Journal of Pioneering Medical Sciences
Received Janauary 05, 2024 Accept March 10, 2024 Publish June 30, 2024.
Volume 13, Issue 3, Pages 21-26

DOI https://doi.org/10.61091/jpms202413304

Anaerobic Abilities Students Using Indirect Tests: Fatigue Index and Peak Power

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Abstract **Background:** Most human movements are supported by its functional capabilities of the anaerobic type, which is dominated by submaximal and maximal sports activities performed in a short time. Functional capabilities of the anaerobic type of man participate in most of his movement activities. Conditioned on adequate and extremely good interaction and functioning of the cardiovascular and respiratory systems, morphological status, metabolic processes, muscle structure, nutritional status, physical activity, etc. **Purpose:** The research was conducted in the conditions of the so-called field testing with the primary goal of assessing the acute state of anaerobic abilities of physical and sports students, by calculating the fatigue index (FI). **Methods:** The sample included 80 students of Physical and Sports Education, different geographical regions, average weight 77.88±8.49kg, age 20-23 years. The Running Anaerobic Sprint Test (RAST) was used to assess FI, and the basic statistical parameters were calculated. **Results:** The average value of the student's leg power is 573.89 watts (378.42 watts vs. 817.99watts), and the recorded average (FI) of 8.35 watts/sec (3.97watts/sec. vs. 16.93watts/sec.). **Conclusions:** The obtained results confirmed the average values of anaerobic capacity which are suitable for the examined population of subjects, while the maximal the value of FI suggests a weaker state of the anaerobic capacity of the individuals (less tolerance to lactates).

Key Words anaerobic capacity, indirect field tests, fatigue index (FI), Peak power (PP), evaluation

1. Introduction

Fatigue as a physiological phenomenon represents a reversible loss of the ability to maintain the strength necessary for the continuous duration of muscular work at a given intensity. It is correlated with reduced muscle performance and increased susceptibility to injury [1], [2]. It is most often a consequence of damage to the neuromuscular system, which causes a lower speed of energy delivery, substrate availability (damage of phosphor creatinine, reduction of glycogen depots, prolonged reduction of oxygen), accumulation of metabolic products, increase in temperature, failure of the contractile muscle mechanism and changes in the neural control of muscle contraction, including failure neural transmission and inhibition from the central nervous system [3]. Naharudin & Yusof [4] define the fatigue index (FI) as a concept of fatigue development during anaerobic activities that can be used to predict an athlete's endurance. They point out that fatigue is primarily caused by the accumulation of hydrogen ions and corresponding acidosis, when during activity the lactates in the blood and muscles rise to a very high level, releasing hydrogen ions. Fatigue factors are often ATP availability, metabolic processes and muscle structures, types of exercise, hypohydration. Anaerobic capacity defines the maximum amount of ATP that can be resynthesized via anaerobic metabolism during maximal activities [5].

Mainly, the maximum accumulated oxygen deficit (MAOD) is considered the gold standard for assessing anaerobic capacity. In addition to being highly sensitive to anaerobic training [6], MAOD is significantly related to high-intensity activity performance and is often used to validate other methods that assess anaerobic capacity [7]–[11]. However, it is not easy to use MAOD to assess anaerobic capacity, as well as during periodic training routines, due to high financial costs. It is very important to identify the application of easier activities at lower costs, which would enable the wide application of procedures (anaerobic tests) in the evaluation and monitoring of sports training. Over the past decades, a number of sport-specific anaerobic field tests have been developed to assess fitness fatigue index-an indicator of anaerobic capacity. The running-based anaerobic repeated sprint test (RAST), which is a running adaptation of the Wingate Anaerobic Test - WanT [12]–[14], is widely used to assess anaerobic fitness. RAST output (ie. peak, power, mean power, fatigue index, peak velocity, and mean velocity) are similar to those determined in WanT, showing high correlations with the same variables. Zagatto, et al. [8] found that RAST is a reproducible and valid procedure for assessing anaerobic power. It is recognized as a good predictor of running performance (35 to 400 m), which can easily be added as a training routine, but not in sprint events [9]–[15]. In addition, this RAST methodology is used to evaluate athletes in many sports [16], [20] but also in physical education and sports students. Anaerobic capacity evaluation tests are classified according to the quantification of anaerobic performance or according to the work assessment of anaerobic capacity. Currently, the WanT is considered the most reliable and valid test in various sports for assessing muscle power production during short-term exhausting exercise. The classification of WanT as an anaerobic test is based on indirect assessments regarding the contribution of anaerobic energy metabolism to performance, including results on oxygen deficit, blood and muscle lactate concentration, indirectly assessing the Fatigue Index [21].

The (FI) is a concept used to study the development of fatigue during anaerobic exercise (the sprint section) relying primarily on glycogen rather than oxygen as an energy source. This Index indicates the rate of power reduction, indirectly enabling the assessment of the ability to maintain the required power output and anaerobic effect over time. The index number indicates the magnitude of the decline in the athlete's power output and is used as an indicator of the athlete's aerobic endurance. If the fatigue index is numerically higher, the ability to maintain strength during a series of sprints is weaker. The lower the value (FI), the greater the possibility that the athlete resists fatigue and continues with the activity. The authors' statements [22] indicate that during intense exercise, lactates in muscles and blood reach high values. It is precisely the increased concentration of lactate that is the cause of the higher concentration of hydrogen ions and acidosis, as the primary factor in muscle fatigue. Athletes with a high fatigue index are recommended to train (exercise) in order to improve lactate tolerance and faster recovery from explosive movements of speed and power. Top sport brings together individuals or groups that participate in national or international competitions, who have had a continuous training process of high training load for several years, which is correlated with the physiological structure. According to [23], the application of complex physical activities affects the reduction of fat tissue, the increase of muscle mass, and therefore the functioning of the cardiovascular and respiratory systems. If the training process is interrupted due to injuries, their anaerobic capacity decreases with age. A study by [24] establishes the reliability and validity of the RAST in the anaerobic assessment and prediction of short-course performance in members of the armed forces. In the first phase, the reliability of the RAST was examined using the test-retest method, and the second phase evaluated the validity of the RAST by comparing the results with the Wingate test and running performance at 35 to 400m. The results of RAST show a significant correlation with the WanT test and the results of sprint running ($p<0.05$).

The main purpose of the study [25] is to examine the relationship between the anaerobic power achieved in repeated anaerobic exercises and the aerobic power of soccer players. Participants were measured in 3 tests (running anaerobic sprint test (RAST), treadmill test (GXT) and multilevel fitness test (20mPST). A statistically significant correlation was found between peak power in GXT and maximum, minimum and average power in RAST. No relationships were found between VO2max obtained from both aerobic tests and performance indices in the RAST. A statistically significant correlation was found between the VO2max obtained from the spiroergometric examination (GXT) and the calculated VO2max at 20mPST. It was found that the VO2max level did not affect the performance indices in the RAST- in elite junior soccer players. Using RAST, authors [26] investigate anaerobic capacity and blood lactate levels of former elite athletes and compare them to non-elite athletes. The measured parameters include the index of minimum and maximum power, speed and fatigue, while the blood lactate level was measured two minutes after the RAST. A difference was found between speed index and body mass between former elite and non-elite athletes ($p=0.000$). There was no difference in anaerobic capacity and blood lactate levels between former elite athletes and non-elite athletes. It has also been shown that age, body mass index and less exercise can affect the reduction in anaerobic capacity of a former elite athlete. The authors' study [27] analyzed differences between male and female hockey players matched for age, training duration, diet, normal physical activity, body weight, and BMI. The results showed that male hockey players have less resistance to the repeated sprint test than female players. Variations in body weight, BMI and strength were positively associated with the fatigue index in both sexes, and low body weight and age were also found only in males, and body fat percentage only in females was associated with the (FI). There are rare studies on the student population of physical education and sports that study anaerobic abilities through RAST measurement and the fatigue index. To that extent, the studies of this population are interesting, primarily because of their sports activities, which are in the description of their studies during their studies. It is generally understood that it is a physically active population, involved in sports activities, which also suggests their leadership when it comes to physical activities and their performance, including anaerobic abilities.

The aim of the study was to define and determine the state of anaerobic abilities (Peak power and Fatigue Index coefficient) of the student population of physical education and sports by applying Running Anaerobic Sprint Test (RAST).

Figure 1: Test configuration for the running anaerobic sprint test (RAST)

2. Methods

A. Participants

The study included a total of 80 male students Faculty of Physical Education and Sport, different geographical regions, age 20-23 years, average weight 77.88±8.49kg. For the evaluation of anaerobic capacity applied to the RAST and calculated Fatigue Index (FI) and Peak Power (PP). All subjects were healthy without any psychosomatic changes and voluntarily participated in the study. The entire research protocol was conducted in accordance with the Helsinki Declaration.

B. Design study [28]

The advantage of using the RAST for measuring anaerobic power is that it allows for the execution of movements more specific to sporting events that use running as the principal style of locomotion, is easily applied and low cost, and due to its simplicity can easily be incorporated into routine training. This procedure is reliable and valid, and can be used to measure running anaerobic power and predict short-distance performances. A 400 m track, 2 cones, 2 stopwatches and 2 assistants were required to conduct this test (Figure 1). After entering the subject's body mass and a 10-minute warm-up, each participant performs six 35-meter sprints with a 10-second recovery between each sprint. The running anaerobic sprint test (RAST) variables were peak power (PP), mean (MP) both presented in units relative to body mass (rel.) and absolute (abs) values, and also the Fatigue index (FI) (FI = (PP – minimal power) x 100) / PP).

C. Statistical analysis

Basic central and dispersion parameters (Mean, Min., Max., Range, SD) were calculated for each variable RAST and Fatigue index parameters of students, and graphically defined the trend of changes during the performance of RAST. Statistical procedures and analyzes were performed using the statistical package STATISTICA 10.0 for Windows.

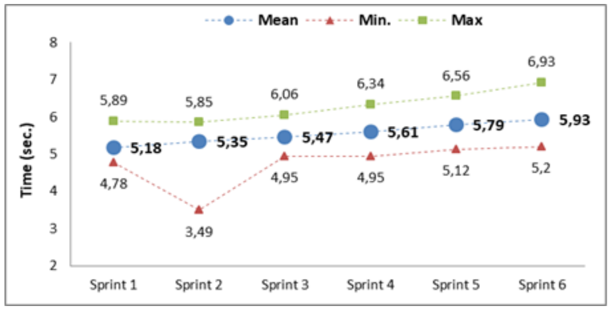

Figure 2: Time of average student results (RAST)

D. Ethical consideration

Participation was completely voluntary. Informed consent forms were signed before the start of the study. The research was carried out in accordance with the professional and ethical standards of the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2013)

3. Results

Table 1 contains the basic statistical parameters of the sample, while the quantitative numerical parameters are valued by the time achieved (sec.) in repeated cycles of sprint running (6x35m), as well as by the power of the lower extremities (Watts). In the analyzed sample, there is a linear decrease in running speed with each repeated sprint (Table 1, Figure 2).

This phenomenon is expected considering the fact that the decrease in speed is a consequence of the accumulation of lactate, when the Ph value decreases with the increase in CO2 secretion, which leads to muscle fatigue. With an increase in the acidity of the body the strength of performing the activity decreases, which was manifested by a loss of strength in each repetition. Average speed vs. the output power of the examinee in the first (I) run ranged from 5.18 sec. vs. 695.67 watts (min. 4.78sec vs. 436.45 watts to max. 5.89 sec vs. 942.06 watts and up to 5.93 sec vs. 470.90 watts in the last, sixth (VI) run.

A total average decrease in speed during RAST of 0.75sec (or 224.67 watts). It is evident that the subjects' strength values were inversely related to speed in each of the six repetitions, which is the expected outcome. A decrease in running speed and thus anaerobic power through repetitions during the test is a consequence of the accumulation of lactate and a decrease in leg strength. The basic statistical parameters of the average Fatigue Index and anaerobic power are contained in Table 2. The average power of the students is 573.89 watts (min. 378.42 watts vs. max. 817.99 watts, Range 439.57 watts). An average Fatigue Index was obtained FI = 8.35 watts/sec (min. 3.97 watts/sec vs. max. 16.93 watts/sec (Figure 3 and 4).

4. Discussion

The fatigue index is considered an important indicator of anaerobic capacity. The lower the fatigue index, the greater

RAST	Mean ± SD	Min.	Max.	Range
Sprint 1 (sec)	5.18 ± 0.13	4.78	5.89	1.11
Watts 1	695.67 ± 131.88	436.45	942.06	505.60
Sprint 2 (sec)	5.35 ± 0.32	3.49	5.85	2.36
Watts 2	632.73 ± 127.05	448.87	965.02	516.15
Sprint 3 (sec)	5.47 ± 0.31	4.95	6.06	1.11
Watts 3	591.83 ± 112.25	386.55	831.55	445
Sprint 4 (sec)	5.61 ± 0.11	4.95	6.34	1.39
Watts 4	552.16 ± 109.36	352.97	806.35	453.38
Sprint 5 (sec)	5.79 ± 0.37	5.12	6.56	1.44
Watts 5	500.06 ± 97.48	344.50	711.75	367.25
Sprint 6 (sec)	5.93 ± 0.44	5.20	6.93	1.73
Watts 6	470.90 ± 92.66	301.20	651.18	349.98

Table 1: Basic statistical parameters of RAST

Indicator RAST	Mean ± SD	Min.	Max.	Range
Total Leg Power (watts)	573.89 ± 109.29	378.42	817.99	439.57
Fatigue Index (watts /sec)	8.35 ± 3.20	3.97	16.93	12.96

Table 2: The basic statistical parameters Fatigue Index and Peak power

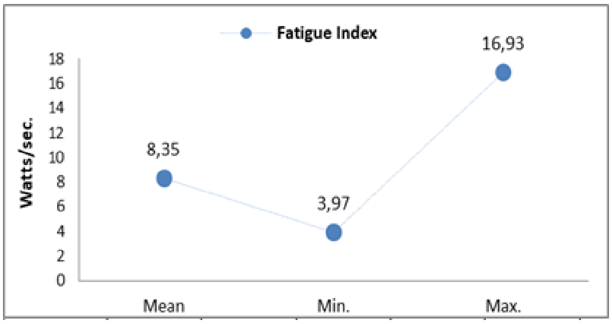

Figure 3: Fatigue Index (FI) of students

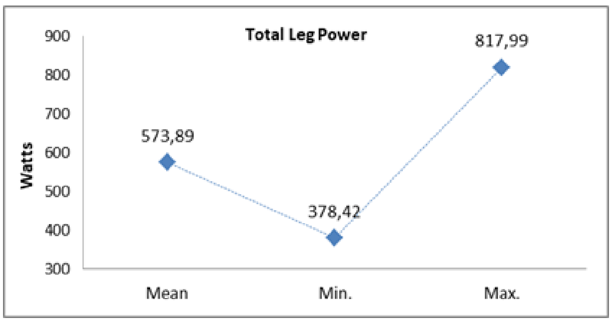

Figure 4: Peak Power (PP) total of students

the body's ability to maintain its power output through anaerobic performance. Running the anaerobic sprint test is widely used by coaches, athletes and researchers to measure lower body anaerobic strength load capacity and fatigue index. According to [21], high-intensity exercise significantly increases the amount of lactate in muscles and blood, as well as the fatigue index value, while the increased accumulation of lactate causes an increased concentration of hydrogen ions and corresponding acidosis as its primary factors.

The study sought to assess the anaerobic capabilities of physical education and sports students by employing the Running Anaerobic Sprint Test (RAST) and determining the Fatigue Index (FI). In Table 1, it shown the fundamental statistical parameters of the participants in the Running Anaerobic Sprint Test (RAST), which includes the time attained in repeated cycles of sprint running (6x35m) and the power of the lower extremities measured in watts. The table illustrates a consistent reduction in running velocity with each successive sprint, suggesting a gradual loss in anaerobic power throughout the test. The individuals exhibited an average leg power ranging from 695.67 watts in the first sprint to 470.90 watts in the sixth sprint, demonstrating a progressive decline in power production with each repeat. The parameter's range of values emphasizes the diversity in performance among the participants.

Based on the presented results (Table 2, Figure 3), it can be concluded that the average Fatigue index (8.35) defines the current anaerobic potential of physical education and sports students and is the result of the state of the cardiovascular system, as well functional abilities of the students, which is confirmed by previous studies [19], [29]. A linear decline in the strength results of a sample of students is expected, because the first signs of fatigue appear, caused by the accumulation of lactate in the blood and the inability of the body to recover sufficiently for the next run, but the activity continues in terms of oxygen debt and increased concentration of lactate in the blood.

The results presented was align with the anticipated results of anaerobic testing, illustrating the decrease in anaerobic power and velocity throughout successive sprints. The decrease in velocity is ascribed to the buildup of lactate, resulting in muscular exhaustion, as stated by the authors [22]. The findings validate the inverse correlation between running velocity and leg strength, which aligns with the anticipated effect of reduced anaerobic power due to repeated trials throughout the examination, as mentioned by [24]. The subjects (athletes) with a high fatigue index should train to improve lactate tolerance and thus enable faster recovery from explosive periods of speed and power during physical activity. The basis is that, on the basis of good aerobic abilities, anaerobic abilities are upgraded, so that the tolerance to lactates would be higher and thus the efficiency of physical activity. Mostly, this includes repeated sprint exercises, which produces high levels of lactic acid, and therefore a better tolerance to lactates and the ability to eliminate them [21].

The established assumption that the level of anaerobic abilities of physical education and sports students is at a good level, has been confirmed with the results of the research. Of course, anaerobic potential is specific to certain sports, which depends on the type of sport and intensity [30]. Anaerobic capacities mainly dominate in activities such as jumping, running and throwing, and anaerobic exercises (sprinting) lead to significant oxidative changes in blood composition [18]. These activities of an anaerobic nature are to a large extent represented in the implementation of teaching programs at the college within the framework of practical exercises in a large number of subjects and sports disciplines and thus define an adequate basis for the development of students' anaerobic capacities.

The results demonstrated that the average anaerobic capacity values were appropriate for the population under investigation, whereas higher values of FI indicated a diminished anaerobic capacity or reduced lactate tolerance. The study utilized a methodology that included 80 male students, aged 20-23, from various geographical regions. The researchers employed the RAST method to evaluate the FI, and basic statistical values were computed. Our results showed better values of anaerobic capacity and FI than some studies on the same population [31], [32], because higher average and maximum power values were achieved, and thus better anaerobic potential and a lower fatigue index. The studied population of physical education and sports students is from different sports disciplines, so anaerobic capacities are mostly primary in their activities, therefore the obtained values of anaerobic capacities are expected, which supports the statements of previous studies [8], [9].

The results of this study align with prior research, specifically the study conducted by [25], which discovered a notable association between the highest level of power achieved in aerobic tests and performance measures in the RAST. In addition, the research conducted by [27] examined disparities between male and female hockey players and discovered that discrepancies in body weight, BMI, and strength were linked to the fatigue index in both genders. These findings affirm the significance of evaluating anaerobic fitness and its correlation with many physiological parameters. In addition, the research conducted by [26] examined the anaerobic capacity and blood lactate levels of former elite athletes. The study revealed that factors such as age, body mass index, and reduced physical activity can contribute to a decline in anaerobic ability. The results of the current study highlight the influence of factors such as age and exercise on anaerobic capacities. Anaerobic performance of repeated short bouts imposes a different physiological stress than a single prolonged activity and therefore may reflect different physiological capacities [14], [33]. It has also been confirmed that anaerobic capacities are independent of morphological dimensions, and that they are correlated with physiological parameters, body metabolic processes and muscle structure [19]. Certain studies that included the student population [34], [35] showed that students who have a lower value of the fitness index and VO^2 max., and a higher fatigue index increase the risk of cardiovascular diseases and metabolic syndrome [36], [37].

To summarize, this study's findings offer useful insights into the anaerobic capabilities of physical education and sports students, affirming the appropriateness of anaerobic capacity for the population under examination. The results align with prior studies and emphasize the significance of evaluating and tracking anaerobic fitness in this particular group. The study's approach and results enhance comprehension of anaerobic capabilities and their ramifications for sports training and performance evaluation.

5. Conclusion

The research included a total of 80 students of Physical Education and Sport from different geographical areas. To evaluate the Fatigue index and Peak power (watts) of students applied to the RAST. The mean value of the student's peak leg power is 573.89 watts (378.42 watts vs. 817.99 watts), and the recorded mean FI of 8.35 watts/s. (3.97 watts/sec. vs. 16.93 watts/sec.) The obtained results confirmed the average values of anaerobic capacity which are suitable for the examined population of subjects, while the maximal the value of FI suggests a weaker state of the anaerobic capacity of the individuals (less tolerance to lactates). This research is a good guideline for future studies of this issue in terms of evaluation of anaerobic capacity and fatigue index of the or different population of students or athletes, especially in today's era of top and professional sports that require an extremely high level of development of aerobic and especially anaerobic capacities.

Conflict of interest

The authors declare no conflict of interests. All authors read and approved final version of the paper.

Authors Contribution

All authors contributed equally in this paper.

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