CHANGES IN REACTION TIME AND BLOOD LACTATE LEVELS IN SERVE RECEIVERS AND SETTERS PLAYING IN ELITE-LEVEL VOLLEYBALL GAMES

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- blood lactate
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- player position,
- volleyball.

Abstract:

Due to the specific nature of volleyball, manifested in limited time of contact with the ball, time to perceive essential events and the fastest possible response to the stimuli are of key importance over the entire game, especially during elite level tournaments. The aim of the study was to determine the reaction time and blood lactate levels in elite athletes during a volleyball championship match.

Participants were athletes from Junior Polish Team and Cadet Polish Team who were students from Private Comprehensive Secondary School of the Athletic Championship School of the Polish Volleyball Federation in Spała, Poland, aged 17 to 18 years. MICROGATE OPTOJUMP system (Italy) was used to measure time of foot contact in the measurement area with accuracy of up to 0.001 s. Lactate levels were measured by means of LACTATE SCOUT portable device (EKF Diagnostics, Germany).

The results obtained for the psychomotor component among serve receivers and setters revealed a reduction in reaction time as early as in the first set of the match (the fastest reaction). Measurements of blood lactate levels in both serve receivers and setters ball showed the highest levels in the first set, with 1.95±0.15 mmol/l and 1.7±0,2 mmol/l, respectively.

INTRODUCTION

In volleyball, skills of perception of the served or attacked ball, which is travelling at enormous speed of over 120 km/h during elite-level matches [9], quick and adequate response and immediate changing the position on the court determine whether a point is scored or not. Reaction time is especially important during serve reception, where the player receiving the ball has to make split-second decisions on the location from which the attack should be performed, direction and trajectory of the ball flight, its speed, location of landing or position of other teammates. The setting player, who performs defensive functions, good reaction time helps him or her optimal handling the ball before the attack, even under conditions of substantial fatigue caused by a match.

The studies that evaluated blood lactate levels during a volleyball game have been published in the literature. Viitasalo [28] was the first to present a physiological picture of a game of volleyball according to previous volleyball regulations. After a series of tests, the researcher found that both pre-game and post-game lactate levels measured in both laboratory environment and on the court were below 3.05 mmol/l. During an elite championship match, higher values were recorded in the winning team, most likely caused by higher playing intensity. These values were close to 4 mmol/l. Analysis of the variation of the position and function of players revealed the highest lactate levels (5.6 mmol/l) in setters [27].

The most of studies have reported low lactate levels, which leads various authors to the conclusions that volleyball is an aerobic sport due to a long time of match duration. During a volleyball game, phosphagen system is mainly used during short bouts of exercise. Minor contribution is made by anaerobic alactic system, connected with short high-intensity exercise in the phase of high activity of a player. There is sufficient scientific evidence that lactate production begins from the onset of match-induced exercise [8, 13, 15, 22, 25] and that anaerobic glycolysis is activated from the onset of an intensive activity [25].

Other studies [10, 11, 12], however, reported high lactate levels. Lactate levels were measured during a match, without disturbing the game, each time when changes were made and players left the court. It was observed for 300 blood samples that 38.10% of them contained between 4 and 8 mmol/l of lactate, whereas 2.8% showed lactate levels higher than 8 mmol/l. Blood lactate levels found in a study by González [10] were high in vollebyall players, which is in contradiction with conclusions presented in the previous publications that related low lactate levels to the length of active phases, pointing to the fact that their short duration prevents from reaching high levels of acidification. Based on these observations, Kunstlinger et al. [14] found that the energy of muscular work during a volleyball game is produced by exclusively anaerobic lactic energy sources, i.e. breakdown of ATP and phosphocreatine. Contrary to the results obtained from the previous studies, blood lactate levels obtained in the study [10] lead to the conclusion that high lactate levels occur during volleyball matches. It is remarkable that these high lactate levels were observed after the change in the game regulations, which caused that match-induced exercise have become shorter and the offensive and defensive actions are more dynamic.

AIM OF THE STUDY

The aim of the study was to determine the reaction time and blood lactate levels in elite athletes during a volleyball championship match.

MATERIAL AND METHODS

Participants of study were players from Junior Polish Team (born in 1991) and Cadet Polish Team (born in 1992), who were students from Private Comprehensive Secondary School of the Athletic Championship School of the Polish Volleyball Federation in Spała, Poland, aged 17 to 18 years. The players were in the lead up to World Junior and Cadet Championships, playing matches at the level of the first and second league. Thirteen players born in 1991 (juniors) and 11 players born in 1992 (cadets) were included in lineups of both teams. The players were characterized by mean body height of 196.6±7.39cm, body mass of 84.07±7.77kg and spike height of 337.2±7.46cm.

MICROGATE OPTOJUMP system (Italy) was used to measure time of foot contact in the measurement area with accuracy of up to 0.001 s. This helped develop the test to gather the results concerning reaction time during the approach run for the attack. Lactate levels were measured by means of LACTATE SCOUT portable device (EKF Diagnostics, Germany). The blood specimens of 5 µl were sampled on disposable test strips at rest (before

the warm-up) and following the athletes leaving the court to determine lactate levels using the analyser.

During the match-induced exercise, i.e. during each of four sets and after end of the match, serve receivers and setters underwent similar experimental procedures, with measurements of blood lactate levels (15 s), followed by the measurements of reaction time (30 s). Detailed description of the methodology used in the study was presented in a publication by Mroczek et al. (2011.)

RESULTS

Reaction time in serve receivers

The results obtained for psychomotor component for serve receivers (see Fig. 1 and Tab. 1) demonstrate that, after determination of the reaction time before the match at the level of 666±100 ms., a statistically significant ($p \leq 0.05$) decline (by 190 ms, 28.5%) was observed in the first set (the shortest reaction over the whole match). A gradual and statistically insignificant elongation in the reaction time to 558±293 ms was found for the second set and to 631±269 ms. in the third. At the end of the match-induced exercise, this time was reduced by 84 ms to the level of 547±283 ms. In all other cases the differences were statistically insignificant.

(Zawodnik przyjmujacy zagrywkę – Serve Receiver; Szybkość reagowania – Reaction time; Wysiłek meczowy – Match-induced exercise; Spoczynek – Rest; I set – Set 1; II set – Set II, III set – Set III, IV set – Set 4)

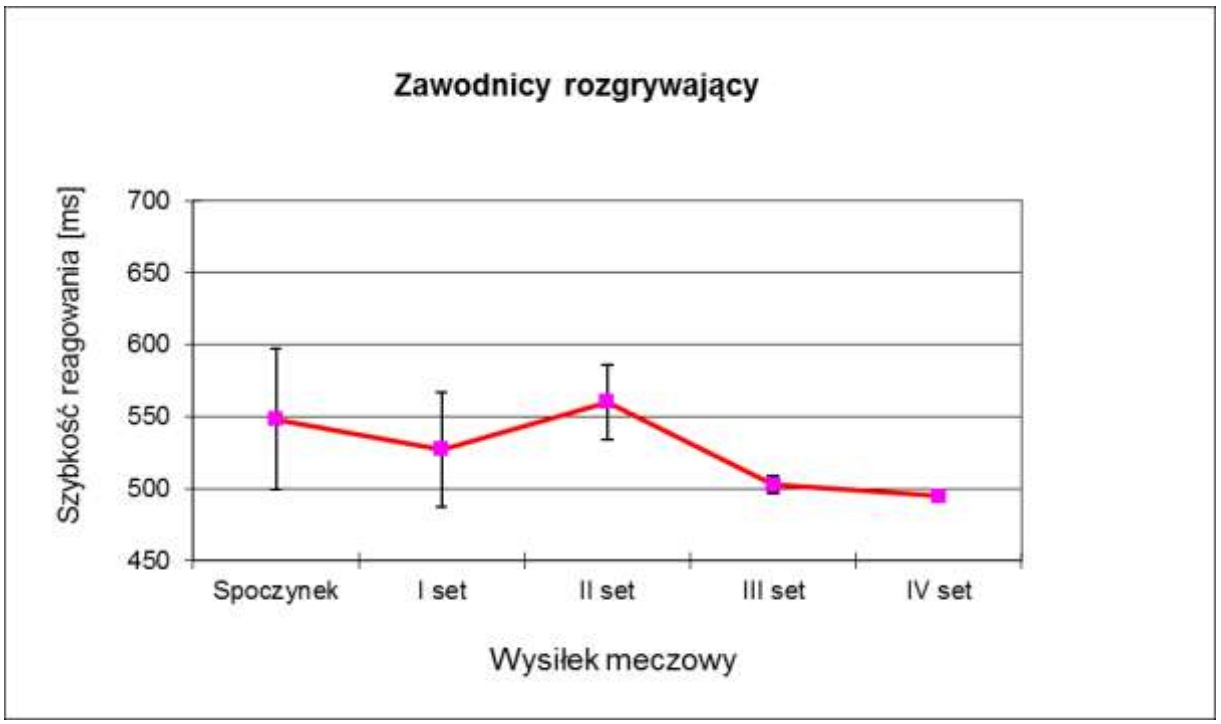
Fig. 1. Reaction time [ms] for serve receivers (*statistically significant difference compared to rest $p \leq 0{,}05$)

Tab. 1. Reaction time for serve receivers [ms] in both teams examined

Player function	Serve receiver I, team A	Serve receiver II, team A	Serve receiver I, team B	Serve receiver II, team B	$\bar{x}$	SE	min	max
Rest	904	500	762	0.497	666	100	497	904
Set 1	771	327	526	0.278	476	112	278	771
Set 2	799	327	824	0.282	558	146	282	824
Set 3	82	474	894	0.335	631	134	335	894
Set 4	92	357	611	0.3	547	142	300	920

Reaction time in setters

Values of the reaction time obtained for individual receivers (Fig. 2 and Tab. 2) show that, after determination of the referential values for the rest (548±49 ms.), variations caused by match-induced exercise were insignificant, ranging from 495±2 to 560±26 ms. Statistically insignificant elongation of the reaction time was observed until the half of the match (the slower reaction), followed by a statistically insignificant improvement in the reaction time, with the fastest reaction found for the fourth set.



(Zawodnik rozgrywający – Setter; Szybkość reagowania – Reaction time; Wysiłek meczowy – Match-induced exercise; Spoczynek – Rest; I set – Set 1; II set – Set II, III set – Set III, IV set – Set 4)

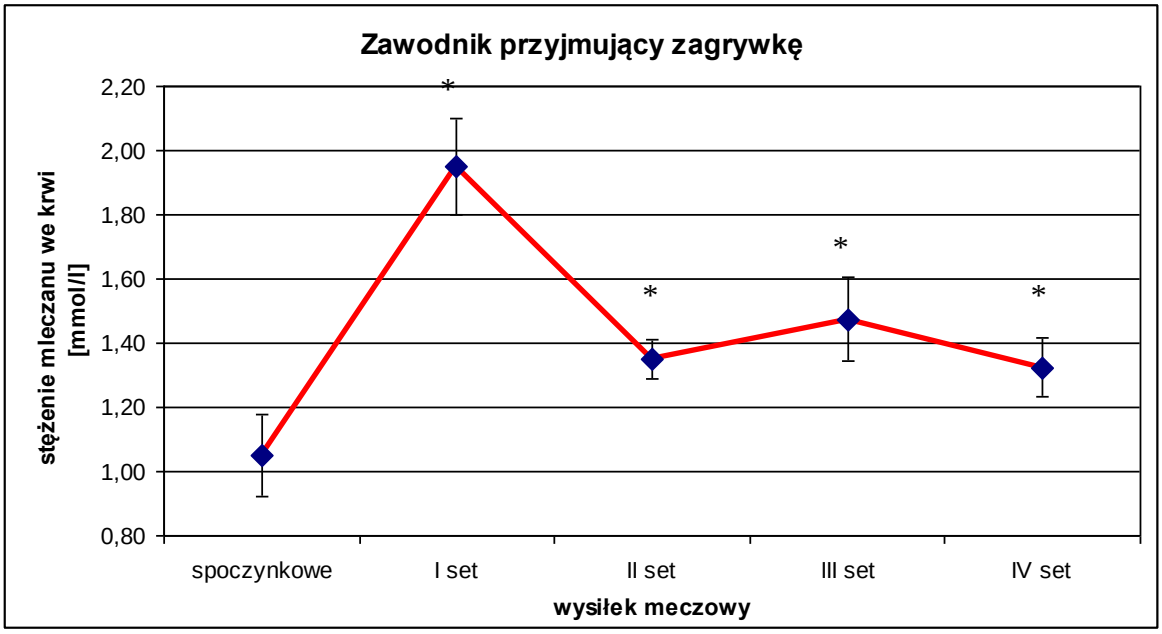
Fig. 2. Changes in reaction times [ms] in setters

Tab. 2 Reaction time for setters [ms] in both teams examined

MEASUREMENT	setter, team A	setter, team B	$\bar{x}$	SE	min	max
Rest	499	597	548	49	499	597
Set 1	567	487	527	4	487	567
Set 2	586	534	560	26	534	586
Set 3	509	496	502.5	6	496	509
Set 4	497	492	494.5	2	492	497

Blood lactate levels in serve receivers

Measurements of blood lactate level in serve receivers (Fig. 2, Tab. 3) revealed the highest levels in the first set (1.95±0.15 mmol/l). The increase compared to the pre-match status (1.05±0.13 mmol/l) was not statistically significant. Blood lactate levels recorded in the second set decreased by 0.6 mmol/l (1.35±0.06 mmol/l) and the difference compared to the first set was also statistically significant. Insignificant modifications in the values of lactate levels were observed in two last sets, ranging from 1.33±0.09 to 1.48±0.13 mmol/l, but no statistically significant differences were found.



(Zawodnik przyjmujący zagrywkę – Serve Receiver; stężenie mleczanu we krwi – blood lactate level; wysiłek meczowy – match-induced exercise; spoczynkowe – rest; I set – set 1; II set – set II, III set – set III, IV set – set 4)

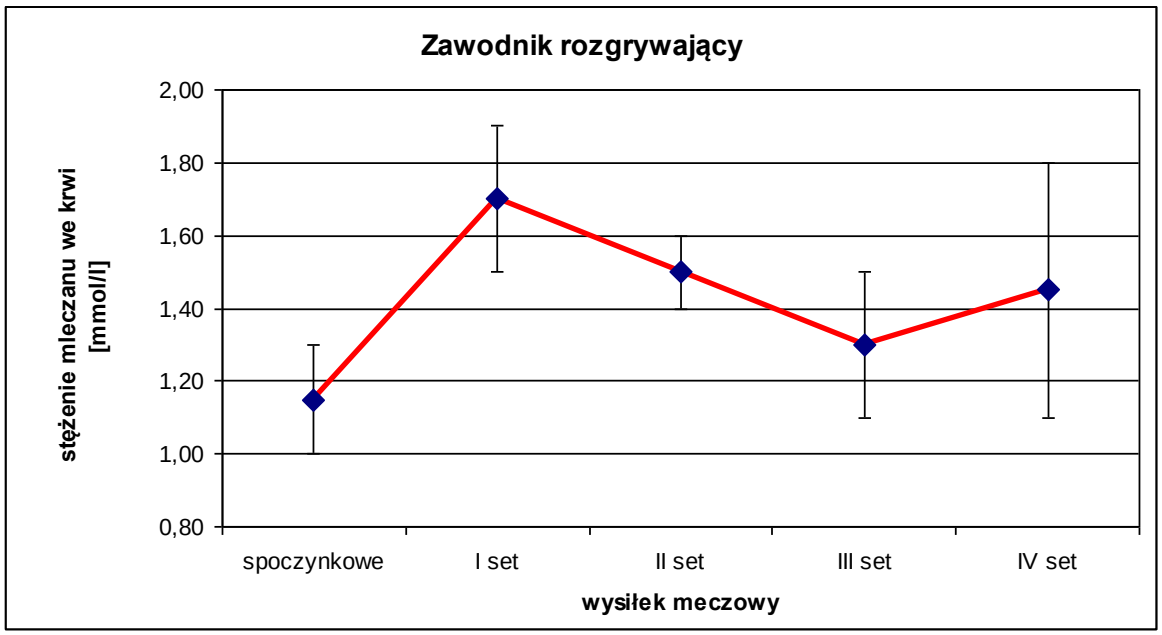
Fig. 3. Blood plasma lactate levels [mmol/l] in serve receivers during measurements in consecutive sets of the match (*statistically significant difference compared to rest p≤0.05)

Tab. 3 Blood plasma lactate levels [mmol/l] in serve receivers

Players	Rest	Set 1	Set 2	Set 3	Set 4
Receiver 1	1.2	2.1	1.2	1.6	1.3
Receiver 2	1.3	1.6	1.4	1.1	1.1
Receiver 1	1	2.3	1.3	1.7	1.5
Receiver 2	0.7	1.8	1.5	1.5	1.4
$\bar{x}$	1.05	1.95	1.35	1.48	1.33
SE	0.13	0.15	0.06	0.13	0.09
Min	0.70	1.60	1.20	1.10	1.10
Max	1.30	2.30	1.50	1.70	1.50

Blood lactate levels in setters

Individual analysis of lactate levels in setters (Fig. 4, Tab. 4) after evaluation of the referential rest status, revealed the highest levels for the first set (1.7±0.2 mmol/l). A linear and statistically insignificant decline in the lactate levels was observed for the second (to 1.5±0.1 mmol/l) and the third set (to 1.3±0.2 mmol/l) In the fourth set, the increase in the parameter by 11.5% was observed (the difference was statistically insignificant).



(Zawodnik rozgrywający – Setter; stężenie mleczanu we krwi – blood lactate level; wysiłek meczowy – match-induced exercise; spoczynkowe – rest; I set – set 1; II set – set II, III set – set III, IV set – set 4)

Fig. 4. Blood plasma lactate levels [mmol/l] in setters during measurements in consecutive sets of the match

Tab. 4. Blood plasma lactate levels [mmol/l] in setters

Player	Rest	Set 1	Set 2	Set 3	Set 4
Setter 1	1	1.5	1.4	1.1	1.1
Setter 2	1.3	1.9	1.6	1.5	1.8
SE	0.15	0.20	0.10	0.20	0.35
Min	1.00	1.50	1.40	1.10	1.10
Max	1.30	1.90	1.60	1.50	1.80

DISCUSSION

The main finding of our experiment was changes in reaction time and blood lactate levels in players during a volleyball game. Reaction time was shortened, which is consistent with the results obtained in previous studies [2, 6, 7, 16]. Furthermore, we found increases in blood lactate levels over the match.

Reaction time during the match in our experiment was shortened statistically significantly during the first set and remained at a relatively steady level until the end of the match. One of the causes of this phenomenon can be complexity of the acyclic movements performed by players during the match. McMorris et al. [18] demonstrated that reaction time following the exercise with maximal load was longer compared to reaction time following the exercise with medium-level load. In our experiment, reaction time was shorter, whereas the exercise intensity determined by means of lactate level was moderate and alternated with short bouts of exercise based on using the phosphagen energy system. The above findings differ from the results obtained during the studies of reaction time based on simple movements such as finger movement or oral response. In such examinations, the reaction times were shorter after the maximum exercise [26].

Shortening of the reaction time in our experiment is consistent with the findings reported elsewhere obtained in laboratory environment [2, 4, 5, 16, 18]. However, the match-induced exercise evaluated in our experiments had an entirely different profile than presented in these studies. McMorris [18] experimented with various variants of slalom depending on a sequence of light stimuli obtained by the athletes. Mean slalom time was 1.5 seconds. The study by Barcelos and Maciel [2] used motor reaction time (MRT) device to measure reaction time in a laboratory environment and found statistically significant differences in players at different positions of the court. The evidence collected in the study leads to the following conclusions: 1) reaction speed and blood lactate levels depend on the specific function of the player on the court and the technical and tactical tasks they perform in the attack or defence during a match; 2) shortening of the reaction time during a volleyball match, where moderate exercise is interspersed with short bouts of intensive work, indicates that this phenomenon has not only peripheral but also central background i.e. increased excitation of the central nervous system.

The examinations conducted in the study lead to the conclusion that shortening of the reaction time may result from the effect of the factors related to the volleyball match as a specific psychophysiological situation: exercise, high complexity of players' movements during a match, elevated excitation of the central nervous system. The above observation is consistent with the findings presented by Rhea et al. [23] and Sibley and Etnier [24], who demonstrated that the exercise induced by a match, especially during a tournament, causes the increase in excitation.

Considering division of players into those performing offensive functions such as serve receivers and those responsible for defensive actions such as setters, a tendency of the former for a relatively steady level of reaction time was observed, with minimal elongation of this value. In setters, shortening of the reaction time over the match reflects the improvement in the reaction abilities. This pattern observed for the parameter analysed in the study results

from the specific nature of the functions performed by players on the court. Players responsible for scoring points perform much more dynamic, maximal and short-time jumps for an attack or block. By contrast, players performing supporting functions connected with preparation of the attack or defence have to run longer distances, as it is the case with setters.

The correlation between lactate levels and peripheral muscle fatigues has been the focus of numerous research studies [3]. Blood lactate levels are significantly related to changes in intensity and duration of exercise. Blood lactate levels in players performing various functions on the court was varied. Some of the highest levels were obtained by serve receivers (2.3mmol/l). Lower lactate levels were observed in setters (1.9mmol/l). The values of blood lactate level obtained in our study were not similar to those reported by Gonzalez [10, 12]. This author found lactate levels in offensive middle blockers ranging from 0.82 to 11.40 mmol/l, whereas these values in defensive liberos ranged from 1.21 to 8 mmol/l.

The discrepancies are likely to have been caused by the fact that blood lactate levels monitored during the match were reflected only by tests performed after a short-term match-specific exercise, immediately following the change or after a player left the court. Additionally, measurements were made when a coach was making changes in players other than middle blockers and liberos, where variability and dynamics of situation on the court is entirely different. It is worth emphasizing that the blood was sampled from the athletes who left the court and took various positions during the change and, consequently, they were exposed to various loads, depending on whether they performed offensive or defensive functions [21]. These discrepancies in findings and high variability of the data obtained by players was however, supported by analogous results obtained in sports with acyclic character such as soccer [1], ice hockey [19] and rugby [17].

CONCLUSIONS

Analysis of the results obtained in the study leads to the following conclusions: 1) shortening of the reaction time in players during a volleyball match, where moderate exercise is interspersed with short bouts of intensive work, indicates that this phenomenon has not only peripheral but also central causes i.e. increased excitation of the central nervous system; 2) tendencies for elongation of the reaction time in consecutive sets of a match can be observed among players performing offensive functions (serve receivers), whereas in defensive players (setters) reaction time is reduced with match-induced exercise: 3) changes in lactate levels during the game point to an insignificant contribution of anaerobic lactic processes in production of energy and development of fatigue during a volleyball match in players regarding of the function performed on the court.

Practical implications

It seems that training programs of serve receivers should be oriented at using short-term (up to 3 seconds) variable training stimuli (in order to maintain the concentration level for the whole duration of exercise during accumulated peripheral fatigue, with particular focus on the central nervous system) whereas training of setters should be focused on using varied (up to 5-8 seconds) training stimuli in order to reach an optimum level of excitation over the whole duration of training exercise.

REFERENCES

1. Bangsbo, J. (1994) The physiology of soccer, with special reference to intense intermittent exercise. University of Copenhagen, Denmark. *Acta Phisiologica Scandinavica,* vol. 151 (619).

2. Barcelos J.L., Morales A.P., Maciel R.N., Azevedo M.M.A., Silva V.F. (2009) Time of practice: a comparative study of the motor reaction time among volleyball players. *Fitness & Performance Journal*. Rio de Janeiro, Mar-Apr;8(2):103-9.
3. Beneke R, Leithäuser RM, Ochentel O. (2011) Blood lactate diagnostics in exercise testing and training. *Int J Sports Physiol Perform*. Mar;6(1):8-24.
4. Bosco C., P. Luhtanen and P.V. Komi. (1983) A simple method for measurement of mechanical power in jumping, *European Journal of Applied Physiology*. 50: 273-282.
5. Bosco C. (1987) La preparación fisica en el voleibol y el desarrollo de la fuerza en deportes de caracter explosivo-balistico. Revista Voley. Buenos Aires.
6. Chmura, J., Nazar, K., Kaciuba-Uscilko, H. (1994) Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. Ankara, Turkey, *International Journal of Sports Medicine* 15, 172-176.
7. Chmura, J., Nazar, K. (2010) Parallel changes in the onset of blood lactate accumulation (OBLA) and threshold of psychomotor performance deterioration during incremental exercise after training in athletes, *International Journal of Psychophysiology* 75, 287-290.
8. Dyba, W. (1982) Physiological and activity characteristics of volleyball. USA, Volleyball Tech, 6 (3).
9. Forthomme B., Croisier J. L.; Ciccarone G.; Crielaard J. M.; Cloes M. (2005) Muscular and physical features correlated with ball velocity during the volleyball spike. *Computer Methods in Biomechanics and Biomedical Engineering*, Volume 8, Issue 4 Supplement 1.
10. González, C. (2001) Análisis del esfuerzo en el voleibol tras los nuevos cambios en el reglamento, mediante una observación sistemática y una medición telemétrica y lactacidémica, Tesis Doctoral. Universidad de Granada.
11. González Millán C., Ureña Espá A., Navarro Valdivielso F., Martín Morell A., Santos del Campo J.A., Llop García F. (2002) La concentración de ácido láctico como índice de valoración de la contribución energética en el voleibol, *Revista Digital* - Buenos Aires - Año 8 - N° 46.
12. Gonzalez C., Ureńa A., Llop F,.Garcia J.M, Martin A., Navarro F. (2005) Physiological characteristic of Libero and central volleyball players, *Biology of Sport*, Vol.22, Nr 1.
13. Hirvonen. J., Rehunen S., Rusko H., Harkonen D. (1987) Breakdown of high-energy phosphate compounds and lactate accumulation during short supramaximal exercise, *Eur.J.Appl. Physiol*. 56:253-259
14. Küntslinger, U.; Ludwig, H.; Stegeman, J. (1987) Metabolic changes during volleyball matches. Ankara, Turkey, *International Journal Sports Medicine* nr 8.
15. McArdle W., Katch F., Katch V. (2000) Essentials of Exercise Physiology, Lippincott Williams Wilkins. Philadelphia.
16. Maciel RN, Morales AP, Barcelos JL, Nunes WJ, Azevedo MMA, Silva VF. (2009) Relation between reaction time and specific function in volleyball players. *Fitness & Performance Journal*. Rio de Janeiro, Nov-Dec; 8(6): 395-9
17. McLean, D.A. (1991) Analysis of the physical demands of international rugby union. *Journal of Sport Sciences*, 10(3): 285-296.
18. McMorris, T., Delves, S., Sproule, J., Lauder, M., Hale, B. (2005) Effect of incremental exercise on initiation and movement times in a choice response, whole body psychomotor task. *British Journal of Sports Medicine*, no 39, 537-541.
19. Montgomery, D.L. Physiology of ice hockey. In: Garret, W.; Kirkendall, D. (eds) (2000) *Exercise and Sport Science.* Philadelphia: Lippincott Williams & Wilkins**.**
20. Mroczek D., Kawczyński A, Chmura J. (2011) Changes of reaction time and blood lactate concentration of elite volleyball players during a game. *J Hum Kinet*. Jun; 28:73-8. doi: 10.2478/v10078-011-0024-y.

21. Mroczek, D., Januszkiewicz, A, Kawczynski, A, Borysiuk, Z., Chmura, J. (2014) Analysis of Male Volleyball Players' Motor Activities During A Top Level Match, *Journal of Strength & Conditioning Research*: doi: 10.1519/JSC.0000000000000425.
22. Navarro F. (1998), La resistencia. Gymnos, Madrid.
23. Rhea, M.R., Landers, D.M., Alvar, B.A., Arent, S.M. (2003) The effects of competition and the presence of an audience on weight lifting performance, *The Journal of Strength & Conditioning Research* 17, 303-306.
24. Sibley, B.A., Etnier, J.L. (2004) Time course of attention and decision making during a volleyball set, *Research Quarterly for Exercise & Sport* 75, 102-106.
25. Spriet L.L. (1995) Anaerobic metabolism during high-intensity. In: M. Hargreaves (ed.) Exercise Metabolism, *Human Kinetics*, Champaign. II. pp. 1-40.
26. Tomporowski, P.D., (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica* (Amst) 112, 297-324.
27. Viitasalo J.T., Komi P.V. (1981) Effects of fatigue on isometric force – and relaxation-time characteristics in human muscles. „*European J. Appl. Physiol*.", 49, s. 7–16.
28. Viitasalo J.T. (1987) Fizjologiczny obraz gry w piłkę siatkową, Warszawa, Sport Wyczynowy nr 10.