

## INDICATORS OF ANEROBIC ABILITIES: DIFFERENCES IN THE FATIGUE INDEX BETWEEN STUDENTS OF PHYSICAL EDUCATION AND SPORTS

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### ABSTRACT

Anaerobic abilities participate in most activities that are characterized by high intensity and short duration of activity. Conditioned by the good functioning of the cardiovascular and respiratory systems, morphological status, metabolism, muscle structure, etc. The research has conducted with the aim of evaluating differences anaerobic abilities of students and Fatigue index (FI) of the Faculty of Physical Education and Sport applying Running Anaerobic Sprint Test (RAST). The sample included a total of 80 male students Faculty of physical education and sport, age 20-21 years (20 students from Eastern Sarajevo, average weight  $76,69 \pm 6,61\text{kg}$ ; 20 students from Novi Sad, the average weight  $76,75 \pm 9,49\text{kg}$ ; 20 students from Nikšić, average weight  $79,40 \pm 9,66\text{kg}$  and 20 students from Sarajevo, average weight  $78,68 \pm 8,20\text{kg}$ ). To determine statistically significant differences in anaerobic capacity and Fatigue index, a T-test for independent samples was applied. After applying the RAST test, the values of anaerobic power of the lower extremities of students were obtained, which define their state of anaerobic capacity. Based on the analysis of the results, differences between students are evident as a consequence of different physiological responses of the organism to testing. Average values of anaerobic capacities ranged from a minimum of 547.96 Watts (Sarajevo), 574.12 Watts (Novi Sad), 579.15 (Nikšić) to a maximum of 594.79 Watts (East Sarajevo). The inverse indicators of student fatigue factor are identical, where the highest fatigue factor was recorded in Sarajevo students ( $\text{FI} = 8.96 \text{ Watts} / \text{sec.}$ ) Who had the lowest lactate tolerance, and the lowest Fatigue factor in East Sarajevo students ( $\text{FI} = 7, 80\text{watts} / \text{sec.}$ ) Who showed the highest tolerance to lactate? Based on the obtained results of FI values, differences between the samples of all students are evident. However, statistically significant differences were realized only between students of East Sarajevo and Sarajevo ( $p < 0.025$ ); Nikšić and Sarajevo ( $p < 0.039$ ).

**Keywords:** Anaerobic abilities, fatigue index, difference, students.

### 1. INTRODUCTION

Fatigue is a reversible loss of the ability to maintain the strength needed to continue muscle work at a given intensity and is often associated with decreased muscle performance and increased susceptibility to injury (Albert, Wrigley, McLean, & Sleivert, 2006; Bishop, 2012). This is most often the result of a combination of damage to the neuromuscular system, which can be caused by: reduced energy delivery speed and substrate availability (phosphocreatinin depletion, glycogen depot depletion, prolonged oxygen depletion), accumulation of metabolic

products (phosphate,  $H^+$  ion, lactic acid), increased temperature, contractile muscle mechanism failure and changes in neuronal control of muscle contraction, including failure of neuronal transmission and inhibition from the central nervous system (Allman, & Rice, 2002; Finsterer, 2012). Naharudin, & Yusof, 2013 define the fatigue index as a concept of fatigue development during anaerobic activities that can be used to predict an athlete's endurance. It is primarily caused by the accumulation of hydrogen ions and the corresponding acidosis, when during the activity, the lactates in the blood and muscles rise to a very high level releasing hydrogen ions. Often the factors of fatigue are the availability of ATP, metabolic processes and muscle structures, types of exercise, hypohydration. Anaerobic capacity represents the maximum amount of adenosine triphosphate (ATP) that can be resynthesized by anaerobic metabolism during the performance of activities of maximum intensity (Minahan, Chia, Inbar, 2007). The gold standard for the assessment of anaerobic capacity is considered to be the maximum accumulated oxygen deficit (MAOD). In addition to sensitivity to anaerobic training, MAOD is highly correlated with maximal intensity activity performance (Scott, Robi, Lohman, & Bunt, 1991; Ramsbottom, Neville, Neville AM, et al. 1997; Roseguini, Silva, & Gobatto, 2008) and uses for the validity of other methods that assess anaerobic capacity (Cooper, Baker, Eaton, & Matthews, 2004; Bertuzzi, Franchini, Ugrinovitch, et al. 2010; Zagatto, Radish, Loures et al. 2011; Queiroga, Cavazzotto, Katayama, et al., 2013). Using MAOD to assess anaerobic capacity is not easy because it requires several submaximal activities and one supramaximal activity, especially during the periodization of the training process (Medbo, Mohn, Tabata et al., 1988), where it is necessary to measure oxygen intake ( $VO_2$ ) during activity, therefore methodologically the use of MAOD is largely financially unprofitable. It is very important to identify the application of lighter activities at a lower cost, which would allow the widespread use of procedures (anaerobic tests) in the evaluation and monitoring of sports training, such as Wingate test, jumping tests, and maximum anaerobic running test (Hoffman, & Kang, 2002; Nummela, Härmäläinen, & Rusko, 2007). These methodologies have been studied for a significant period of time and are applied in assessing both the anaerobic abilities of athletes (Moore, Murphy, 2003) and healthy individuals and heart patients (Gardner, Osborne, D'auria, & Jinkins, 2003; Mezzani, Corrà, and Andriani, 2008). Some studies (Minahan, Chia, & Inbar, 2007) have shown a relationship between parameters measured by the Wingate anaerobic test (WAnT) and anaerobic capacity where it was confirmed that average strength and fatigue index correlated with MAOD. In this regard, average strength, lactate peak, and fatigue index can assess the activity of glycolytic composition and represent the rate of anaerobic capacity.

The anaerobic repeat sprint test (RAST) is a kind of WAnT adaptation widely used to assess anaerobic abilities (Paradisis, Tziortzis, Zacharogiannis, et al. 2005; Meckel, Machnai, & Eliakim, 2009) and the results obtained through the RAST test are similar those identified in WAnT show a high correlation with the same variables and are a good indicator in the assessment of anaerobic capacity. RAST is recognized as a good predictor in running performance (35 to 400 m), to which the epithet of a training routine can easily be added, but not in sprint disciplines (Adamczyk, 2011). Also, this test is used to assess the anaerobic capacity of athletes in many sports (Balciunas, Stonkus, Abrantes, & Sampaio, 2006; Alizadeh, Hovanloo, & Safania, 2010; da Silva, Guglielmo, & Bishop, 2010; Keir, Thériault, & Serresse, 2013; Burgess, Holt, Munro, and Swinton, 2016; Pekas, Trajković, & Krističević, 2016). In general, the Fatigue Index indicates the rate at which power decreases, and therefore indirectly provides an assessment of the ability to maintain the required power output and anaerobic effect over time. The lower the value of FI, the greater the possibility for the athlete to resist fatigue and continue with the activity. The purpose of study Kaminagakura, et al. (2012) was to determine if the use of the running-based anaerobic sprint test (RAST) could be used to predict anaerobic capacity in running athletes. The maximum accumulated oxygen deficit (MAOD) was determined during running on a treadmill, and the RAST was

determined during running on a track. None of the variables associated with RAST output (peak power, mean power, fatigue index, and maximal and mean velocities) was significantly correlated with MAOD. Thus, the findings indicate that the use of the RAST does not predict anaerobic capacity in running.

The connection between the kinematic parameters measured during the first 10 seconds of the 100m sprint and anaerobic endurance test male students of physical education conducted Berthoin, Dupont, Mary, & Gerbeaux, (2001). Study Nesser, Latin, Berg, & Prentice (1996) examined 20 male athletes on a number of physiological variables to determine which may account for the most variation in 40-m sprint performance. The athletes were tested on 40-m sprint, 10-m sprint, a 5-step jump, vertical jump, Wingate anaerobic cycle power, and isokinetic peak torque of the knee and hip at speeds differences were identified as predictors of 40-m sprint performance. The results indicate that both 10-m sprint and 5-step jump can be used to predict 40-m sprint performance. Zagatto, Beck, & Gobatto (2009) was to investigate the reliability and validity of the running anaerobic sprint test (RAST) in anaerobic assessment and predicting short-distance performance. Forty members of the armed forces were recruited for this study. The study was divided in two stages. The first stage investigated the reliability of the RAST using a test-retest method; the second stage aimed to evaluate the validity of the RAST comparing the results with the Wingate test and running performances of 35, 50, 100, 200, and 400 m. The RAST had significant correlations with the Wingate test (peak power, mean power, fatigue index) and 35, 50, 100, 200, and 400 m performances scores ( $p < 0.05$ ). The main purpose of the study Cipryan, & Gajda (2011) is to investigate the relationship between anaerobic power achieved in repeated anaerobic exercise and aerobic power of 40 soccer players. All participants performed 3 tests: a running-based anaerobic sprint test (RAST), a graded treadmill test (GXT), and a multistage fitness test (20mPST). A statistically significant correlation was found among peak power in the GXT and the maximum, minimum and average power in the RAST. No relationships were found between  $VO_{2max}$  obtained from both aerobic tests and any performance indices in the RAST. A statistically significant correlation was found between the  $VO_{2max}$  obtained from the spiroergometry examination (GXT) and the calculated  $VO_{2max}$  of 20mPST. In conclusion, the level of  $VO_{2max}$  does not influence the performance indices in the RAST in elite junior soccer players. It is possible that the modification of anaerobic test protocol or a more heterogeneous study group would influence the results. The estimation of the  $VO_{2max}$  in the 20mPST is too inaccurate and should not replace the laboratory spiro ergometry examination. A similar study of the author (Kolic, Babic, & Šentija, 2012) with the aim of comparing the parameters of aerobic capacity, measured by two tests of progressive load on the treadmill of varying duration in the runner. Research has shown that when comparing the results of tests of progressive burden necessary to take account of the implemented protocol, or the duration of the test. The studies exploring the influence of resistance training on endurance in men have produced inconsistent results.

The aim of study Šentija, Maršić, & Dizdar (2009) was to examine the influence of an Olympic weight lifting training programme on parameters of aerobic and anaerobic endurance in moderately physically active men. (eleven physical education students, age:  $24.1 \pm 1.8$  yr, height:  $1.77 \pm 0.04$  m, body mass:  $76.1 \pm 6.4$  kg) underwent a 12-week, 3 times/wk training programme of Olympic weight lifting. Specific exercises to master the lifting technique, and basic exercises for maximal strength and power development were applied, with load intensity and volume defined in relation to individual maximal load. Parameters of both, aerobic and anaerobic endurance were estimated from gas exchange data measured during a single incremental treadmill test to exhaustion, which was performed before, and after completion of the 12-wk programme. After training, there was a small, but significant increase in body mass and peak  $VO_2$  ( $p < 0.05$ ), with no significant change of the running speed at the anaerobic threshold (VAT) and at exhaustion ( $V_{max}$ ) (both  $p > 0.05$ ). However,

there was a significant increase of anaerobic endurance, estimated from the distance run above VAT, from VAT to  $V_{max}$  ( $p < 0.01$ ). The results of this study indicate that changes in both, anaerobic and aerobic endurance due to a 12-wk period of strength training in untrained persons can be determined from a single incremental treadmill test to exhaustion. The possible causes of those training effects include several possible mechanisms, linked primarily to peripheral adaptation.

Elite athletes are individuals or groups who participate in national or international competitions; they have been training regularly for several years with a large training load, which is related to the physiological structure. The application of complex physical activities affects the reduction of adipose tissue, increase of muscle mass, and in turn increases the functioning of the cardiovascular and respiratory systems (Kim, 2017). If the training process is interrupted due to injuries, their anaerobic capacity decreases with age. Nasuka, Santosa, Setiowati, & Indrawati (2018) using RAST investigate the anaerobic capacity and lactate levels in the blood of former elite athletes and compare them with non-elite athletes. The measured parameters include the index of minimum and maximum strength, speed and fatigue, while the level of lactate in the blood was measured two minutes after RAST. The results show that the rate of maximum power of the former elite athlete is 387.3W, minimum power 242.2W, fatigue index 3.67 Watts/sec. and blood lactate levels 7.20mmol/L. The maximum power rate of a non-elite athlete was 445.8W, the minimum power 282.4 W, and the fatigue index 4.57 Watts/sec. and blood lactate level 7.01mmol/L. There was no difference between maximum strength, minimum strength, fatigue index and blood lactate levels. The difference was found between the Speed and Body Mass Index between former elite and non-elite athletes ( $p = 0.000$ ). There was no difference in anaerobic capacity and blood lactate levels between the former elite athlete and the non-elite athlete. It has also been shown that age, body mass index and less exercise can affect the reduction of anaerobic capacity of a former elite athlete.

Hanjabam and Kailashiya (2015) analyze differences between male and female hockey players that coincide with age, training duration, diet, normal physical activity, body weight, and BMI. Research has shown that male hockey players have less resistance against repeated sprint fatigue than female players. Variation in body weight, BMI, and strength were positively associated with fatigue index in both genders and low body weight and age were also found in men only, and body fat percentage in women only was associated with fatigue index. Rare are studies which analyze the anaerobic capacity of students physical education and sport by applying RAST. Zemkova and Hamar (2004) on a sample of 17 students of Physical Education conducted a survey with the aim of comparing parameters of anaerobic capacity (maximum and average power, fatigue index and blood lactate) obtained the maximum 30 second test performed on the isokinetic cycle ergometer with those parameters collected running test on treadmill with overcoming resistance. Correlation analysis showed a high correlation between the parameters of anaerobic capacity obtained during the run on the carpet for a period of 30 seconds with the driving resistance of the driving isokinetic cycle ergometer, such as maximum power, average power and fatigue index. Run with overcoming resistance and isokinetic cycling did not differ significantly even at maximum power either at the average strength. However, the fatigue index and blood lactate concentrations were significantly higher in the maximum were running with overcoming resistance. Taking into account that showed no statistically significant difference in the manifest average and maximum power used between the modalities of exercise, it can be concluded that the maximum running on the treadmill for 30 seconds with overcoming resistance to an acceptable alternative for the assessment of anaerobic capacity. However, compared to isokinetic cycling, can be expected over the index values of fatigue and blood lactate concentrations.



The aim of study Taskin (2016) was to analyze aerobic capacity and anaerobic power levels of the male and female students who is department physical education and department business. Anaerobic power was measured with Running Anaerobic Sprint Test (RAST) and Oxygen consumption was estimated 20-m shuttle run test. We found that was aerobic and minimum anaerobic capacity of physical education students higher than aerobic and minimum anaerobic capacity of business students. On the other hand, we didn't found differences between physical education female and male students and business female and male students in maximal anaerobic capacity and average anaerobic capacity. We found that was aerobic and minimum anaerobic capacity of female and male students in department physical education higher than aerobic and minimum anaerobic capacity of female and male students in department of business. In addition, fatigue index of female students in department physical education lower than fatigue index of female students in department of business was found.

The research (Pavlović et al., 2016) has conducted with the aim of evaluating fatigue index of students of the Faculty of Physical Education and Sports. The sample included a total of 50 male students from Eastern Sarajevo and Nikšić, the average weight  $78,05 \pm 8,14$ kg). For the evaluation of fatigue index of students applied to the Running Anaerobic Sprint Test (RAST). The results showed values of anaerobic capacity of students who "are expected" for this population. Average index of fatigue was recorded with students (FI=8,00 watts/sec) and max. value FI about 17watts/sec suggesting a weaker state of anaerobic capacity or lower tolerance to lactate, despite the fact that it is a physically active population.

The study was is the implemented with students of physical education and sport different geographical regions (BIH, Serbia, Montenegro). The main objective of the research is to evaluating differences in the anaerobic capacity of students by applying Running Anaerobic Sprint Test.

## **2. METHODS AND MATERIALS**

### **2.1 Participants**

The study included a total of 80 male students Faculty of physical education and sport, age 20-21 years (20 students from Eastern Sarajevo, average weight  $76,69 \pm 6,61$ kg; 20 students from Novi Sad, the average weight  $76,75 \pm 9,49$ kg; 20 students from Nikšić, average weight  $79,40 \pm 9,66$ kg and 20 students from Sarajevo, average weight  $78,68 \pm 8,20$ kg). For the evaluation of anaerobic capacity of students applied to the Running Anaerobic Sprint Test (RAST) and calculated Fatigue Index (FI). The entire research protocol was conducted in accordance with the Helsinki Declaration.

### **2.2 Description of the Experimental Procedure (Draper and Whyte, 1997)**

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.

### **2.3 Required Resources**

To undertake this test, a 400 metre track, 2 Cones, 2 Stopwatches, and 2 Assistants were required.

In this test the athlete requires to undertake six 35 metre sprints with 10 seconds recovery between each sprint. For data collection following sequences were adopted-

The 1<sup>st</sup> assistant weighs and records the athlete's weight then the athlete warms up for 10 minutes. The assistants mark out a 35 metre straight on the track with the cones. After that each athlete completes six 35 metre runs at maximum pace with 10 seconds allowed between each sprint for turn around as follows:

1. The athlete, using a standing start, gets ready to sprint
2. The 2<sup>nd</sup> assistant gives the command GO for the athlete to start and the 1<sup>st</sup> assistant starts his/her stopwatch
3. When the athlete completes the 35 metres the 1<sup>st</sup> assistant stops his/her stopwatch, records the time and resets the stopwatch and the 2<sup>nd</sup> assistant starts stopwatch to time the 10 second turnaround
4. When 10 seconds has elapsed the 2<sup>nd</sup> assistant gives the command GO for the athlete to start, rests the stopwatch and the 1st assistant starts his/her stopwatch.

3 and 4 are repeated six times.

### 3. RESULTS

**Table 1: Basic statistical parameters of all students in Running Anaerobic Sprint Test (RAST)**

Sample	Indicator RAST	Mean	Min.	Max.	Range	SD	Skew.	Kurt.
East Sarajevo (n=20)	Time 1	5,10	4,46	6,18	1,72	,47	,49	,39
	Watts 1	733,46	410,50	1064,40	653,90	177,42	,25	-,34
	Time 2	5,31	4,63	6,20	1,57	,41	,14	,27
	Watts 2	646,01	406,50	933,10	526,60	142,29	,43	-,01
	Time 3	5,44	4,72	6,40	1,68	,43	,27	,46
	Watts 3	601,11	369,60	881,10	511,50	133,24	,61	,43
	Time 4	5,52	4,63	6,50	1,87	,45	-,05	,77
	Watts 4	579,71	352,80	951,40	598,60	143,15	1,07	1,95
	Time 5	5,70	4,82	6,60	1,78	,49	-,07	-,56
	Watts 5	525,38	337,00	843,30	506,30	131,73	,94	,86
Novi Sad (n=20)	Time 6	5,87	5,10	7,10	2,00	,52	,71	,81
	Watts 6	482,21	270,70	711,90	441,20	113,62	,28	-,07
	Time 1	5,15	4,79	5,84	1,05	,32	-,20	-,95
	Watts 1	700,14	401,80	894,70	492,90	140,19	,19	-,80
	Time 2	5,38	4,57	5,73	1,16	,32	,33	-,39
	Watts 2	617,74	464,70	1082,70	618,00	143,52	,62	1,22
	Time 3	5,41	4,80	5,93	1,13	,30	,01	-,33
	Watts 3	604,20	381,00	904,60	523,60	126,23	,66	,53
	Time 4	5,63	4,90	6,44	1,54	,38	,37	,21
	Watts 4	539,03	317,70	774,40	456,70	113,26	,18	,16
Nikšić (n=20)	Time 5	5,74	5,36	6,41	1,05	,30	,98	,03
	Watts 5	502,04	375,90	656,40	280,50	85,82	,33	-,70
	Time 6	5,88	4,99	6,86	1,87	,42	,16	,79
	Watts 6	481,49	313,20	698,80	385,60	110,14	,30	-,65
	Time 1	5,17	4,86	5,61	,75	,22	,42	-,91
	Watts 1	712,57	472,00	1011,70	539,70	128,54	,29	,61
	Time 2	5,26	5,00	5,65	,65	,19	,49	-,71
	Watts 2	672,84	503,10	943,70	440,60	102,84	,53	1,34
	Time 3	5,51	5,18	5,83	,65	,19	-,05	-,60
	Watts 3	585,91	420,50	815,90	395,40	93,13	,63	,60
Sarajevo (n=20)	Time 4	5,64	5,21	6,05	,84	,22	-,39	-,17
	Watts 4	545,71	407,80	729,00	321,20	80,41	,45	-,13
	Time 5	5,83	5,05	6,25	1,20	,29	-1,31	2,14
	Watts 5	492,71	385,10	724,70	339,60	82,32	1,25	2,10
	Time 6	5,96	5,39	6,89	1,50	,37	,99	1,42
	Watts 6	465,20	354,10	596,00	241,90	72,51	,29	-,80
	Time 1	5,32	5,01	5,96	,95	,23	,36	-,30
	Watts 1	636,52	461,50	799,60	338,10	81,37	,36	,17
Sarajevo (n=20)	Time 2	5,47	4,72	5,84	1,12	,29	-,14	-,75
	Watts 2	594,34	421,20	900,50	479,30	119,56	,37	-,35
	Time 3	5,54	5,10	6,10	1,00	,32	,55	-,96

	<b>Watts 3</b>	576,08	375,10	724,70	349,60	96,40	-,45	-,13
	<b>Time 4</b>	5,65	5,09	6,37	1,28	,35	,24	-,90
	<b>Watts 4</b>	544,26	360,60	771,40	410,80	101,19	,20	,03
	<b>Time 5</b>	5,90	5,25	6,98	1,73	,41	,58	,76
	<b>Watts 5</b>	480,13	279,40	622,00	342,60	90,08	-,36	-,18
	<b>Time 6</b>	6,00	5,32	6,90	1,58	,43	,55	-,02
	<b>Watts 6</b>	454,69	266,8	597,90	331,10	87,90	-,53	,32

**Abbreviation:** Mean (average value); Min (minimal result); Max (maximal result); Rang (range result); SD (standard deviation); Skew. (skewness), Kurt. (kurtosis)

Table 1 shows the basic statistical parameters of the entire population of the defined sample of students of physical education and sport. Quantitative numerical parameters were valorized by the time achieved in six repeated sprint running cycles (35m) as well as by the strength of the lower extremities expressed in watts (Watts). In the analyzed sample, a linear decrease in running speed with each repeated sprint is evident, which is expected (Figure 1). The decrease in velocity occurs as a consequence of lactate accumulation, when Ph decreases with increasing CO<sub>2</sub> secretion leading to muscle fatigue (Jonathan, & Euan, 1997). With the increase of the acidity of the organism, the power of performing the activity also decreases, which was manifested by the loss of strength in each repetition. The average speed of the first run (35m) of students ranged from 5.10sec./733.46W (East Sarajevo) to 5.32sec./636.52 Watts (Sarajevo), or the sixth repetition of 5.87sec./482.21Watts (East Sarajevo) up to 6.00sec/454.69 Watts (Sarajevo). The time on the track achieved by the students of Nikšić (5.17s/712.57Watts) and Novi Sad (5.15sec./700.14Watts) in the first run was numerically slightly higher (in this case weaker) than the sample of students in East Sarajevo, and numerically smaller (in this case better) than the sample from Sarajevo (Table 1). As can be seen, the values of the power results were inversely monitored by the speed values, which is the expected outcome. The decrease in running speed and thus anaerobic strength from the first to the sixth repetition is a consequence of the accumulation of lactate and a decrease in limb strength. The range of achieved speed ranged from a minimum of 0.68sec. (Sarajevo students) up to a maximum of 0.79sec. (Nikšić students), while students in East Sarajevo and Novi Sad ranged between these values. Precisely these differences between the time of repeated sprint running is an indicator of the homogeneity of the same sample of students and their anaerobic capacities, i.e. fatigue resistance.

**Table 2: The basic statistical parameters Index Fatigue (FI) and leg Power students (Watts)**

Sample	Indicator RAST	Mean	Min.	Max.	Range	SD	Skew.	Kurt.
East Sarajevo	Watts Total	594,79	357,80	897,70	539,70	132,90	,58	,89
	Fatigue Index	7,80	3,59	16,76	13,18	3,91	1,21	,51
Novi Sad	Watts Total	574,12	403,20	733,50	330,30	100,53	,01	-1,18
	Fatigue Index	8,45	4,46	16,58	12,12	3,12	,93	,82
Nikšić	Watts Total	579,15	423,76	804,55	379,73	93,29	,57	,93
	Fatigue Index	8,20	3,83	17,39	13,56	3,75	1,22	1,16
Sarajevo	Watts Total	547,96	378,80	706,80	328,00	82,74	-,13	-,22
	Fatigue Index	8,96	4,01	16,99	12,98	1,98	,77	-,30

**Abbreviation:** Mean (average value); Min (minimal result); Max (maximal result); Rang (range result); SD (standard deviation); Skew. (skewness), Kurt. (kurtosis)

Table 2 presents the basic statistical parameters of the average Fatigue Index (FI), minimum and maximum values of anaerobic power of students. The results showed that the students of East Sarajevo achieved the highest average power (594.79 Watts), from a minimum of 357.80 Watts to a maximum of 897.70 Watts. Based on these numerical parameters, their total average Fatigue Index (FI = 7.80 Watts/sec.) was obtained, which is in the range of a minimum of 3.59 Watts/sec. up to a maximum of 16.76 Watts/sec (Figure 2.3). The average

anaerobic power of Novi Sad students was 574.12 Watts, ranging from 403.20 Watts to 733.50 Watts, which resulted in a slightly higher average Fatigue Index FI = 8.45 Watts/sec. The increased value of the FI sample in Novi Sad indicates a weaker state of anaerobic capacity compared to students in East Sarajevo, i.e. lower tolerance to lactates. Students from Nikšić had a slightly higher average power compared to students from Novi Sad (579.15 Watts) ranging from 423.76Watts to 804.55Watts. This in turn defined a decrease in the average value of the fatigue index (FI=8.20 Watts/sec.), from a minimum of 3.83 Watts/sec. up to a maximum of 17.39 Watts/sec. The sample of Sarajevo students achieved on average the lowest anaerobic power of the lower extremities, (547.96 Watts) in the range of 378.80 Watts. to 706.80 Watts, which resulted in a higher Fatigue Index (FI=8.96 Watts/sec.). It turns out that Sarajevo students had the lowest anaerobic power as assessed by RAST (Figures 2, 3). The overall average fatigue index of the entire student sample was 8.35 Watts/sec, with an average anaerobic power of 574 Watts.

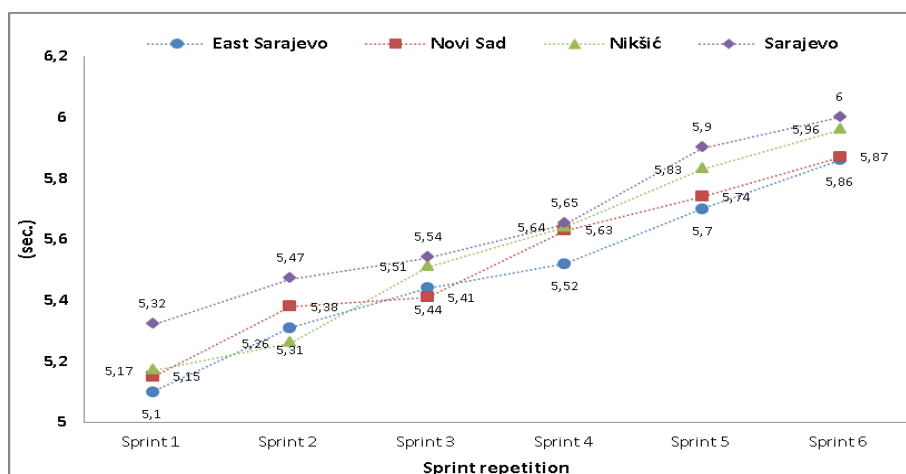
**Table 3: Differences in Fatigue Index between samples of students**

Indicator	Sample	Mean±SD	t-value	p< Sig. (2-tailed)*
Fatigue Index (watts/sec)	East Sarajevo	7,80±3,91	-0,334	p>0,225
	Novi Sad	8,45±3,12		
	East Sarajevo	7,80±3,91	-0,761	p>0,137
	Nikšić	8,20±3,75		
	East Sarajevo	7,80±3,91	-1,311	p<0,025*
	Sarajevo	8,96±1,98		
	Novi Sad	8,45±3,12	0,778	p>0,460
	Nikšić	8,20±3,75		
	Novi Sad	8,45±3,12	-0,511	p>0,329
	Sarajevo	8,96±1,98		
	Nikšić	8,20±3,75	-1,423	p<0,039*
	Sarajevo	8,96±1,98		

**Abbreviation:** Mean (average value), standard deviation (SD), coefficient of t-test value (T-value); significance level p (Sig. \*p<0,05)

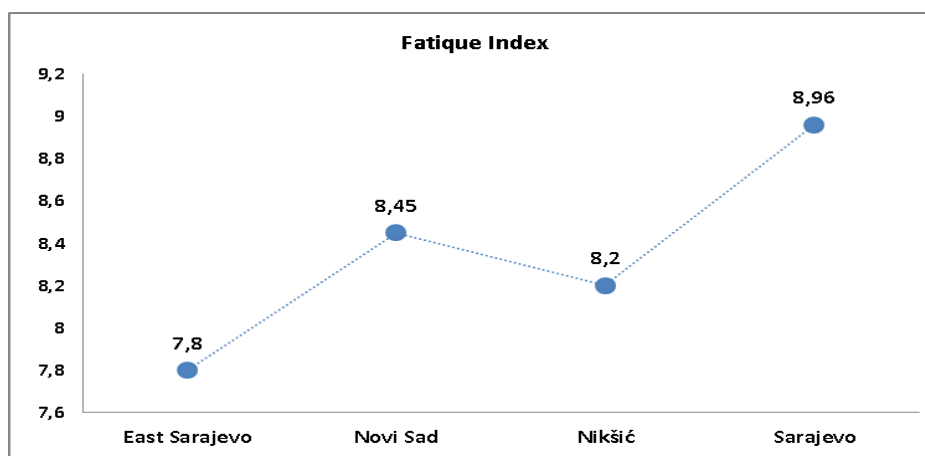
To determine statistically significant differences in anaerobic capacity, a *t*-test for small independent samples was applied. Based on the obtained FI results, differences between the samples of all students are evident. However, statistically significant differences were realized only between students of East Sarajevo and Sarajevo ( $p < 0.012$ ); Nikšić and Sarajevo ( $p < 0.039$ ).

**Figure 1: Time of average student results (RAST)**

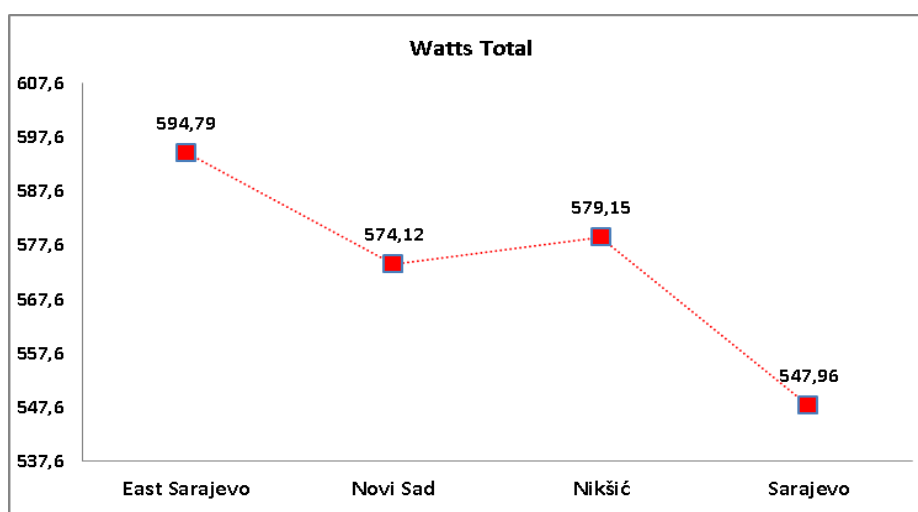




**Figure 2: Fatigue Index mean of all students**



**Figure 3: Power total mean of all students**



#### 4. DISCUSSION

Monitoring and measuring the physical and physiological performance of individuals engaged in sports are important for practice thus assessing the advantages and possible disadvantages of athletes for their sports. According to the measurement results, people who play sports will have information about their physical and physiological ability and will organize a training process on the basis of that information (Bangsbo, 2006).

The current research was conducted with the aim of analyzing the state of anaerobic abilities and primarily determining the differences in the Fatigue Index of students of physical education and sports in different geographical areas (East Sarajevo, Novi Sad, Sarajevo, Nikšić). Assessment of anaerobic abilities was performed using the Running Anaerobic Sprint Test. What defined this research is the fact that it is mainly a population whose field of activity is sports, i.e. physical activity.

Also, the starting point of this research is the assumption that the level of aerobic and anaerobic abilities of students is at a high level, given the fact that they are a healthy young population, physically active through teaching and non-teaching activities, activities through sports clubs, recreation programs, etc. This was largely confirmed by the results of the research. According to Townsend et al., (2013) the anaerobic potential of an individual is specific mainly to individual sports and primarily depends on the nature of the sport, i.e. on

the intensity of sports activity. Anaerobic abilities mainly dominate in short-term activities (jumping, running, throwing). Earlier studies (Granier et al., 1995; Groussard et al., 2003) confirmed that anaerobic sprint running exercises lead to significant oxidative changes in blood composition, increasing lactates to high levels, disturbing the acid-base balance of the organism and reducing the Ph value of the blood. Accumulation of lactate in the blood leads to increased concentration of hydrogen ions and inevitable acidosis as the primary factors of muscle fatigue. The fact is that athletes with a high coefficient of the Fatigue Index need to improve their lactate tolerance through training in order to recover faster and more successfully from explosive activities. Lactate tolerance training is mainly related to the middle of the pre-season, after a certain aerobic base has been formed by continuous or interval training. Then, during the activity, a large amount of lactic acid is produced, and with the increase of the organism's tolerance to lactates, the ability of the organism for efficient removal increases (da Silva, Guglielmo, & Bishop, 2010). Based on the obtained results of the current research, it is evident that the anaerobic capacities of the entire population of physical education and sports students are average for this population (574 Watts) of the average Fatigue Index ( $FI = 8.35$  watts/sec). Statistically significant differences were recorded between the samples of individual faculties (East Sarajevo and Sarajevo,  $p < 0.012$ ; Nikšić and Sarajevo,  $p < 0.039$ ) as a result of different conditions of the cardiovascular system and functional abilities of students, which was confirmed in similar previous studies (Weber & Schneider, 2002; Mezzani, Corr, & Andriani, 2008; Keir, Theriault, & Serresse, 2013). In such activities as RAST, a linear decrease in student strength scores with the number of repetitions is generally expected because the first signs of fatigue appear due to the accumulation of lactate in the blood and the body's inability to recover enough for the next run. Although RAST is performed on the principle of changing activity and rest, rest is not enough for the body to recover, but the activity continues on the basis of oxygen debt and increased concentration of lactate in the blood (Nesser et al., 1996; Zagatto, Beck & Gobatto, 2009). The conclusion is that students who failed to adapt to the given load have less anaerobic power and a higher Fatigue Index. This is noticeable in the case of the sample of Sarajevo students ( $FI=8.96$ Watts/sec) in relation to the students of East Sarajevo ( $FI=7.80$ Watts/sec.) and the students of Nikšić ( $FI=8.20$ Watts/sec.) where statistically significant differences were found as a consequence of different adaptive capabilities of the organism.

In general, students in East Sarajevo recorded the highest average anaerobic power and thus the lowest Fatigue Index (FI), which is certainly a good indicator of higher tolerance to lactates. The obtained results of this research differ significantly from the results of previous research (Zemková, & Hamar, 2004), because our sample reached higher values of average and maximum power (Watts), and thus better anaerobic potential. Also in relation to the research Taskin (2016) on the sample of Turkish students, our sample has a lower average Fatigue index and a higher average anaerobic power, i.e. better lactate tolerance. From a physiological point of view, our students made better use of the transformation of ATP into ADP and released energy during work. According to Scott (2005) when ATP is involved in muscle it is stored and transformed into ADP, and the energy released is used in muscle contractions for movements. This is also an indicator of good condition and aerobic abilities. As is well known, anaerobic potential is dominant in sprinting, or running at 100, 200 and 400m. Paradisis et al., (2005) in their study found significant correlations of racing performance with the RAST test, especially the 200m and 400m disciplines with the average strength of the subjects. It turns out that RAST has correlated significant changes with short-distance performance and can be used as a training tool in anaerobic mode. According to Jonathan and Euan (1997), anaerobic activity is impossible to perform for a long time, because muscles are active more than constant oxygen metabolism, when the level of lactate in the blood follows muscle activity, Ph level decreases with increasing  $CO_2$  secretion and

muscle fatigue occurs. Explosive strength, limb muscle strength, speed, agility and endurance that are important for individuals to show performance in their sport are at the maximum level of movement that requires a high level of anaerobic capacity in individuals (Stone, 2007). In individuals with a high level of anaerobic capacity, recovery after exercise becomes faster and muscle fatigue does not occur suddenly. Adequate energy that is expended during maximum exercises is provided from fat and therefore, if athletes have a high anaerobic capacity, their capacity for sweating is higher. When individuals develop aerobic capacity, their heart rate and body composition also develop (Israel, 1993). As an indicator of the functional capacities of the circulation, respiration and metabolic systems, the maximum aerobic power depends on the functions of the cardiovascular and pulmonary system, the capacity of blood diffusion and the activity of mitochondrial enzymes. When the capacities of these systems are physiologically high, the maximum aerobic capacity will increase (Scott, 2005). It turns out that our sample had both good aerobic potential and good functioning of the organism. Although there are noticeable differences between our students, the general situation is quite good for this population.

The running-based anaerobic sprint test (RAST) has been adapted from the Wingate anaerobic test (WAnT) protocol as a tool to assess RSA and anaerobic power (Keir, Thériault, & Serresse (2013). Also, some studies examine possible gender differences in terms of aerobic and anaerobic endurance (Novak, Vučetić, & Žugaj, 2013). The results indicate that values achieved by tennis players approximate most different those of the middle and long distance runners. This singles out the possible importance of the anaerobic capacity and the high level of sprint endurance in tennis players. The possibility of improvements were anaerobic endurance and its performance can be achieved through circuit training, which is designed to be performed 3 days a week during 10 weeks of training, improves sprint-agility and anaerobic endurance (Taskin, 2009).

Plevnik et al., (2013) found differences between male and female athletes competing in the 400-meter run, in the parameters for assessing not only aerobic and anaerobic energy abilities, but also other physiological parameters. They found a statistically significant difference in the parameters for assessing the ability of aerobic energy in favor of male athletes compared to women, while in other physiological parameters there were no statistically significant differences. The main of study da Silva, Guglielmo, & Bishop (2010) are to investigate the relationship between physiological variables related to aerobic fitness (maximal oxygen uptake:  $\text{VO}_{2\text{max}}$ ; the minimum velocity needed to reach  $\text{VO}_{2\text{max}}$ :  $v\text{VO}_{2\text{max}}$ ; velocity at the onset of blood-lactate accumulation:  $v\text{OBLA}$ ) and repeated sprint ability (RSA) in elite soccer players. A significant negative correlation was found between both  $v\text{OBLA}$  ( $r=-0.49$ ,  $p<0.01$ ) and  $v\text{VO}_{2\text{max}}$  and MT during the RSA test ( $r=-0.38$ ,  $p<0.05$ ) respectively. There were also negative correlations between  $S_{\text{dec}}$  and  $v\text{OBLA}$  ( $r=-0.54$ ),  $v\text{VO}_{2\text{max}}$  ( $r=-0.49$ ) and  $\text{VO}_{2\text{max}}$  ( $r=-0.39$ ). The multiple regression revealed that the aerobic ( $v\text{OBLA}$ ) and anaerobic (FT) components explained approximately 89% of the variance of MT. The results of this study demonstrated that RSA is more strongly correlated with  $v\text{OBLA}$  and  $v\text{VO}_{2\text{max}}$  than the more commonly measured  $\text{VO}_{2\text{max}}$ . Based on the results, it can be concluded that the anaerobic capacities are extremely important regardless in what form will be their evaluation, by which protocol and on which population (Novak, Vucetic, & Žugaj, 2013).

It is evident that anaerobic abilities are closely related to aerobic and very specific to the specific activity, physiological parameters and level of training of the organism. It has also been confirmed that anaerobic capacities are independent of morphological dimensions and are correlated with physiological parameters, metabolic processes of the body and muscle structure (Keir, Theriault, & Serresse, 2013). In this research, the analyzed population of students of physical education and sport is from different sports disciplines of monoststructural and polystructural character. It is concluded that anaerobic capacities are

primary in their activities, which is why the expressed values of anaerobic capacities are expected, which is supported by previous research (Zagatto et al., 2011; Kaminagakura et al., 2012; Taskin, 2016). However, despite that fact, there are obvious differences between them, some of which are statistically significant, as is the case between students from Sarajevo, East Sarajevo and Nikšić. Precisely in these students, aerobic capacities were at a higher or lower level, so they had a better or worse state of anaerobic capacities. The same is true for most sports where the aerobic system plays a significant role in maintaining intensity levels during short-term activities, when the anaerobic effect of repeated short efforts imposes different physiological stress from one prolonged activity reflecting different physiological abilities (Brocherie et al., 2014), which is very often the result of endogenous factors, e.g. altitude.

## 5. CONCLUSION

The study included a total of 80 male students of Physical Education and Sport from Eastern Sarajevo, Novi Sad, Nikšić, and Sarajevo. For the evaluation of anaerobic capacity and Fatigue index of students applied to the Running Anaerobic Sprint Test. The results showed numerical differences in fatigue index values between all student samples. However, the results of the *t*-test identified statistically significant differences in the Fatigue Index (FI) only between students from East Sarajevo and Sarajevo ( $p < 0.025$ ) and Nikšić and Sarajevo ( $p < 0.039$ ). In general, the fatigue index numerically showed the highest value in the sample of Sarajevo students as a factor of lower tolerance to lactates and test performance. This research is a good guideline for future studies of this type in terms of determining anaerobic capacity and fatigue index of different populations from different areas and different sports activities, or in relation to gender and length of sports experience.

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