EFFECT OF VARIABLE-INTENSITY RUNNING TRAINING AND CIRCUIT TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS OF SOCCER PLAYERS

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Abstract Proper planning of the training process based on individual LT[1] and AT[2] metabolic thresholds is essential to improve athletic performance. Development of endurance in soccer players is mainly based on continuous runs and variable-intensity runs, supplemented with strength conditioning and sport-specific training.

The aim of the study was to analyse selected parameters of physical capacity of soccer players after 8-week variable-intensity running training and circuit training.

The experiment was carried out in a group of 34 soccer players aged 21 to 26 years. The athletes were divided into two groups: 17 people in the experimental group and 17 people in the control group. The experimental group was involved in 30-minute tempo runs two times a week for 8 weeks with variable intensity at AT. In the same period, the control group performed two 60-minute continuous runs at the intensity of 70–75%HRmax. The determination of metabolic thresholds used two indirect tests: the multistage shuttle run test (beep test) and maximal lactate steady state test (MLSS) with author's own modification. In order to evaluate maximal heart rate (HRmax), the research procedure was started from the beep test (distance: 20 m). The speed at the first level was 8.5 km/h and increased with each level by 0.5 km/h.

Training of the experimental group where variable exercise intensity was used caused a statistically significant increase in HRmax (by 1.9%) and blood lactate levels at the AT (by 20.5%). The training in the experimental group led to the statistically significant ($p < 0.05$) increase in the parameters of the following variables: HRmax (by 1.9%); lactate level (by 7.85); HR at the AT (by 1,9%); lactate level at the AT (by 20.5%). The assumptions of the experimental training did not cause statistically significant

[1] LT – lactate threshold, where blood lactate levels are elevated over the resting levels.

[2] AT – anaerobic threshold, which is followed by a sharp increase in lactic acid build up.

changes in pretest vs. posttest HRmax and blood lactate levels for the LT. Endurance training with high intensity is more effective in soccer players compared to training with moderate intensity. Development of special endurance in soccer should also assume the intensity and method of working similar to the method used during sport competition.

Key words physiological parameters, soccer players, circuit training, variable-intensity running training

Introduction

A multifaceted and proportional improvement of individual motor abilities is critical to the process of motor preparation of athletes from team sports. Depending on the sport, a specific structure of motor development is used, determined by specific requirements of sport competition. Undoubtedly, all the team games are connected with the necessity of particular care for a high level of endurance.

In the case of soccer, which is characterized by work at high intensity, high level of endurance allows for performance of tactical actions and the use of technical skills over the entire match. Bangsbo (2014) analysed the energy systems engaged in soccer and demonstrated that the aerobic system was used in 70%, glycolytic system in 20% and the phosphagen system in 10%. The evaluation of the volume and intensity of the exercise in this sport leads to the conclusion that development of a high level of general and special endurance is essential in elite players.

The tools for evaluation of aerobic capacity in soccer players are used in the process of endurance development. Level of VO_2max, which reflects the level of aerobic capacity, determines athlete's endurance during sport-specific motor tasks. Proper planning of the training process based on individual LT and AT metabolic thresholds is essential to improve athletic performance (Hill-Haas, Dowson, Couts, 2010). Development of endurance in soccer players is mainly based on continuous runs and variable-intensity runs, supplemented with strength conditioning and sport-specific training. Skilful utilization of individual training methods using a specific configuration should be conducive to the improvement in physiological parameters.

The aim of the study was to analyse selected parameters of physical capacity of soccer players after 8-week variable-intensity running training and circuit training.

Material and Methods

The study participants were 34 soccer players from a first-league adult soccer team. The age of participants ranged from 21 to 26 years. Using a random number generator, the athletes were randomized into two groups (experimental and control), with 17 participants in each group. The experimental group was in involved in 30-minute tempo runs two times a week for 8 weeks with variable intensity at AT (Figure 1). In the same period, the control group performed two 60-minute continuous runs at the intensity of 70–75% HRmax.

After 4 weeks in the experimental group, the running time at the AT was elongated by 1 minute (Figure 1). Furthermore, both groups participated twice a week in circuit training sessions over the entire period of the experiment.

The experiment was approved by the Bioethics Committee at the Regional Medical Chamber No. 42/KBL/OIL/2015 as of 15 April 2015.

Metabolic thresholds were determined based on two indirect tests: multistage shuttle run test (beep test) and maximal lactate steady state test (MLSS) with author's own modification (Billat, 1996; Beneke, 2003; Billat, Sirvent, Py, 2003).

In order to evaluate the maximal heart rate (HRmax), the research procedure was started from the beep test (the distance used in the test was 20 m). The speed at the first level was 8.5 km/h and increased with each level by 0.5 km/h. With the increasing frequency of the beeps, participants moved on to increasing running speed and they covered the section at the faster rate. The test was continued to exhaustion i.e. the point when the athlete was unable to continue the test task. The heart rate was monitored using Polar Sport Tester. Immediately after exhaustion and athlete's refusal to continue the test, the heart rate was recorded as the HRmax and the blood lactate level was measured.

The MLSS test with the author's own modification was performed on the soccer field, where running sections were marked between the lines of the penalty area. The experiment started with the measurement of lactate level and a 3-minute run at the intensity of 60% HRmax. The lactate level was also measured after completion of the first stage. The next step was a 3-minute run with the intensity increased by 5% HRmax. In light of the values of maximum heart rates achieved by players, 5% HRmax represented the individual increase in running intensity by 9–10 HR/min. Similar intensification during the monitoring of the maximal constant HR was used by Vobejda. Fromme, Samson (2006). The procedure was successively repeated by increasing the intensity by 5% HRmax/3min until exhaustion. The pattern of frequency of blood sample collecting used in our study during performance of the MLSS protocol was also employed by Palmer, Potteiger, Nau (1999). Similar approach was used by Goodwin, Harris, Hernández (2007), who recommended the use of exercise intervals from 1 to 4 minutes. Regular monitoring of lactate levels at increasing intensity was used to indirectly evaluate the metabolic thresholds in athletes. The measurements were performed using the Lactate Scout analyser.

Figure 1. Design of the running training in the experimental group

Furthermore, both groups performed the circuit training sessions twice a week, comprising 10 general strength conditioning and functional exercises. With the same training volume, the experimental group used free weight exercises and body weight exercises while the control group performed only isolated exercises for individual muscle groups. The principle of alternate muscle work was employed in both groups, with particular focus on the muscles of the lower limbs. The assumptions for this training are illustrated in Table 1.

Table 1. Methodological assumptions for the circuit training for both groups

Circuit training using the equipment and free weights	
Number of circuits	3
Number of exercises in a circuit	10
Number of repetitions	15
Percentage of maximum weight	50%
Speed of performing the exercise	Fast
Rests between circuits	3 min

Statistical Analysis

The statistical analysis used 6 separate bivariate analyses of variance (group [training vs. control] × time [pretest vs. posttest]). Furthermore, the t-test for dependent variables and independent variables with Bonferroni correction was also used. Effect size was calculated based on partial eta squared (η^2_P), with its values of > 0.01, 0.06 and 0.14 corresponding to small, medium and large effect size, respectively (Miles, Shevlin, 2001; Cohen, 1988; Cohen, Cohen, West, 2003). The statistical calculations were performed using the STATISTICA ver. 11 software. For all comparison, the level of alpha for $p \leq 0.05$ was adopted as statistically significant. All the descriptive data were presented in the form of mean ± SD. In order to maintain transparency of presentation, the results in the figures were presented in the form of mean ± SE.

Results

Table 2 shows the results of the statistical analysis: mean values, percentage of changes in mean values, interaction values (group [training vs. control] × time [pretest vs. posttest]) and partial eta squared.

Figure 2 presents the difference in heart rate per minute, post-pretest with interaction with the level of LT and AT. Furthermore, Figure 3 shows a graphical representation of pretest-posttest lactate concentrations for HRmax, AT and LT.

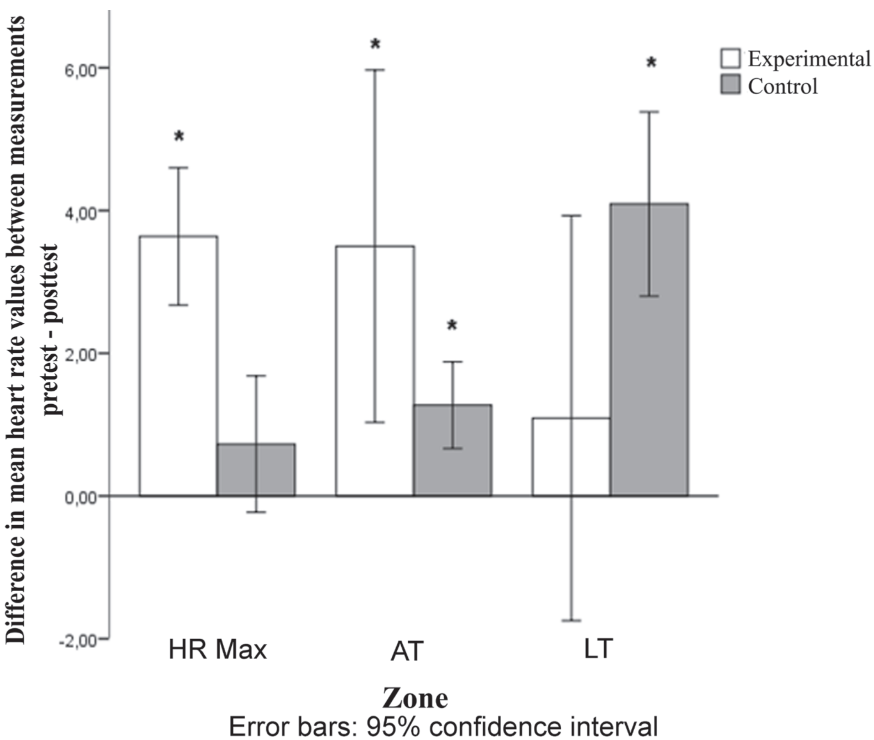
"The Normal Gaussian distribution of the data was verified by the Shapiro-Wilk's test. Homoscedasticity was tested by the Levene test."

Evaluation of the maximal heart rate (HRmax) revealed a significant interaction: group [training vs. control] × time [pretest vs. posttest] (p < 0.001). The analysis using the t-test for independent samples did not show statistically significant differences between the groups during pretest (p = 0.775) and posttest measurements (p = 0.219). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HRmax in the experimental group (p < 0.001). No statistically significant changes were found for this variable in the control group.

Table 2. Mean values, percentage of changes in mean values, interaction values (group[training vs. control] x time [pretest vs. posttest]) and partial eta squared

Variable		Control group		% change	Training group		% change	Interaction (p)	Partial Eta Square ($\eta^2 p$)
		Pre	Post		Pre	Post			
HRmax (beats/min)		192.2 ±4.9	192.7 ±5.6	0.4	191.5 ±5.2	195.1 ±4.9‡	1.9	<0.001	0.342
Lactate levels (mmol/l)		12.7 ±0.9	12.8 ±1.2	1.2	12.0 ±1.6	13.0 ±1.9‡	7.8	0.167	0.061
Aerobic threshold zone	HR	180.0 ±5.9	181.3 ±5.8‡	0.7	180.9 ±5.9	184.4 ±9.5‡	1.9	0.201	0.052
	Lactate levels (mmol/l)	6.7 ±1.7	6.5 ±1.8	–3.1	5.4 ±1.3 §	6.5 ±2.0‡	20.5	0.046	0.123
Lactate threshold zone	HR	159.6 ±4.0	163.7 ±4.5‡	2.6	167.2 ±8.5§	168.3 ±4.5	0.7	0.141	0.069
	Lactate levels (mmol/l)	2.5 ±0.5	2.7 ±0.4	7.7	2.5 ±0.7	2.6 ±0.6	6.8	0.873	0.001

§ – intergroup differences pretest $p < 0.05$.
§§ – intergroup differences posttest $p < 0.05$.
‡ – intergroup differences pretest – posttest $p < 0.05$.



* statistically significant difference ($p < 0.05$) between pretest – posttest measurements.

Figure 2. The change in the post – pretest measurements of HR and lactate levels for the HRmax, AT and LT thresholds in the control and experimental group

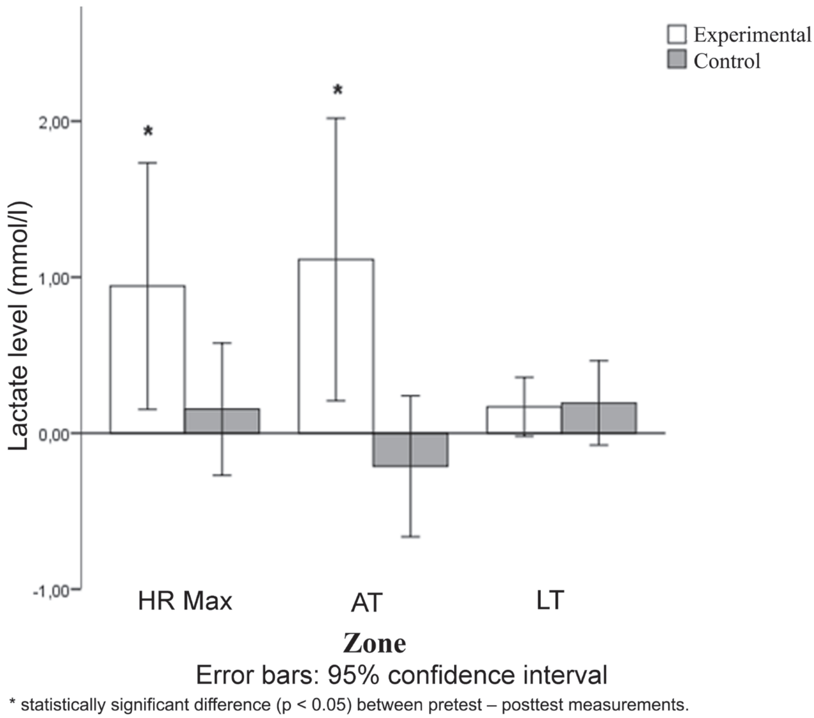


Figure 3. The change in the post – pretest measurements of HR and lactate levels for the HRmax, AT and LT thresholds in the control and training group

Blood lactate levels for HRmax did not reveal a significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.167$). The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest ($p = 0.775$) and posttest measurements ($p = 0.219$). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest lactate levels for HRmax in the training group ($p < 0.001$). No statistically significant changes were found for this variable in the control group.

With respect to the AT for HR, the significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.201$) was not found. The analysis using the t-test for independent samples did not reveal statistically significant differences between the groups during pretest ($p = 0.226$) and posttest ($p = 0.832$) measurements. The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HR for the AT zone in the training group ($p = 0.001$) ($p = 0.008$) and the control group ($p = 0.001$).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.046$) was found for the lactate concentration in the AT zone. The analysis based on the t-test for independent variables showed a statistically significantly higher lactate levels in the AT zone in the experimental group at the point of pretest measurements ($p = 0.021$). However, no statistically significant differences were found for the results of the posttest measurements ($p = 0.976$). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest lactate levels for the AT zone in the training group (p = 0.018). No statistically significant changes were found for this variable in the control group.

The interaction between the LT for HR did not reveal the significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.141). The analysis using the t-test for independent variables showed statistically significantly higher values of HR for the LT zone in the training group (p = 0.009) for the pretest measurements. No significant differences were observed in the case of posttest measurements (p = 0.155). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest HR for the LT zone in the control group (p < 0.001) whereas statistically significant changes were not found in the training group (p = 0.433).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.001) was found for the measurements of lactate concentration in the LT zone. The analysis based on the t-test for independent variables did not reveal statistically significant differences in lactate levels in the LT zone between the groups studied for both measurements. The analysis of t-test for dependent variables did not show a statistically significant increase in the pretest-posttest increase in the lactate level for the LT zone both in the experimental (p = 0.077) and control groups (p = 0.142).

Evaluation of the maximal heart rate (HRmax) revealed a significant interaction: group [training vs. control] × time [pretest vs. posttest] (p < 0.001). The analysis using the t-test for independent samples did not show statistically significant differences between the groups during pretest (p = 0.775) and posttest measurements (p = 0.219). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HRmax in the training group (p < 0.001). No statistically significant changes were found for this variable in the control group.

Blood lactate levels for HRmax did not reveal a significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.167). The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest (p = 0.775) and posttest measurements (p = 0.219). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest lactate levels for HR_{max} in the training group (p < 0.001). No statistically significant changes were found for this variable in the control group.

With respect to the AT for HR, the significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.201) was not found. The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest (p = 0.226) and posttest measurements (p = 0.832). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HR for the AT zone in the training group (p < 0.001) (p = 0.008) and the control group (p = 0.001).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.046) was found for the lactate concentration in the AT zone. The analysis based on the t-test for independent variables showed a statistically significantly higher lactate levels in the AT zone in the experimental group at the point of pretest measurements (p = 0.021). However, no statistically significant differences were found for the results of the posttest measurements (p = 0.976). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest lactate levels for the AT zone in the training group (p = 0.018). No statistically significant changes were found for this variable in the control group.

The interaction between the LT for HR did not reveal the significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.141). The analysis using the t-test for independent variables showed statistically significantly higher values of HR for the LT zone in the training group (p = 0.009) for the pretest measurements.

No significant differences were observed in the case of posttest measurements ($p = 0.155$). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest HR for the LT zone in the control group ($p < 0.001$) whereas statistically significant changes were not found in the training group ($p = 0.433$).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.001$) was found for the measurements of lactate concentration in the LT zone. The analysis based on the t-test for independent variables did not reveal statistically significant differences in lactate levels in the LT zone between the groups studied for both measurements. The analysis of t-test for dependent variables did not show a statistically significant increase in the pretest-posttest increase in the lactate level for the LT zone both in the experimental ($p = 0.077$) and control groups ($p = 0.142$).

Discussion

The results of this study lead to the conclusion that the planned training process yielded positive results. The improvement in the physiological parameters after the experimental period is likely to have been caused by new training stimuli which had not been used in the preparatory training of this soccer team. Claeesens, Lefevre (1992) find that the change in the physical activity may contribute to the improvement in motor effects and certain somatic changes in study participants. Based on the examinations, the authors hypothesized that the modified curriculum for physical education was one of the factors in achievement of better results in individual physical fitness tests.

Endurance tests demonstrated that the AT in the experimental group was statistically significantly moved to the right, with such a tendency observed in the control group only for the LT. This shows that the repeated training with high intensity at around the AT (which is typical of soccer) yields more favourable results in development of aerobic-anaerobic endurance. Denis, Fouquet, Poty (1982), who used training at the level of 85%VO_2max for 1 hour and 3 times a week over the initial 10 weeks of the experiment, documented the shift in AT by 10%. After 40 weeks, the authors found a total improvement by 18% and the increase in maximal workload (MWL) by 22%. Londeree (1997) found that training at the LT also yielded positive results. However, it represents insufficient stimuli for well-trained athletes, who need greater training intensity. This observation is consistent with the results recorded for the control group, where, in the context of variable exercise profile typical of soccer, the shift in the LT may not produce the favourable outcomes. Tabata, Nishimura, Kouzaki (1996) analysed the effect of a 6-week aerobic training at moderate intensity (70%VO_2max) and reported an improvement in VO_2max by 5 ml x min^{-1}x kg^{-1}, yet without a positive impact on anaerobic capacity. The author concluded that the improvement in both parameters should involve the increase in training work intensity. The results of the experimental group in our study, which demonstrated the shift in the AT, are partly consistent with this thesis and suggest an improvement in anaerobic capacity. No statistically significant changes in the indices of the LT were found. Denadai, Figueira Favaro (2004) analysed training of cyclists at the level of AT and found that the duration of the effort at this level while maintaining the steady state was not reflected by aerobic capacity.

In light of the results of our study, it can be concluded that training units should be intensified in order to induce the expected physiological adaptations. Helegerud, Høydal, Wang (2007) compared three types of training work oriented at improvement in physical capacity and demonstrated that training at the level of 85% HRmax at around anaerobic transitions yielded more favourable effect than the moderate-intensity training at 70% HRmax. However, it should be found that the third interval method, at very high intensity of 90–95% HRmax, demonstrated the most beneficial changes in capacity in study participants. It seems that the above study demonstrated a tendency for changes in training work towards short-term exercise at high intensity. The findings of Gomreley, Swain, High (2008) are consistent with this observation. In a 6-week experiment in three study groups, the increasing work intensity was correlated with positive effects in development of $VO_{2max.}$. In three training groups where work intensity occurred at the levels of 50% Vo_2R, 75% Vo_2R and 95% Vo_2R, an improvement in VO_2max was observed (by 3.4, 4.8 and 7.2 ml × min^{-1} × kg^{-1}, respectively).

In our study, the lactate levels in the experimental group during reaching of the second AT after the training cycle revealed an improvement in athlete's body tolerance to presence of lactate during the exercise. This is conducive to e.g. elongation of working time at the level of maximal lactate steady state (MLSS) or the AT (Faude, Kindermann, Meyer, 2009). In light of the high correlation between MLSS and work performance in endurance sports (correlation coefficient: 0.92 with 8k run and 0.87 with 5k run), it seems justified to take this fact into consideration during selection of the training methodologies in the period of preparation to the soccer season.

In the period of the experiment, variances were introduced in the circuit training for 2 times a week. Many studies have demonstrated that the adequate resistance training positively supports the training process and intensifies its outcomes. In the aspect of supporting the endurance training, the effectiveness of circuit training was confirmed by Marcinik (1988) and Marcinik, Potts, Schlabach (1991). These authors found improvements in work performance on the cycle ergometer and a shift in the LT after a 12-week circuit training cycle performed 3 times a week. Similar phenomenon was observed in both soccer groups in our study, where circuit training was used with two different variants. Johnson, Quinn, Kertzer (1997) demonstrated that combination of strength training with capacity training yields enhanced motor effects compared to only capacity training. These authors showed not only the improvement in muscle strength (upper body muscle groups by 24.4% and lower body muscles by 33.8%), but also in the economy of muscular work during running. These phenomena were not recorded in the group with capacity training. It seems that the obtained outcomes of the author's own studies in both groups are also the effect of the supplementary strength training. It should be noted that the group that performed the high-intensity circuit training with free weights, which was based on the biomechanical nature of the muscular work typical of soccer, demonstrated more beneficial tendencies in the results obtained. It can be expected that the combination of free weight training with functional and sport-specific exercises may contribute to enhanced movement economy, which can yield more beneficial effects in control tests. Stanton, Reaburn, Humphries (2004) concluded that the choice of appropriate set of exercises that provide the adequate training stimuli may be of key importance in achievement of the goals. Karp (2010) argues that introduction of weight training induces activation of greater number of muscle tissues, which activates the nervous system. This improvement in sensitivity of receptors and facilitation of work of the neuromuscular system will presumably contribute to the improvement in work effectiveness in long-term efforts (work economy). Cotterman, Darby, Skelly, (2005) compared two types of muscular work using free weights or Smith machine and found that the first work was more efficient. In both cases of 1RM tests, the level of generated power (i.e. greater engagement in the muscular system) was better during barbell squat exercise and bench press. Shick, Coburn, Brown (2010) emphasized that coaches should note that the free weight strength conditioning is conducive to improved activation and effectiveness of muscular work compared to isolated machine workout. These observations should be taken into consideration during the choice of exercises for soccer players. Soccer training engages the entire kinematic chain of muscular work. Physical preparation should involve the exercises that require synergy and high activation of muscle groups. Hoff, Helegerud (2004) argue that the contemporary training work in soccer is based on the conglomeration of endurance and strength conditioning. As observed by these authors, both forms of work translate into high intensity of exercise. These observations are consistent with the results of our experiment, where we found more beneficial physiological parameters in the experimental group, engaged in high-intensity training sessions compared to the group of players where the intensity of exercises remained at a moderate level.

Conclusions

The assumptions of the experimental training performed in the 8-week training of soccer players contributed statistically significantly to the improvement in the following physiological parameters:

1. Compared to the results documented for the control group, training of the experimental group where variable exercise intensity was used caused a statistically significant increase in HRmax (by 1.9%) and blood lactate levels at the AT (by 20.5%).
2. The training in the experimental group led to the statistically significant increase in the parameters of the following variables: HRmax (by 1.9%); lactate level (by 7.85); HR at the AT (o 1,9%); lactate level at the AT (by 20.5%).
3. The assumptions of the experimental training did not cause statistically significant changes in HRmax and blood lactate levels for the LT in soccer players examined in the study.

The results of the experiment lead to the following conclusions of practical importance to planning the process of preparation in soccer:

1. Endurance training with high intensity is more effective in soccer players compared to training with moderate intensity.
2. Development of special endurance in soccer should also assume the intensity and method of working similar to the method used during sport competition.

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