ORIGINAL ARTICLE

Comparison of correlation between cardiorespiratory endurance (VO_2 max) and autonomic function test parameters in athletes and sedentary individuals

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Maximal oxygen uptake (VO_2max) is considered the gold standard measure of aerobic capacity and reflects integrated cardiovascular, respiratory, and muscular adaptations to endurance training. Regular physical training is associated with enhanced parasympathetic tone and reduced sympathetic activity. Despite the use of autonomic function tests for evaluating cardiovascular autonomic regulation, the relationship between VO_2max and autonomic function test parameters remains a subject of practical interest. The study aim was to evaluate the relationship between VO_2max and autonomic function test parameters in athletes and sedentary individuals aged 18–25 years.

Material and Methods This cross-sectional comparative study included 80 healthy male volunteers divided into athletes (n = 40) and sedentary individuals (n = 40). VO_2max was directly measured using a cycle ergometer ramp protocol with incremental workload (10 W/min) and breath-by-breath gas analysis. Autonomic function was assessed using parasympathetic tests: Valsalva ratio, E:I ratio (deep breathing), and 30:15 ratio, and sympathetic tests: blood pressure response to standing and the isometric handgrip test (IHGT). Pearson correlation coefficient was used to evaluate associations between VO_2max and AFT parameters.

Results Mean VO_2max was 27.47 ± 8.96 mL/kg/min in athletes and 26.06 ± 9.10 mL/kg/min in sedentary individuals. In all subjects (n = 80), correlations between VO_2max and AFT parameters were weak and statistically non-significant: Valsalva ratio (r = 0.067, p = 0.549), E:I ratio (r = −0.114, p = 0.313), IHGT response (r = −0.073, p = 0.516), fall in systolic BP on standing (r = −0.035, p = 0.753), and 30:15 ratio (r = 0.100, p = 0.375). In athletes, VO_2max showed a weak negative correlation with the E:I ratio (r = −0.274, p = 0.087) and IHGT response (r = −0.234, p = 0.145), although these were not statistically significant. Similar non-significant findings were observed in sedentary individuals.

Conclusions VO_2max demonstrated no significant correlation with conventional autonomic reflex parameters in healthy young adults. This suggests that aerobic capacity and resting autonomic reflex function may represent relatively independent physiological domains.

Keywords: VO_2max, autonomic function tests, valsalva ratio, E:I ratio, 30:15 ratio, isometric handgrip test, athletes, sedentary individuals

Introduction

Cardiorespiratory fitness reflects the capacity of the cardiovascular and respiratory systems to support sustained physical activity and is commonly evaluated using maximal oxygen uptake (VO_2max). Aerobic performance is influenced by regulatory mechanisms that maintain cardiovascular stability during rest and physiological stress, including autonomic control of heart rate and blood pressure. Regular physical training is associated with adaptations in autonomic regulation that contribute to functional differences between athletes and sedentary men. These physiological characteristics form the basis for examining the relationship between aerobic capacity and autonomic function in young adults.

Maximal oxygen uptake (VO_2max) is widely regarded as the most comprehensive index of aerobic capacity and cardiorespiratory endurance, reflecting the integrated efficiency of the pulmonary, cardiovascular, and muscular systems during maximal exertion [1, 2]. VO_2max provides an objective measure of the body's ability to deliver and utilize oxygen for energy production during exercise [2]. Regular physical training, especially endurance exercise, is known to enhance VO_2max through physiological adaptations such as increased stroke volume, cardiac output, and mitochondrial density [3, 4].

Beyond its role in metabolic performance, VO_2max is associated with autonomic nervous system (ANS) regulation. The ANS maintains cardiovascular homeostasis by balancing sympathetic and parasympathetic influences on heart rate, vascular

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tone, and blood pressure. Physical training induces adaptive changes in autonomic control. These changes are typically characterized by increased vagal tone (parasympathetic dominance) and reduced sympathetic drive at rest [5, 6, 7]. Conversely, sedentary behavior has been linked with autonomic imbalance, diminished heart rate variability, and higher cardiovascular risk [8, 9]. Autonomic function tests (AFTs) provide standardized methods for assessing the integrity of both parasympathetic and sympathetic branches of the ANS [10].

Parasympathetic function is commonly evaluated using the following tests. The Valsalva ratio is defined as the ratio of the longest R-R interval following strain to the shortest R-R interval during strain and reflects cardiac vagal responsiveness. The E:I ratio (deep breathing test) is defined as the ratio of the longest R-R interval during expiration to the shortest during inspiration while performing deep breathing at six breaths per minute. The 30:15 ratio is defined as the ratio of R-R intervals at the 30th and 15th beats following active standing and assesses baroreceptor-mediated vagal control [11, 12, 13, 14].

Sympathetic function is evaluated using the following tests. Blood pressure response to standing assesses vasoconstrictor sympathetic activity and baroreflex function. The isometric handgrip test (IHGT) evaluates sympathetic efferent activity by measuring the rise in diastolic blood pressure during sustained isometric contraction [11, 12, 13, 14, 15].

Previous studies have demonstrated that trained athletes exhibit enhanced parasympathetic modulation and reduced sympathetic excitability compared with sedentary individuals, suggesting that endurance training augments autonomic efficiency [16, 17]. Studies of heart rate variability and baroreflex sensitivity support the concept that increased aerobic fitness is accompanied by greater vagal activity and improved cardiovascular adaptability [18, 19, 20].

However, limited data are available directly correlating VO_2max, the gold standard measure of aerobic capacity, with standardized AFT parameters including the Valsalva ratio, E:I ratio, 30:15 ratio, blood pressure response to standing, and IHGT within the same population. Correlation analysis of these parameters provides insight into the relationship between cardiorespiratory fitness and autonomic regulation. Reduced VO_2max and autonomic dysfunction are independent predictors of cardiovascular morbidity and mortality [21, 22, 23, 24, 25].

Analysis of research findings has shown that aerobic fitness is associated with adaptive changes in autonomic regulation and with differences in cardiovascular reflex responses between trained and sedentary men. Researchers emphasize that autonomic regulation during rest reflects the coordinated interaction of sympathetic and parasympathetic mechanisms and contributes to cardiovascular stability under standardized functional conditions. At the same time, the physiological relationships between cardiorespiratory endurance and autonomic reflex parameters remain insufficiently characterized in young adults. Clarification of these relationships is necessary for a more consistent interpretation of the functional links between aerobic capacity and autonomic regulation.

The study aim was to evaluate the relationship between VO_2max and autonomic function test parameters in athletes and sedentary individuals aged 18–25 years.

Materials and Methods

Participants

A total of 80 healthy male volunteers aged 18–25 years were recruited and divided into two groups:

- Group A (Athletes, n = 40): Individuals engaged in organized endurance sports or aerobic training ⩾ 2.5 hours per week (e.g., runners, swimmers, cyclists).
- Group B (Sedentary, n = 40): Healthy individuals not participating in any structured physical training program.

Exclusion criteria:

- History of cardiovascular, respiratory, neurological, or endocrine disorders.
- Use of drugs affecting heart rate or autonomic tone.
- Smoking or alcohol consumption.

This cross-sectional comparative study was conducted in the Department of Physiology, SMS Medical College, after obtaining Institutional Ethical Committee approval (MC/EC/2024) on 9 October 2024. All participants provided written informed consent.

Study Design

Anthropometric and Baseline Measurements. Height, weight, and body mass index (BMI) were recorded. Resting heart rate (HR) and blood pressure (BP) were measured after 10 minutes of supine rest using a digital sphygmomanometer.

Direct Estimation of Cardiorespiratory Endurance (VO_2max) by Ramp Protocol on a Bicycle Ergometer. Cardiorespiratory endurance, expressed as maximal oxygen uptake (VO_2max), represents the highest rate at which oxygen can be taken up, transported, and utilized by the body during intense exercise. It is a direct indicator of aerobic fitness and cardiovascular efficiency. Direct measurement of VO_2max involves analyzing the volume and gas concentrations of inspired and expired air during a graded exercise test to determine the point of maximal oxygen utilization. The ramp protocol is a graded incremental exercise test performed on a cycle ergometer where the workload increases continuously or in small frequent steps (10 W per minute) until the subject reaches volitional exhaustion. This approach ensures a smooth transition between workloads and allows a more precise assessment of physiological responses and an accurate determination of VO_2max.

Pre-Test Preparation. Participants were instructed to avoid heavy meals, caffeine, alcohol, and strenuous exercise for at least 12 hours prior to the test. Resting heart rate and blood pressure were recorded after 10 minutes of seated rest. Equipment was calibrated for volume and gas concentration using certified calibration gases before each test.

Procedure

Participants began cycling at a constant cadence of 60–70 revolutions per minute (rpm). The test started with a 3-minute warm-up at a workload of 20 watts (W). The ramp workload increment was then initiated, increasing continuously at a rate of 10 W per minute. The subject continued cycling until one of the following criteria was reached: volitional exhaustion, inability to maintain cadence above 60 rpm, or achievement of physiological indicators of maximal effort. After exhaustion, participants performed a 3-minute active recovery at zero load, followed by 2 minutes of passive recovery. Heart rate and blood pressure were continuously monitored until baseline recovery levels were approached. During the test, expired gases were continuously collected. Oxygen uptake (VO_2), carbon dioxide output (VCO_2), ventilation (VE), and respiratory exchange ratio (RER) were recorded breath-by-breath. Heart rate was monitored continuously via ECG.

The ramp protocol provides smooth and individualized workload progression and minimizes abrupt physiological transitions. It produces more accurate VO_2 kinetics data due to continuous workload increments. It is suitable for athletes and sedentary individuals, as increments can be tailored to expected fitness levels. It reduces test time variability and improves reproducibility compared with step or Bruce-type protocols.

Autonomic Function Tests (AFTs)

Tests were conducted in the morning in a quiet, temperature-controlled laboratory (22–24°C). Subjects were instructed to avoid caffeine, alcohol, and exercise for 24 hours prior.

A. Parasympathetic Function Tests

1. Deep Breathing Test (E:I Ratio): The subject was instructed to breathe deeply at a controlled rate of six breaths per minute for one minute. During this period, heart rate variability was assessed by calculating the expiratory-to-inspiratory (E:I) ratio. This ratio was determined by dividing the longest R–R interval recorded during expiration by the shortest R–R interval recorded during inspiration. An E:I ratio greater than 1.2 is considered normal and indicates adequate parasympathetic (vagal) function and a normal cardiac autonomic response to deep breathing.
2. Valsalva Maneuver (Valsalva Ratio): The subject was instructed to exhale forcefully into a mouthpiece while maintaining a pressure of 40 mmHg for 15 seconds to perform the Valsalva maneuver. During this procedure, heart rate changes were recorded and the Valsalva ratio (VR) was calculated. The VR was determined by dividing the longest R–R interval observed immediately after the release of strain by the shortest R–R interval recorded during the strain phase. A Valsalva ratio greater than 1.45 is considered normal and reflects intact autonomic, particularly parasympathetic, cardiac function.
3. 30:15 Ratio: Upon standing from a supine position, the subject's heart rate response was evaluated by measuring the R–R intervals at the 15th and 30th heartbeats after assuming the upright posture. The 30:15 ratio was calculated by dividing the R–R interval at the 30th beat by the R–R interval at the 15th beat. A value greater than 1.04 is considered normal and indicates an appropriate autonomic cardiovascular response to postural change and intact parasympathetic function.

B. Sympathetic Function Tests

1. BP Response to Standing: The fall in systolic blood pressure (ΔSBP) was recorded as the difference between the supine and standing positions to assess the cardiovascular response to postural change. This measurement reflects the integrity of autonomic regulation of blood pressure during standing. A decrease of less than 10 mmHg is considered normal and indicates an adequate compensatory response and intact sympathetic function.
2. Isometric Handgrip Test (IHGT): The participant was instructed to maintain 30% of maximal voluntary contraction using a handgrip dynamometer for four minutes to perform the isometric handgrip test. During this period, the rise in diastolic blood pressure (ΔDBP) was recorded to evaluate the sympathetic component of autonomic function. A normal response is characterized by an increase in diastolic blood pressure of 10–20 mmHg and indicates appropriate sympathetic activation.

Statistical Analysis

The data were analyzed using SPSS version 25.0. All results were expressed as mean ± standard deviation (SD). An independent t-test was applied to compare variables between the athlete and sedentary groups. Pearson correlation coefficient (r) was used to assess the association between VO_2max and autonomic parameters. A p-value less than 0.05 was considered statistically significant.

Results

Anthropometric characteristics and VO_2max values of athletes and sedentary individuals are presented in Table 1. The two groups were comparable in terms of age, body mass index, and VO_2max values.

Table 1. Comparison of mean values of anthropometric parameters

Parameter	Athletes n = 40 (Mean ± SD)	Sedentary n = 40 (Mean ± SD)
Age (years)	20.92 ± 2.49	21.05 ± 2.43
Weight (kg)	62.51 ± 8.90	57.56 ± 10.48
Height (cm)	169.64 ± 6.26	164.58 ± 7.29
BMI (kg/m^2)	21.62 ± 3.04	22.06 ± 4.08
VO_2max (mL/kg/min)	27.47 ± 8.96	26.06 ± 9.10

Athletes demonstrated higher mean values of height and body weight compared with sedentary individuals. Body mass index values were similar in both groups. VO_2max values were slightly higher in athletes than in sedentary individuals, although the difference was small.

Correlations between VO_2max and autonomic function test parameters in all subjects are presented in Table 2. Weak correlations were observed between VO_2max and all autonomic function test parameters, and none of the associations were statistically significant. VO_2max showed weak positive correlations with the Valsalva ratio and the 30:15 ratio, and weak negative correlations with the E:I ratio, handgrip BP response, and fall in systolic blood pressure on standing.

Table 2. Correlation of VO_2max with autonomic function test parameters in total subjects

No.	VO_2max and autonomic function test parameters	Total subjects (n = 80) r-value	p-value
1	VO_2max and Valsalva ratio	0.067	0.549
2	VO_2max and E:I ratio	−0.114	0.313
3	VO_2max and handgrip BP response	−0.073	0.516
4	VO_2max and fall in systolic blood pressure from supine to standing	−0.035	0.753
5	VO_2max and 30:15 ratio	0.100	0.375

Correlations between VO_2max and autonomic function test parameters in athletes and sedentary individuals are presented in Table 3. Weak correlations were observed between VO_2max and autonomic function test parameters in both groups, and none of the associations were statistically significant. In athletes, VO_2max showed weak positive correlations with the Valsalva ratio and the 30:15 ratio, and weak negative correlations with the E:I ratio, handgrip BP response, and fall in systolic blood pressure on standing. In sedentary individuals, VO_2max showed weak positive correlations with the Valsalva ratio and fall in systolic blood pressure on standing, and weak negative correlations with the E:I ratio, handgrip BP response, and the 30:15 ratio.

Discussion

The study aim was to evaluate the relationship between VO_2max and autonomic function test parameters in athletes and sedentary individuals

Table 3. Correlation of VO_2max with autonomic function test parameters in athletes and sedentary individuals

No.	VO_2max and autonomic function test parameters	Athletes (n = 40)		Sedentary individuals (n = 40)	
		r-value	p-value	r-value	p-value
1	VO_2max and Valsalva ratio	0.023	0.886	0.098	0.543
2	VO_2max and E:I ratio	−0.274	0.087	−0.079	0.585
3	VO_2max and handgrip BP response	−0.234	0.145	−0.035	0.828
4	VO_2max and fall in systolic blood pressure from supine to standing	−0.235	0.143	0.111	0.491
5	VO_2max and 30:15 ratio	0.187	0.246	−0.150	0.352

aged 18–25 years. The results showed that VO_2max values were comparable between athletes and sedentary individuals, while anthropometric characteristics were generally similar in both groups. Correlation analysis demonstrated weak and statistically non-significant associations between VO_2max and all autonomic function test parameters in the total sample as well as within the athlete and sedentary groups. These findings indicate that aerobic capacity and autonomic reflex parameters showed no clear linear relationships under the conditions of the present study.

The present study evaluated the association between cardiorespiratory endurance (VO_2max) and autonomic function test parameters in athletes and sedentary young adults and found no statistically significant correlations in either group. These findings suggest that aerobic fitness and autonomic reflex function, as assessed by conventional autonomic tests, may represent relatively independent physiological domains in healthy young adults.

Endurance training is known to induce adaptations in autonomic regulation, particularly an increase in parasympathetic tone and a reduced resting heart rate, commonly observed in trained athletes [6, 17, 26]. However, the absence of significant correlations between VO_2max and indices such as the Valsalva ratio, E:I ratio, and 30:15 ratio in the present study indicates that higher aerobic capacity does not necessarily translate into enhanced autonomic reflex responses measured under resting or mildly stressful conditions. This may be explained by the fact that VO_2max reflects integrated central and peripheral adaptations, such as increased stroke volume, maximal cardiac output, and improved skeletal muscle oxygen extraction, rather than isolated autonomic reflex control [1, 24, 27].

Autonomic function tests primarily assess short-term cardiovascular reflexes mediated by the parasympathetic and sympathetic nervous systems, including heart rate variability during controlled maneuvers and blood pressure responses to static exercise or postural change [14, 28]. These tests may lack sensitivity to detect subtle training-related autonomic differences in young healthy populations with limited physiological variability. Moreover, several studies have reported that improvements in aerobic fitness may occur independently of resting autonomic indices, particularly when assessed cross-sectionally rather than longitudinally [17, 29].

In sedentary individuals, similarly weak correlations were observed. This was likely due to a narrow range of VO_2max values and preserved autonomic function within a healthy age group. Previous research suggests that significant impairments in autonomic function are more commonly associated with aging, cardiovascular disease, or metabolic disorders rather than differences in fitness alone among young adults [14, 25, 28, 29]. These findings indicate that VO_2max should not be considered a surrogate marker of autonomic nervous system function in young adults.

Limitations and Future Studies

The present study has several limitations that should be considered when interpreting the findings. The sample size was modest (n = 80). Only male subjects were included, and gender-based differences were not assessed. Future studies should include longitudinal training interventions. Studies employing dynamic measures of autonomic regulation, such as heart rate variability during exercise and recovery or baroreflex sensitivity, along with longitudinal training interventions may provide greater insight into the relationship between aerobic fitness and autonomic control.

Conclusions

The present study showed no significant correlations between VO_2max and autonomic function test parameters in athletes and sedentary young adults. Weak positive correlations were observed between VO_2max and some parasympathetic indices, while weak negative correlations were observed with some sympathetic parameters, but none of these associations were statistically significant. These findings indicate that aerobic capacity and autonomic reflex function may represent relatively independent physiological characteristics in healthy young adults.

Conflict of Interest

The authors declares no conflict of interest.

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