$	$p = 0.40$ $\eta^2 = 0.04$
torque of the extensor muscles of the right knee joint	240.5 ± 28.61	237.6 ± 31.38	214.4 ± 44.63	216.5 ± 56.93	$p = 0.95$ $\eta^2 = 0.0002$	$p = 0.20$ $\eta^2 = 0.09$	$p = 0.65$ $\eta^2 = 0.01$

torque of the flexor muscles of the right knee joint	127.9 ±26.09	123.6 ±24.84	112.5 ±25.68	112.2 ±23.45	p = 0.52 η ² = 0.02	p = 0.24 η ² = 0.08	p = 0.58 η ² = 0.02
Endurance test (180°/s)							
torque of the extensor muscles of the left knee joint	166.3 ±28.99	168.3 ±28.79	149.6 ±39.26	156.2 ±40.41	p = 0.24 η ² = 0.08	p = 0.36 η ² = 0.05	p = 0.51 η ² = 0.03
torque of the flexor muscles of the left knee joint	92.48 ±21.60	92.58 ±19.86	91.45 ±24.59	80.35 ±17.52	p = 0.13 η ² = 0.13	p = 0.48 η ² = 0.03	p = 0.12 η ² = 0.13
torque of the extensor muscles of the right knee joint	164.8 ±20.63	166.2 ±21.35	166.6 ±43.11	162.1 ±41.28	p = 0.62 η ² = 0.01	p = 0.94 η ² = 0.004	p = 0.33 η ² = 0.05
torque of the flexor muscles of the right knee joint	93.5 ±17.09	94.62 ±19.24	92.59 ±21.72	87.15 ±23.55	p = 0.42 η ² = 0.04	p = 0.65 η ² = 0.01	p = 0.23 η ² = 0.08

The training loads applied during the preparatory period did not influence changes in the maximal torque of the internal and external rotators of the shoulder joint, as assessed at an angular velocity of 60°/s under isokinetic conditions in highly trained wrestlers (Table 2). No significant differences were observed between athletes in groups P and A ($p > 0.05$). A similar pattern was found in the evaluation of maximal torque of the shoulder joint rotators at an angular velocity of 180°/s, corresponding to the endurance test.

Table 2. Maximum upper limb muscle torque (shoulder joint) during an isokinetic test 2, before (term I) and after (term II) an 8-week wrestling training program combined with ashwagandha (A) or placebo (P) supplementation (M & SD).

Shoulder joint (Nm)	Group P		Group A		Main effects: p-values; effect size η ²		
	term I	term II	term I	term II	term	group	term x group interaction
Tensile test (60 deg/s)							
external rotators of the left upper limb	39.79 ±15.12	37.72 ±7.93	35.81 ±8.47	37.91 ±6.90	p = 0.16 η ² = 0.11	p = 0.17 η ² = 0.11	p = 0.09 η ² = 0.23
internal rotators of the left upper limb	80.78 ±16.89	74.10 ±14.0	75.65 ±18.69	75.44 ±15.33	p = 0.20 η ² = 0.09	p = 0.79 η ² = 0.004	p = 0.23 η ² = 0.08
external rotators of the right upper limb	44.83 ±15.68	43.06 ±15.96	42.65 ±17.99	35.16 ±9.18	p = 0.18 η ² = 0.10	p = 0.43 η ² = 0.04	p = 0.39 η ² = 0.04
internal rotators of the right upper limb	82.57 ±17.31	80.88 ±15.63	76.14 ±22.93	78.84 ±22.32	p = 0.78 η ² = 0.005	p = 0.63 η ² = 0.01	p = 0.23 η ² = 0.08
Endurance test (180°/s)							
external rotators of the left upper limb	35.65 ±7.58	36.63 ±9.28	32.29 ±6.90	32.56 ±9.08	p = 0.66 η ² = 0.01	p = 0.31 η ² = 0.06	p = 0.81 η ² = 0.003
internal rotators of the left upper limb	70.90 ±15.20	71.34 ±11.64	69.20 ±18.93	66.36 ±15.84	p = 0.49 η ² = 0.03	p = 0.63 η ² = 0.01	p = 0.35 η ² = 0.05
external rotators of the right upper limb	36.35 ±9.74	39.12 ±9.84	33.65 ±9.34	33.28 ±10.26	p = 0.52 η ² = 0.02	p = 0.32 η ² = 0.06	p = 0.40 η ² = 0.04
internal rotators of the right upper limb	71.92 ±15.74	72.26 ±13.31	66.91 ±21.87	66.04 ±18.04	p = 0.87 η ² = 0.002	p = 0.48 η ² = 0.03	p = 0.70 η ² = 0.009

For the upper limbs, no significant main effects were observed for maximum power, total work performed, or the time required to reach and maintain maximum power ($p > 0.05$). A trend toward a time $\times$ group interaction was noted for mean power ($p = 0.05$); however, post hoc analysis did not reveal any significant differences (Table 3). The only statistically significant effect was observed for the rate of decline in maximum power (time $\times$ group interaction; $p = 0.04$), with a significant increase in group P ($p < 0.05$), whereas no change was found in group A ($p > 0.05$).

Table 3. Changes in anaerobic capacity of upper limbs indicators in elite wrestlers before (term I) and after (term II) an 8-week wrestling training program combined with ashwagandha (A) or placebo (P) supplementation (M & SD).

Anaerobic capacity (indicator)	Group P		Group A		Main effects: p-values; effect size η^2		
	term I	term II	term I	term II	term	group	term $\times$ group interaction
maximum power (W kg^{-1})	11.74 ± 2.89	13.25 ± 1.96	13.14 ± 1.43	13.32 ± 3.64	$p = 0.27$ $\eta^2 = 0.07$	$p = 0.42$ $\eta^2 = 0.04$	$p = 0.37$ $\eta^2 = 0.04$
total work (J kg^{-1})	191.9 ± 28.24	186.5 ± 37.28	188.8 ± 39.55	197.7 ± 42.07	$p = 0.71$ $\eta^2 = 0.007$	$p = 0.80$ $\eta^2 = 0.003$	$p = 0.14$ $\eta^2 = 0.12$
mean power (W kg^{-1})	6.90 ± 0.95	6.57 ± 1.38	6.65 ± 1.37	6.96 ± 1.47	$p = 0.93$ $\eta^2 = 0.0004$	$p = 0.90$ $\eta^2 = 0.0008$	$p = 0.05$ $\eta^2 = 0.19$
time to reach maximum power (s)	1.66 ± 1.29	1.01 ± 0.48	1.01 ± 0.17	1.11 ± 0.51	$p = 0.24$ $\eta^2 = 0.07$	$p = 0.29$ $\eta^2 = 0.06$	$p = 0.11$ $\eta^2 = 0.13$
time to maintain maximum power (s)	6.14 ± 5.16	3.97 ± 3.55	3.66 ± 1.79	3.67 ± 2.08	$p = 0.15$ $\eta^2 = 0.11$	$p = 0.33$ $\eta^2 = 0.05$	$p = 0.15$ $\eta^2 = 0.11$
maximum power decline rate (%)	59.59 ± 12.32	72.13 $\pm 11.53^*$	69.98 ± 14.34	65.42 ± 14.17	$p = 0.32$ $\eta^2 = 0.05$	$p = 0.67$ $\eta^2 = 0.009$	$p = 0.04$ $\eta^2 = 0.21$

* $p < 0.05$, significant differences between term I and term II, within the same group.

Similar patterns were identified for the anaerobic capacity indicators of the lower limbs (Table 4). No significant main effects were observed for total work, mean power, or time to reach maximum power ($p > 0.05$). In the case of maximum power, only a trend toward a time $\times$ group interaction was observed ($p = 0.06$), with no significant differences in post hoc comparisons. A tendency toward a significant time effect was noted for the rate of power decline ($p = 0.07$), with an increase observed in group P ($p < 0.05$). Additionally, a significant time $\times$ group interaction was found for the duration of maximum power maintenance ($p = 0.049$), characterized by a significant decrease in group P ($p < 0.05$), while no changes were observed in group A ($p > 0.05$).

Table 4. Changes in anaerobic capacity of lower limbs indicators in elite wrestlers before (term I) and after (term II) an 8-week wrestling training program combined with ashwagandha (A) or placebo (P) supplementation (M & SD).

Anaerobic capacity (indicator)	Group P		Group A		Main effects: p-values; effect size η^2		
	term I	term II	term I	term II	term	group	term x group interaction
maximum power ($W \cdot kg^{-1}$)	16.91	17.89	17.76	16.77	p = 0.98	p = 0.87	p = 0.06
	± 2.11	± 1.73	± 1.83	± 2.38	$\eta^2 = 0.0001$	$\eta^2 = 0.001$	$\eta^2 = 0.18$
total work ($J \cdot kg^{-1}$)	264.2	263.2	256.4	254.5	p = 0.71	p = 0.36	p = 0.89
	± 21.51	± 25.22	± 15.88	± 20.9	$\eta^2 = 0.007$	$\eta^2 = 0.05$	$\eta^2 = 0.0009$
mean power ($W \cdot kg^{-1}$)	9.32	9.22	9.07	8.95	p = 0.41	p = 0.42	p = 0.93
	± 0.78	± 0.83	± 0.52	± 0.80	$\eta^2 = 0.04$	$\eta^2 = 0.04$	$\eta^2 = 0.0004$
time to reach maximum power (s)	1.24	0.96	1.29	1.04	p = 0.14	p = 0.64	p = 0.95
	± 0.31	± 0.27	± 0.88	± 0.33	$\eta^2 = 0.12$	$\eta^2 = 0.01$	$\eta^2 = 0.0003$
time to maintain maximum power (s)	6.05	4.65	4.01	4.60	p = 0.40	p = 0.31	p = 0.049
	± 2.03	$\pm 2.15^*$	± 2.38	± 3.38	$\eta^2 = 0.04$	$\eta^2 = 0.06$	$\eta^2 = 0.20$
maximum power decline rate (%)	62.07	65.40	64.22	64.41	p = 0.07	p = 0.84	p = 0.1
	± 7.51	$\pm 7.30^*$	± 6.25	± 5.47	$\eta^2 = 0.16$	$\eta^2 = 0.002$	$\eta^2 = 0.14$

* $p < 0.05$, differences between term I and term II, within the same group.

4. Discussion

The aim of this study was to evaluate the effect of ashwagandha supplementation on changes in selected indicators of muscle strength and anaerobic capacity in the upper and lower limbs of elite wrestlers during an 8-week training program.

No significant differences in muscle strength were observed between wrestlers receiving ashwagandha and those receiving a placebo following the 8-week intervention. Several factors may account for these findings. For instance, the athletes' high level of performance, particularly in terms of muscular strength, may have limited the effectiveness of supplementation, or the specific properties of the supplement may not have aligned with the requirements for further development of this motor ability. Additionally, the training loads applied during the study period did not primarily emphasize strength development.

It should be noted that other studies have reported improvements in muscle strength following ashwagandha supplementation using a regimen comparable to that employed in the present study (i.e., 600 mg/day for 8 weeks). However, these investigations assessed strength under training conditions using one-repetition maximum (1-RM) tests [42, 43], and were conducted in untrained individuals undergoing resistance training. Ziegenfuss et al. [44], in a cohort of recreationally active individuals engaged in resistance training (performed independently, without researcher supervision), observed improvements in muscle strength (1-RM in the bench press and squat) following ashwagandha supplementation at a slightly lower dose (500 mg/day) administered over a longer period (12 weeks). Similarly, Coope et al. [28], in a group of professional athletes (female soccer players), reported a

significant time $\times$ group interaction in handgrip strength, suggesting a potential ergogenic effect of ashwagandha supplementation (8 weeks, 600 mg/day); however, no statistically significant differences were found in post hoc analyses. Taken together, these findings suggest that elite athletes may require higher doses of ashwagandha or a longer supplementation period to elicit measurable improvements in strength-related outcomes.

On the other hand, in the present study, supplementation with 600 mg of ashwagandha (300 mg twice daily) appeared to be a differentiating factor among wrestlers with respect to changes in anaerobic capacity parameters of the upper and lower limbs in response to an 8-week training program. Although no significant between-group differences were observed in the examined indicators after the intervention (post-test), significant within-group changes were identified. These changes occurred in athletes who received a placebo during the preparatory period and were manifested as a decline in selected performance indicators, namely an increased rate of power decrease in the upper limbs and a reduced duration of maximum power maintenance in the lower limbs during a 30-second maximal anaerobic effort. These differences were evident between the two measurement sessions (pre- and post-intervention). This effect can most likely be attributed to accumulated fatigue resulting from participation in an intensive 8-week preparatory training phase. It should be emphasized that during this period, particularly in its latter stages, training initially emphasized the development of technical skills through task-oriented sparring, strength endurance, and dynamic strength, as well as speed and sport-specific fitness. Subsequently, the training focus shifted toward the improvement of sport-specific endurance, technical and tactical skills, speed, and overall sport-specific fitness. The process primarily involved specialized exercises and sparring sessions. Consistent with the adopted periodization model, the workload was predominantly of a mixed and anaerobic nature [39, 35, 36]. These findings indicate that the applied training methods were appropriately selected and aligned with the principles of sports training, in which the development of fatigue, or even a state approaching overreaching, may constitute a desirable adaptation. Notably, such a decline in performance was not observed in the group receiving ashwagandha supplementation. This may suggest a beneficial effect of ashwagandha on recovery processes and a more rapid attenuation of fatigue-related effects, as no significant changes in the rate of power decline or the duration of maximum power maintenance were observed in the experimental group (A).

One of the mechanisms underlying the attenuation of fatigue during maximal exercise following ashwagandha supplementation may involve its favourable effects on stress hormone levels and the anabolic–catabolic balance. The biological activity of ashwagandha is primarily attributed to ergostane-based steroidal lactones, known as withanolides, which represent the principal bioactive compounds found in various parts of the plant, particularly in its roots [45].

Clinical trial findings suggest that ashwagandha supplementation may be associated with a modest reduction in serum cortisol levels and an increase in serum testosterone concentrations in both men and women [45]. Another potential mechanism contributing to reduced fatigue and enhanced recovery following ashwagandha supplementation involves the attenuation of oxidative stress. It has been reported that ashwagandha root extract contains compounds with antioxidant and anti-inflammatory properties [46, 47]. Consequently, ashwagandha may support overall health status and facilitate post-exercise recovery. However, some authors emphasize

the need for further research to confirm these effects and to better elucidate the underlying mechanisms [48].

In the present study, an 8-week ashwagandha supplementation regimen appeared to contribute to a reduction in fatigue among elite athletes, which may have translated into more effective exercise performance. However, no significant effects of ashwagandha were observed on changes in maximal power, total work performed, or indices of upper and lower limb muscle strength. These findings should be interpreted with caution, as they are preliminary in nature. It is noteworthy that the deterioration in anaerobic capacity parameters observed in group P, but not in group A, may be partially explained by baseline intergroup differences (albeit not statistically significant) at the initial testing phase (Term I). Specifically, the mean value of the power decline index in Term I was slightly lower in group P than in group A, whereas the mean duration of maximum power maintenance was slightly higher in group P compared to group A. Due to the limited number of studies investigating the effects of ashwagandha on key motor abilities in highly trained Greco-Roman wrestlers, direct comparisons with existing literature are challenging. This underscores the need for further research aimed at elucidating the mechanisms underlying the potential fatigue-reducing effects of ashwagandha.

It is widely acknowledged that detecting the benefits of various interventions—including supplementation—is more challenging in highly trained athletes than in individuals with low or moderate levels of physical activity. Nevertheless, this does not diminish the need to explore novel approaches and strategies aimed at enhancing and sustaining athletic performance at a high level, thereby contributing to the attainment of athletic excellence.

One of the strengths of the present study is the use of a pedagogical experimental design. Two groups—an experimental group and a control group—were randomly selected from among highly trained athletes. It is also noteworthy that the 8-week training intervention preceded participation in major competitive events and was conducted under the supervision of qualified coaches, with athletes additionally supported by a qualified dietitian. Furthermore, wrestling-specific tests were employed to assess key motor abilities of Greco-Roman wrestlers. The findings of this study provide valuable supplementary evidence regarding the effects of ashwagandha supplementation on exercise capacity in highly trained Greco-Roman wrestlers [29, 30].

Among the limitations of the present study is the relatively short duration of the supplementation period. Unfortunately, the two phases of the preparatory period (the second and third) preceding major competitions of this type were of limited duration, and extending them would have necessitated modifications to the training structure and its primary objectives. Another limitation is the small sample size, which is attributable to the naturally limited population of elite athletes. Moreover, the study included athletes competing at the national level, which may further restrict the generalizability of the findings.

Given the specific nature of competitive wrestling, analyses that incorporate multiple dimensions of athlete preparation—such as technical, tactical, and psychological factors—hold greater practical relevance, particularly in the context of performance at the highest competitive level. Such comprehensive approaches may contribute to the development of more reliable criteria for talent identification and the formulation of effective training strategies. Experimental research is needed to examine the

complex and multifactorial determinants of elite athletic performance, thereby enabling the identification of new directions for optimizing the training process in wrestlers. Future studies should also focus on evaluating the effects of various dietary supplements and training interventions on the exercise capacity of wrestlers across different levels of athletic proficiency, styles of combat, and genders. A better understanding of the factors influencing optimal physical preparation in wrestlers may provide a foundation for rationalizing the training process, particularly in the domain of physical conditioning. These considerations should be taken into account when selecting training methods aimed at the development of specific components of a wrestler's physical fitness.

The skills developed through hand-to-hand combat training extend beyond purely athletic and competitive contexts and are also highly relevant in everyday life, where individuals encounter various challenges and demands. The pursuit of new methods to enhance combat effectiveness aligns with the second component of the mission promoted by the recently established applied science field of INNOAGON [49-53], namely, survival in its broadest sense. Improving athletes' physical performance is thus closely associated with personal safety, understood in a comprehensive and holistic manner [31-33].

5. Conclusions

In highly trained wrestlers undergoing a preparatory training program, an 8-week supplementation regimen with 600 mg of ashwagandha daily does not appear to enhance muscle strength; however, it may improve athletes' tolerance to fatigue associated with an intensive preparatory period, as reflected in the anaerobic capacity of the upper and lower limb muscles.

To further identify strategies for optimizing the training process, future research should consider extending the duration of supplementation or adjusting the dosage of ashwagandha and other supplements, particularly in the context of developing muscular strength and endurance in wrestling. It is also recommended that study populations be expanded to include athletes of different performance levels, genders, and wrestling styles. Additionally, other variables determining performance effectiveness in competitive wrestling should be investigated.

Conflict of interest: The authors declare no existing conflict of interest for the content of the article.

Approval by the Ethical Committee: The study was carried out on the basis of the principles of the Declaration of Helsinki and the study protocol was approved by the Ethical Committee of Józef Piłsudski University of Physical Education in Warsaw (SKE 01-43/2022).

Source of support: The research was carried at the Faculty of Physical Education and Health in Białą Podlaską, using specialized equipment on the premises of the Regional Center for Research and Development in Białą Podlaską. The study was conducted within university research project no. UPB7 of the Faculty of Physical Education and Health in Białą Podlaską, Józef Piłsudski University of Physical Education in Warsaw.

Informed Consent Statement: Not applicable

References

1. Vanttinen T. Strength and training profiles of top Greco-Roman wrestlers in Finland. In: *Applicable Research in Wrestling: International Scientific and Professional Conference on Wrestling*. M. Baić, P. Drid, W. Starosta et al. eds. Novi Sad, Zagreb 2017; 253.
2. Cieśliński I, Gierczuk D, Sadowski J. Identification of success factors in elite wrestlers - An exploratory study. *Plos One* 2021; 16 <https://doi.org/10.1371/journal.pone.0247565>
3. Gierczuk D, Sadowski J. Fitness profiles of successful and less successful Greco-Roman and freestyle wrestlers. *J Phys Educ Sport* 2021; 21(6): 3541-3546 <https://doi.org/10.7752/jpes.2021.06479>
4. Tutar M, Biyikli T, Ildem C et al. An investigation of some motoric characteristics of national elite wrestling athletes. *Sci Mov Health* 2024; 24(1): 50-57
5. Baić M, Sertić H, Starosta W. Differences in physical fitness levels between the classical and the free style wrestlers. *Kinesiol* 2007; 39(2): 142-149 <https://hrcak.srce.hr/21952>
6. Ackland TR, Elliott B, Bloomfield J. *Applied Anatomy and Biomechanics in Sport* 2nd ed., Hum Kinet 2009
7. Mirzaei B, Curby DG, Barbas I et al. Anthropometric and physical fitness traits of four-time World Greco-Roman wrestling champion in relation to national norms: A case study. *J Hum Sport Exerc* 2011; 6: 406-413 <https://doi.org/10.4100/jhse.2011.62.21>
8. Nikooie R, Cheraghi M, Mohamadipour F. Physiological determinants of wrestling success in elite Iranian senior and junior Greco-Roman wrestlers. *J Sports Med Phys Fitness* 2017; 57: 219-226 <https://doi.org/10.23736/S0022-4707.16.06017-5>
9. Sadowski J, Cieslinski I, Gierczuk D. Response time of athletes with different sports specializations. *Arch Budo J Inn Agon* 2024; 20: 162-173
10. Baić M, Trajković N, Đorđević D et al. Strength profile in wrestlers—a systematic review. *Arch Budo* 2022; 18: 151-164
11. Özbay S, Ulupınar S. Strength-power tests are more effective when performed after exhaustive exercise in discrimination between top-elite and elite wrestlers. *J Strength Cond Res* 2022; 36(2): 448-454 <https://doi.org/10.1519/JSC.0000000000003456>
12. Hübner-Woźniak E, Kosmol A, Lutoslawska G et al. Anaerobic performance of arms and legs in male and female free style wrestlers. *J Sci Med Sport* 2004; 7: 473-480 [https://doi.org/10.1016/S1440-2440\(04\)80266-4](https://doi.org/10.1016/S1440-2440(04)80266-4)
13. Gierczuk D, Hübner-Woźniak E, Długolecka B. Influence of training on anaerobic power and capacity of upper and lower limbs in young Greco-Roman wrestlers. *Biol Sport*; 2012; 29(3): 235-239 <https://doi.org/10.5604/20831862.1003449>
14. Mirzaei B, Curby DG, Rahmani-Nia F et al. Physiological profile of Iranian junior freestyle wrestlers. *J Strength Cond Res* 2009; 23: 2339-2344 <https://doi.org/10.1519/JSC.0b013e3181bb7350>
15. Demirkan E, Koz M, Kutlu M et al. Comparison of physical and physiological profiles in elite and amateur young wrestlers. *J Strength Cond Res* 2015; 29: 1876-1883 <https://doi.org/10.1519/JSC.0000000000000833>
16. Azizov A. The integration of complex technical-tactical and physical movements in Greco-Roman wrestling. *Ment Enligh Sci-Methodol J* 2025; 6(01): 42-47 <https://doi.org/10.37547/mesmj-V6-I1-06>
17. Sterkowicz S, Starosta W. Selected factors influencing the level of general fitness in elite Greco Roman wrestlers. *J Hum Kinet* 2005; 14: 93-104
18. Nilsson J, Csörgö S, Gullstrand L et al. Work-time profile, blood lactate concentration and rating of perceived exertion in the 1998 Greco-Roman wrestling World Championship. *J Sports Sci* 2002; 20(11): 939-945 <https://doi.org/10.1080/026404102320761822>
19. García-Pallarés J, López-Gullón JM, Muriel X et al. Physical fitness factors to predict male Olympic wrestling performance. *Eur J Appl Physiol* 2011; 111(8): 1747-1758 <https://doi.org/10.1007/s00421-010-1809-8>
20. López-Gullón JM, Muriel X, Torres-Bonete MD et al. Physical fitness differences between Freestyle and Greco-Roman elite wrestlers. *Arch Budo* 2011; 7(4): 217-225
21. Starosta W, Fostiak D. Levels of Movement Coordination in Elite Freestyle and Classical Style Wrestlers of Different Ages. *Int J Wrestl Sci* 2013; 3(1): 134-147

22. Kraemer WJ, Fry AC, Rubin MR, et al. Physiological and performance responses to tournament wrestling. *Med Sci Sports Exerc* 2001; 33: 1367-1378.
23. Nilsson J, Csergő S, Gullstrand L et al. Work-time profile, blood lactate concentration and rating of perceived exertion in the 1998 Greco-Roman wrestling World Championship. *J Sports Sci* 2002; 20(11): 939-945 <https://doi.org/10.1080/026404102320761822>
24. Chaabene H, Negra Y, Bouguezzi R et al. Physical and physiological attributes of wrestlers: An update. *J Strength Cond Res* 2017; 31: 1411-1442 <https://doi.org/10.1519/JSC.0000000000001738>
25. Lopresti AL, Smith SJ, Malvi H et al. An investigation into the stress-relieving and pharmacological actions of an ashwagandha (*Withania somnifera*) extract: A randomized, double-blind, placebo-controlled study. *Med* 2019; 98(37) <https://doi.org/10.1097/MD.00000000000017186>
26. Bonilla DA, Moreno Y, Gho C et al. Effects of Ashwagandha (*Withania somnifera*) on physical performance: Systematic review and bayesian meta-analysis. *J Funct Morphol Kinesiol* 2021; 6(1): 20 <https://doi.org/10.3390/jfmk6010020>
27. Jayawardena R, Weerasinghe K, Sooriyaarachchi P. The effect of Ashwagandha (*Withania somnifera*) on sports performance: a systematic review and meta-analysis *Turk J Sports Med* 2025; 60(2): 64-73 <https://doi.org/10.47447/tjism.0862>
28. Coope OC, Reales Salguero A, Spurr T et al. Effects of Root Extract of Ashwagandha (*Withania somnifera*) on Perception of Recovery and Muscle Strength in Female Athletes. *Eur J Sport Sci*. 2025; 25(3): e12265 <https://doi.org/10.1002/ejsc.12265>
29. Długolecka B, Jówko E, Kotowska J et al. Effects of Ashwagandha (*Withania Somnifera*) Supplementation on Body Composition and Blood Health Indices in Professional Wrestlers. *Pol J Sport Tourism* 2023; 30(4): 26-32 <https://doi.org/10.2478/pjst-2023-0022>
30. Gierczuk D, Jówko E, Zawadzki W et al. Effects of Ashwagandha (*Withania somnifera*) Supplementation on Special Endurance and Response Time of Elite Wrestlers. *J Strength Cond Res* 2025; 39(12): p e1387-e1395 <https://doi.org/10.1519/JSC.0000000000005234>
31. Kalina RM. Multidimensional tests as a fundamental diagnostic tool in the prophylactic and therapeutic agonology – the methodological basis of personal safety (Part I: non-motoric simulation). *Arch Budo Sci Martial Art Extreme Sport* 2017; 13: 191-201
32. Gaśienica-Walczak B, Kruszewski A, Kruszewski M. The body balance disturbance tolerance skills during increasing physical exertion as an important criterion for assessing personal safety. *Arch Budo Sci Martial Art Extreme Sport* 2021; 17: 103-111
33. Litwiniuk A, Gaśienica-Walczak B, Jagiello W et al. Body balance disturbance tolerance skills combat sports athletes and people with other motor experiences in dynamically changing circumstances in own research – a perspective for predicting personal safety during real-life performance in extreme situations. *Arch Budo* 2023; 19: 41-49
34. Papassotiropoulos I, Nifli AP. Assessing performance in pre-season wrestling athletes using biomarkers. *Biochem Med* 2018; 28: 020706–328 <https://doi.org/10.11613/BM.2018.020706>
35. Gómez J, Díaz R. Structure for planning in youth Olympic wrestling through the integrated macrocycle with accented loads-an alternative. *Int J Wrestl Sci* 2022; 12(1): 8
36. Krymov A. Model of Long-Term Improvement for the Efficiency of the Training Process in Greco-Roman Wrestling: Physiological, Psychological, and Technical Aspects, Individualization of Training. *Theor Pract Phys Cult* 2025; (2): 16-19
37. Nagovitsyn R, Volkov P, Miroshnichenko A et al. The influence of special graduated weight load in Greco-Roman wrestling on the growth of students' sports results. *Phys Educ Stud* 2017; 21(6): 294-301 <https://doi.org/10.15561/20755279.2017.0606>
38. Shiyan VV. Specific features of planning training loads in the macrocycle of pre-competition training of highly qualified wrestlers. *Int J Wrestl Sci* 2019; 9: 7–18
39. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol Perform* 2019; 14: 270–273 <https://doi.org/10.1123/ijsp.2018-0935>
40. Gierczuk D, Bujak Z, Cieslinski I et al. Response time and effectiveness in elite Greco-Roman wrestlers under simulated fight conditions. *J Strength Cond Res* 2018; 32: 3433–3440 <https://doi.org/10.1519/JSC.0000000000002868>
41. Inbar O, Bar-Or O, Skinner JS. The Wingate Anaerobic Test. *J Hum Kinet. Champaign*, 1996; 95-104

42. Wankhede S, Langade D, Joshi K et al. Examining the effect of *Withania somnifera* supplementation on muscle strength and recovery: A randomized controlled trial. *J Int Soc Sports Nutr* 2015; 12: 43. <https://doi.org/10.1186/s12970-015-0104-9>
43. Verma N, Gupta SK, Patil S et al. Effects of Ashwagandha (*Withania somnifera*) standardized root extract on physical endurance and VO₂max in healthy adults performing resistance training: An eight-week, prospective, randomized, double-blind, placebo-controlled study. *F1000Res* 2024; Apr 8; 12:335. <https://doi.org/10.12688/f1000research.130932.2>
44. Ziegenfuss T, Kedia A, Sandroock J et al. Effects of an aqueous extract of *withania somnifera* on strength training adaptations and recovery: The STAR Trial. *Nutrients* 2018; 10(11): 1807 <https://doi.org/10.3390/nu10111807>
45. Salve J, Kale S, Prajapati BL et al. Safety of 12-Months Administration of Ashwagandha (*Withania somnifera*) Standardized Root Extract in Healthy Adults: A Prospective, Observational Study. *Phytother Res*. 2025; 0: 1–11 <https://doi.org/10.1002/ptr.70096>
46. Gómez Afonso A, Fernandez-Lazaro D, Adams DP et al. Effects of *Withania somnifera* (Ashwagandha) on Hematological and Biochemical Markers, Hormonal Behavior, and Oxidant Response in Healthy Adults: A Systematic Review. *Curr Nutr Rep*. 2023; 12(3): 465-477 <https://doi.org/10.1007/s13668-023-00481-0>
47. Guo S, Rezaei MJ. The benefits of ashwagandha (*Withania somnifera*) supplements on brain function and sports performance. *Front Nutr* 2024; 11: 1439294 <https://doi.org/10.3389/fnut.2024.1439294>
48. Wiciński M, Fajkiel-Madajczyk A, Kurant Z et al. Ashwagandha's Multifaceted Effects on Human Health: Impact on Vascular Endothelium, Inflammation, Lipid Metabolism, and Cardiovascular Outcomes-A Review. *Nutrients*. 2024; 16(15): 2481 <https://doi.org/10.3390/nu16152481>
49. Kalina RM. Innovative Agonology – Its Definition, Detailed Theories, General Rule of Struggle, and Laws. *Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023)*; 2023 Jul 20-24; San Francisco, USA. *Healthcare and Medical Devices* 2023; 79: 272-279 <https://doi.org/10.54941/ahfe1003497>
50. Kalina RM, Kruszewski A. INNOAGON is an acronym for ‘innovative agonology’, but is not synonymous with ‘science of martial arts’. *Arch Budo* 2023; 19: 193-204
51. Waszkiewicz E. Multidimensional Educational Models Recommended by Innovative Agonology – Examples of Physical Education and Music Education. In: *Healthcare and Medical Devices*, Vol. 79: *Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics (AHFE 2023) and the Affiliated Conferences*; 2023 Jul 20-24; San Francisco Marriott Marquis, San Francisco, California, USA. 2023; p. 290-298 <https://doi.org/10.54941/ahfe1003499>
52. Kalina RM. BUDO & INNOAGON – historical complexity but similar missions. *Arch Budo J Inn Agon* 2024; 20: 1-15
53. Kruszewski A, Cherkashin I, Kruszewski M et al. Interpretation of Chinese Hand-to-Hand Fighting Systems and Therapeutic Exercises From the Perspective of the INNOAGON Methodology. *Human Factors in Sports, Performance and Wellness* 2024; 150: 74-83 <https://doi.org/10.54941/ahfe1005292>

Authors:

Gierczuk Dariusz: <https://orcid.org/0000-0002-1131-8095>

Jówko Ewa: <https://orcid.org/0000-0002-4687-6281>

Sacewicz Tomasz: <https://orcid.org/0000-0002-4417-9220>

Długołęcka Barbara: <https://orcid.org/0000-0002-5360-062X>

Gierczuk Wiktoria: <https://orcid.org/0009-0003-1360-9157>

Sadowski Jerzy: <https://orcid.org/0000-0002-1751-9613>

Citation: Gierczuk D, Jówko E, Sacewicz T et al. Effects of ashwagandha (*withania somnifera*) supplementation on strength and anaerobic capacity of upper and lower limbs of elite wrestlers. *Arch Budo J Inn Agon* 2026; 22: 58-73