ORIGINAL RESEARCH ARTICLE CLINICAL

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

Shweta Shenoy, Udesh Chaskar, Jaspal S. Sandhu, Madan Mohan Paadhi[1]

Faculty of Sports Medicine and Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, [1]Central Council for Research in Ayurvedic Sciences, New Delhi, India

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_2 max), 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. There was significant improvement in the experimental group in all parameters, namely, VO_2 max ($t = 5.356$; $P < 0.001$), METS ($t = 4.483$; $P < 0.001$), and time for exhaustion on treadmill ($t = 4.813$; $P < 0.001$) in comparison to the placebo group which 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. [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.[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.[3] These central factors include maximal cardiac output, pulmonary diffusion, blood volume, and blood flow.[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_2 max).[5]

Endurance training enhances the VO_2 max 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

Address for correspondence:
Dr. Shweta Shenoy, Faculty of Sports Medicine and Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India.
E-mail: shwet1999@yahoo.com

Received: 26-Apr-2012
Receised: 16-May-2012
Accepted: 10-Jul-2012

Access this article online

Quick Response Code:

Website: www.jaim.in

DOI: 10.4103/0975-9476.104444

for extended durations. The maximal amount of oxygen that is consumed during exercise, defined as VO_2 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 VO_2 max is centrally limited, that is, by the rate of oxygen delivery.[6] Therefore, alterations to the oxygen transport system have the potential to enhance VO_2 max further.[7]

Another aspect, which could play an important role in enhancing an athlete's VO_2 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.[8] 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.[9] 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.[10] Ashwagandha, also known as *Withania Somnifera* or Indian winter cherry, has been an important traditional herbal medicine for over 3,000 years.[10] *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, improve overall health and longevity, and prevent disease in athletes, the elderly, and during pregnancy.[11]

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.).[12]

It is also a *rasayana* drug,[12] 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,[13] which are important factors determining the cardiovascular performance of an elite athlete.[14] 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 VO_2 max.[15]

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*.[16] in 2010 in young sedentary adults suggested an improvement in VO_2 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 (n20) 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 ≥ 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 $mLO_2 \cdot kg/1 \cdot min/1$ or which is also equal to 1 $kcal \cdot kg/1 \cdot h/1$or 4.184 $kJ \cdot kg/1 \cdot h/1$].

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*.[8] 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.[20] 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.'[21] *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 VO_2 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 VO_2 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[25] 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 VO_2 max is genetically determined after accounting for differences in the volume and intensity of training.[25]

After the eight-week supplementation with *Ashwagandha*, the atheletes showed an increase of 13% in VO_2 max, a statistically significant improvement from 46 mL/kg/min to 52 m/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 VO_2 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*.[13] 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[15] 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.[31] This was demonstrated by the significant improvement in the time to exhaustion of the experimental group in the VO_2 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 *rasayana* or the 'rejuvenation' effect. This property is also expected to boost physical and mental health, revitalizing the body.[11,32] 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 VO_2 max than men. Yet, apart from gender and genetics, other factors that influence variations in VO_2 max values include age, training status, exercise modes, and body composition.[15] 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)	17.4	25.1	20.8 ± 2.5	16.2	23.5	19.6 ± 1.9
VO_2 max (mL/kg/min)	39.0	52.0	44.6 ± 4.3	40	51	46.3 ± 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

Levene's test for equality of variances			*t*-test for equality of means						
Parameters	F	Sig	T	Df	*P* value	Mean difference	Std error diff	95% confidence	
								Lower	Upper
Time (min)	2.769	0.105	4.813	35	0.000	1.129	0.234	0.653	1.605
VO_2 max (ml/kg/min)	3.035	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	.040	0.027	-.015	0.096

‡1 MET = 3.5 mL O_2 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 1.00 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
VO2 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	
							Group	Sig
Time to exhaustion	Between groups	30.370	3	10.123	14.578	0.000	1 and 2	**
	Within groups	22.222	32	0.694			3 and 4	NS
	Total	52.592	35					
VO_2 (ml/kg/min)	Between groups	708.248	3	236.083	42.444	0.000	1 and 2	***
	Within groups	177.989	32	5.562			3 and 4	NS
	Total	886.236	35					
RER	Between groups	0.003	3	0.001	0.259	0.854	1 and 2	NS
	Within groups	0.114	32	0.004			3 and 4	NS
	Total	0.117	35					
METs	Between groups	52.098	3	17.366	31.072	0.000	1 and 2	***
	Within groups	17.885	32	0.559			3 and 4	NS
	Total	69.983	35					

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

of elite athletes. Thus this study supports the reference to *Ashwagandha* as the 'queen of herbs'.

ACKNOWLEDGMENT

The authors would like to acknowledge the role of the Central Council for Research in Ayurveda and Siddha (CCRAS) and Dabur India Ltd. in the subsidization, preparation, and standardization of the *Ashwagandha* capsules used in this research.

REFERENCES

1. Coyle EF, Coggan AR, Hopper MK, Walters TJ. Determinants of endurance in well-trained cyclists. J Appl Physiol 1988;64:2622-30.
2. Hawley JA, Stepto NK. Adaptations to training in endurance cyclists: Implications for performance. Sports Med 2001;31:511-20.
3. Daussin FN, Ponsot E, Dufour SP, Lonsdorfer-Wolf E, Doutreleau S, Geny B, *et al*. Improvement of VO_2max by cardiac output and oxygen extraction adaptation during intermittent versus continuous endurance training. Eur J Appl Physiol 2007;101:377-8.
4. Bassett DR, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc 2000;32:70-84.
5. Robergs RA, Roberts S. Exercise physiology: Exercise, performance, and clinical applications. St Louis, Missouri: Mosby; 1997.
6. Wagner PD. Determinants of maximal oxygen transport and utilization. Annu Rev Physiol 1996;58:21-50.
7. Schmidt W, Prommer N. Impact of alterations in total hemoglobin mass on VO_2 max. Exerc Sport Sci Rev 2010;38:68-75.
8. Lin JY. The effects of creatine supplementation on body composition, muscular strength and power. Department of health and physical education, Northern State University, USA; 1999.
9. Kreider RB. Effects of creatine supplementation on performance and training adaptations. Mol Cell Biochem 2003;244:89-94.
10. Mishra LC, Singh BB, Dagenais S. Scientific basis for the therapeutic use of Withania Somnifera (Ashwagandha): A review. Altern Med Rev 2000;5:334-46.
11. Archna R, Namasivayan A. Antistressor effect of Withania Somnifera. J Ethnopharmacol 1999;64:91-3.
12. Sharma PV. Dravyaguna Vinjana. Vol. 2. Vegetable Drugs. Chaukhambha Bharati Academy, Varanasi; 1999. p. 763-5.
13. Ziauddin M, Phansalkar N, Patki P, Diwanay S, Patwardhan B. Studies on the immunomodulatory effects of Ashwagandha. J Ethnopharmacol. 1996;5069-76.
14. Reeves JT. Is increased hematopoiesis needed at altitude? J Appl Physiol2004;96:1579-80.
15. Mc Ardle WD, Katch FI, Katch VL. Exercise physiology: Energy, nutrition and human performance. 4th ed. Philadelphia: Lea and Febiger; 1996.
16. Sandhu JS, Shah B, Shenoy S, Chauhan S, Lavekar GS, Padhi MM. Effects of Withania Somnifera (Ashwagandha) and Terminalia Arjuna (Arjuna) on physical performance and cardiorespiratory endurance in healthy young adults. Int J Ayurveda Resear 2010;1);:144-9.
17. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 6th ed. Philadelphia: Lippincott William and Wilkins; 2000.
18. Howley Edward T, David R, Basset JR,Welch HG. Criteria for maximal oxygen uptake: Review and commentary. Med Sci Sports Exerc 1995;27:1292-301.
19. Chad K, Roberts M. Supplements for endurance athletes. Strength Cond J 2010;32:55-64.
20. Chaurasiya ND, Uniyal GC, Lal P, Misra LN, Sangwan NS, Tuli R,*et al*. Analysis of withanolides in root and leaf of Withania somnifera by HPLC with photodiode array and evaporative light scattering detection phytochem. Phytochem Anal 2008;19:14854.
21. Widodo N, Takagi Y, Shrestha BG, Ishii T, Kaul SC, Wadhwa R. Selective killing of cancer cells by leaf extract of Ashwagandha: Components, activity and pathway analyses. Cancer Lett 2008; 262:37-47.
22. Lucía A, Rabadán M, Hoyos J, Hernández-Capilla M, Pérez M, San Juan AF, *et al*. Frequency of the VO_2 max plateau phenomenon in world-class cyclists. Int J Sports Med 2006;27:984-92.
23. Launana J, Campion F, Noakes TD, Medelli J. Relationship between %HRmax, %HR reserve, %VO_2 max, and %VO_2 reserve in elite cyclists. Med Sci Sports Exerc 2007;39:350-7.
24. Elias Z, Vasilis A, Giorgos P, Nikos D, Ageliki S, Vagelis R,*et al*. Time to exhaustion at 90 and 100% VO_2 max in elite cyclists. MedSci Sports Exerc2011;43:159.
25. Bouchard C, An P, Rice T, Skinner JS, Wilmore JH, Gagnon J,*et al*. Familial aggregation of VO_2 max response to exercise training: Results from the HERITAGE Family Study. J Appl Physiol 1999;87:1003-8.
26. Costill DL. Metabolic responses during distance running. J Appl Physiol 1970;28:2515.
27. Pette D,Staron RS. Cellular and molecular diversities of mammalian muscle fibers. Rev Physiol Biochem Pharmacol. 1990;116:1-76.
28. Honig CR, Connett RJ, Gayeski TE. O2 transport and its interaction with metabolism: A systems view of aerobic capacity. Med Sci SportExerc 1992;24:47-53.
29. Principles and labs for fitness and wellness., Wadsworth Cengage Learning USA;2009. p. 201.
30. Hautier CA, Arsac LM, Deghdegh K, Souquet J, Belli A, Lacour JR. Applied Sciences: Biodynamics influence of fatigue on EMG/force ratio and contraction in cycling. Med Sci Sports Exerc 2000;32:839-43.
31. Mishra LC. Scientific basis for Ayurvedic therapies. CRC Press; Florida 2003.
32. Archna R, Namasivayan A. Antistressor effect of Withania Somnifera. J Enthnopharmacol 1999; 64: 91-93.
33. Abdel-Magied EM, Abdel-Rahman HA, Harraz FM. The effect of aqueous extracts of Cynomorium coccineum and Withania Somnifera on testicular development in immature Wistar rats. J Ethnopharmacol. 2001; Apr;75:1-4.

How to cite this article: Shenoy S, Chaskar U, Sandhu JS, Paadhi MM. Effects of eight-week supplementation of *Ashwagandha* on cardiorespiratory endurance in elite Indian cyclists. J Ayurveda Integr Med 2012;3:209-14.

Source of Support: Nil, **Conflict of Interest:** None declared.