Effects of eight-week supplementation of Ashwagandha on cardiorespiratory endurance in elite Indian cyclists

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ABSTRACT

Background: Cycling is an endurance sport relying mainly on aerobic capacity to provide fuel during long-duration cycling events. Athletes are constantly searching for new methods to improve this capacity through various nutritional and ergogenic aids. Purpose: The aim of the study was to find out the effect of Ashwagandha on the cardiorespiratory endurance capacity, that is, aerobic capacity of elite Indian cyclists. Materials and Methods: Forty elite (elite here refers to the participation of the athlete in at least state-level events) Indian cyclists were chosen randomly and were equally divided into experimental and placebo groups. The experimental group received 500 mg capsules of aqueous roots of Ashwagandha twice daily for eight weeks, whereas the placebo group received starch capsules. Outcome Measures: The baseline treadmill test for the cyclists were performed to measure their aerobic capacity in terms of maximal aerobic capacity (VO\textsubscript{2max}), metabolic equivalent, respiratory exchange ratio (RER), and total time for the athlete to reach his exhaustion stage. After eight weeks of supplementation, the treadmill test was again performed and results were obtained. Results: There was significant improvement in the experimental group in all parameters, whereas the placebo group did not show any change with respect to their baseline parameters. Conclusion: Ashwagandha improved the cardiorespiratory endurance of the elite athletes.

Key words: Ashwagandha, cardiorespiratory endurance, Indian cyclist

INTRODUCTION

Cycling is an endurance sport, where in success often accompanied by superior endurance physiology.\cite{1} Years of endurance training, combined with a favorable genetic disposition, results in a series of physiological adaptations, designed to maximize endurance performance by increasing the amount of oxygen, which can be delivered to and utilized by working muscles.\cite{2}

These adaptations can be broadly divided into central and peripheral. The peripheral adaptations include increased vascularization, mitochondrial density and enzyme activity, which help in increasing the rate of oxygen extraction and usage. Those adaptations that occur centrally, that is involving the cardiovascular system, affect the rate at which oxygen can be delivered to the entire body.\cite{3} These central factors include maximal cardiac output, pulmonary diffusion, blood volume, and blood flow.\cite{4} Therefore the ability of the cardiorespiratory system to transport oxygen to the exercising muscles is considered the central component of the maximal aerobic capacity (VO\textsubscript{2max}).\cite{5}

Endurance training enhances the VO\textsubscript{2max} through adaptations of heart contractility and function, blood volume, and oxygen-carrying capacity. When the peripheral and central systems are highly adapted, as in the case of an elite endurance cyclist, high rates of work can be achieved.
for extended durations. The maximal amount of oxygen that is consumed during exercise, defined as VO₂ max, is dependent on both the delivery and utilization of oxygen, and is limited by the system that is least adapted. In the elite endurance cyclist, it is generally believed that VO₂ max is centrally limited, that is, by the rate of oxygen delivery. Therefore, alterations to the oxygen transport system have the potential to enhance VO₂ max further.

Another aspect, which could play an important role in enhancing an athlete’s VO₂ max, is the use of nutritional aids or supplements, supported by evidence-based research in sports sciences. In recent years, nutritional supplements and ergogenic aids have played an important role in the sports arena. An ergogenic aid is a technique or practice that increases the performance capacity, the efficiency to perform work, the ability to recover from exercise, and the quality of training, thereby promoting greater training adaptations. Increasing world-class achievements or performance has been known to be backed by the judicious use of ergogenic aids.

Though Ayurveda is one of the oldest branches of medicines and therapy, very few clinical trials have been performed to demonstrate its therapeutic, ergogenic and nutritive effects, especially in the context of athletic performance. Ashwagandha, also known as Withania Somnifera or Indian winter cherry, has been an important traditional herbal medicine for over 3,000 years. W. Somnifera is a densely pubescent shrub up to 1 m tall belonging to the family of Solanaceae. Its root contains flavonoids and many active ingredients like alkaloids and steroidal lactones, which are commonly called withanolides. The chemical constituents of Ashwagandha include three natural powerful antioxidants, superoxide dismutase, catalase, and glutathione peroxidise. It is an ingredient in many formulations prescribed for a variety of musculoskeletal conditions (e.g., arthritis, rheumatism), and as a general tonic to increase energy, work, the ability to recover from exercise, and the quality of training, thereby promoting greater training adaptations. Increasing world-class achievements or performance has been known to be backed by the judicious use of ergogenic aids.

According to the pharmacodynamic principles of Ayurveda, this herb possesses the rasa (~ taste) of tikta (~ bitter), katu (~ pungent), and madhura (~ sweet). Further, its gunas (~ properties) are laghu (~ light) and snigdha (~ unctuous), vipaka (~ effect observed after digestion)is madhura, and virya (~ potency / active principle) is usna (~ hot). Its karma (~ action) is to correct the deranged bodily humor vata (~ functional element of nervous system / circulatory system) and kapha (~ mucoid / fluid substance, etc.).

It is also a rasayana drug, whose action is to clear all channels of the body, provide optimum nutrients to cells of the body at the micro level and to keep all the tissue/ systems, sense organs/physiological functions of the body in healthy condition. Apart from this, according to Ayurvedic principles, each drug has some specific effects, which cannot be predicted, and they are likely to happen because many properties/active principles exist in a combination naturally. Considering such properties and actions of W. Somnifera, the drug is supposed to act on increasing cardiorespiratory and vascular endurance.

Many pharmacological studies have been conducted to investigate the properties of Ashwagandha in an attempt to authenticate its use as a multipurpose herb. Several studies have suggested that Ashwagandha improves the hemoglobin (Hb) count and red blood cell (RBC) count, which are important factors determining the cardiovascular performance of an elite athlete. The increase in RBC mass leads to an increase in the capacity of blood to transport oxygen at a greater capacity to the peripheral system, thus ensuring a greater VO₂ max.

Despite the long tradition of use of Ashwagandha by medical practitioners and sportsmen in India, randomized controlled trials investigating its effects on key aspects of performance such as aerobic capacity in trained athletes is rare. Though a study by Sandhu et al. in 2010 in young sedentary adults suggested an improvement in VO₂ max after eight weeks of Ashwagandha supplementation, there have been no such studies on athletes. Thus this study aims to investigate the efficacy of Ashwagandha supplementation as an ergogenic aid in enhancing the aerobic performance of elite Indian cyclists.

**MATERIALS AND METHODS**

**Participants**

Forty elite Indian cyclists (20 males and 20 females) were randomly selected for this study from around the northern Punjab region. Sample size was obtained from the online sample size calculator (www.stat.uiowa.edu), with the power of the study 0.8694. To participate in this study, subjects had to meet the following inclusion criteria: Age 18–27 years, having been at least state-level medal winners in previous cycling competitions, not consuming any dietary supplements or ergogenic aids during the entire study duration, and understanding and willingness to participate. The study was approved by the Institutional Ethical Committee of the Guru Nanak Dev University.

The subjects were then randomly assigned, by using the block randomization method, into two groups: Experimental (n = 20) who consumed Ashwagandha extract capsules, and placebo (n=20) who consumed placebo starch capsules. Each group comprised of an equal number of males and females. During this study, three
male subjects dropped out due to inconsistent attendance in training sessions. One was from the placebo group and the two from the experimental group. Apart from the supplementation, both groups continued to train for the national camp during the eight weeks of the study.

Baseline measures
After taking a written informed consent from all participants, basic demographic data of each subject was noted, which included age, sex, date of birth, personal best achievements (graded on a scale of 1–5), height (cm) using a stadiometer with a precision of 1 mm, and weight (kg) using the Seca scale with a precision of 0.1 kg.

Assessment of \( VO_2 \) max
A graded exercise test (GXT) was performed on a treadmill (FitNex 200 treadmill), running on the Bruce protocol in which subjects were asked to perform till volitional exhaustion. This GXT test was performed as pre test, prior to beginning Ashwagandha supplementation and post test, upon completion of the eight-week intervention.

All participants completed the GXT. Protocol included electronic heart rate monitor, full nose-mouth piece and rating of perceived exertion (RPE) was evaluated using Borg scale on all participants prior to testing. During the maximal GXT, metabolic gases were collected using the Vista MX-Turbofit metabolic measurement system. The \( VO_2 \) max and respiratory exchange ratio (RER) were computed automatically, averaged and saved by a computer every 15 seconds. The exercise heart rate (HR) and RPE scores of the participants were monitored from time to time and recorded at the end of each stage. \( VO_2 \) max was considered valid when at least two of the following three criteria were met:\[17,18\]

- Maximal heart rate within 15 beats of age-predicted maximal heart rate
- \( RER \geq 1.10 \)
- Plateau in \( VO_2 \) despite an increase in workload

Ashwagandha supplementation
The Ashwagandha (\( W. \) Somnifera) used was in the form of standardized aqueous root extract, which was obtained in the form of capsules from Dabur India Limited. This had been standardized to the in-house specifications of Sanat Products Limited, the vendors of Dabur India, certified by the Government of India, Ministry of Health and Family Welfare, Department of AYUSH, with the purchase order no. 4500579974, challan no. 291, and receipt no. 5000427895. The supplementation was in the form of 500 mg gelatin capsules. The capsules were given over eight weeks, at a dosage of two capsules (each capsule containing 500 mg) a day, 1,000 mg/day (taken daily in the morning and evening).

Placebo supplementation
In this study, the placebo group was supplemented equally with placebo capsules containing starch powder for the duration of eight weeks. These capsules were also prepared by the same company (Dabur India Ltd.).

Statistical analysis
Statistical analysis was prepared using Microsoft Office 2011 Excel and Statistical Package for Social Sciences (SPSS) version 16.0. Levene’s test was used to find intergroup differences in pre and post protocol. One-way analysis of variance (ANOVA) and post-hoc Scheffe’s test were used to analyze the differences in males and females of experimental and control groups. The \( P \) value used for statistical significance was 0.05 for all cases and entire results were expressed as mean ± standard deviation (SD).

RESULTS
Table 1 indicates that the mean age for the study participants was 20 ± 2 years for the placebo and 19.6 ± 1.4 years for the experimental group. Mean height and weight was 56.6 ± 8.7 kg and 164.7 ± 6.6 cm for the placebo group, while the experimental group was 54.9 ± 7.1 kg and 167.39 ± 8.8 cm respectively. No statistical differences were observed between these parameters for both groups.

Results of the experimental group revealed a statistically significant result. The parameters that showed progressive improvement were :- time to volitional exhaustion (to complete the \( VO_2 \) max test), post-test \( VO_2 \) max values, and metabolic equivalents (METs) [1 MET = 3.5 mLO\(_2\)·kg/1·min/1 or which is also equal to 1 kcal·kg/1·h/1or 4.184 kJ·kg/1·h/1].

DISCUSSION
Endurance athletes expend a remarkable amount of energy and challenge the recovery processes of their bodies.[19] They rely on various nutritional supplements or ergogenic aids to meet these excess bodily demands. Lin et al.[20] in 1999 elaborated that nutritional supplements have been long and widely used in the sports arena to increase performance; hence, athletes and coaches search for new options and alternatives to increase their endurance capacity in a healthier way. This was when the consumption of Ayurvedic herbs began. Analytical reports on Ashwagandha suggest that this herb has a rich array of a diverse spectrum of bioactive compounds.[21] The abundance of phytochemicals with antioxidant properties, such as phenolic, flavonoids, and carotenoids may be held responsible for the rejuvenating activity of this medicinal herb. This explains the inclusion of this herb in the Indian...
system of Ayurvedic lists in promoting longevity and other pharmacological effects and earning the title of the ‘queen of Ayurvedic herbs.’ Ashwagandha is said to increase one’s stamina and has many other beneficial properties. In spite of the many properties attributed to Ashwagandha, there is a paucity of clinical scientific evidence for its use in athletes. This study was designed to provide a scientific basis for the use of this supplementation by athletes.

In our study, we found that the baseline VO₂ max of the Indian elite cyclist was in the range of 39.0 to 52.0 mL/kg/min, with the mean value of 45.5 mL/kg/min [Table 1]. Studies in Western countries have indicated higher VO₂ max values, as in Spain: 72.0 mL/kg/min,[22] France: 70.9 mL/kg/min,[23] and Greece: 69.7 mL/kg/min.[24] Various factors might have contributed to these differences. These include genetic disposition,[24] variations in muscle fiber types[26,27] and composition of enzymes,[28] and a difference in body fat percentage and lean tissue, as well as training.[29] There are indications that almost 10-30% of the variations in VO₂ max is genetically determined after accounting for differences in the volume and intensity of training.[25]

After the eight-week supplementation with Ashwagandha, the athletes showed an increase of 13% in VO₂ max, a statistically significant improvement from 46 mL/kg/min to 52 mL/kg/min [Table 3], that is, an increase of 13% [P value of 0.000; Table 2]. Contrary to this, the athletes in the placebo group did not show any improvement. Therefore, this statistical improvement verifies the potency of Ashwagandha in increasing VO₂ max. Though there are many factors that could contribute to the increase in the maximal oxygen consumption, we believe that an increase in the count of RBCs and Hb could have played a role; a study by Ziauddin et al[31] in 1996 indicated that Ashwagandha increased both the RBC and Hb count. The increase in RBC mass leads to an increase in the capacity of the blood to transport oxygen directly to the exercising muscles, thereby enhancing the aerobic capacity[13] directly, enhancing the aerobic capacity. Further studies on RBC and Hb count would provide conclusive evidence regarding the mechanism of the ergogenic effect of Ashwagandha.

As reported by Hautier et al,[30] fatigue in cycling may be because of thermoregulatory, psychological, cardiovascular, or centrally governed factors. Providing an antifatigue medication may help reduce the negative effect of these factors, thereby increasing the aerobic capacity. Ashwagandha has been proved to have an anti-fatigue action.[23] This was demonstrated by the significant improvement in the time to exhaustion of the experimental group in the VO₂ max test from a mean pretest time of 15.79 minutes to a post-test time of 16.93 minutes [Table 3, P < 0.000].

An effect attributed to Ashwagandha, similar to caffeine, is an improvement of clarity and focus. In Ayurveda, this is also known as ratayana or the ‘rejuvenation’ effect. This property is also expected to boost physical and mental health, revitalizing the body.[11,12] Though it was not our aim to explore the site of fatigue at which the action of Ashwagandha was most potent, yet it is hypothesized that, similar to caffeine, it may have increased the free fatty acid oxidation hence conserving glycogen stores.

Comparing genders, women have a lower VO₂ max than men. Yet, apart from gender and genetics, other factors that influence variations in VO₂ max values include age, training status, exercise modes, and body composition.[13] Though the study population comprised an equal number of males and females, a significant difference was noted in

### Table 1: Baseline parametric values of the study population

| Parameter                | Placebo group (n=19)* | Experimental group (n=18)† |
|--------------------------|-----------------------|---------------------------|
|                          | Min | Max   | Mean (±SD)          | Min | Max   | Mean (±SD)          |
| Age (years)              | 18  | 24.20 | 20 ± 2.0            | 18  | 23    | 19.6 ± 1.4          |
| Weight (kg)              | 45  | 80.56 | 56.6 ± 8.7          | 47  | 70    | 54.9 ± 7.1          |
| Height (cm)              | 152 | 180   | 164.7 ± 6.6         | 148 | 188   | 167.4 ± 8.8         |
| BMI (kg/m²)              | 27.4| 25.1  | 20.8 ± 2.5          | 26.2| 23.5  | 19.6 ± 1.9          |
| VO₂ max (mL/kg/min)      | 39.0| 52.0  | 44.6 ± 4.3          | 40  | 51    | 43.1 ± 3.2          |

* with 1 dropout, †with 2 dropouts. BMI: Body mass index. VO₂ max: maximal oxygen consumption

### Table 2: Intergroup comparison of experimental and placebo groups by Levene’s test

| Parameters | F     | Sig   | T    | DF  | P value | Mean difference | Std error diff | 95% confidence Lower | 95% confidence Upper |
|------------|-------|-------|------|-----|---------|----------------|---------------|----------------------|---------------------|
| Time (min) | 2.769 | 0.105 | 4.813| 35  | 0.000   | 1.129          | 0.234         | 0.653                | 1.605               |
| VO₂ max (mL/kg/min) | 3.095 | 0.090 | 5.356| 35  | 0.000   | 5.860          | 1.094         | 3.639                | 8.081               |
| METs†      | 0.784 | 0.382 | 4.873| 35  | 0.000   | 1.615          | 0.331         | 0.942                | 2.287               |
| RER        | 8.883 | 0.005 | 1.479| 35  | 0.148   | 0.040          | 0.027         | -0.015               | 0.096               |

†1 MET = 3.5 mL O₂ kg⁻¹ min⁻¹ or equivalently 1 kcal kg⁻¹ h⁻¹ or 4.184 kJ kg⁻¹ h⁻¹
the experimental group. In percentage, time to exhaustion in males had increased by 10.7%, in comparison to females in whom it increased by only 4.3%, thus also resulting in higher VO$_2$ max values of 16.1% in males as compared to 9.0% in females [Table 4]. Statistical analysis revealed that both parameters were highly significant with a $P$ value of 0.000 [Table 5]. This implies that males were more responsive to the supplementation than females, perhaps mediated by an effect of Ashwagandha on the endocrine system. An animal study done by Abdel-Magied et al.[33] on Wistar mice reported that the effect of Ashwagandha was evident as it had increased the testicular weight of these animals.

This research only aimed to investigate the effects of Ashwagandha on the aerobic performance of the elite Indian cyclist. Thus, the effect of Ashwagandha on blood biochemistry and hormonal status was not investigated. No side effects were reported during this study however, it was noted that one athlete from the experimental group complained of mild indigestion during the first week of supplementation, though we cannot directly attribute this to be the effect of the herb intake.

Though majority of the parameters changed significantly after supplementation of Ashwagandha, the RER value was not significant. RER refers to the ratio of carbon dioxide produced to oxygen consumed during a particular activity of time, which is usually above 1 in exhaustive exercises.[15]

This study provides definite evidence for the improvement of aerobic performance of elite cyclists with the dosage used. Yet, research regarding dose-time effects as well as the principle mechanism of action, that is its effects on physiological parameters such as hormonal status, blood chemistry including RBC, Hb and so on were not studied. A longer study of perhaps 16 weeks with different dosages and with change in the above parameters being recorded every two weeks, would increase clarity on how this herb affects physiological parameters and the time of point at which it demonstrates an improvement. This would also clarify the minimum period of time that is required to affect various systems, allowing the physician to make definite recommendations regarding its duration and dosage for performance enhancements.

### CONCLUSION

To date, most of the properties of Ashwagandha have been studied, investigated and reported only in sedentary healthy subjects having low fitness levels. Thus, this study was designed to analyze its effectiveness in improving performance in well-trained athletes. Considering the fact that it is difficult to detect minor changes in elite athletes, this study was the first of its kind to document the significant improvements in aerobic performance with regard to cardiorespiratory and cardiovascular endurance.

### Table 3: Mean values (±SD) of pre-post readings of experimental and placebo groups

| Variables          | Experimental | Placebo |
|--------------------|--------------|---------|
|                    | Pre test     | Post test | Pre test     | Post test |
| Time to exhaustion (min) | 15.79 ± 0.8 | 16.93 ± 1.3 | 15.62 ± 1.0 | 15.64 ± 1.0 |
| VO$_2$ max (mL/kg/min) | 46.2 ± 3.2  | 52.0 ± 4.8  | 44.6 ± 4.3  | 44.4 ± 5.7  |
| METs               | 13.2 ± 1.0  | 14.8 ± 1.3  | 12.8 ± 1.3  | 12.7 ± 1.6  |
| RER                | 1.07 ± 0.1  | 1.09 ± 0.1  | 1.12 ± 0.1  | 1.10 ± 0.1  |

### Table 4: Mean percentage (%) difference of pre-post readings of males and females

| Variables | Males               | Females              |
|-----------|---------------------|----------------------|
|           | Experimental | Placebo | Experimental | Placebo |
| Time to exhaustion (min) | 10.7 | -0.9 | 4.3 | 1.1 |
| VO$_2$ max (mL/kg/min) | 16.1 | 3.7 | 9 | -4.2 |
| METs | 15.8 | 3.2 | 7.6 | -4.8 |
| RER | 1.8 | -0.9 | 1.5 | -2.5 |

### Table 5: Analysis of variance of pre-post readings in males vs. females of the experimental group

| Variables | Description | Sum of squares | Df | Mean square | $F$ | Sig | Posthoc scheffe test |
|-----------|-------------|----------------|----|-------------|-----|-----|---------------------|
| Time to exhaustion | Between groups | 30,370 | 3 | 10.123 | 14.578 | 0.000 | 1 and 2 ** Group 1 = Males pre test *P < 0.05, Group 2 = Males post test **P < 0.01, Group 3 = Females pre test ****P < 0.001, Group 4 = Females post test |
| VO$_2$ (mL/kg/min) | Between groups | 708.248 | 3 | 236.083 | 42.444 | 0.000 | 1 and 2 *** Group 3 = Females pre test ***P < 0.001, Group 4 = Females post test |
| RER | Between groups | 0.003 | 3 | 0.001 | 0.259 | 0.854 | 1 and 2 NS Group 2 = Males post test |
| METs | Between groups | 52.098 | 3 | 37.966 | 31.072 | 0.000 | 1 and 2 *** Group 3 = Females pre test ***P < 0.001, Group 4 = Females post test |

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of elite athletes. Thus this study supports the reference to Ashwagandha as the ‘queen of herbs’.

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