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Aerobic capacity and sprint velocity of Leagues I and IV football players

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Summary

Study aim: To assess the aerobic capacity, sprint velocity and changes in biochemical variables in football players preparing for the spring round of matches.

Material and methods: Football players from League I (n = 19) and League IV (n = 15) were subjected twice to a graded running tests at the beginning and at the end of the pre-season preparation period. The following variables were recorded: maximum running velocity (km/h), $\dot{V}O_2$max (ml/kg/min), pulmonary ventilation (VE), load at the lactate threshold (LT) expressed as the threshold velocity (LTV; km/h) or %$\dot{V}O_2$max, activities of enzymes in plasma – creatine kinase (CK) and lactate dehydrogenase (LDH), concentrations of lactate (La), ammonia (NH_3) and of glucose (Gl) in plasma. At the end of the study the players were also subjected to a 30-m sprint test.

Results: In League I players, LT significantly ($p<0.05$) increased from 11.9 ± 0.8 (at the beginning) to 12.6 ± 0.7 km/h (at the end of the pre-season preparation period) and the maximum load – from 17.4 ± 0.9 to 18.3 ± 1.0 km/h, respectively. Also, the concentrations of NH_3 and Gl significantly ($p<0.05$) increased and enzyme activities tended to increase ($p<0.10$) following the graded running test. Moreover, they attained significantly ($p<0.05$) higher velocity at the first 5 m of the 30-m sprint test than their League IV mates.

Conclusions: The negligible differences between football players from Leagues I and IV in their aerobic capacity and speed abilities, and the marked distance from world elite players in those indices, call for substantial changes in training strategies and schedules.

Key words: Football players – VO_2max – Lactate threshold – Sprint velocity

The contemporary football requires perfection in game techniques and tactics, and in physical fitness [3,27,30]. The players ought to exhibit a high level of aerobic ca-pacity , speed and strength, as aerobic energy sources and, in short periods of a match, also the anaerobic ones are dominating [1,27]. Highly fit players are more efficient in a match than the less fit ones [26], their capacity to cover as long distances as 10 – 12 km during a match (aerobic capacity) and to perform multiple sprints (anaerobic capacity) is thus a prerequisite for attaining highest sport competence [14,29]. One of the measures of aerobic capacity and, thus, of competence in football, is maximal oxygen uptake ($\dot{V}O_2$max) [1], the elite European football players attaining, on the average, 60 ml/kg/min [19,30]. That approach has been recently questioned since oxygen uptake does not increase, in running exertions, proportionally to body mass both at submaximal and maximal loads [4] and relating the $\dot{V}O_2$max to (body mass)$^{0.75}$ has been recommended [4,15,33]. That approach is considered a reliable measure of aerobic capacity in running sports and in football; the $\dot{V}O_2$max then ranges from 155 to 205 ml/kg$^{0.75}$/min in players from the best world teams [18,30,33].

Another measure of aerobic capacity is the widely used lactate threshold (LT) which ranges 80 – 90% HRmax or 82 – 88% $\dot{V}O_2$max [9,15,25]. It was reported [9,25,33] that players having a high LT were capable of performing more sprints at lower lactate accumulation compared with those with lower LT. This is important since despite predominantly aerobic work, about 10% of the total distance covered during a match consists of sprints [32]. However, the term 'sprint' has to be defined in terms of running velocity. On the average, football players run

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5 – 20 m distances, lasting 2 – 4 s, every 90 s [17] at a speed exceeding 9 m/s (32 km/h) [2].

In order to meet those requirements, football players should train exercises of diverse intensities, rapid changes in the direction and velocity of running, sprints and runs for the ball with maximum speed [19]. Thus, football training ought to shape not only aerobic capacity but strength-speed fitness as well, since the latter are often decisive in scoring a goal [32]. The aim of the study was to assess the aerobic capacity, sprint velocity and changes in biochemical variables in football players preparing for the spring round of matches and differing in experience.

Material and Methods

Subjects: Football players from League I (n = 19) and League IV (n = 15) volunteered to participate in the study which covered the pre-season preparation period for the spring round (January – February/March). Their basic anthropometric data are presented in Table 1. The subjects were informed about the study objective and protocol which was approved by the local Ethics Committee. All players submitted their written consents to participate.

Methodology: Throughout the 2-month period, the players participated in typical training tasks. The structure of that training period is presented in Table 2.

Aerobic capacity was assessed twice, at the beginning (Pre) and at the end (Post) of the 2-month training period, by applying graded treadmill test until exhaustion, using electric treadmill (LE 300C; Jaeger, Germany) at no inclination. The results of the 'Pre' test served to set the training loads in the consecutive microcycles (one week each). Oxygen uptake ($\dot{V}O_2$) and lung ventilation (VE) were recorded throughout the test using an ergospirometer (Oxycon Alpha; Jaeger, Germany). The initial treadmill velocity was 6 km/h and was increased by 2 km/h every 3 min, spaced by breaks lasting several seconds in order to sample blood from fingers for lactate determination. The lactate threshold (LT) was determined from the lactate curve using the D-max method [10]. Before the test and 3 – 4 min after the test blood was withdrawn from the antecubital vein for biochemical assays.

Immediately after the training period had been terminated, all players were subjected to a 30-m sprint test [12] in a sports hall equipped with a line of photocells. Running velocities were determined for the following distances: 5 m (0 – 5 m), 20 m (0 – 20 m), 30 m (0 – 30 m), 15 m (5 – 20 m) and 10 m (20 – 30 m). The test was applied twice, 1 h apart, better results being saved. All exercise tests were conducted in the mornings.

In fresh blood samples, collected into heparinised tubes, hematocrit (Ht) and haemoglobin concentration were determined; these served to correct other determinations for changes in plasma volume [13]. Biochemical assays in fresh plasma samples were conducted using commercial kits for lactate and ammonia concentrations (BioMérieux, France), glucose concentrations (Analco, Poland), creatine kinase (CK: E.C. 2.7.3.2) and lactate dehydrogenase (LD: E.C.1.1.1.27) activities (Randox, N.Ireland).

Data analysis: Aerobic capacity variables were subjected to one-way ANOVA followed by *post-hoc* Tukey's test, other measurements were subjected to two-way ANOVA followed by *post-hoc* Bonferroni's test. The between-group differences were assessed using the Mann-Whitney's U-test. STATISTICA 6.0 software was used in data analysis, the level of $p \leq 0.05$ being considered significant.

Results

League I football players were significantly ($p<0.05$) taller and had lower BMI than the League IV ones (Table 1). No marked differences between the players from both leagues were found in the numbers of training days or training units but the training loads were somewhat lower in League IV than League I players.

Table 1. Mean values (±SD) of somatic data of football players at the beginning (Pre) and at the end (Post) of the pre-season preparation period for the spring round

Group / Variable	League I (n = 19)		League IV (n = 15)	
Age (years)	26.05 ± 3.56		27.66 ± 5.98	
Body height (cm)	181.7 ± 5.8*		176.7 ± 5.7	
	Pre	Post	Pre	Post
Body mass (kg)	75.5 ± 3.3	74.9 ± 2.7	74.6 ± 6.0	74.0 ± 5.6
BMI	22.8 ± 1.0*	22.7 ± 1.4*	23.8 ± 1.2	23.7 ± 1.2

* Significantly ($p<0.05$) different from League IV football players (by U-test)

Table 2. Structure of the pre-season preparation period and training loads applied

Period	Pre (Mesocycle 1)		Post (Mesocycle 2)	
Group	League I (n = 19)	League IV (n = 15)	League I (n = 19)	League IV (n = 15)
Variable	4 microcycles	4 microcycles	3 microcycles	4 microcycles
No. of training days	23	21	20	22
No. of training units (TU)	34	33	28	27
No. of control matches	–	–	5	3
Mean duration of TU (min)	90	90	100	85
Training load (%HR_{max})	67	63	75	71

Table 3. Mean values (±SD) of aerobic capacity variables in football players at the beginning (Pre) and at the end (Post) of the pre-season preparation period for the spring round

Group	League I (n = 19)		League IV (n = 15)	
Variable	Pre	Post	Pre	Post
Maximum running speed (km/h)	17.4 ± 1.0	18.3 ± 1.0*^{o}	16.9 ± 1.1	17.3 ± 1.6
$\dot{V}O_2$max (ml/kg/min)	53.9 ± 4.1	54.8 ± 4.2	52.3 ± 4.2	53.2 ± 5.1
$\dot{V}O_2$max (ml/ $kg^{0.75}$/min)	158.9 ± 11.7	161.5±11.7	153.3 ± 9.8	156.2± 13.5
Peak lactate concentration (mmol/L)	9.31 ± 1.73	10.44 ± 2.40*	8.38 ± 1.74	8.53 ± 2.75
Lactate threshold (%VO_2max)	68.7 ± 4.6	69.2 ± 6.6	67.8 ± 4.3	70.2 ± 7.9
Threshold velocity (km/h)	11.9 ± 0.8	12.7 ± 1.3 ^{o}	11.6 ± 0.8	12.1 ± 1.6

* Significantly ($p<0.05$) different from League IV football players (by U-test); ^{o} Significantly ($p<0.05$) different from the 'Pre' value

Table 4. Mean values (±SD) of haematological and metabolic variables and of enzyme activities in football players at the beginning (Pre) and at the end (Post) of the pre-season preparation period for the spring round

Group		League I (n = 19)		League IV (n = 15)	
Variable		Pre	Post	Pre	Post
Hematocrit (%)	R	42.2 ± 1.0	41.8 ± 1.5	42.0 ±1.3	42.3 ± 2.0
	E	45.3 ± 0.9 ^	45.6 ± 1.4 ^	45.0 ± 1.3 ^	45.2 ± 2.0 ^
Haemoglobin (g/dl)	R	14.7 ± 0.4*	14.9 ± 0.7*	15.2 ± 0.6	14.2 ± 1.2
	E	15.6 ± 0.3*^	16.9 ± 0.7* ^ ^{o}	16.2 ± 0.9 ^	15.3 ± 1.3 ^
Lactate (mmol/L)	R	2.30 ± 0.10	2.08 ± 0.40*	2.14 ± 0.11	1.75 ± 0.28 ^{o}
	E	9.3 ± 1.7 ^	10.4 ± 2.4*^	8.4 ± 1.7 ^	8.5 ± 2.7 a
NH_3 (µg/dl)	R	59.8 ± 25.8	58.9 ± 29.7	62.6 ± 21.6	56.9 ± 54.0
	E	131.5 ± 41.3 ^	135.0 ± 67.2*^	105.2 ± 35.0 ^	99.4 ± 64.2 ^
Glucose (mg/dl)	R	86.8 ± 9.6*	83.1 ± 9.7	100.4 ± 17.4	88.2 ± 12.9
	E	110.5 ± 19.6 ^	129.5 ± 20.7 ^ ^{o}	115.7 ± 17.0 ^	116.5 ± 21.1 ^
Creatine kinase (U/L)	R	309.2 ± 181.8	162.1 ± 62.6*	238.3 ± 97.7	225.9 ± 71.2
	E	349.9 ± 190.6	155.6 ± 57.7*^{o}	268.5 ± 117.6 ^	241.9 ± 78.0
Lactate dehydro-genase (U/L)	R	263.2± 35.0*	226.3 ± 46.5	229.5 ± 27.0	248.9 ± 34.7
	E	290.4 ± 54.7*	272.1 ± 78.0 ^	244.5 ± 29.5	279.9 ± 29.8 ^

Legend: R – Resting (pre-exercise) values; E – Post-exercise values; ^ Significantly ($p<0.05$) different from the resting value (by Bonferroni's test); ^{o} Significantly ($p<0.05$) different from the respective 'Pre' value; * Significantly ($p<0.05$) different than in League IV football players (by U-test)

Mean values of most aerobic capacity variables were in both groups of players alike but maximum running speed and peak lactate concentration were significantly ($p<0.05$) lower in League IV players than in the League I ones. The training brought about significant ($p<0.05$) improvements in maximum and threshold running velocities but only in League I players (Table 3).

Table 4 presents haematological and biochemical data recorded before and after the graded running test, the post-test values being corrected for changes in plasma volume. The exercise induced significant ($p<0.05$) changes in lactate, glucose and ammonia concentrations, and in LDH activities, in both groups of players and on in both examinations (pre- and post-training period). Creatine kinase activities increased significantly ($p<0.05$) only in League IV players in the 'Pre' situation. Elevated levels of CK, exceeding the respective upper normal limit (195 U/L) were noted in most players before the exercise test.

Table 5. Mean values (±SD) of velocities recorded in the sprint test by football players at the end (Post) of the pre-season preparation period for the spring round

Distance (m)	League I (n = 19)	League IV (n = 15)
5 (0 – 5 m)	4.70 ± 0.16*	4.54 ± 0.26
20 (0 – 20 m)	6.57 ± 0.15 [1]	6.43 ± 0.26
30 (0 – 30 m)	7.10 ± 0.16 [2]	6.97 ± 0.25
15 (5 – 20 m)	7.58 ± 0.18	7.48 ± 0.24
10 (20 – 30 m)	8.46 ± 0.25	8.40 ± 0.32

Different from League IV football players (by *t*-test): * ($p<0.05$); [1] $p<0.06$; [2] $p<0.08$

Mean velocities attained in the 30-m sprint test were alike in both groups of players (Table 5). League I players were superior to the League IV ones only in the first 5-m distance ($p<0.05$) and tended to be superior at 20 m and full distance ($p<0.06 – 0.08$).

Discussion

Over 90% of energy expenditure during a football match is derived from aerobic processes, whose efficiency depends, to a high degree, on the aerobic capacity of players [1,20,26] expressed as $\dot{V}O_2max$. That latter, in turn, depends on the transport of oxygen into the mitochondria and its utilisation there, i.e. on factors like cardiac output, lung ventilation, haemoglobin concentration, muscle capillarisation, number of mitochondria and activities of mitochondrial enzymes [24]. Cardiac output is considered the principal factor in a dynamic work performed by large muscle groups, like in football [15,30,33]. Interval training of an intensity equal to 90 – 95% $\dot{V}O_2max$ was shown to be most effective in increasing cardiac output [15,32]. High $\dot{V}O_2max$ enhances the post-exercise recovery and the utilisation of fat depot as an energy source thus saving muscle glycogen stores [3,7,23]. Football players having high $\dot{V}O_2max$ are capable of running longer distances during a match and of performing more sprints than those with low $\dot{V}O_2max$ [9,15,18]. Highest levels of $\dot{V}O_2max$ may be attained by football players just after the pre-season preparation period [16] or only in the last phase of the peak season [8].

In this study, $\dot{V}O_2max$ did not exceed 55 ml/kg/min (or 162 ml/kg$^{0.75}$/min) in most players and only in 3 of them from League I and in 2 from League IV exceeded 60 ml/kg/min (171.6 ml/kg$^{0.75}$/min). This is much less than reported for Norwegian League I players (63.7 ml/kg/min or 188.6 ml/kg$^{0.75}$/min [33], or 67.8 ml/kg/min or 200.4 ml/kg$^{0.75}$/min [18]).

Another measure of aerobic capacity is the load at the lactate threshold (LT); it has been often employed and considered superior to $\dot{V}O_2max$ [25]. Well conducted endurance training may be expected to improve LT and, in result, the players would attain higher speed at lower acidification [22]. Average relative LT values reported for world elite players ranged from 80 to 90% HR_{max} or from 82 to 88% $\dot{V}O_2max$ [9,15,25,33]. None of our players attained that high level of LT which in most of them did not exceed 70% $\dot{V}O_2max$ and was not significantly improved by the training. This is in accordance with reports that LT increases parallel to increasing $\dot{V}O_2max$ [15,25]. Running velocity at LT, averaging in all our players 11.6 – 12.1 km/h, was also lower than reported by other authors (over 13.5 km/h [8,15]). The training significantly improved the velocity at LT only in League I players.

It was reported [15,22,32] that a significant improvement in the $\dot{V}O_2max$ may be attained by applying interval training of high intensity (above 90% HR_{max}), the strongest stimulus for increasing maximal cardiac output. The observed lack of progress in the aerobic capacity expressed as $\dot{V}O_2max$ and threshold velocity could thus suggest that the training loads in the preparatory period were too low in relation to the work potential of players.

World elite football players undertake 150 – 250 short sprints every 4 – 6 s during a match [30]. Those highly intense anaerobic exertions result in accumulation of lactate in blood and in muscles [23]. Thus, football training is supposed to shape a high resistance to exercise-induced acidosis, i.e. to a faster metabolism of lactate [29]. The responses to the graded treadmill test were typical – increased concentrations of lactate, glucose (liberated from liver stores [5]) and ammonia, the latter generated probably in the augmented amino acid catabolism [28] and purine deamination [17,31]. The significant, training-induced increases in lactate and ammonia concentrations noted in League I players were suggestive of a more efficient training, which was supported by a higher maxi-mal velocity attained in the treadmill

test, as compared with their League IV mates. Similar results were reported by Krustrup *et al*. [23] who observed match-induced increases in lactate (over 5-fold), glucose (by over 20%) and ammonia (nearly 4-fold) concentrations in plasma, the latter being shown to result from an increased AMP deamination.

In addition to the changes discussed above, muscle work may induce mechanical microlesions of muscle cell membranes and peroxidative lesions of membrane lipids, due to increased oxygen utilisation, resulting in a leakage of intracellular enzymes into the blood stream [6]. Increased activities of creatine kinase and lactate dehydrogenase are typical of athletes, not only post-exercise but at rest as well [21] and this was observed in our players also.

According to recent studies, over 95% of all sprints performed in course of a match are at distances shorter than 30 m [29], and about 50% do not exceed 10 m [15]. The numbers of sprints performed by world elite players range from over 10 to several tens, every 40 – 60 s on average [29]. Shaping the speed abilities in football players is thus of great importance although difficult to attain in adults; moreover, that ability is strongly dependent on genetic factors [3].

Among the tests used to assess speed abilities in football players is the 30-m sprint with recording lap times [12]. League I players proved superior to their League IV mates – significantly at the first 5 m and nearly significantly at the full distance, the overall difference amounting to 0.19 m/s. This means that when running for ball at a 5-m distance, run in 1 s, the League I players would gain advantage of 20 cm over the League IV players. It should be emphasised that in the post-training test only 4 League I players and 3 League IV players finished the test at a velocity exceeding 20 km/h and only in one League I player lung ventilation exceeded 180 L/min which ranked him in the world elite [16]. Moreover, the players studied by us attained markedly lower velocities at the 30-m distance (7.10 ± 0.16 and 6.97 ± 0.25 m/s – Leagues I and IV, respectively) than players from the Brazilian League (7.68 ± 0.28 m/s) [11].

Cometti *et al*. [12] studied French football players and noted that the velocity at the first 5 m of sprints could be used to classify players as high or medium class. Our players could not meet those classification criteria, at least in that training period. In conclusion, the negligible differences observed between football players from Leagues I and IV in their aerobic capacity and speed abilities, and the marked distance from world elite players in those indices, call for substantial changes in pre-season preparation programmes which would then enable appropriate shaping of their fitness in that respect.

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