**EVALUATION OF ANAEROBIC THRESHOLD IN ELITE HANDBALL PLAYERS ON DIFFERENT PLAYING POSITIONS USING RATING OF PERCEIVED EXERTION**

*Tomislav Uzelac-Šćiran, Vlatko Vučetić*

*Faculty of Kinesiology, University of Zagreb, Croatia*

**Abstract**

Team handball (TH) is a physically demanding sport in which anaerobic threshold (AT) plays a significant role. Although the AT estimation tests are mainly performed in laboratory conditions, assessment of AT in TH is possible in the field, too, using only rating of perceived exertion (RPE). The aim of this paper is to determine possible differences in the determination of AT underpinned by the V-slope method and AT estimated with RPE at the treadmill progressive test in handball players (HP) on different playing positions. The sample included 17 elite HP, members of the Croatian Senior Handball Team. A sample of 12 variables was obtained using a treadmill spiroergometric test, and on the basis of RPE assessment by the respondents during the test. The absence of a statistically significant difference (P=0.59) in the variables running speed at the ventilation threshold (km/h) and running speed at RPE7 (km/h) between the HP, confirmed the hypothesis of this work-HP on different playing positions estimate their AT based on their RPE equally well.

***Key words****: handball, top players, functional test, endurance, playing positions, analysis*

**Introduction**

TH, combining aspects of basketball, soccer and baseball, is a physically demanding sport; nonetheless, it is one of the most popular sports in the world (Gorostiaga et al., 2006; Sporiš et al., 2010). According to Granados et al. (2007), combined with muscle strength and power, high levels of aerobic capacity are vital for successful competition performance in both male and female HP. On the contrary, some studies (Noakes, 2003) disproved the importance of aerobic capacity, especially the concept of VO2max in high-level competitive performance. Additionally, some of TH studies (Rannou et al., 2001) highlighted the importance of anaerobic, contrary to aerobic characteristics in achieving high-level competitive results. It can be highlighted that HG make a large number of explosive movements, therefore the emphasis is on the anaerobic capacity of the HP, i.e., their ability to maintain a maximum-intensity activity over a short period of time (15-60 s) without significant drops in intensity; however the significance of aerobic capacity should not be disregarded.

In every team sport, there are differences in demands on different playing positions. With respect to the differences between playing positions, according to Šibila et al. (2004), there are significant discrepancies in the percentage of the time spent in maximum intensity activities, which is 4 % for wings, 3 % for backcourt players, and 2 % for pivots. During a handball match, the average intensity is around 70 % of VO2max (Thorlund et al., 2008) and ratio between the high- and low-intensity is between 1:3 and 1:5 (Šibila et al., 2004, according to Bon, 2001).

A very important endurance factor in TH is the AT height. Untrained persons exceed AT at 60-80 % of VO2max, and top aerobic athletes at 80-95 % of VO2max. This means that the trained person will endure prolonged and high load without disorders of homeostasis and drop capabilities due to acidification of the body. AT is a subject of great interest to the scientific community, and long-term controversies related to the AT concept are still not resolved. The reason for this is its great practical application.

AT estimation tests are generally progressive, and they can be performed on a treadmill in laboratory setting. This paper will describe the V-slope method for determining AT. V-slope method is based on the slope of the VCO2 in relation to VO2 curve during progressive exercise test. The method is called the V-slope because it uses the slope of the gas interconnection curve (CO2 and O2). This method has significant advantages over other ventilation methods because it does not depend on the regulation of breathing patterns and respiratory chemosensibility of the subject, which can lead to inability or difficulty in determining AT.

Dosage and distribution of the training intensity is one of the most important components for achieving top results in sports. There are several ways of dosing, estimating and controlling the intensity of the load: RPE; heart rate; pace; power and lactate. No method of dosing and intensity control is complete, i.e., no method can explicitly define the intensity of the activity. Therefore, simultaneous use of multiple methods is recommended, which increases reliability of the measurement.

Comprehensive theory of perceived exertion does not exist yet (Garcin, 2006; Watt & Grove, 1993). Numerous studies have been conducted to identify different physiological components involved in physical exertion and to find out how they vary in relation to perceived exertion (Borg & Ottoson, 1986; Borg, 1998). Perceived exertion is a multidimensional construct based on integration of manifold sensory inputs related to numerous physiological, psychological, and experiential factors (Hassmen, 1995; Borg, 1998). Various of scales have been used to estimate perceived exertion. The RPE scale from 6 to 20 is the most commonly used in clinical, ergonomic, pedagogical and sporting applications (Borg, 1998).

Previous investigators have only dealt with the physiological response that can account for the RPE during cycling exercise (Pandolf et al, 1984) or the contribution of differentiated RPE to overall exertion while swimming (Ueda et al., 1993). Only Garcin (1997) studied both physiological and performance variables for RPE and Estimated Time Limit, especially at the intensity corresponding to the AT. Garcin et al., 2006, used 94 regional to national level athletes (47 endurance-trained runners, 11 sprinters, and 36 HP) to show that RPE and Estimated Time Limit at the lactate threshold was mainly mediated by factors relative to the performance expressed in percentage of the maximum aerobic velocity. Secondary factors that contribute significantly as perceptual predictors were related to various classes of factors, except for psychological factors.

The aim of this paper was to analyze possible differences in the determination of AT underpinned by the V-slope method and AT estimated with RPE at the treadmill progressive test in elite HP on different playing positions. Hypothesis states that HP on different playing positions assess the transition of an AT based on their RPE equally well.

**Methods**

The sample consisted of 17 elite HP, members of the Croatian Senior Handball Team. HP were divided by criterion-playing position (2 goalkeepers, 8 backcourt players, 2 pivots and 5 wingers). The test was conducted at the Diagnostic Center of the Faculty of Kinesiology in Zagreb, within the Olympic Games preparation cycle. Participant assent were obtained in advance of the study, and ethical approval for the research was granted by the University Research Ethics Committee in accordance with the Declaration of Helsinki.

*Table 1. The physical characteristics of respondents.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Valid N** | **A**  **(years)** | **BH**  **(cm)** | **BM**  **(kg)** | **BMI**  **(kg/m2)** |
| **G** | 2 | 25,9 ± 1,2 | 196,7 ± 3,8 | 100,3 ± 18,5 | 25,7 ± 3,7 |
| **B** | 8 | 27,7 ± 2,3 | 197,6 # ± 6,3 | 100,8\* ± 7,8 | 25,8 ± 1,5 |
| **P** | 2 | 29,1 ± 3,7 | 200,6° ± 3,0 | 112,9® ± 1,8 | 28,0 ± 1,3 |
| **W** | 5 | 26,5 ± 2,9 | 184,7 # ° ± 9,0 | 86,1\* ®  ± 3,8 | 25,3 ± 1,8 |
| **M ± SD** |  | 27,3 ± 2,5 | 194,0 ± 8,9 | 97,8 ± 11,3 | 25,9 ± 1,9 |

Legend: G-goalkeepers; B-backcourt players; P-pivots, W-wingers; M-mean; SD-standard deviation; A-age; BH-body height; BM-body mass; BMI-body mass index.

Notice: \*-statistically significant difference between B and W (P˂0,05); #-statistically significant difference between B and W (P˂0,05); °-statistically significant difference between P and W (P˂0,05); ®-statistically significant difference between P and W (P˂0,05).

A sample of variables was obtained using a spiroergometric test on a treadmill and on the basis of RPE assessment by the respondents during the test: Maximum absolute oxygen uptake-VO2max (lO2/min); Maximum relative oxygen uptake-RVO2max (mlO2/kg/min); Maximum running speed-vmax (km/h); Running speed at the ventilation threshold-vVT (km/h); Running speed at the RPE 7-vRPE7 (km/h); Maximum heart rate-HRmax (o/min); Heart rate at ventilation threshold-HRVT (o/min); Heart rate at RPE 7-HRRPE7 (o/min); Maximum relative oxygen uptake at ventilation threshold-RVO2VT (mlO2/kg/min); Maximum absolute oxygen uptake at ventilation threshold-VO2VT (lO2/min); Percentage of VO2max at ventilation anaerobic threshold-%/VO2max (%), Percentage of HRmax at ventilation anaerobic threshold-%/HRmax (%).

All parameters were obtained based on the treadmill spiroergometric test and the standard protocol (KF05) for the functional abilities evaluated at the Faculty of Kinesiology, University of Zagreb. A progressive treadmill test was carried out. The test records a 1 km/h increment of every minute with a steady inclination of 1.5 %. The breath by breath, spiroergometer, mobile wrist and telemetry heart rate monitor provide on-line monitoring and subsequent analysis of ventilation and metabolic parameters. Constant microclimate conditions in the laboratory increase high reliability of measurement data. Before the measurement, respondents were adequately prepared and dressed. They were familiar with the purpose and protocol of the test. Before the test, the measurer explained the protocol, security and the communication mode during the test. Measurer put the heart rate monitor rubber band on the respondent chest, and he placed a respiratory mask on his face. The mask was connected to the analyzer thorugh the tube. During the test, the respondent did not talk because he had a mask on, only the fingers of his hands showed the signs of the RPE to the measurer.

The actual effort is closely related to the athletic psychological intensity experience and can be quantified by using the Borg scale with values from 6 to 20. For the initial and final value of the scale, values 6 and 20 are taken from the analogy with the HR at rest (60) and HR at maximum effort (200). Diagnostic center on our Faculty uses a modified Borg Scale (0-13, where 0 is very light effort and 13 is extremely difficult effort).

During the first minute on a treadmill respondent is relaxed, then he starts to walk at a speed of 3 km/h and a constant incline of 1.5 %. This speed is constant for 2 minutes and after a total of 3 minutes, the treadmill begins to continuously accelerate by 1 km/h every minute. Test runs to the maximum, i.e., until the subject is no longer able to track the speed of the treadmill. It is important to note that the test can be interrupted every half of full minute when the respondent decides to stop because he cannot keep up with the treadmill speed. During testing, before the end of each load level, asked by the measurer, respondent uses his fingers to show the RPE value in concordance with the modified Borg scale.

After the measurements were performed, the data were analyzed by the program Statistics for Windows 13.2, and standard descriptive parameters were calculated: arithmetic mean, standard deviation, skewness, kurtosis, minimum and maximum value. A univariate variance of analysis was used to analyze differences in functional and anthropometric characteristics, while the Fisher post-hoc test was used to further determine differences in playing positions.

**Results**

Analyzing the results of Table 1., which shows the basic anthropometric characteristics of HP by playing positions, a statistically significant difference (P˂0,05) between the backcourt players and the wings in the parameter body height was observed; the same goes for the difference between pivots and wings in body height; between backcourt players and wings in the body mass and in the same parameter between the pivots and wings.

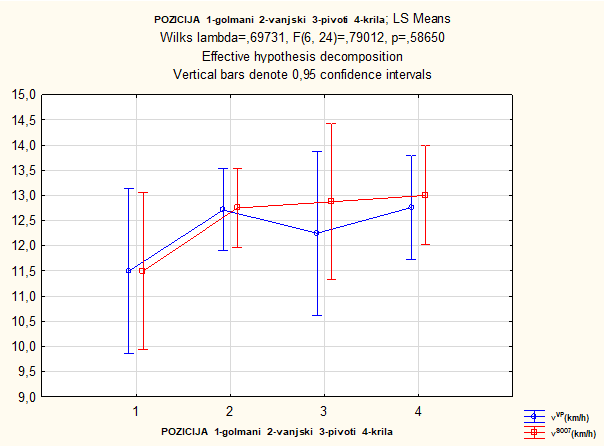
*Table 2. Basic descriptive parameters for the selected sample of variables obtained by treadmill spiroergometric test with marked variables that statistically differ according to the playing positions.*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **TEST** | **GOALKEEPERS** | | **BACKCOURT PLAYERS** | | **PIVOTS** | | **WINGERS** | |
| **M ± SD** | **MIN ± MAX** | **M ± SD** | **MIN ± MAX** | **M ± SD** | **MIN ± MAX** | **M ± SD** | **MIN ± MAX** |
| **VO2max**  (lO2/min) | 5,1 ± 0,0 | 5,1 ± 5,1 | 5,6 ± 0,3 | 5,2 ± 6,4 | 5,7 ± 0,2 | 5,5 ± 5,9 | 4,9 ± 0,8 | 3,9 ± 5,9 |
| **RVO2max** (mlO2/kg/min) | 51,9 ± 9,1 | 45,4 ± 58,3 | 54,7 ± 4,5 | 49,1 ± 61,6 | 50,8 ± 1,4 | 49,8 ± 51,8 | 56,7 ± 7,3 | 48,7 ± 66,6 |
| **vmax**  (km/h) | 15,5 ± 2,8 | 13,5 ± 17,5 | 17,0 ± 1,0 | 16,0 ± 18,5 | 16,3 ± 0,4 | 16,0 ± 16,5 | 17,3 ± 0,6 | 16,5 ± 18,0 |
| **vVT**  (km/h) | 11,5 ± 2,1 | 10,0 ± 13,0 | 12,7 ± 0,9 | 11,7 ± 14,5 | 12,3 ± 0,4 | 12,0 ± 12,5 | 12,8 ± 1,0 | 11,5 ± 14,0 |
| **VRPE7**  (km/h) | 11,5 ± 2,1 | 10,0 ± 13,0 | 12,8 ± 0,8 | 11,8 ± 14,0 | 12,9 ± 1,6 | 11,8 ± 14,0 | 13,0 ± 0,6 | 12,0 ± 13,5 |
| **HRmax**  (o/min) | 190,5 ± 23,3 | 174,0 ± 207,0 | 191,0 ± 5,9 | 184,0 ± 200,0 | 187,5 ± 7,8 | 182,0 ± 193,0 | 192,4 ± 6,3 | 182,0 ± 197,0 |
| **HRVT**  (o/min) | 176,5 ± 20,5 | 162,0 ± 191,0 | 169,9 ± 5,8 | 160,0 ± 175,0 | 165,0 ± 12,7 | 156,0 ± 174,0 | 169,8 ± 6,8 | 159,0 ± 176,0 |
| **HRRPE7**  (o/min) | 177,0 ± 21,2 | 162,0 ± 192,0 | 169,0 ± 6,6 | 162,0 ± 176,0 | 170,0 ± 2,8 | 168,0 ± 172,0 | 170,8 ± 6,7 | 159,0 ± 175,0 |
| **RVO2VT** (mlO2/kg/min) | 47,7 ± 3,2 | 45,4 ± 50,0 | 46,1 ± 4,4 | 39,3 ± 52,7 | 44,1 ± 0,2 | 44,0 ± 44,2 | 47,7 ± 5,3 | 42,4 ± 54,4 |
| **VO2VT**  (lO2/min) | 4,4 ± 0,0 | 4,4 ± 4,4 | 4,6\*± 0,2 | 4,3 ± 4,9 | 5,0# ± 0,1 | 4,9 ± 5,0 | 4,1\* # ± 0,6 | 3,4 ± 4,8 |
| **% / VO2max**  (%) | 85,5 ± 0,7 | 85,0 ± 86,0 | 84,4 ± 3,8 | 78,0 ± 89,0 | 86,5 ± 2,1 | 85,0 ± 88,0 | 84,4 ± 4,0 | 79,0 ± 89,0 |
| **% / HRmax**  (%) | 92,5 ± 0,7 | 92,0 ± 93,0 | 89,6 ± 2,5 | 86,0 ± 93,0 | 88,0 ± 2,8 | 86,0 ± 90,0 | 88,2 ± 1,1 | 87,0 ± 90,0 |

Legend: M-mean; SD-standard deviation; MIN-minimum score; MAX-maximum score; VO2max (lO2/min)-maximum absolute oxygen uptake, RVO2max (mlO2/kg/min)-maximum relative oxygen uptake; vmax (km/h)-maximum running speed; vVT (km/h)-running speed at the ventilation threshold; vRPE7 (km/h)-running speed at the RPE 7; HRmax (o/min)-maximum heart rate; HRVT (o/min)-heart rate at ventilation threshold; HRRPE7 (o/min)-heart rate at RPE 7; RVO2VT -maximum relative oxygen uptake at ventilation threshold; VO2VT (lO2/min)-maximum absolute oxygen uptake at ventilation threshold; %/VO2max (%)-percentage of VO2max at ventilation anaerobic threshold; %/HRmax (%)-percentage of HRmax at ventilation anaerobic threshold.

Notice: \*-statistically significant difference between B and W (P˂0,05); # -statistically significant difference between P and W (P˂0,05).

*Figure 1. Running speed ratio in variables running speed at the ventilation threshold (km/h) and running speed at RPE7 (km/h) between the HP according to their playing positions.*



Legend: POZICIJA-playing position; 1-goalkeepers; 2-backcourt players; 3-pivots; 4-wingers,vVP (km/h)-running speed at the ventilation threshold; vSOO7 (km/h)-running speed at the RPE 7.

**Discussion**

Results that were obtained in the Table 1. were not surprising given the fact that in the HG each playing position is characterized by specific anthropometric characteristics of selected HP. The same results were obtained by Ghobadi et al. (2013); Chaouachi et al. (2009); Povoas et al. (2012).

Table 2. contains basic descriptive parameters with marked variables that statistically differ according to the playing positions. Mean values of RVO2max taken from wing players (56.7±7.3 ml/kg/min), backcourt players (54.7±4.5 ml/kg/min) and pivots (50.8±1.4 ml/kg/min) were somewhat higher than the values measured in the papers of Chaouachi et al. (2009) and Sporiš et al. (2010).

Higher values of RVO2max than measured in this paper, have been reported by Milanovic et al. (2015) on a sample of 70 HP of the 1st Croatian Handball League. Dispersion of the results in the RVO2max variable was greater due to the selection of players, i.e., the sport-specific requirements needed for each playing position.

The mean measured values of VO2max variable according to the playing positions are somewhat higher than those measured in the researches of Chaouachi et al. (2009); Sporiš et al. (2010), and slightly below the results obtained by Milanovic et al. (2015).

The same applies to the average values according to the playing positions of variables vmax and vvp, in which Chaouachi et al. (2009) and Sporiš et al. (2010) showed lower results, and Milanovic et al. (2015) slightly higher results.

A statistically significant difference was found in the variable absolute oxygen supply at the ventilation threshold (VO2VT) between the backcourt players and the wingers, and between the pivots and wingers, which can be attributed to the specificities associated with the requirements of the playing position. By analyzing the variable VO2VT, as well as all the other parameters of functional abilities, we have to consider the fact that the sample in this paper was too small (especially in the goalkeeper position-2 players, and the pivot position-2 players), and that for a good interpretation of the measured variables a greater number of HP of the same qualitative rank is needed.

Analyzing the results from Table 2. and observing Figure 1., we come to the conclusion that the results in vVT and vRPE7 variables are not different. This fact, namely the absence of a statistically significant difference (P=0.58) in the mentioned variables between the playing positions, confirmed the hypothesis of this work-HP of different playing positions estimate their AT based on the their RPE equally well.

**Conclusion**

High anaerobic capacity is an important element for every HP who wants to be successful in training and competition, especially today-HG accelerated due to change of rules. The most important parameter that needs to be known, especially for each individual, before the start of endurance training programming, is the AT. In the training process, the smallest mistakes can affect the ultimate aim of the training, which means achieving top-sports results. Training mistakes can be minimized by precise determination of the work zone based on the defined AT. The ultimate goal of any HP, regardless of the playing position, is to endure a high level of load without disturbance of homeostasis and loss of ability due to acidification.

The results of this paper have shown that top HP of all playing positions can accurately estimate the transition of their AT based on their RPE.

A top HP must understand the importance of training in the intensive aerobic zone to be able to raise the AT level to its maximum limits, while simultaneously eliminating the possibility of overtraining as a result of excessive load.

**References**

Borg, G. V., & Ottosond. The perception of exertion in physical work. London: *Macmillan Press*. Pp. 293-302, 1986.

Borg, G. V. Borg's Percetved Exertionand Pain Scales. Champaign, IL: *Human Kinetics*. Pp. 298-300, 1998.

Chaouachi, A., Brughelli, M., Levin, G., Boudhina, N.B., Cronin, J., & Chamari, K. (2009). Anthropometric, physiological and performance characteristick of elite team-handball players. *Journal of Sport Science 25*(2), 151-157.

Garcin, M., *Perceived exertion study during graded and constantrun exercise up to exhaustion.*Unpublished doctoral dissertation, Univer. Paris VI, 1997.

[Garcin, M](https://www.ncbi.nlm.nih.gov/pubmed/?term=Garcin%20M%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Mille-Hamard, L](https://www.ncbi.nlm.nih.gov/pubmed/?term=Mille-Hamard%20L%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Duhamel, A](https://www.ncbi.nlm.nih.gov/pubmed/?term=Duhamel%20A%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Boudin, F](https://www.ncbi.nlm.nih.gov/pubmed/?term=Boudin%20F%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Reveillere, C](https://www.ncbi.nlm.nih.gov/pubmed/?term=Reveillere%20C%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Billat, V](https://www.ncbi.nlm.nih.gov/pubmed/?term=Billat%20V%5BAuthor%5D&cauthor=true&cauthor_uid=17037643)., [Lhermitte, M](https://www.ncbi.nlm.nih.gov/pubmed/?term=Lhermitte%20M%5BAuthor%5D&cauthor=true&cauthor_uid=17037643). Factors associated with perceived exertion and estimated time limit at lactate threshold. [*Percept Mot Skills.*](https://www.ncbi.nlm.nih.gov/pubmed/17037643) 103(1):51-66, 2006.

[Ghobadi, H](https://www.ncbi.nlm.nih.gov/pubmed/?term=Ghobadi%20H%5BAuthor%5D&cauthor=true&cauthor_uid=24511357)., [Rajabi, H](https://www.ncbi.nlm.nih.gov/pubmed/?term=Rajabi%20H%5BAuthor%5D&cauthor=true&cauthor_uid=24511357)., [Farzad, B](https://www.ncbi.nlm.nih.gov/pubmed/?term=Farzad%20B%5BAuthor%5D&cauthor=true&cauthor_uid=24511357)., [Bayati, M](https://www.ncbi.nlm.nih.gov/pubmed/?term=Bayati%20M%5BAuthor%5D&cauthor=true&cauthor_uid=24511357)., [Jeffreys, I](https://www.ncbi.nlm.nih.gov/pubmed/?term=Jeffreys%20I%5BAuthor%5D&cauthor=true&cauthor_uid=24511357). Anthropometry of World-Class Elite Handball Players According to the Playing Position: Reports From Men's Handball World Championship 2013. [*J Hum Kinet*.](https://www.ncbi.nlm.nih.gov/pubmed/24511357)31;39:213-20, 2013.

Gorostiaga, E.M., Granados, C., Ibanez, J., Gonzalez-Badillo, J.J. andIzquierdo, M. Effects of anenti reseason on physical fitness changes in elite male handball players. *Medicine and Science in Sports and Exercise* 38, 357-366, 2006.

Granados C., Izquierdo, M., Ibanez, J., Bonnabau, H. and Gorostiaga, E.M. Differences in physical fitness and throwing velocity among elite and amateur female handball players. *International Journal of Sports Medicine* 28, 860-867, 2007.

Hassmen, P. Modifiers of perceived exertion. In G. W. Neely (Ed.), *Perception and psychophysics in theory and application*. Stockholm: Stockholm Univer. Pp. 53-66, 1995.

Luig, P., Manchado-Lopez, C., Perse, M., Kristan, M., Schander, I., Zimmermann, M., Henke, T., Platen, P., Motion characteristics according to playing position in international men’s team handball. In: Proceedings (*13th Annual Congress of the European College of Sports Science*, Estoril, 2008).

Milanović, L. etal.: Differences in aerobic and an aerobic parameters between handball players on different playing positions. *Acta Kinesiologica* 9, 2: 77‐82, 2015.

Noakes, T. D., *Lore of running*, Human Kinetics Publishers, Champaign, IL, 2003.

Pandolf K,. B., Billing D, . S., Drolet L, . L., Pimenthal, N. A., & Sawka M, . N. Differentiated ratings of PE and various physiological responses during prolonged upper and lower body exercise. *European Journal of Applied Physiology* 53, 5-11, 1984.

Póvoas, S. C., Seabra, A. F., Ascensão, A. A., Magalhães, J., Soares, J. M., Rebelo, A. N. Physical and physiological demands of elite team handball. *J StrengthCondRes*. 26(12):3365–3375, 2012.

Rannou, F., Prioux, J., Zouhal, H., Gratas-Delamarche,A. and Delamarche, P. Physiological profile of handball players. *Journal o fSports Medicine and Physical Fitness* 41, 349-353, 2001.

Skinner, J. S., Hustler, R., Beregsteinova, V. & Buskirk, E., R. The validity and reliability of a rating scale of perceived exertion. *Medicine and Science in Sports and Exercise* 5, 94-96, 1973.

Sporis, G., Vuleta, D. and Milanovic, D. Fitness Profiling in Handball: Physical and Physiological Characteristics of Elite Players. *Collegium Antropologicum* 34, 1009-1014, 2010.

Stamford B., A. Validity and reliability of subjective ratings of perceived exertion during work. *Ergonomics* 19, 53-60, 1976.

Šibila, M.,Vuleta, D., & Pori, P. Position-related differences in volume and intensity of large-scale cyclic movements of male players in handball. *Kinesiology* 36 (1), 56-68, 2004.

Thorlund, J.B., Michalsik, L.B., Madsen, K. and Aagaard, P. Acute fatigue-induced changes in muscle mechanical properties and neuromuscular activity in elite handball players following a handball match. *Scandinavian Journal of Medicine and Science in Sports*18, 462-472, 2008.

Ueda, T., Kurokawa, T., Kikkawa, K., & Choi, T. Contribution of differentiated ratings of perceived exertion to overall exertion in women while swimming. *European Journal of Applied Physiology* 66, 196-201, 1993.

Watt, B.& Grove, R. Perceived exertion antecedents and applications. *Clinics in Sports Medicine* 15, 225-241, 1993.