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Research article

A COMPARISON OF THE PWC170 BETWEEN VOLLEYBALL AND SOCCER PLAYERS FROM ADAPTED MARGARIA AEROBIC STEP TEST

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Abstract
*Journal of Sports Science and Physical Education 2(*1): 34–44, 2014 - Margaria aerobic step test adapted by originally elaborated equations for estimation of PWC170 was published in our previous studies. The aim of this study was to compare the PWC170 and HR values between volleyball and soccer players from the adapted Margaria aerobic step test. Two groups of 10 volleyball and 10 soccer players (Mean±SD) age 20.1±1.45, 20.7±1.6; body mass 78.25±6.94, 78.6 ±6.81 and BMI 23±1.7, 23±2.2 carried out on the 40 cm platform adapted Margaria aerobic step test (AMAST), consists of two submaximal loads. HR was measured by Suunto t6c monitor. PWC170 was computed by Arakchiiski's equations. The absolute and relative PWC170 mean (SD) from AMAST were as follows: volleyball group -1378±182 [$kgm.min^{-1}$]; 17.6±2.21 [$kgm.min^{-1}.kg^{-1}$] and soccer group -1323±133 [$kgm.min^{-1}$]; 16.8±0.98 [$kgm.min^{-1}.kg^{-1}$]. Comparing of PWC170 and HR (rest, work and recovery) values between both groups showed insignificant differences ($p>0.05$). It was concluded that both groups have the same level of physical working capacity and HR recovery.These findings suggest that the AMAST is appropriate for comparing the physical working capacity in team sports and the test has wide practical applicability in all conditions, because only one platform is needed.

Keywords: physical working capacity, heart rate

Introduction

Submaximal tests getting popular and are increasingly implemented in the sports-teaching practice because of their accessibility. They are easily applicable and feasible, some of them in all conditions, laboratory and field. Likewise also they are applied by a wide range of sports specialists without reductions in the frequency throughout the annual cycle. Submaximal tests are widely used in exercise physiology for predicting VO2max through the linear extrapolation method and assessment the ability of the cardiorespiratory system. The predictability of VO_2max has been studied using a variety of submaximal treadmill, cycle ergometer, step, walking and run tests (Arts, Kuipers, Jeukendrup, & Saris, 1993; Àstrand & Ryhming, 1954; Jetté, Campbell, Mongeon, & Routhier, 1976; Léger & Lambert, 1982; Margaria, Aghemo, & Rovelli, 1965; Siconolfi, Cullinane, Carleton, & Thompson, 1982; Sproule, Kunalan, McNeill, & Wright, 1993; Swank et al., 2001; Widrick, Ward, Ebbeling, Clemente, & Rippe, 1992). From the point of practical view it is important to get more information from them such as for physical working capacity. Analysis of published data about submaximal tests showed that they are divided into groups for aerobic (Arts et al., 1993; Àstrand & Ryhming, 1954; Ekblom-Bak, Björkman, Hellenius, & Ekblom, 2014; Fitchett, 1985; Patton, Vogel, & Mello, 1982; Verma, Sen Gupta, & Malhotra, 1976) and physical capacity measurements (Karpman, Belotzerkovskii, & Gudkov, 1974; Krastev, 1983; Sjöstrand, 1947; Wahlund, 1948). Indirect tests to determine maximum oxygen uptake and physical capacity were developed based on the existing linear relationship between heart rate, oxygen consumption and power load under the conditions of steady state. Physical working capacity plays an important role in clarifying the functional state and capabilities of the body to perform mechanical work. Significant place in functional studies have submaximal tests to determine the physical working capacity (PWC170) at the working heart rate 170 beats per minute [bpm] (Boreham, Paliczka, & Nichols, 1990; Karpman et al., 1974; Krastev, 1983; Pavlova, Mavrodieva, & Dobrev, 1981; Sjöstrand, 1947; Wahlund, 1948). There is scant data for the assessment of physical working capacity (PWC170) from the applied predictive VO_2max tests. It was found that PWC170 and predicted VO2max data are only from implementation of two-load cycle ergometer PWC170 test and three-load Eurofit test (Dimitrova, 2001; Karpman et al., 1974; Pavlova, Mineva, & Uzunova, 2010; Petkov, Toteva, & Maznev, 2006). The results of ergometer and step-tests for indirect VO_2 max measurements are conflicting because of the difference between cycling and stepping (Keren, Magazanik, & Epstein, 1980; Siconolfi, Garber, Lasater, & Carleton, 1985). In the literature is not available information for PWC170 step tests unlike the established cycle ergometer models. This issue is somewhat related to calculation of the mechanical work in step tests (Pavlova, Somlev, & Uzunova, 2009). Widespread approach for predicting PWC170 has been considered PWC170 Cycle Test (Uzunova, Pavlova, & Somlev, 2009) but more precise results are obtained from step-test escaping incorrectness from reflex mechanism in cycle ergometer (Pavlova, Uzunova, & Arakchiiski, 2007). Nevertheless submaximal step-tests are more applicable under different conditions. The results from the conventional Margaria aerobic step test adapted for estimation of PWC170 by originally elaborated equations were published in our previous studies (Pavlova, Arakchiiski, & Uzunova, 2007; Pavlova, Uzunova, & Arakchiiski, 2007; Pavlova, Uzunova, & Arakchiiski, 2009; Uzunova, & Pavlova, 2012). The endurance fitness is a factor contributing to performance in soccer and volleyball (Boraczyński et al., 2012; Watson, 1977). The aim of this study was to compare the PWC170 and HR values between volleyball and soccer players from the adapted Margaria aerobic step test.

Method

Subjects

Two groups of 10 volleyball and 10 soccer players (Mean±SD) age 20.1±1.45 yrs., 20.7±1.6 yrs.; body mass 78.25±6.94 kg, 78.6 ±6.81 kg; height 184.25±4.91 cm, 182.96±5.86 cm and BMI 23±1.7 kg/m^2, 23±2.2 kg/m^2 were studied. Prior to the investigation were received all necessary approvals to conduct them. The subjects were carefully informed of the procedures of the study before they voluntarily signed an informed consent.

Design

The research was conducted morning at least hour and a half from the last meal. Heart rate of athletes in sitting position during the 5 minute rest was recorded continuously. After warming up all subjects carried out adapted Margaria aerobic step test (AMAST) followed by 5 minutes recovery in sitting position.

Submaximal step test protocol

Protocol of Margaria aerobic step test consists of two submaximal loads each one of them with 5 minutes duration. For the first load constant pace is 15 steps per minute and for the second one is 25 steps per minute. Test performance is stepping up and down on a platform at constant pace controlled by metronome. The height of platform is 0.4 m.

Measurements

The Suunto t6c HRM was used to record heart rate data during three consecutive stages: 5 min rest, 10 min two-load Margaria step test, 5 min recovery (Pavlova, Uzunova, & Somlev, 2009; Somlev, & Uzunova, 2009; Somlev, Uzunova, & Pavlova, 2009). The monitor was set to record R-R intervals. After each recording the timer was reset to obtain a separate file for each stage. Physical working capacity (absolute and relative) at a heart rate of 170 beats per minute was calculated from the conventional Margaria aerobic step test. The test was adapted (AMAST) for physical working capacity measurement by Arakchiiski's equations for assessing external mechanical work and Karpman's equation for PWC170 (Karpman, Belotzerkovskii, & Gudkov, 1974; Pavlova, Uzunova, & Arakchiiski, 2007).

For work out the Margaria step test work equations one step is divided into two phases – upward and downward movement (Pavlova, Uzunova, & Arakchiiski, 2007).

Total external work for one step (Wstep) is:

$$W_{STEP} = W_{POS} + W_{NEG} = F_G.h + F_G.h - 2.F_G.h^2/g.t^2 = 2.F_G.h.(1 – h/g.t^2),$$

where: W_{POS} is external (positive) work during first phase, W_{NEG} is external (negative) work during second phase, F_G is weight of body, *h* is height of the platform, *g* is gravitational acceleration (9.81 $m.s^{-2}$), *t* is the time of downward movement first single support.

Total external work is obtained by multiplying the W_{STEP} with number of steps for each of the two loads of Margaria test.

Absolute (PWC170) and relative (PWC170/kg) physical working capacity is calculated by following equations (Karpman, Belotzerkovskii, & Gudkov, 1974; Pavlova, Uzunova, & Somlev, 2012):

1. Absolute PWC170

$$PWC170 = N1 + (N2 - N1)\frac{170 - HR1}{HR2 - HR1}$$

PWC170 [$kgm.min^{-1}$] - physical working capacity at a heart rate of 170 beats per minute

N1 [$kgm.min^{-1}$] - power of 1st step load;

N2 [$kgm.min^{-1}$] - power of 2nd step load

HR1 [bpm] - steady state heart rate at 1st step load

HR2 [bpm] - steady state heart rate at 2nd step load

2. Relative PWC170/kg

$$PWC170/kg = \frac{PWC170}{kg}$$

PWC170/kg [$kgm.min^{-1}.kg^{-1}$] - PWC170 per kg body mass

Dobdev's coefficients are calculated by equations for analysis of HR recovery after adapted Margaria aerobic step test (Pavlova, Uzunova, & Somlev, 2012).

1. HRcoeff.¹

$$HRcoeff. = \frac{100 + 6.(HR10 - HR60)}{\sum HR}$$

2. HRcoeff.²

$$HRcoeff. = \frac{100+6.(HR10-HR60)}{\sum HR} + \frac{100+6.(HR10-HRV10)}{\sum HRI-V}$$

HR10 – HR for first 10 s in 1st minute of recovery
HR60 –HR for last 10s in 1st minute of recovery
HRV10 – average HR for 10s of 5th minute
∑HR – HR for 1st minute
∑HRI-V – HR for five minutes of recovery
∑HRI-V = HR1´ + HR2´ + HR3´ + HR4´+ HR5´

Statistical analysis

Microsoft Excel, SPSS Statistics 19 and GraphPad Prism 6 were used for the statistical analysis of the experimental results. Verification for the distribution normality of the data was made by test of Shapiro–Wilk. Experimental values are presented as mean±standard deviation (M±SD). Wilcoxon Signed Ranks Test was applied to compare intensity of two test loads determined by HR in each group. Two-Independent Samples Test (Mann-Whitney U) was used for comparison of PWC170 and HR (rest, work and recovery) values between both groups. The alpha level was set at $p<0.05$ for all analyses.

Results

Mean values and standard deviation (M±SD) of variables HR rest [bpm], HR Ist AMAST load [bpm], HR IInd AMAST load, absolute PWC170 [$kgm.min^{-1}$], relative PWC170/kg [$kgm.min^{-1}.kg^{-1}$], Dobrev1 coeff, Dobrev2 coeff, Dobrev1,2 coeff for volleyball players are given in Table 1. The same variable values for soccer players are presented in Table 2.

Table 1: Descriptive statistics (Mean±SD) of variables for volleyball players (n = 10).

Variable	Mean	SD
HR rest [bpm]	**68.0**	**10.07**
HR Ist load AMAST [bpm]	**123.4**	**10.53**
HR IIst load AMAST [bpm]	**155.8**	**13.31**
PWC170 [$kgm.min^{-1}$]	**1377.7**	**182.10**
PWC170/kg [$kgm.min^{-1}.kg^{-1}$]	**17.64**	**2.208**
Dobrev 1 coeff	**1.04**	**0.149**
Dobrev 2 coeff	**0.32**	**0.033**
Dobrev 1,2 coeff	**1.37**	**0.167**

Table 2: Descriptive statistics (Mean±SD) of variables for soccer players (n = 10).

Variable	Mean	SD
HR rest [bpm]	**65.6**	**6.74**
HR Ist load AMAST [bpm]	**130.2**	**12.62**
HR IIst load AMAST [bpm]	**159.9**	**7.71**
PWC170 [$kgm.min^{-1}$]	**1322.6**	**132.95**
PWC170/kg [$kgm.min^{-1}.kg^{-1}$]	**16.83**	**0.977**
Dobrev 1 coeff	**1.03**	**0.114**
Dobrev 2 coeff	**0.34**	**0.036**
Dobrev 1,2 coeff	**1.37**	**0.144**

Wilcoxon Signed Ranks Test outcomes demonstrated that HR values at rest and in the 5th minute of recovery as well as HR values of first and second loads of adapted Margaria step test in the groups of volleyball and soccer players are differ considerably ($p<0.05$).

Comparison results (Mann-Whitney Test) of physical characteristics variables (age, body mass, height and BMI) of subjects showed insignificant differences between two groups ($p>0.05$). HR values in rest, Ist and IInd test loads, 5-min recovery (M±SD) are illustrated in Figure 1.

Dobrev coefficients for fast phase, slow phase and for the entire 5 minute recovery period are given in Figure 2. It was found from the comparison (Two-Independent Samples Test) between volleyball and soccer players that the differences for all values of variables are insignificant. The alpha level was $p>0.05$.

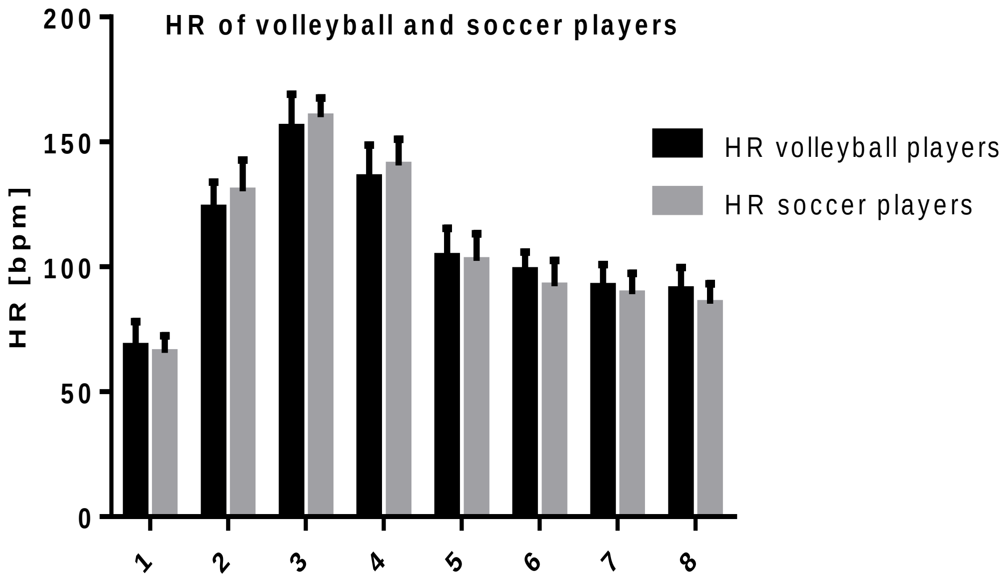

Figure 1 HR in rest (1),Margaria step test (2,3) and recovery (4-8)

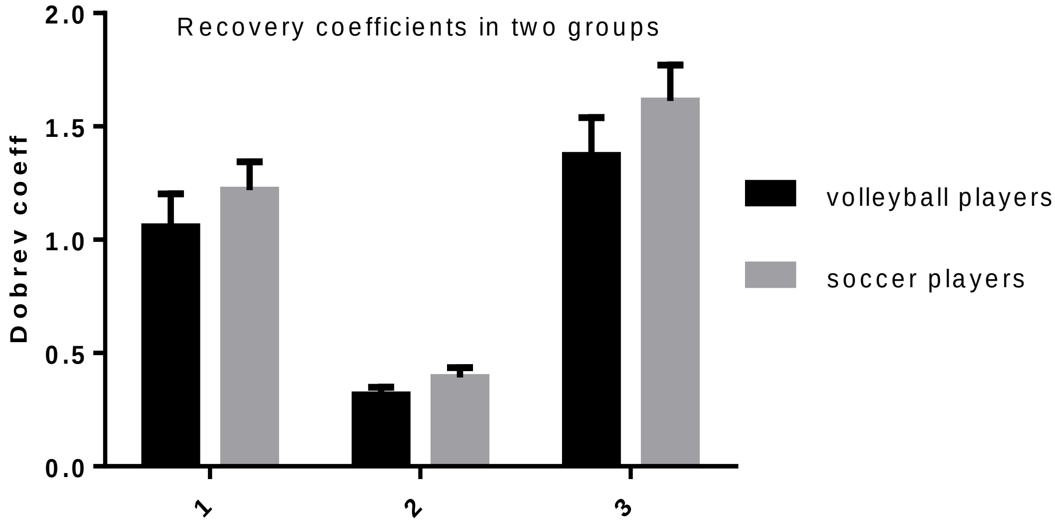

Figure 2 Dobrev recovery coefficients for fast phase (1), slow phase (2) and 5 minute recovery period (3)

Discussion

Examining the indices of physical characteristics of the two groups is an important prerequisite for the comparative analysis of the exercise responses to the adapted Margaria aerobic step test. The volleyball and soccer players do not differ significant in age, body mass, height and BMI (p>0.05). BMI values are in norm limits in accordance with Word Health Organization that means healthy weight category. Given these results in the interpretation of the parameters of physical working capacity, heart rate at rest, in the two loads test, recovery and Dobrev coefficients we could assume that in the comparison should take into account the essential role of training level of the athletes. In this study we consider that when comparing the obtained absolute and relative PWC170 values with reported by other authors should not ignore the difference between steady state protocol on the treadmill, cycle ergometer or stepping bench. This is in accordance with our previous published data and other reported results (Carter, Brooks, & Sparks, 2011; Pavlova, Somlev, & Uzunova, 2009). Two reasons are possible for that: biomechanical characteristics and structure of movements; to what extent the participants are familiar with the mode of testing which affects the economy of exercise. Movements in step-test are closer to the natural and involve more muscle groups, objective prerequisites to achieve higher PWC170. In the present study, as well as in our previous studies it has made verification of the intensity of AMAST two loads (Pavlova, Uzunova, & Arakchiiski, 2007). The established significant difference for HR between the test loads shows that the PWC170 procedure requirements have been observed which increases the reliability of PWC170 outcomes (Karpman, 1988). Pre-exercise mean values of HR have been determined as normocardia. On the basis of obtained data for absolute and relative PWC170 it could be suggested that volleyball and soccer players have the equal level of physical working capacity. Established data by other authors indicate that relative PWC170 indeces for soccer players aged 18 were significantly higher than for volleyball players at the same age (Boraczyński et al., 2012).

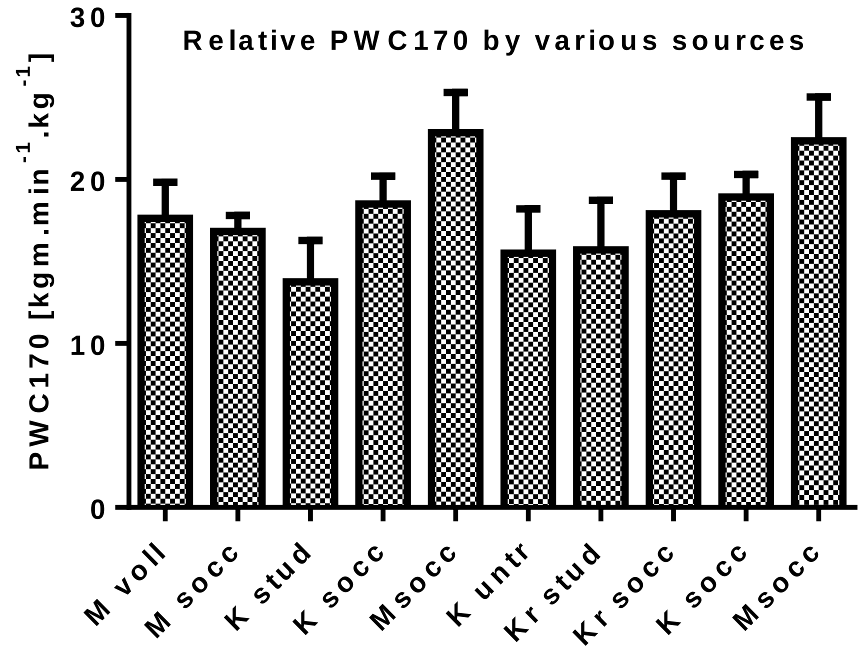

Figure 3 Relative physical working capacity in cycle and step test

In Figure 3 (first and second column) are given the relative values of PWC170 of volleyball and soccer players put together with data from our previous studies and other authors (Karpman, Belotzerkovskii, & Gudkov, 1974; Pavlova, & Uzunova, 2012; Pavlova, Somlev, & Uzunova, 2009; Pavlova, Uzunova, & Somlev, 2009; Petkov, Toteva, & Maznev, 2006). On the basis of this illustration it could be said the following: the level of physical working capacity of studied volleyball and soccer players is above average; the untrained subjects have lowest relative PWC170; the PWC170 values from the adapted Margaria aerobic step test in almost cases are higher than those from the submaximal cycle ergometer tests (with one or two loads). Obtained substantial differences ($p<0.05$)) between the HR values pre- and post test in the fifth minute is an expression of an unreleased HR in examined recovery period in both groups of athletes. Results on recovery coefficients of the volleyball and soccer players are assessed with "good" according to estimates of 5-degree system by Dobrev, which is interpreted as corresponding to the training state (Dobrev, 1976).

Practical application

Periodically testing and comparing the data on the physical working capacity of athletes are important objective tools to control the training process. The present findings suggest that the adapted Margaria aerobic step test is appropriate for comparing the physical working capacity in team sports and the test has wide practical applicability in all conditions, because not requires special equipment and is only necessary platform.

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References

1. Arts, F. J. P., Kuipers, H., Jeukendrup, A. E., & Saris, W. H. M. (1993). A short cycle ergometer test to predict maximal workload and maximal oxygen uptake. *International Journal of Sports Medicine, 14*(8), 460-464. Retrieved from http://arno.unimaas.nl/show.cgi?fid=1666
2. Àstrand, P. -O., & Ryhming, I. (1954). A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. *Journal of Applied Physiology, 7,* 218-221. Retrieved from http://jap.physiology.org/content/jap/7/2/218.full.pdf
3. Boraczyński, T., Boraczyński, M., Obmiński, Z., Stasiewicz, P., Podstawski, R., Stasiewicz, K., & Surmański, R. (2012). Body composition and physical fitness of soccer and volleyball players aged from 16 to 18. *Polish Journal of Sports Medicine, 28*(1), 39-49. DOI: 10.5604/1232406X.991347
4. Boreham, C. A., Paliczka, V. J., & Nichols, A. K. (1990). A comparison of the PWC170 and 20-MST tests of aerobic fitness in adolescent schoolchildren. *Journal of sports medicine and physical fitness, 30*(1), 19-23. PMID:2366530
5. Carter, J. G., Brooks, K. A., & Sparks, J. R. (2011). Comparison of the YMCA cycle sub-maximal VO2 max test to a treadmill VO2 max test. *International Journal of Exercise Science, Conference Proceedings, 5*(2). Article 40. Available at: http://digitalcommons.wku.edu/ijesab/vol5/iss2/40
6. Dimitrova, D. (2001). *Physical ability of adolescents in relation to age changes in bodily dimensions and composition of body mass* [in Bulgarian]. Dissertation. NSA, Sofia.
7. Dobrev D. (1976). *Lab exercises in physiology*. Ed. by D. Dobrev, Sofia, Medicine & Physical Culture, 294-299, [in Bulgarian].
8. Ekblom-Bak, E., Björkman, F., Hellenius, M. -L., & Ekblom, B. (2014). A new submaximal cycle ergometer test for prediction of VO2max. *Scandinavian Journal of Medicine & Science in Sports, 24*(2), 319–326. DOI: 10.1111/sms.12014
9. Fitchett, M. A. (1985). Predictability of VO2 max from submaximal cycle ergometer and bench stepping tests. *British Journal of Sports Medicine, 19*(2), 85–88. PMC1478528 Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1478528/pdf/brjsmed00050-0023.pdf
10. Jetté, M., Campbell, J., Mongeon, J., & Routhier, R. (April 17, 1976). The Canadian Home Fitness Test as a predictor of aerobic capacity. *Canadian Medical Association Journal, 114*(8), 680-682. PMC1956894
11. Karpman, V., Belotzerkovskii, Z., & Gudkov, Y. (1974). *Study of physical working capacity in athletes.* Physical culture and Sport, Moscow [in Russian].
12. Karpman, V. L. (1988). *Testing in sports medicine*. Physical culture and Sport, Moscow, Russian Federation [in Russian].
13. Keren, G., Magazanik, A., & Epstein, Y. (1980). A comparison of various methods for the determination of VO2max. *European*

Journal of Applied Physiology and Occupational Physiology, 45 (2-3), 117-124. PMID: 7193123
14. Krastev, K. (1983). Cardiorespiratory Test. *Lab exercises in physiology*. Ed. by D. Dobrev, Medicine & Physical Culture, Sofia, 232-234 [in Bulgarian].
15. Léger, L. A., & Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict VO2 max. *European Journal of Applied Physiology and Occupational Physiology, 49*(1), 1-12. Retrieved from http://www.sportexperts.org/publication/56.pdf
16. Margaria, R., Aghemo, P., & Rovelli, E. (1965). Indirect determination of maximal O_2 consumption in man. *Journal of Applied Physiology, 20*(5), 1070-1073.
17. Oja, P., & Tuxworth, B. eds. (1995). *Eurofit for Adults: Assessment of Health-Related Fitness*. Finland: Council of Europe Publishing; 46-51.
18. Patton, J. F., Vogel, J. A., & Mello, R. P. (1982) Evaluation of a maximal predictive cycle ergometer test of aerobic power. *European Journal of Applied Physiology and Occupational Physiology, 49*(1), 131-140. PMID:7201925
19. Pavlova, E., & Uzunova, G. (2012). A comparison of submaximal cycle ergometer and step tests for predicting VO2max in soccer players. XVI International Scientific Congress "Olympic Sport and Sport for All" and VI International Scientific Congress "Sport, Stress, Adaptation", 17-19 May 2012, Sofia, Proceeding Book, II Part, *Journal of Sport and Science, Extra Issue*, 36-39.
20. Pavlova, E., Arakchiiski, Z., & Uzunova, G. (2007). Calculation of PWC170 with the equation for the mechanical work in Margaria step test [in Bulgarian]. *Proceedings of the 2nd International Scientific Conference "Kinesiology" 2007, 18-19 October 2007, Veliko Tarnovo*, 159-163.
21. Pavlova, E., Mavrodieva, M., & Dobrev, D. (1981). Study of some particularities in PWC170 test for functional assessment of athletes. *Matters of Physical Culture, 5*, 314-319, [in Bulgarian].
22. Pavlova, E., Mineva, M., & Uzunova, G. (2010). Physical working capacity in female athletes of sport aerobics [in Bulgarian]. Fifth International Scientific Congress "Sport, Stress Adaptation", 23-25 April Sofia, *Journal of Sport and Science, Special Issue, Part II*, 441-445.
23. Pavlova, E., Somlev, P., & Uzunova, G. (2009). PWC170 and VE equivalent at cycle ergometer test and step test. Scientific Conference with international participation - 25 years Faculty of Pedagogy, Veliko Tarnovo, 6-7 November 2009, *Proceedings*, 512-516, [in Bulgarian].
24. Pavlova, E., Uzunova, G., & Arakchiiski, Z. (2007). Margaria step test for estimating PWC170. *4th FIEP European Congress Physical Education and Sports (Teachers' Preparation and Their Employability in Europe), August 29th- 31st, 2007 Bratislava, Slovakia*, 160-166. ISBN: 978-80-89324-00-2.
25. Pavlova, E., Uzunova, G., & Arakchiiski, Z. (2009). Comparison between PWC170 Estimated by Equation and Krastev's Table in Step Test. *World Congress of Performance Analysis of Sport VIII "Current Trends in Performance*

Analysis, Magdeburg, 3-6 September 2008., Shaker Verlag Aachen 2009, Physiology/Injury Risk, Magdeburg, 386-389.
26. Pavlova, E., Uzunova, G., & Somlev, P. (2009). Suunto t6c heart rate monitor for estimating PWC170 and ventilatory equivalent. In: *PROCEEDINGS of 5th FIEP European Congress and 2nd Serbian Congress of P.E. September 23-26, 2009, Nis*, Publishead by PANOPTIKUM Nis 2010, Ed.Nenad Zivanovic, pp 174-181.
27. Pavlova, E., Uzunova, G., & Somlev, P. (2012). Dynamics of heart rate recovery after cycle ergometric PWC170 test in soccer players. *Scripta Scientifica Medica, 44*(1), 27-30, Supplement 1. ISSN 0582-3250
28. Petkov, St., Toteva, M., & Maznev, I. (2006). *Practical Exercises in Sports Medicine*. First part, NSA, Sofia, [in Bulgarian].
29. Siconolfi, S. F., Cullinane, E. M., Carleton, R. A., & Thompson, P. D. (1982). Assessing VO2max in epidemiologic studies: modification of the Astrand-Rhyming test. *Medicine and Science in Sports Exercise 14*(5), 335-338. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7154887 PMID:7154887
30. Siconolfi, S.F., Garber, C.E., Lasater, T.M., & Carleton, R.A. (1985). A simple, valid step test for estimating maximal oxygen uptake in epidemiologic studies. *American Journal of Epidemiology, 121*(3), 382-390. Retrieved from http://www.slideshare.net/Munneywin/am-j-epidemiol-1985siconolfi38290#
31. Sjöstrand, T. (1947). Changes in the respiratory organs of workmen at an ore smelting works. *ActaMedica Scandinavica 196*, suppl.687 – 699.
32. Somlev, P., & Uzunova, G. (2009). The use of Suunto t6c heart rate monitor during standard submaximal test. *Journal of Sport and Science*, *1*, 93 – 97.
33. Somlev, P., Uzunova, G., & Pavlova, E. (2009). Changes of respiratory parameters during submaximal test indirectly determined with Suunto t6c heart rate monitor. In: *PROCEEDINGS of 5th FIEP European Congress and 2nd Serbian Congress of P.E. September 23-26, 2009, Nis*, Publishead by PANOPTIKUM Nis 2010, Ed.Nenad Zivanovic, pp 134-137.
34. Sproule, J., Kunalan, C., McNeill, M., & Wright, H. (1993). Validity of 20-MST for predicting VO2max of adult Singaporean athletes. *British Journal of Sports Medicine, 27*(3), 202-204. doi:10.1136/bjsm.27.3.202
35. Swank, A. M., Serapiglia, L., Funk, D., Adams, K. J., Durham, M., & Berning, J. M. (2001). Development of a branching submaximal treadmill test for predicting VO_2max. *Journal of Strength and Conditioning Research, 15*(3), 302–308. Retrieved from http://www.uta.edu/faculty/ricard/stats/Lectures/Chapter%207/Regress%2016%20good.pdf
36. Uzunova, G., & Pavlova, E. (2012). PWC170 estimation from two loads and one load in step test. XVI International Scientific Congress "Olympic Sport and Sport for All" and VI International Scientific Congress "Sport, Stress, Adaptation", 17-19 May 2012, Sofia, Proceeding Book, II Part, *Journal of Sport and Science, Extra Issue*, 193-196.
37. Uzunova, G., Pavlova, E., & Somlev, P. (2009). Physical working capacity

and respiratory parameters in a two-load cycle ergometer test. Scientific Conference with international participation -25 years Faculty of Pedagogy, Veliko Tarnovo, 6-7 November 2009, *Proceedings*, 553-557, [in Bulgarian] .

38. Verma, S. S., Sen Gupta, J., & Malhotra, M. S. (1977). Prediction of maximal aerobic power in man. *European Journal of Applied Physiology and Occupational Physiology, 36*(3), 215- 222. DOI: 10.1007/BF00421752
39. Wahlund, H. (1948). Determination of physical working capacity. A physiological and clinical study with reference to standardization of cardio-pulmonary function tests. *Acta Medica Scandinavica 132,* suppl.215, 1-78
40. Watson, A. W. (1977). A study of the physical working capacity of Gaelic footballers and hurlers. *British Journal of Sports Medicine*, *11*(3): 133–137. DOI: 10.1136/bjsm.11.3.133
41. Widrick, J., Ward, A., Ebbeling, C., Clemente, E., & Rippe, J. M. (1992). Treadmill validation of an over-ground walking test to predict peak oxygen consumption. *European Journal of Applied Physiology and Occupational Physiology*, *64*(4), 304-308. Retrieved from http://link.springer.com/article/10.1007%2FBF00636216

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