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Fatique Index - Indicator of Anerobic Abilities Students

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Abstract

Anaerobic abilities is the dominant activity in submaximal and maximal intensity. 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 fatique 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 (age 21±0,5years, the average weight 78,05±8,14kg). For the evaluation of fatique 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 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

Keywords: anaerobic abilities, Fatique index, diagnostics, students.

Introduction

Anaerobic capacity is defined as the maximum amount of adenosine triphosphate that can be resynthesized via anaerobic metabolism (both alactic and lactic systems) during maximal exercise (Minahan, Chia, & Inbar, 2007). Currently, the maximum accumulated oxygen deficit (MAOD) is considered the gold standard to estimate anaerobic capacity. In addition to being sensitive to anaerobic training (Ramsbottom, Nevill, Nevill AM, et al. 1997; Roseguini, Silva, & Gobatto, 2008), MAOD is correlated with performance in high intensity efforts (Scott, Roby, Lohman, & Bunt,1991) and it is used to validate other methods that evaluate anaerobic conditioning (Bertuzzi, Franchini, Ugrinowitsch, et al. 2010; Cooper, Baker, Eaton, & Matthews, 2004; Maxwell, & Nimmo, 1996; Zagatto, Redkva, Loures, et al. 2011; Kaminagakura, Zagatto, Redkva, et al. 2012; Pilianidis, Mantzouranis, Smirniotou, Zaggelidis, & Proios, 2016).

Anaerobic tests are divided into tests which measure anaerobic power and capacity (Vandewalle, et al., 1987). The anaerobic capacity tests can be classified according to whether they attempt to quantify anaerobic performance, or provide a work estimation of anaerobic capacity (Gastin, 1994). Currently, the Wingate Anaerobic Test (WAnT) is considered to be the most reliable and valid test and it is used in a number of laboratories and in a variety of sports for the evaluation of the muscle power generation during short term exhaustive exercise. The classification of the WAnT as an anaerobic test has been based on indirect assessments concerning the contribution of anaerobic energy metabolism in performance and it includes reports of oxygen deficits and oxygen debt (Inbar, Bar-Or, & Skinner, 1996), blood lactate concentration (Bar-Or, 1987) and muscle lactate concentrations (Jacobs, Tesch, Bar-Or, et al., 1993), estimating the fatigue index.

The fatigue index is a concept used in the study of the development of fatigue during anaerobic exercise. Anaerobic exercise consists of activities - such as sprinting - that rely on glycogen rather than oxygen for fuel. The index number indicates the rate at which an athlete's power output declines. It can be used as an indicator of an athlete's aerobic endurance. The higher the fatigue index, the lower your ability to maintain power over a series of sprints. During intense exercise, muscle and blood lactate can rise to very high levels. Lactate accumulation causes an increased concentration of hydrogen ions and corresponding acidosis, a primary factor in muscle fatigue. Athletes with high fatigue index numbers should train to improve lactate tolerance in order to promote quicker recoveries from explosive bursts of speed and power. Lactate tolerance training usually starts midway through the pre-season, after an aerobic base has been built with continuous or interval training (Pavlović, Mihajlović, & Radulović, 2015). Drills involving repetitions of sprints and shuttle runs produce high levels of lactic acid; as the body's tolerance to lactate grows, so does its capacity for efficient removal. Most of the tests that are designed to measure the characteristics of the anaerobic performance are time dependent. These tests were extensively used in order to evaluate the anaerobic capacity of the involved muscle groups. To use MAOD to estimate anaerobic capacity is not easy. It requires several submaximal exercise bouts and one supramaximal exercise bout (Medbo, Mohn, Tabata, et al. 1988). It is also difficult to use MAOD during the periodized training routine. Furthermore, it is necessary to measure the oxygen uptake (VO2) during the exercise bouts, which makes the methodological use of MAOD a high financial cost.

During the last decades a number of sport specific anaerobic field tests have been developed (Borsetto, Ballarin, Casoni, et al., 1989; Wragg, Maxwell, & Doust, 2000; Thomas, Plowman,

& Looney, 2002), in order to assess the fitness fatigue - indicator anaerobic capabilities. The running-based anaerobic sprint test (RAST), which is adaptation of the WAnT to running (Zacharogiannis, Paradisis, & Tziortzis, 2004; Paradisis, Tziortzis, Zacharogiannis, et al., 2005; Meckel, Machnai, & Eliakim, 2009), has been widely used to assess anaerobic fitness. The RAST output (i.e., peak, power, mean power, fatigue index, maximal speed, and mean speed) are similar to those determined in WAnT, showing high correlations with the same variables. Zagatto, et al. 2011 showed that the RAST is a reproducible and valid procedure for assessing anaerobic power. It is acknowledged as a good predictor of running performance (35 to 400 m), which can be easily added to be training routine. Additionally, this methodology is used to evaluate athletes in many sports such as soccer (Alizadeh, Hovanloo, & Safania, 2010; da Silva, Guglielmo, & Bishop, 2010; Keir, Thériault & Serresse, 2013), basketball (Balciunas, Stonkus, Abrantes & Sampaio, 2006), running athletes (Nesser, Latin, Berg & Prentice, 1996; Kaminagakura, Zagatto, Redkva, et al. 2012), differences between male and female athletes (Plevnik, Vučetić, Sporiš, et al. 2013) or students physical education and sports (Berthoin, Dupont, Mary & Gerbeaux, 2001; Zemkova, & Hamar, 2004).

In the absence of research on the population of students of physical education and sport emerged the idea for this research. Considering the fact that students of physical education and sport are among the physically active population, the assumption is that they have a good anaerobic capacity, and lower fatigue index. Guided by this assumption, the goal of the research was to be based on the quantitative value of the index of fatigue, as one of the relevant indicators, determine the status of anaerobic capacity Physical Education and Sport of students.

Method

Participants

The study included a total of 50 students of Physical Education and Sport of East Sarajevo and Nikšić (age 21±0,5years, the average weight 78,05 ± 8,14kg) males. For the evaluation of fatique index of students using to the Running Anaerobic Sprint Test (RAST). The research was conducted in October 2015 as part of practical teaching of Athletics. All subjects were healthy without any psychosomatic changes and voluntarily participated in the study.

The sample of variables

Description of the experimental procedure RAST (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.

RAST is similar to the Wingate Anaerobic 30 cycle Test (WANT) in that it provides coaches with measurements of power and fatigue index. WANT is more specific for cyclists whereas the RAST provides a test that can be used with athletes where running is the primary method of movement.

Required Resources

To undertake this test you will require (400 metre track, Two Cones, Two Stopwatches, Two Assistants).

This test requires the athlete to undertake six 35 metre sprints with 10 seconds recovery between each sprint.

- The 1st assistant weighs and records the athlete's weight
- The athlete warms up for 10 minutes
- The assistants mark out a 35 metre straight on the track with the cones
- The assistants each have a stopwatch
- The athlete completes six 35 metre runs at maximum pace with 10 seconds allowed between each sprint for turnaround as follows:

1. The athlete, using a standing start, gets ready to sprint
2. The 2nd assistant gives the command GO for the athlete to start and the 1st assistant starts his/her stopwatch
3. When the athlete completes the 35 metres

- the 1st assistant stops his/her stopwatch, records the time and resets the stopwatch

- the 2nd assistant starts his/her stopwatch to time the 10 second turnaround

4. When 10 seconds has elapsed the 2nd assistant gives the command GO for the athlete to start, rests the stopwatch and the 1st assistant starts his/her stopwatch
5. 3 and 4 are repeated six times

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).

Results and Discussion

Table 1. Basic statistical parameters of students (n=50)

	Mean	*Min.*	*Max.*	*Range*	*SD*
Time 1	5,14	4,66	5,89	1,23	,34
Watts 1	723,02	441,25	1038,05	596,80	97,98
Time 2	5,29	4,81	5,92	1,11	,30
Watts 2	659,43	454,80	938,40	483,60	122,56
Time 3	5,48	4,95	6,11	1,16	,31
Watts 3	593,51	395,05	848,50	453,45	113,18
Time 4	5,58	4,92	6,27	1,35	,34
Watts 4	562,71	380,30	840,20	459,90	111,78
Time 5	5,77	4,94	6,42	1,48	,39
Watts 5	509,06	361,05	784,00	422,95	107,02
Time 6	5,92	5,24	6,99	1,75	,44
Watts 6	473,71	312,40	653,95	341,55	93,06

Legend: Mean (average value); Min (minimal result); Max (maximal result); Rang (range result); SD (standard deviation)

Table 2. The basic statistical parameters Fatigue Index (FI) and leg Power students

	Mean	*Min.*	*Max.*	*Range*	*SD*
Time Total	5,53	4,92	6,26	1,34	,35
Watts Total	586,97	390,78	851,12	460,34	113,09
Fatigue Index (watts/sec)	8,00	3,71	17,07	13,36	3,83

Legend: Mean (average value); Min (minimal result); Max (maximal result); Rang (range result); SD (standard deviation)

In Tables 1 are presented with basic statistical parameters defined sample of students. The numerical parameters are defined earned time in six replicate runs (35m) as well as the strength of the lower extremities expressed in watts. Looking at Table 1, may be concluded with a sample of students is serious homogeneity in the results of repeated running in the test (RAST) as evidenced by the range of results and the value of SD (Table 1). In this sample is notable linear decrease the speed of running as expected because a consequence of fatigue accumulation of lactate in the blood and decrease power limbs (Chart 1,3). The average time in the first running accounted for 5,14sec. (Watts 1=723,02), and in the last six 5,92sec (Watts 6=473,71). From the first to the sixth running, decreased rate of 0,78 sec. The minimum result moving from 4,66 sec (441,25 Watts 1) to 5,24 sec. (312,40 Watts 6) with a range 0,58sec., maximum results of 5,89sec (1038,05 Watts 1) to 6,99sec. (653,95 Watts 6) in the range 1,10sec.

Table 2 defines the basic statistical parameters the overall average time RAST, Fatigue Index and the overall average, minimum and maximum values of the lower extremities students. The average power of students amounted to 586,97 Watts, with a minimum score of 390,78Watts and a maximum of 851,12Watts in the range 460,34 Watts. The average time total RAST of students amounted to 5,53 sec. with a minimum score of 4,92 sec. and a maximum of 6,26 sec. in the range 1,34 sec. Based on the strength values obtained Fatigue index (FI) of 8,00 Watts/sec, with a minimum values of FI=3,71 Watts/sec and a maximum 17,07 Watts/sec, in the range 13,36 Watts/sec. Slightly higher average index of fatigue was recorded with students which indicates weaker state of anaerobic capacity, or lower tolerance to lactate (Chart 2).

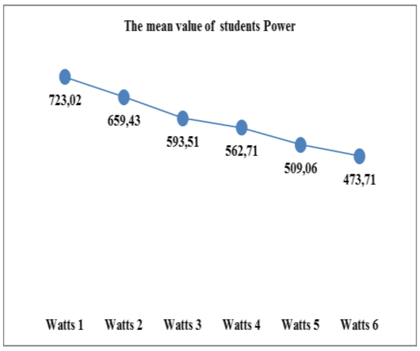

Chart 1. Power Watts students

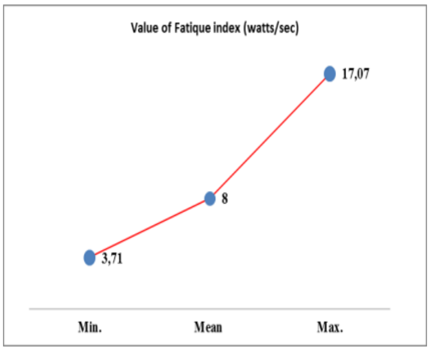

Chart 2. Fatique index of students

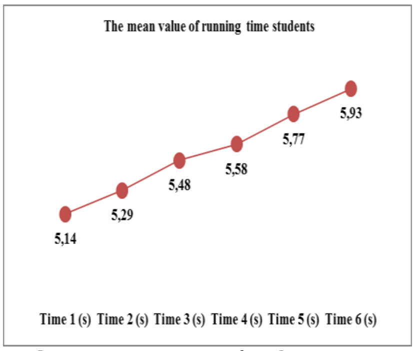

Chart 3. Time running of students

The research was conducted in order to evaluate the fatique index (anaerobic abilities) of students of Physical Education and Sports from East Sarajevo and Nikšić using Running Anaerobic Sprint Test (RAST). The assumption is that the level of their anaerobic capabilities is at a high level, as not confirmed by the results of research. Anaerobic potential is specific to individual sports and it depends on the nature of sport, that is from their intensity (Townsend, Stout, Morton, Jajtner, et al., 2013). Anaerobic capacities mainly dominate in the activities of short duration (jumping, running, throwing). Studies by other authors (Granier et al., 1995; Groussard., Rannou-Bekono, Machefer, & et al. 2003) have confirmed that anaerobic sprint exercises lead to significant oxidative changes in the composition of blood (da Silva, Guglielmo, & Bishop, 2010). During intense exercise, muscle and blood lactate can rise to very high levels, and of increased value of the fatique index. Lactate accumulation causes an increased concentration of hydrogen ions and corresponding acidosis, a primary factor in muscle fatigue. Athletes with high fatigue index numbers should train to improve lactate tolerance in order to promote quicker recoveries from explosive bursts of speed and power. Lactate tolerance training usually starts midway through the pre-season, after an aerobic base has been built with continuous or interval training. Drills involving repetitions of sprints and shuttle runs produce high levels of lactic acid as the body's tolerance to lactate grows, so does its capacity for efficient removal. Based on the presented results, it can be concluded that the fatique index anaerobic potential of students of Physical Education and Sports East Sarajevo and Nikšić is average are the result of the state of the cardiovascular system, as well as the functional abilities of students, that has been confirmed in earlier studies (Mezzani, Corr, & Andriani, 2008; Keir, Thériault, & Serresse, 2013).

Linear decrease of power results in students is expected, because experiencing the first signs of fatigue, caused by the accumulation of lactic acid in the blood and the inability of the body to recover enough for the next running. Although RAST is performed on the principle of changing of activity and rest, rest is insufficient to recover the body, but the activity continues in terms of oxygen debt and an increased concentration of lactate in the blood (Nesser, Latin, Berg, & Prentice, 1996; Zagatto, Beck, & Gobatto, 2009). The total average power of students about 587 Watts, with a min. result of 390,78 Watts and a max. of 851,12 Watts. Average of fatique index of students amounted to 8,00 Watts/sec, with min. 3,71watts/sec and max. 17,07 Watts/sec. suggesting a weaker condition of anaerobic capacity or the lower tolerance to lactic acid (lactate). The total average time of test RAST students amounted 5,53 sec., with a min. result of 4,92 sec. and a max. of 6,26 sec. Our results differ significantly from the results of Zemkova and Hamar (2004), Taşkin (2009) because it reached higher values of average and maximum power, and thus are of better anaerobic potential and smaller fatique index.

The aim of study (Paradisis, Tziortzis, Zacharogiannis, et al. 2005) was to investigate the corerelations of the running-based anaerobic sprint test (RAST) and performance on the 100, 200, 400m distance tests. The correlations coefficients were statisticallz significant with an exception of the fatigue index 2, where the performance of the 100m was higly correlated and the 200m and 400m were higly correlated with the average power. It could be concluded that RAST correlated significants with the performance in short distances and it could predict anz changes in the performance and could be used as a training tool in anaerobic training.The running-based anaerobic sprint test (RAST) has been adapted from the Wingate anaerobic test (WAnT) protocol as a tool to assess RSA and fatique index (Keir, Thériault, & Serresse, 2013). Also, some studies examine possible gender athletics differences in terms of aerobic and anaerobic endurance, fatique index, other physiological parameters (da Silva, Guglielmo, & Bishop, 2010; Novak, Vučetić, & Žugaj, 2013; Plevnik, Vučetić, Sporiš, et al. 2013).

The studied population of students of physical education and sport is from different sports disciplines so the anaerobic capacities are primary in their activities, that's why were expected expressed values of anaerobic capacities, what supports the research of Zagatto, et al. (2011), Kaminagakura, et al. (2012). The same applies to most sports, for example in football the aerobic system plays a significant role in the maintenance of intensity level during a soccer game, which is characterized by short bursts of activities (Cooper, Baker, Eaton, & Matthews, 2004). Anaerobic performance of repeated brief efforts imposes different physiological stress than a single prolonged activity and, thus, may reflect different physiological capabilities (Meckel, Machnai, & Eliakim, 2009; Brocherie, Girard, Forchino, Al Haddad, et al. 2014). It has been also confirmed that the anaerobic capacities are independent of morphological dimensions, and they are in correlation with physiological parameters, metabolic processes of the body and muscle structure (Gastin, 1994; Keir, Thériault, & Serresse, 2013).

Certain studies involving the population of university students (Watanabe, Nakadoma, Maeda, 1994; Tongprasert & Wattanapan, 2007; Mazurek, et al., 2010; Pavlović, Savić & Tosic, 2012) have shown that students who have less value of fitness index and VO^2 max., and a higher fatigue fitness are at increased risk of cardiovascular diseases (Paffenbarger, Hyde, Wing, et al, 1984; Kokkinos, et al., 1995; Sadhan, Koley, Sandhu, 2007; Sharma, Subramanian & Arunachalam, 2013).

This research is a good guideline for future studies of this issue in terms of determination and evaluation of anaerobic capacities and fatigue index of the same or different populations students or sportsmen.

Conclusion

The study included a total of 50 students males of Physical Education and Sport of East Sarajevo and Nikšić (age 21±0,5 years, the average weight 78,05 ± 8,14kg). For the evaluation of Fatique index (anaerobic capacity) of students applied to the Running Anarobic Sprint Test-RAST. The results showed values of Fatique index of students who "are expected" for this population. The average strength (power) of the lower extremities of students Physical Education and Sports amounted to about 587 Watts (average Fatique index=8,00 watts/sec) which in some tolerable limits. The obtained values of power and fatigue index value of more than 17watts/sec indicates point to weaker state of anaerobic abilities or lower tolerance to lactate, that weaker body anaerobic power students. Based on these results it can be concluded that the general situation of anaerobic capacity is still (un)satisfactory, considering that this is a population of students of physical education and sport, who are engaged in sports activities, through teaching and extra-curricular activities, mainly sports clubs. In fact, research in the last three decades has shown that physical inactivity with a negative impact of everyday life is seriously threatening the health and physical condition of the human body. As a result of hypokinesian lifestyle we have a situation that it is the most common risk factor for cardiovascular diseases. Attention must be directed at upgrading their anaerobic capacity in terms of raising awareness about the benefits of good physical condition of each individual, the possible unintended consequences that may result in extremely unpleasant consequences (Kingwell, & Jennings, 1993; Sadhan, Koley, & Sandhu, 2007).

Conflict of Interest

The authors have not declared any conflicts of interest.

REFERENCES

Alizadeh, R., Hovanloo, F., Safania, AM. (2010). The relationship between aerobic power and repeated sprint ability in young soccer players with different levels of VO2 max. *J Phys Educ Sport Manag.* 27:86-92.

Bar-Or, O. (1987). The Wingate Anaerobic Test. An Update on Methodology, Reliability and Validity. *Sports Medicine*, 4(6), 381-394.

Borsetto, C., Ballarin, E., Casoni, I., Cellini, M., Vitiello, P., & Conconi, F. (1989). A Field Test for Determining the Speed Obtained Through Anaerobic Glycolysis in Runners. *International Journal of Medicine*,10 (5), 339-345.

Berthoin, S., Dupont, G., Mary, P., Gerbeaux, M. (2001). Predicting Sprint Kinematic Parameters From Anaerobic Field Tests in Physical Education Students. *Journal of Strength & Conditioning Research*, 15 (1), 75-80.

Balciunas, M., Stonkus, S., Abrantes, C., Sampaio, J. (2006). Long term effects of different training modalities on power, speed, skill and anaerobic capacity in young male basketball players. *J Sports Sci Med*. 5: 163-170.

Bertuzzi, RCM., Franchini, E., Ugrinowitsch, C., et al. (2010). Predicting MAOD using only a supramaximal exhaustive test. *Int J Sports Med*. 3:477-481.

Brocherie, F., Girard, O., Forchino, F., Al Haddad., H., Dos Santos, GA., Millet, GP. (2014). Relationships between anthropometric measures and athletic performance, with special reference to repeated-sprint ability, in the Qatar national soccer team. *J Sports Sci*. 32(13), 1243-1254.

Cooper, SM., Baker JS., Eaton, ZE., Matthews, N. (2004). A simple multistage field test for the prediction of anaerobic capacity in female games players. *Br J Sports Med*. 38:784-789.

Gastin, PB. (1994). Quantification of anaerobic capacity. *Scand J Med Sci Sports*. 4:91-112.

Granier, P., Mercier, B., Mercier, J., Anselme, F., Préfaut,C (1995). Aerobic and anaerobic contribution to Wingate test performance in sprint and middle-distance runners. *European Journal of Applied Physiology and Occupational Physiology*, 70 (1), 58-65.

Groussard, C., Rannou-Bekono, F., Machefer, G., Chevanne, M., Vincent, S., Sergent, O., . . . Gratas-Delamarche, A. (2003). Changes in blood lipid peroxidation markers and antioxidants after a single sprint anaerobic exercise. *European journal of applied physiology*, 89 (1), 14-20

Inbar, O., Bar-Or, O., & Skinner, S. (1996). *The Wingate Anaerobic Test*. Champaign: Human Kinetics

Jacobs, I., Tesch, P.A., Bar-Or, O., Karlsson, J., & Dotan, R. (1993). Lactate in human skeletal muscle after 10 and 30s of supramaximal exercise. *Journal of Applied Physiology and Respiratory Environmental Exercise Physiology*, 55(2), 365-367.

Kingwell, B.A., & Jennings, G.L. (1993). Effects of walking and other exercise programs upon blood pressure in normal subjects. *The Medical Journal of Australia*, 158 (4), 234-238.

Kokkinos, P.F., Narayan, P., Colleran, J.A., Pittaras, Notargiacomo, A.A., Reda, D.D., & Papademetriou, V. (1995). Effects of regular exercise on blood pressure and left ventricular hypertrophy in african-american men with severe hypertension. *The New England Journal of Medicine*, 333 (22), 1462-1467.

Kaminagakura, EI., Zagatto, AM., Redkva, PE., Gomes, EB.,Loures, JP., Kalva-Filho, CA., Franco, VH., Papoti, M. (2012). Can Running-Based Anaerobic Sprint Test be used to Predict Anaerobic Capacity? *Journal of Exercise Physiology*, 15 (2), 90-99.

Keir, DA., Thériault, F., Serresse, O. (2013). Evaluation of the running-based anaerobic sprint test as a measure of repeated sprint ability in collegiate-level soccer players. *J Strength Cond Res*. 27 (6),1671-1678.

Medbo, J., Mohn, A., Tabata, I., et al. (1998). Anaerobic capacity determined by maximal accumulated O2 deficit. *J Appl Physiol*. 64:50-60.

Maxwell, N., & Nimmo, M. (1996). Anaerobic capacity: a maximal anaerobic running test versus the maximal accumulated oxygen deficit. *Canadian Journal of Applied Physiology*, 21, 35-47.

Minahan, C., Chia, M., Inbar, O. (2007). Does power indicate capacity? 30-s Wingate anaerobic test vs. maximal accumulated O2 deficit. *Int J Sports Med*. 28:836-843.

Mezzani, A., Corrà, U., Andriani, C., et al. (2008). Anaerobic and aerobic relative contribution to total energy release during supramaximal effort in patients with left ventricular dysfunction. *J Appl Physiol.* 104:97–102.

Meckel, Y., Machnai, O., Eliakim, A. (2009). Relationship among repeated sprint tests, aerobic fitness, and anaerobic fitness in elite adolescent soccer players. *J Strength Cond Res*. 23 (1), 163-169.

Mazurek, K., Żmijewski P., Czajkowska A., Lutosławska G. (2010). Cardiovascular risk instudents with different level of aerobic capacity. Biology of Sport, 27 (2), 105-109.

Nesser, TW., Latin, RW., Berg, K., Prentice, E. (1996). Physiological Determinants of 40-Meter Sprint Performance in Young Male Athletes. *Journal of Strength & Conditioning Research*, 10 (4), 263-267.

Novak, D., Vučetić, V., Žugaj, S. (2013). Differences in Energy Capacities between Tennis Players and Runners. *Coll. Antropologicum*, 37 suppl. 2 (2), 107-112.

Paffenbarger, RS Jr, Hyde, RT., Wing, AL., Steinmetz, CH. (1984). A natural history of athleticism and cardiovascular health. *JAMA*, 252: 491-495.

Paradisis, GP., Tziortzis, E., Zacharogiannis, A., Smirniotou, A. & Karatzanos, L. (2005). Correlation of the running-based anaerobic sprint test (RAST) and performance on the 100m,200m and 400m distance tests. *Journal of Human Movement Studies*, (49), 77-92.

Pavlović, R., Savić, V., & Tošić, J. (2012). The influence of morphological, motor and functional parameters in the assessment of the fitness index and maximal oxygen consumption. *Sport and Health*, 7 (3), 30-37.

Pavlović, R., Mihajlović, I., Radulović, N. (2015). Evaluation of anaerobic abilities of physical education and sports students applying the running anaerobic sprint test. *SPORT SCIENCE- International Scientific Journal on Kinesiology*, 8 (2), 32-38.

Plevnik, M., Vučetić, V., Sporiš, G., Fiorentini, F., Milanović, Z., Miškulin, M. (2013). Physiological Responses in Male and Female 400m Sprinters. *Croatian Journal of Education*, 15 (4), 93-109.

Pilianidis, T., Mantzouranis, N., Smirniotou, A., Zaggelidis, G., Proios, M. (2016). Validity evaluation of a ne anaerobic performance field test. *Journal of Physical Education and Sport* ® (JPES), 16 (1), 28 -32.

Ramsbottom, R., Nevill, ME., Nevill, AM., et al. (1997). Accumulated oxygen deficit and shuttle Run performance in physically active men and women. *J Sports Sci*. 15:207-214.

Roseguini, AZ., Silva, AS., Gobatto, CA, (2008). Determinações e relações dos parametros anaeróbios do RAST, do limiar anaerobio e da resposta lactacidemica obtida no inicio, no intervalo e ao final de uma partida oficial de handebol. *Braz J Spors Med*. 14:46-50.

Scott, CB., Roby, FB., Lohman, TG., Bunt, JC. (1991). The maximally accumulated oxygen deficit as an indicator of anaerobic capacity. *Med Sci Sports Exerc*. 23:618-624.

Sadhan, B., Koley, S., Sandhu, J.S. (2007). Relationship between cardiorespiratory fitness, body composition and blood pressure in Punjabi collegiate population. *J Hum Ecol*. 22(3), 215–219.

da Silva, JF, Guglielmo, LG., Bishop, D. (2010). Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. *J Strength Cond Res*. 24(8), 2115-2121.

Sharma, V.K., Subramanian, S.K., & Arunachalam, V. (2013). Evaluation of body composition and its association with cardio respiratory fitness in south Indian adolescents. *Indian J Physiol Pharmacol*. 57(4), 399–405

Thomas, C., Plowman, A.S., & Looney, A.M. (2002). Reliability and Validity of the Anaerobic Speed Test and the Field Anaerobic Shuttle Test for Measuring Anaerobic Work Capacity in Soccer players.*Measurement in Physical Education and Exercise Science* 6(3), 187-205.

Tongprasert, S., Wattanapan, P. (2007). Aerobic Capacity of Fifth-Year Medical Students at Chiang Mai University. *J Med Assoc Thai*. 90 (7), 1411-1416

Taşkin, H. (2009). Effect of circuit training on the sprint-agility and anaerobic endurance. *J Strength Cond Res.* 23(6), 1803-1810.

Townsend, J.R., Stout,J.R., Morton, A.B., Jajtner,A.R., Gonzalez,A.M., Wells,A.J., Mangine, G.T., Mc Cormack, W.P., Emerson, N.S., Robinson, E.H., Hoffman, J.R., Fragala, M.S., Cosio-Lima, L. (2013). Excess post-exercise oxygen consumption (epoc) following multiple effort sprint and moderate aerobic exercise. *Kineziology*, 45 (1), 16-21.

Vandewalle, H., Peres, G., & Monod, H. (1987). Standard Anaerobic Exercise Tests. *Sports Medicine*, 4, 268-289.

Zacharogiannis, E., Paradisis, G., Tziortzis, S. (2004). An evaluation of tests of anaerobic power and capacity. *Med Sci Sports Exercise*, 36, 116.

Zemková, E., & Hamar, D. (2004). “All-Out” tethered running as an alternative to Wingate anaerobic test. *Kinesiology*. 36:165-172.

Zagatto, AM., Beck, WR., Gobatto, CA. (2009) Validity of the Running Anaerobic Sprint Test for Assessing Anaerobic Power and Predicting Short-Distance Performances. *Journal of Strength & Conditioning Research, 2*3 (6): 1820-1827.

Zagatto, AM, Redkva, P., Loures, J., et al. (2011). Anaerobic contribution during maximal anaerobic running test: Correlation with maximal accumulated oxygen deficit. *Scand J Med Sci Sports*.1:1-9.

Watanabe, K., Nakadomo, F., & Maeda, K. (1994). Relationship between body composition and cardiorespiratory fitness in Japanese junior high school boys and girls. *Ann Physiol Anthropol*. 13(4), 167–174.

Wragg, C.B., Maxwell, N.S., & Doust, J.H. (2000). Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Applied Physiology*, 83, 77-83.