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Research article

Heart Rate and Blood Lactate Recovery after Queen's College Step Test for Predicting VO_2Max

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Abstract
*Journal of Sports Science and Physical Education 2(*1): 58–67, 2014 - Literature data showed validation of Queen's College Step Test (QCT) based on heart rate (HR) in various experimental designs. The aim of this study was to increase the information on reliability of the functional capacity from recovery data of HR and blood lactate after QCT applying of indirect VO_2max in volleyball and soccer players. Ten volleyball and ten soccer players age 20.3±1.42, 20.7±1.64 years; weight 78.2±6.94, 78.6±6.8 [kg]; height 184.6± 5.55, 183.0±5.86 [cm]; BMI 23±1.64, 23.4±2.19, performed QCT on 41.3 cm step box. HR was monitored and VO2max calculated by equation. Blood lactate (La) was measured pre- and post-test in the 1st, 3rd and 5th minute. Blood La values in the groups showed statistical difference between rest and recovery ($p<0.05$) but not between the 1st, 3rd and 5th min. The difference in HR, predicted VO_2max and La between the two groups was insignificant. Despite the technical difference in volleyball and football both groups of athletes have the same aerobic capacity. Lactate mean values [1.22-2.7mmol.l^{-1}] showed that the applied QCT was really submaximal for the subjects. For practical application it is suggested that for more reliability when possible in group comparisons from QC to measure La and HR in 3 -5 min recovery period.

Keywords: step box, aerobic capacity, submaximal

Introduction

Physical exercises directed towards improving the aerobic capacity form an essential part of the modern balanced exercise program of team sports. Measurement of the maximal amount of oxygen that the organism can use per unit of time is considered the best indicator for cardiorespiratory fitness and aerobic endurance. The determination of maximal oxygen uptake or VO_2max is the gold standard measure of aerobic capacity (Carlson, 1995). High VO_2max is a prerequisite for successful athletic performance. The oxygen uptake gives an accurate measure of the aerobic power, and it is highly related to the cardiac output, heart rate, and stroke volume (Astrand, 1976). According to Astrand, (1976) the VO_2max under standardized conditions is a highly reproducible characteristic of the individual's aerobic fitness.

Data have been presented suggesting that the maximal transport of oxygen (cardiac output X oxygen content of arterial

blood) is limited by the central circulation rather than by the tissues' ability to utilize the oxygen. There is a conflicting opinion (Noakes & Marino, 2009) on the classical hypothesis (Bergh, Ekblom, & Astrand, 2000) that under normal conditions cardiac output is limiting maximal aerobic power during dynamic exercise engaging large muscle groups. It is however indisputable that the determination of VO_2max allows correct assessment of the aerobic (fitness) levels of athletes as well as monitoring the effectiveness of training. The maximal oxygen uptake (VO_2max) is determined directly by group of tests performed to exhaustion (Robergs, 2007) or indirectly through group of submaximal tests (Àstrand & Ryhming, 1954; Bandyopadhyay, 2008; D'Alonzo, Marbach, & Vincent, 2006; Margaria, Aghemo, & Rovelli, 1965). VO_2max outcomes of comparisons between different tests are reported in many scientific articles (Benassi et al., 2013; Chatterjee et al., 2004; Chavda et al., 2013; Gayen, Bandyopadhyay, & Mitra, 2012; Lima, Silva, & Souza, 2005; Moradi & Jafari, 2012; Narkhede, Jaimala, & Amita, 2014; Perroni et al., 2013; Prabha, 2009; Sproule et al., 1993).

Direct determination of VO_2max has a great advantage as a reliable method but its application is associated with a number of limitations: specialized laboratories with expensive equipment, professionally trained team, strong motivation and volitional effort, potential risk, and a limited number of investigations annually. Taking into account such factors as cost, safety, and the time required for direct VO_2max tests, the submaximal tests for predicting VO_2max are preferable in most situations (Harrison et al., 1980). Queens College Step Test (QCST) is a well-known and widespread 3-minute test for indirect VO_2max determination (Hada, Amatya, & Gautam, 2013; Laxmi, 2008). Published research data show validation of QCST based on heart rate (HR) in various experimental designs (Moradi & Jafari, 2012, Zwiren et al., 1991). Not found during recent years in the available sources are results of blood lactate determination in the recovery period after submaximal tests. In spatial review article with the emphasis on the recovery of heart rate after physical exercise it was concluded that the post-exercise heart rate recovery (HRR) provides information that is complementary to the traditional cardiovascular fitness indices and should be added to the list of indicators of cardiovascular fitness (Dimkpa, 2009). Dimkpa (2009) notes that post-exercise HRR, though a readily obtainable parameter, is often overlooked as an indicator of cardiovascular fitness. By monitoring the heart rate pre-, during and post submaximal exercise the analysis of functional response to the test and the regulatory mechanisms could be enriched (Hagberg et al., 1980; Mitchell, 1985; Perini et al., 1989).

The aim of this study was to increase the information reliability on the functional capacity from recovery data of HR and blood lactate after Queen's College Test for predicting VO_2max in volleyball and soccer players.

Method

Participants

Two groups of twenty healthy trained athletes (10 volleyball and 10 soccer players) volunteered to participate in the study and gave written informed consent according to the required ethical approvals. The characteristics of all subjects are detailed in Table 1.

Table 1: Physical characteristics of volleyball and soccer players (Mean ± SD)

Group	N	Age (years)	Weight [kg]	Height [cm]	BMI [kg/m^2]	Percentile
volleyball	10	20.3±1.42	78.2±6.94	184.6±5.55	23±1.64	43.50±11.128
soccer	10	20.7±1.64	78.6±6.81	183.0±5.86	23.4±2.19	46.40±14.230

Design

Both groups were tested on separate days in the morning. Participants were instructed to refrain from eating for at least an hour and a half before Queen's College Step Test (QCST). Heart rate rest was recorded for 5 minutes in sitting position. The athletes were required to perform the test after warm-up. On completion the athlete remains upright 20 seconds and then sits up to 5 minutes to study the recovery period.

Queen's College step test protocol

The submaximal QCST is a 3-minute step test. Stepping cadence was 24 ascents/minute on a 4 phase step. The height of step box is 41.3 cm. The pace is controlled by a metronome which is set to 96 beats per minute.

Measurements

The Suunto t6c HRM was used for monitoring of HR pre-, HR 3-minute test and 5-minute HR post–test. The monitor was set to record R-R intervals. After each recording the timer was reset to obtain a separate file for the 3 periods: pre-test, test, post-test. The following equation for predicting relative VO_2max [ml.kg^{-1}.min^{-1}] was then used:

Men: VO_2max [ml/kg/min] = 111.33 - 0.42 x heart rate [bpm],

where HR is measured up to the 20 seconds immediately on completion of the test.

Blood samples were taken from the ear lobe for determination of blood lactate concentration using portable lactate test analyzer (Lactate Scout, SensLab GmbH, Leipzig, Germany). Three portable blood lactate analyzers were evaluated and despite the fact that the results are better for the other two analyzers the authors noted that Lactate Scout also displayed relatively good reliability (Tanner, Fuller, & Ross, 2010). Blood lactate concentration measurements were done in arterialized capillary blood before (at rest) and the end of 1st, 3rd and 5th minutes after the tests.

Statistical analysis

The statistical analysis was done by using Microsoft Excel, SPSS Statistics 19 and GraphPad Prism 6. Shapiro–Wilk Test was applied for the distribution normality verification of the data. The experimental results were statistically processed by means of Descriptive Statistics, Repeated Measures ANOVA and Two-Independent Samples Test (Mann-Whitney U).

Results

Comparison of the physical characteristics values (age, weight, height, BMI, percentile) between volleyball and soccer players revealed no significant differences ($p>0.05$).

Predicted relative and absolute VO_2max (Mean±SD) values are in: volleyball players 4412±418.11 [ml.min^{-1}], 56.44± 3.214 [ml.kg^{-1}.min^{-1}]; soccer players 4163±470.22 [ml.min^{-1}], 52.99±4.46 [ml.kg^{-1}.min^{-1}].

HR values (Mean±SD) in rest and 5-minute recovery for both groups are presented in Figure 1.

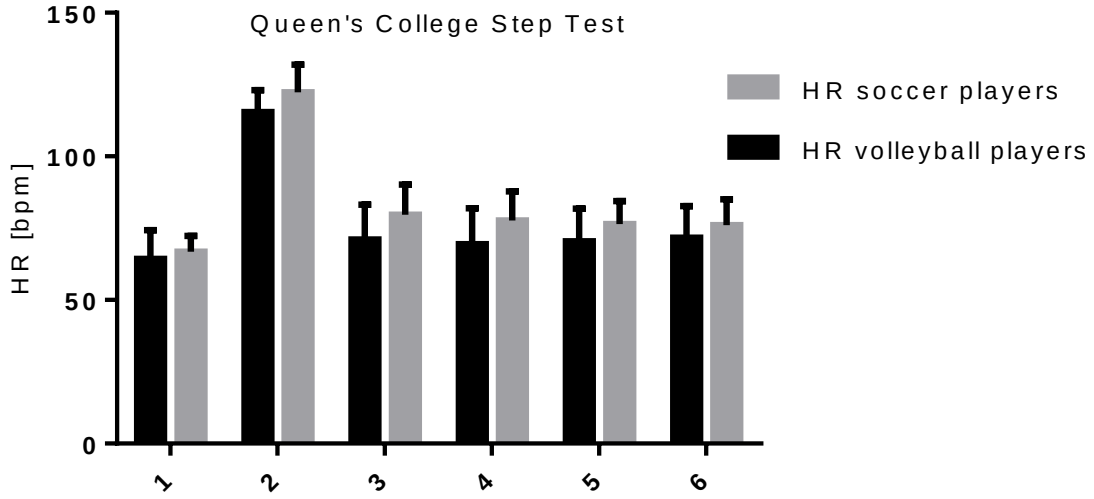


Figure 1. HR rest (1) and 5 minute recovery(2-6)

Mean and standard deviations for blood La concentration values of the two groups of athletes are given in Table 2.

Table 2: Blood lactate concentration [mmol.l^{-1}] in volleyball and soccer players (Mean ± SD)

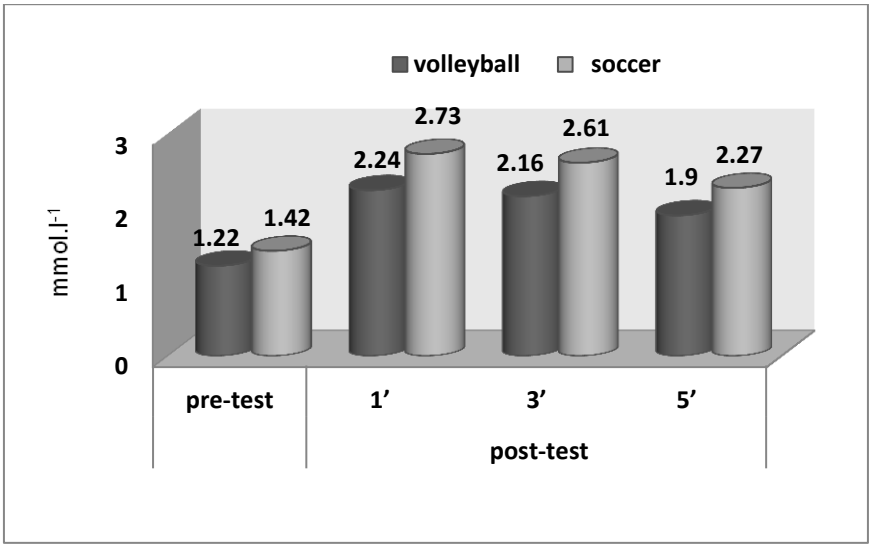
Group	N	Blood La pre-test	Blood La 1' post-test	Blood La 3' post-test	Blood La 5' post-test
volleyball	10	1.22±0.426	2.24±0.667	2.16±0.622	1.90±0.424
soccer	10	1.42±0.346	2.73±0.869	2.61±0.767	2.27±0.702

Mean peak blood lactate concentration (La max) 2.24±0.667 [mmol.l^{-1}] (range: 1.3-3.2) in volleyball players and 2.73±0.869 [mmol.l^{-1}] (range: 1.5-4.2) in soccer players was observed one minute after QCST. Five minutes after the step test blood lactate had decreased to 1.9±0.424 [mmol.l^{-1}] and 2.27±0.702 [mmol.l^{-1}] respectively.

Comparison data from Repeated Measures ANOVA (Adjustment for multiple comparisons: Bonferroni) for blood La values in each group showed statistical differences between rest and recovery ($p<0.05$) but not between the 1st, 3rd and 5th minute.

Figure 2 illustrates blood lactate measurements in volleyball and soccer players.

Figure 2: Blood lactate measurements [mmol.l^{-1}] pre- and post QCST



Comparison between the two groups ((Mann-Whitney U) revealed insignificant differences in HR, predicted VO_2max and blood La ($p>0.05$).

Discussion

Both groups were homogeneous in terms of physical characteristics. The effects of age and training on VO_2max, maximal cardiac output and stroke volume are known but cannot be fully explained by differences in body composition (Ogawa et al., 1992; Trappe et al., 1996). In our case the main physical characteristics including BMI do not differ and we could conclude that the level of training influences the aerobic capacity of studied volleyball and soccer players. The mean values of relative VO_2max yielded by QCST in this study were higher than the reported QCST values (47.32±4.11 ml/kg/min) of young male subjects (Prabha, 2009) and the other published data (D'Alonzo, Marbach, & Vincent, 2006; Hada, Amatya, & Gautam, 2013; Liu, & Lin, 2007; Narkhede, Jaimala, & Amita, 2014,). Our opinion is in accordance with that of several researchers (Smith, Roberts, & Watson, 1992) and namely characterized volleyball as an 'interval' sport with both anaerobic and aerobic components. Obtained VO_2max for volleyball players are close to those (56.7 ml/kg/min) of the Canadian national team players (Smith, Roberts, & Watson, 1992). This result gives grounds to assume that the computed VO_2max from the 3-minute step test overestimates the aerobic capacity of volleyball players. The mean value of the relative VO_2max of our soccer players is lower than predicted VO_2max (58.5 ± 8.5 ml/kg/min) of indoor soccer players and, reported by other authors (Lima, Silva, & Souza, 2005). In professional soccer also, a significant amount of training time is used to improve players' aerobic capacity (Hoff et al., 2002). The findings from a robust data set of 1545 male soccer players tested for VO_2max at the Norwegian Olympic Training Center between 1989 and 2012 indicate that VO_2max values ~62-64 [ml.kg^{-1}.min^{-1}] fulfill the demands for aerobic capacity in men's professional soccer (Tonnessen et al., 2013).

Significant differences are demonstrated by different category of players and physical education students in

heart rate responses to varying intensities of exercise and at different points of recovery (Desalegn & Verma, 2008). These results support our understanding respect to the study of post exercise heart rate as sensitive indicator reflective differences in physiological responses to physical loads. Although no statistically significant differences between the mean HR pre- and post-test values of the two groups Repeated Measures Anova outcomes show better recovery for volleyball players.

The state of physical fitness, and the type and duration of the exercise are amongst the conditions that influence the rate and magnitude of the accumulation of lactate in blood and muscles (Gollnick, Bayly, & Hodgson, 1986). Blood lactate concentration values in this study were obtained under standardized conditions, following 5 minutes QCST in both groups. Induced changes in blood lactate measured after the test is low and typical for submaximal exercise. Energy yield of this moderate activity occurs primarily by aerobic mechanisms as the component of anaerobic glycolysis is very small. Some authors conclude that blood lactate concentration is not an accurate indicator of lactate disposal and oxidation (Mazzeo et al., 1986).

These findings pointed out that despite the difference in technique of volleyball and football both groups of athletes have the same aerobic capacity. Dynamics of HR recovery and blood lactate mean values showed that the applied QCST was really submaximal for the subjects.

Practical application

Cardiorespiratory fitness can be assessed easily by QCST, as it is very applicable in the field and does not require special equipment. When possible for more complete functional assessment in group comparisons after QSCT to measure blood lactate and heart rate for 3 or 5 minute recovery period.

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References

1. Astrand, P. O. (1976). Quantification of exercise capability and evaluation of physical capacity in man. *Progress in Cardiovascular Diseases, 19*(1), 51-67. DOI: 10.1016/0033-0620(76)90008-6
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. Bandyopadhyay, A. (2008). Queen's college step test as an alternative of Harvard step test in young indian women. *International Journal of Sport and Health Science, 6,* 15-20. Retrieved from http://jlc.jst.go.jp/JST.JSTAGE/ijshs/6.15
4. Benassi, R., Fontes, C. A. S., Gonçalves, L. C. O., de Oliveira, A. L. B., & de Araujo, A. H. B. (2013). Análise comparativa entre os protocolos de banco e equação preditiva para avaliação indireta do consumo máximo de oxigênio (VO2máx), e suas aplicações práticas. *RBPFEX-Revista Brasileira de Prescrição e Fisiologia do Exercício, 7*(41), 484-493. Retrieved from http://oaji.net/articles/809-1399746623.pdf

5. Bergh, U., Ekblom, B. & Astrand, P. O. (2000). Maximal oxygen uptake "classical" versus "contemporary" viewpoints. *Medicine and Science in Sports and Exercise, 32*(1)**,** 85-88. Retrieved from http://journals.lww.com/acsm-msse/pages/articleviewer.aspx?year=2000&issue=01000&article=00013&type=abstract
6. Carlson, D. J. (1995). VO2max: the gold standard? *Chest,* 108(3)**,** 602-603. doi:10.1378/chest.108.3.602
7. Chatterjee, S., Chatterjee, P., Mukherjee, P. S., & Bandyopadhyay, A. (2004). Validity of Queen's College step test for use with young Indian men. *British journal of sports medicine, 38*(3), 289-291. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1724834/pdf/v038p00289.pdf
8. Chavda, D. V. V., Rajput, D. M. H., ChintansinhParmar D., Gokhale D. P. A., Mehta, D. H. B. & Shah, D. J. (2013). Predicted maximal oxygen consumption (VO2max) values obtained during the maximal treadmill test using different protocols. *National Journal of Integrated Research in Medicine, 4* (2), 149-155. Retrieved from http://www.scopemed.org/fulltextpdf.php?mno=36927
9. D'Alonzo, K. T., Marbach, K. & Vincent, L. (2006). A comparison of field methods to assess cardiorespiratory fitness among neophyte exercisers. *Biological Research for Nursing, 8*(1), 7-14. doi: 10.1177/1099800406287864
10. Desalegn, M., & Verma, S. K. (2008). Comparison of cardiovascular responses to exercise and recovery pattern in players. *Journal of Exercise Science and Physiotherapy, 4*(1), 55-65. Retrieved from http://medind.nic.in/jau/t08/i1/jaut08i1p55.pdf
11. Dimkpa, U. (2009). Post-exercise heart rate recovery: an index of cardiovascular fitness. *Journal of Exercise Physiology Online, 12*(2), 10-22. Retrieved from http://www.asep.org/asep/asep/Dimpka12_1_10-22.pdf
12. Gayen, A., Bandyopadhyay, S. & Mitra, S. (2012). Estimation of VO2max by different exercise testing methods. *International Journal of Health, Physical Education and Computer Science in Sports,12*(1),101-104. Retrieved from http://www.ijhpecss.org/internationaljournal-12.pdf#page=105
13. Gollnick, P. D., Bayly, W. M. & Hodgson, D. R. (1986). Exercise intensity, training, diet, and lactate concentration in muscle and blood. *Medicine and Science in Sports and Exercise*, *18*(3), 334-340. PMID:3523106)
14. Hada, S., Amatya, S., & Gautam, K. (2013). Cardiopulmonary fitness test among Nepalese students. *Janaki Medical College Journal of Medical Science, 1*(1), 3-8. DOI: http://dx.doi.org/10.3126/jmcjms.v1i1.7879
15. Hagberg, J. M., Hickson, R. C., Ehsani, A. A. & Holloszy, J. O. (1980). Faster adjustment to and recovery from submaximal exercise in the trained state. *Journal of Applied Physiology: respiratory, environmental and exercise physiology, 48*(2), 218-224. PMID:7364606
16. Harrison, M. H., Bruce, D. L., Brown, G. A. & Cochrane, L. A.

(1980). A comparison of some indirect methods for predicting maximal oxygen uptake. *Aviation, Space and Environmental Medicine, 51*(10)**,** 1128-33. PMID:6781464

17. Hoff, J., Wisloff, U., Engen, L. C., Kemi, O. J. & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine, 36*(3)**,** 218-221. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1724499/pdf/v036p00218.pdf
18. Laxmi, C. C. (2008). *A Study of effect of body mass index on cardiorespiratory fitness in young males* (Doctoral dissertation, Rajiv Gandhi University of Health Sciences). http://hdl.handle.net/123456789/1734
19. Lima, A. M. J. D., Silva, D. V. G., & Souza, A. O. S. D. (2005). Correlation between direct and indirect VO2max measurements in indoor soccer players. *Revista Brasileira de Medicina do Esporte, 11*(3), 164-166. http://dx.doi.org/10.1590/S1517-86922005000300002
20. Liu, C. M., & Lin, K. F. (2007). Estimation of VO2max: A comparative analysis of post-exercise heart rate and physical fitness index from 3-minute step test. *Journal of Exercise Science and Fitness, 5*(2), 118-123. Retrieved from http://scsepf.org/doc/020108/Paper7.pdf
21. Margaria, R., Aghemo, P., & Rovelli, E. (1965). Indirect determination of maximal O2 consumption in man. *Journal of Applied Physiology, 20*(5)**,** 1070-1073.
22. Mazzeo, R. S., Brooks, G. A., Schoeller, D. A., & Budinger, T. F. (1986). Disposal of blood [1-13C]lactate in humans during rest and exercise. *Journal of Applied Physiology, 60*(1)**,** 232-241. Retrieved from http://jap.physiology.org/content/60/1/232
23. Mitchell, J. H. (1985). Cardiovascular control during exercise: central and reflex neural mechanisms. *The American journal of cardiology, 55*(10), D34-D41. DOI: 10.1016/0002-9149(85)91053-7
24. Moradi, H. & Jafari, A. (2012). Rockport and Queen exercise tests validity for estimation of VO2 max in east Azerbaijan male Karatekas. *Annals of Biological Research, 3***,** 3029-3032. Retrieved from http://scholarsresearchlibrary.com/ABR-vol3-iss6/ABR-2012-3-6-3029-3032.pdf
25. Narkhede, P. R., Jaimala, S., & Amita, M. (2014). Comparison of maximal oxygen consumption values estimated from six minute walk test and Queens College step test. *Indian Journal of Physiotherapy & Occupational Therapy-An International Journal, 8*(1)**,** 154-158. Retrieved from http://www.i-scholar.in/index.php/ijpot/article/view/46915
26. Noakes, T. D. & Marino, F. E. (2009). Point: counterpoint: maximal oxygen uptake is/is not limited by a central nervous system governor. *Journal of Applied Physiology, 106(1)***,** 338-339. DOI: 10.1152/japplphysiol.90844.2008
27. Ogawa, T., Spina, R. J., Martin, W. H., Kohrt, W. M., Schechtman, K. B., Holloszy, J. O. & Ehsani, A. A. (1992). Effects of aging, sex, and physical training on cardiovascular responses to exercise. *Circulation,*

86(2)**,** 494-503. Retrieved from http://circ.ahajournals.org/content/86/2/494.full.pdf

28. Perini, R., Orizio, C., Comandè, A., Castellano, M., Beschi, M., & Veicsteinas, A. (1989). Plasma norepinephrine and heart rate dynamics during recovery from submaximal exercise in man. *European Journal of Applied Physiology and Occupational Physiology, 58*(8)**,** 879-883. Retrieved from http://link.springer.com/article/10.1007/BF02332222#page-2
29. Perroni, F., Cortis, C., Minganti, C., Cignitti, L., & Capranica, L. (2013). Maximal oxygen uptake of Italian firefighters: laboratory vs. field evaluations. *Sport Sciences for Health, 9*(2), 31-35. DOI 10.1007/s11332-013-0142-0
30. Prabha, V. (2009). *A comparative study of maximal oxygen consumption by Queen's College step test and treadmill jogging test in young males* (Doctoral dissertation, Rajiv Gandhi University of Health Sciences). Retrieved from http://14.139.159.4:8080/jspui/bitstream/123456789/1760/1/CDMPHGY00058.pdf
31. Robergs, R. A. (2007). Simplified method and program for incremental exercise protocol development. *Journal of Exercise Physiology online (ASEP), 10***,** 1-23. Retrieved from http://www.asep.org/asep/asep/RobergsApril2007.pdf
32. Smith, D. J., Roberts, D., & Watson, B. (1992). Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *Journal of sports sciences, 10*(2), 131-138. DOI**:**10.1080/02640419208729915
33. 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. Retrieved from http://bjsm.bmj.com/content/27/3/202.full.pdf
34. Tanner, R. K., Fuller, K. L., & Ross, M. L. (2010). Evaluation of three portable blood lactate analysers: Lactate Pro, Lactate Scout and Lactate Plus. *European journal of applied physiology, 109*(3), 551-559. DOI:10.1007/s00421-010-1379-9
35. Tønnessen, E., Hem, E., Leirstein, S., Haugen, T., & Seiler, S. (2013). Maximal aerobic power characteristics of male professional soccer players, 1989-2012. *International journal of sports physiology and performance, 8*(3), 323-329. Retrieved from http://brage.bibsys.no/xmlui/bitstream/id/91123/Tonnessen-2013-Maximal
36. Trappe, S. W., Costill, D. L., Vukovich, M. D., Jones, J. , & Melham, T. (1996). Aging among elite distance runners: a 22-yr longitudinal study. *Journal of Applied Physiology, 80*(1), 285-290. Retrieved from http://jap.physiology.org/content/80/1/285
37. Zwiren, L. D., Freedson, P. S., Ward, A., Wilke, S., & Rippe, J. M. (1991). Estimation of VO2max: A comparative analysis of five exercise tests. *Research Quarterly for Exercise and Sport, 62*(1)**,** 73-78. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2028096

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