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PRESEASON AEROBIC PHYSIOLOGICAL CHARACTERISTICS IN BOSNIA AND HERZEGOVINA PROFESSIONAL FOOTBALL PLAYERS

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Abstract
Aim of the study was to investigate and quantify initial pre-season aerobic physiological characteristics (VO2max and AT) in Bosnia and Herzegovina professional football players. Additionally, the authors examined differences in aerobic characteristic by playing positions. Sample of 39 male football players (23.5 ± 4.6 yrs, 182.0 ± 5.6 cm, 77.8 ± 5.8 kg) playing for two best teams in BiH Premier league were subject to maximal incremental treadmill run on two separate occasions. No changes were observed for VO2max in players. Relative oxygen uptake at anaerobic threshold was lower in forwards compared to wide midfielders by 6.8 ml/kg/min ($p = 0.033$) Running velocity at anaerobic threshold was lower in CM in comparison to WM by 1.6 km/h ($p = 0.037$). Central defenders were higher compared to WB for 8 cm ($p = 0.020$) CM for 6.4 cm ($p = 0.042$), WM for 9.3 cm ($p = 0.014$) and F for 6.5 cm ($p = 0.056$). Central defenders' weight was significantly higher compared to WB for 7 kg ($p = 0.053$).
Study provides aerobic power characteristics before preseason in football players and differentiation by playing positions. The findings from relatively low number of subjects indicate that BiH professional players have low VO2max compared to the elite standards which is insufficient to perform at professional level. Study reveled that differences among playing positions in aerobic capacity do not exist, with central midfielder being inferior to other players. Coaches can use results to create training programs to meet football specifics in terms of aerobic physiological demands.

Key words: **soccer, VO2max, anaerobic threshold, body composition, BiH**

Introduction

Football is a competitive game and most popular sport in the world both as recreational activity and as professional competition. It is estimated that in 2009 there were roughly about 65000 professional football players in the world. Beside its popularity, football has become one of the research fields in sports science with remarkable number of topics related to physical activity during game and its relation to physiological capacities in players (Sporis, Jukic, Ostojic, & Milanovic, 2009).
Football is physically demanding sport and beside technical and tactical aspect it requires speed, precision, agility and stamina (Al'Hazzaa, Almuzaini, Al-Refaee, & Sulaiman, 2001). Aerobic power in football seems to be very important for overall performance (Castagna, Chamari, Stolen, & Wisloff, 2005; Tønnessen, Hem, Leirstein, Haugen, & Seiler, 2013). Maximal oxygen uptake (VO_2max) is an valid estimate of the aerobic capacity and in footballers it ranges between 50 and 75 ml/kg/min^{-1} (Al'Hazzaa et al., 2001; Castagna et al., 2005; Tønnessen et al., 2013). Some authors claim that VO_2max threshold of >60 ml/kg/min^{-1} is physiological essence to become elite professional player (Reilly, Bangsbo, & Franks, 2000). Maximal aerobic capacity is related to total running distance of 10-12 km in a game (Stølen, Chamari, Castagna, & Wisløff, 2005) as well for fast recovery after high intensity runs, sprints and duels (Aziz, Chia, & Teh, 2000). Anaerobic threshold (AT) is a term used to describe point of workload (O_2 uptake point) from which above the acidosis occurs in a body and it is correlated to performance and used as aerobic fitness level indicator (Sporis et al., 2009). Anaerobic threshold ranges from 76% and 90% of maximal heart rate, which is in the range of HR during game (Stølen et al., 2005). Midfield players tend to have higher relative aerobic capacity and to cover more distances compared to other playing positions.

It is evident that in last decade several papers reported (Al'Hazzaa et al., 2001; Davis, Brewer, & Atkin, 1992; Sporis et al., 2009; Stølen et al., 2005; Tønnessen et al., 2013) large number of data about aerobic and anaerobic characteristics in football players. Specifics about VO_2max is that it can vary day – to – day and it is different deepening from period of the competition in a year. Some authors found that maximal aerobic power appears at the end of season (Casajús, 2001) while most common opinion is that highest aerobic capacity players have at the end of pre – season period (Magal, Smith, Dyer, & Hoffman, 2009). As known last study that investigated initial pre-season characteristics of aerobic capacities in football players was performed in 1992 by Davis et al.

Bosnia and Herzegovina Premier football league is specific since there is a 30 day off period prior to the beginning of the pre-season. This can decrease gross and specific abilities and can cause decay of aerobic and anaerobic capacities. So far there were no published studies that reported physical demands, physical activity and performance level including aerobic physiological characteristics in players of BiH.

Thus, the aim of this study was to quantify aerobic characteristics of VO_2max, anaerobic threshold and body composition in male professional football players in Bosnia and Herzegovina elite league. Additionally, we also examined possible differences in aerobic characteristics by playing position.

Methods

Subjects

Thirty-nine healthy professional men football players aged 23.5 (SD 4.6) years with a body mass, body mass index, fat percentage and muscle percentage of 77.8 (SD 5.8) kg, 23.5 (SD 1.3) kg/m^2, 10.3 (SD 3.2) % and 45.3 (SD 2.8) %, were subjected to testing procedures. Participants were football players in Premier league of Bosnia and Herzegovina, playing for two best clubs in BiH with average playing experience of 3.7 (SD 1.8) years in Premier league. Prior to testing, all subjects were medically examined and signed written contest which guarantied possibility to forfeit at any time during study. Sample was sub grouped according to the playing position in team featuring central defenders (CD, n = 4), wide backs (WB, n = 8), central midfielders (CM, n = 14), wide midfielders (WM, n = 5) and forwards (F, n = 8). The study was approved by the ethical committee of Faculty of Sport and Physical Education, University of Sarajevo.

Measuring and test procedures

Morphologic characteristics were measured followed by the VO_2max (CT) test. This ensured valid and reliable data which could be compared to many normative parameters presented in scientific databases. Most specific information about fitness status in football (soccer) players are those related to aerobic power capacities and body composition. Measurements were performed at two separate occasions: first day of the precompetitive (preparation) period in January of 2016/2017 season and second day of the precompetitive (preparation) period in January of 2018/2019. Prior to the testing, players had period without training for almost of 30 days due to specifics of competition in BiH football league.

Anthropometry and body composition

Body height was determined for each subject with the help of Holton Anthropometer. Subjects were barefoot and height was measured at end of a normal expiration. Weight and body composition was estimated using leg – to – leg BIA Tanita (BC420SMA scale; Tanita Corp, Tokyo, Japan) (Ritchie, Miller, & Smiciklas-Wright, 2005). Tanita uses principles of electrical impedance (Jebb, Cole, Doman, Murgatroyd, & Prentice, 2000) and it is accurate in measuring up to the $\pm$0.1 kg. Body composition analysis was performed in the morning after at least 4 hours without consumption food and beverages before testing and no caffeine or alcohol consumption within 12 hours of test. Subjects were standing erect with bare feet on the analyzer footpads and only wore shorts without any jewelry or metal on their body. Body mass index was calculated using formula weight (kg)/(height (m))^2. Percentages of body fat and muscle mass was estimated using the Tanita's specific calculation using height, weight, and age specifics.

Continuous running incremental test

Subjects were familiarized with all test procedures before study started. To determine aerobic power, HR load and running velocity performance players performed continuous running test (CT) was performed on motor driven treadmill (Cosmed, Rome, Italy) at slope angle of 1.5 °. Testing procedure was performed as suggested by modified Taylor (1955) protocol in laboratory conditions. Maximal oxygen uptake (VO_2max), ventilation and HR were determined by pulmonary gas exchange measurements (K4b2, Cosmed, Rome, Italy) with HR strap monitor (Polar Team System, Polar Electro Oy). After at least 12 min of warm-up, the subjects carried out an incremental test to exhaustion, consisting of initial stage of subject monitoring at speed of 3 km/h for 3 min. Treadmill velocity was than increased to 7 km/h followed by automated speed increase of 1 km/h each minute. Individual values, VO_2max and pulmonary ventilation were averaged for 5s, respectively. Highest VO_2 consumption presented as average of 4 intervals of 5s was defined as the maximal oxygen uptake (VO_2max). Heart rate at VO_2max was used as maximal heart rate. End running velocity reached at VO_2max presented tests end speed (Vmax). Anaerobic threshold (AT) was determined from the slopes of the CO_2 uptake (VCO_2) vs. O2 uptake (VO_2) plot. Anaerobic threshold refers as a point which detects the beginning of the excess CO_2 output generated from the buffering of [H^+], termed the V-slope method (Beaver, Wasserman, & Whipp, 1986). Oxygen uptake at point of anaerobic threshold was noted as VO_2 consumption at AT. Heart rate and running velocity at AT reflection point was noted as heart rate at AT and running velocity at AT. Percentage of VO_2max at AT was calculated using formula: (VO_2 consumption at AT/ VO_2max) *100. To ensure maximal effort when tested subjects had to fulfil individual pre-setup parameters: Maximal heart rate within 5% of the maximal predicted HR (220-age), respira-

tory exchange ratio above 1.15, VE/VO_2 below 30 and blood lactate concentration above 8mmol/l. Gas analyzer was calibrated prior to each test (Duffield et al., 2004).

Statistical analysis

Statistical software SPSS (23.0 IBM Corp., New York) was used for data processing. Normality of the data distribution was inspected using Shapiro – Wilks test. One-way analysis of variance (ANOVA) was used to detect significant differences between results, while least significance (LSD) test detected differences between groups by playing positions (CD, WB, CM, WM and F). All data are presented as mean ± standard deviation. Results are presented in tables and figures. Statistical significance was set to convectional 95% ($p<0.05$).

Results

Height, age and body composition

Table 1 shows that Central defenders were 8 cm higher compared to WB ($p = 0.020$; 95% CI (1.3; 14.7)), 6.4 cm to CM ($p = 0.042$; 95% CI (0.3; 12.6)), 9.3 cm to WM ($p = 0.014$; 95% CI (2.0; 16.6)) for 6.5 cm to F ($p = 0.056$; 95% CI (-0.2;13.2)). Central defenders' weight was significantly higher compared to WB for 7 kg ($p = 0.053$; 95% CI (-0.1; 14.1)) and CM ($p = 0.030$; 95% CI (0.8; 13.9)). No significant differences between positions were observed for age, percentage of both fat and muscle mass, and body mass index.

Physiological aerobic characteristics and treadmill test results

Relative oxygen uptake at anaerobic threshold was lower in forwards compared to the wide midfield players by 6.8 ml/kg/min ($p = 0.033$; 95% CI (-12.9; -0.6)) (figure 1). Running velocity at anaerobic threshold was lower in CM in comparison to WM by 1.6 km/h ($p = 0.037$; 95% CI (-3.1; 0.1)) (figure 2). Nonsignificant differences between playing positions were observed for absolute VO_2max, relative VO_2max, absolute VO_2 at AT, percentage of VO_2max at AT, heart rate at AT, maximal heart rate and VAT.

Table 1 Age, height, body composition, oxygen consumption, heart rate load and running velocities during maximal aerobic test in Bosnia and Herzegovina Premier football league players with sub comparisons for different playing positions.

	Overall (n = 39)	CD (n = 4)	WB (n = 8)	CM (n = 14)	WM (n = 5)	F (n = 8)
Age (years)	23.5 ± 4.6	22.3 ± 3.4	24.9 ± 4.4	22.1 ± 5.0	24.4 ± 3.0	24.6 ± 5.8
Height (cm)	182.0 ± 5.6	188.5 ± 5.7	180.5 ± 4.7 [b]	182.1 ± 5.3 [b]	179.2 ± 7.6 [b]	182.0 ± 4.2 [b]
Weight (kg)	77.8 ± 5.8	83.8 ± 7.9	76.8 ± 1.8 [b]	76.4 ± 5.3 [b]	78.2 ± 7.9	77.9 ±6 .4
Fat mass (%)	10.3 ± 3.2	9.9 ± 2.7	9.8 ± 3.3	9.9 ± 3.5	10.1 ± 2.5	12.0 ± 3.6
Muscle mass (%)	45.3 ± 2.8	44.8 ± 1.8	46.1 ± 2.0	45.7 ± 2.6	45.5 ± 0.2	44.3 ± 4.1
BMI (kg/m^2)	23.5 ± 1.3	23.5 ± 0.9	23.6 ± 1.0	23.0 ± 1.0	24.3 ± 1.0	23.5 ± 1.9
Absolute VO_2max (ml/min)	3906 ± 376	4122 ± 479	3925 ± 244	3750 ± 337	4095 ± 501	3931 ± 388
Relative VO_2max (ml/kg/min)	50.3 ± 4.2	51.5 ± 4.1	51.1 ± 3.3	49.4 ± 4.9	52.5 ± 2.3	49.2 ± 4.9
Absolute VO_2 consumption at AT (ml/min)	3526 ± 493	3820 ± 740	3577 ± 356	3347 ± 342	3828 ± 646	3449 ± 561
Relative VO_2 consumption at AT (ml/kg/min)	45.0 ± 5.5	47.4 ± 5.9	46.0 ± 4.0	44.1 ± 4.6	48.9 ± 5.6	42.2 ± 7.1 [a]
Percentage of VO_2max at AT (%)	88.5 ± 7.1	91.8 ± 7.0	88.3 ± 6.4	87.9 ± 5.9	93.0 ± 7.0	85.4 ± 9.0
Maximal heart rate (beats/min)	186 ± 8.0	193 ± 14.0	187 ± 5.0	184 ± 8.6	183 ± 7.3	185 ± 7.0
Heart rate at AT (beats/min)	174.0 ± 9.0	181 ± 9.0	175 ± 8.0	173 ± 9.0	174 ± 13.9	172 ± 6.0
Running velocity at AT (VAT) (km/h)	14.3 ± 1.5	15.3 ± 1.3	14.4 ± 1.0	13.8 ± 1.3 [a]	15.4 ± 1.1	14.1 ± 2.1
Running velocity at VO_2max (Vmax) (km/h)	17.3 ± 1.0	17.8 ± 0.5	17.4 ± 0.9	16.8 ± 1.1	17.4 ± 0.5	17.6 ± 1.2

Values are presented in mean ± SD.
CD - Central defender; WB - Wide back; CM - Central midfield; WM - Wide midfield; F – Forward; VO2max – maximal oxygen consumption; AT – anaerobic threshold
[a] Significantly lower ($p<0.05$) compared to Wide midfield players [b] Significantly lower ($p<0.05$) compared to Central defender players

Figure 1 Relative VO_2 maximal uptake and VO_2 at anaerobic threshold for central defenders (CD, n = 4), wide backs (WB, n = 8), central midfield (CM, n = 14), wide midfield (WM, n = 5) and forwards (F, n = 8) obtained from treadmill running test.

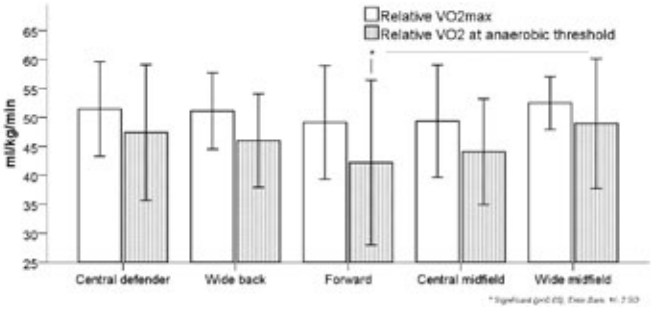
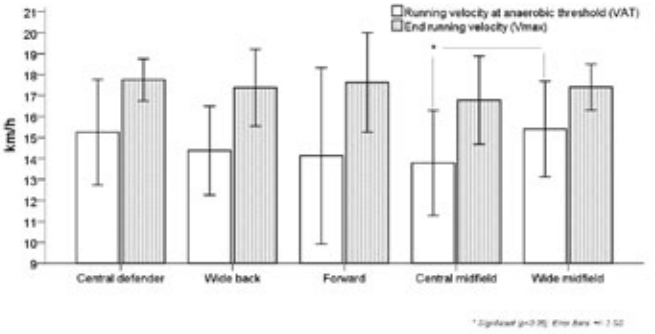


Figure 2 Running velocities at anaerobic threshold (VAT) and at maximal oxygen uptake (Vmax) for central defenders (CD, n = 4), wide backs (WB, n = 8), central midfield (CM, n = 14), wide midfield (WM, n = 5) and forwards (F, n = 8) obtained from treadmill running test.



Discussion

Aim of the present study was to quantify aerobic and body composition characteristics in professional football players of Bosnia and Herzegovina and to evaluate possible differences by playing position. Sample of 39 players from two best teams in the elite league was subjected to maximal treadmill run in laboratory conditions prior to the beginning of pre-season and outcome measures were measured using gas analyzer and BIA scale. Aerobic capacities in BiH players are much lower (mean = 50.3 ml/kg/min) compared to other leagues. Poorest relative O_2 uptake at anaerobic threshold was in forwards and tended to be significantly lower compared to the wide midfield players. Also, surprising was that central midfield players had lowest O_2 uptake and running velocity at anaerobic threshold.

Before summarizing the results, it is important to highlight two key aspects that affected the results. Firstly, heterogeneity of the results and players is obvious, and it can be related to the previous playing experience in quality leagues and mix arising from variety of geographical areas and players nationalities. Secondly, and more importantly is the fact that testing was performed before preparation period in winter time. Players had off season period lasting approximately 30 days, intercepted by some moderate physical activity. This is very specific for BiH elite league and it can negatively affect players abilities. Goalkeepers were not included in the study.

On average BiH players with 23.5 ± 4.6 years were younger compared to the results presented in other studies (Al'Hazzaa et al., 2001; Aziz et al., 2000; Castagna et al., 2005; Sporis et al., 2009; Stølen et al., 2005; Tønnessen et al., 2013). Central defenders were significantly taller compared to other players and had highest body weight (<6 kg) significantly different to wide backs and central midfielders. This may be result of specific requirements of the playing position which generally demands more strength than extensive aerobic expenditure. Defenders cover distances lower than 10 km during a match and perform lower number of sprints compared to the other playing positions, so this may be one of the reasons for having higher body weight. In present study central defenders were 22 years of age which is different to the findings given by Sporiš et. al. (2009) in Croatia players. This remains relatively unclear since the defender's position is related to playing experience. Body fat is in range to the results of players from Croatia, Norway and England (Davis et al., 1992; Sporis et al., 2009; Tønnessen et al., 2013) with no differences between playing positions.

Present study demonstrates that maximal aerobic capacity distinguishes players in BiH elite league to standards of the elite players (Al'Hazzaa et al., 2001; Beaver et al., 1986; Castagna et al., 2005; Stølen et al., 2005; Tønnessen et al., 2013). Average VO_2max ranged from 49 - 52 ml/kg/min. between playing positions and it is lower than those observed in previously published papers (Castagna et al., 2005; Stølen et al., 2005; Tønnessen et al., 2013). Main cause for such low value was that players refrain from severe physical activity for almost a full month. High intensity activates with HR load >95% (such as football training and game) can help improving and maintaining aerobic capacities. Aerobic power can decrease suddenly in 2-week period adds the fact why are the results in present study were bellow any professional standard. Impact of season phase on VO_2max may be explained by varying fitness programs which have not manage to maintain adequate aerobic abilities in off season.

Nonsignificant differences between playing positions for VO_2max were observed, with central midfielders' tendency to have lowest maximal aerobic capacity as observed in Iceland players in study by Arnason et al. (2004). Maximal oxygen uptake value was not in accordance to the previously published results (Bangsbo, 1994; Reilly et al., 2000; Tønnessen et al., 2013). The demands for high running distances above 12 km, specifics of intermittent activity during a game and high relation to aerobic capacities make midfielders players with highest VO_2max which was not case in BiH players. More specifically, central midfield players were inferior to wide midfield players when it comes to running velocity at anaerobic threshold for around 1.6 km/h. This suggests that acidosis occurs earlier in central midfield players, and that their capacity is not adequate for professional competition. Such result could be related to

the playing style, since traditionally in BiH CM are technically the best players and only task was to distribute ball on the side of pitch for WM.

Study demonstrates that aerobic characteristics in BiH football players are on the lower boundary found in professional players and that heterogeneity between players and playing position is low. Study findings can help in creating directions for fitness coaches to create suitable training program respecting the differences and demands for different playing positions.

Study limitation is relatively low number of participants and the fact that goalkeepers were excluded from study. Future studies should investigate VO_2max changes during season and to compare the differences at the end of the season and at the beginning of the preparation period.

Conclusion

Football is a complex game with variety of physical demands on players. Aerobic power is one of the aspects for maximal performance in a game but cannot explain the success by its own. Success on the top level depends not just on individual players abilities rather than combining them in a team. Study revealed that physical aerobic capacity in BiH players remains one of the breaking points for further development of league. Maximizing training sessions in order to benefit on physical preparedness should be focus in the future. Training should be differenced by requirements for different playing styles.

References

Al'Hazzaa, H., Almuzaini, K., Al-Refaee, S., & Sulaiman, M. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness, 41*(1), 54.

Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., & Bahr, R. (2004). Physical fitness, injuries, and team performance in soccer. *Medicine & Science in Sports & Exercise, 36*(2), 278-285.

Aziz, A., Chia, M., & Teh, K. (2000). The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *Journal of Sports Medicine and Physical Fitness, 40*(3), 195.

Bangsbo, J. (1994). The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica. Supplementum, 619*, 1-155.

Beaver, W. L., Wasserman, K., & Whipp, B. J. (1986). A new method for detecting anaerobic threshold by gas exchange. *Journal of applied physiology, 60*(6), 2020-2027.

Casajús, J. A. (2001). Seasonal variation in fitness variables in professional soccer players. *Journal of Sports Medicine and Physical Fitness, 41*(4), 463-469.

Castagna, C., Chamari, K., Stolen, T., & Wisloff, U. (2005). Physiology of soccer, An Update. *Sports med, 35*(6), 501-536.

Davis, J., Brewer, J., & Atkin, D. (1992). Pre-season physiological characteristics of English first and second division soccer players. *Journal of Sports Sciences, 10*(6), 541-547.

Jebb, S. A., Cole, T. J., Doman, D., Murgatroyd, P. R., & Prentice, A. M. (2000). Evaluation of the novel Tanita body-fat analyser to measure body composition by comparison with a four-compartment model. *British Journal of Nutrition, 83*(2), 115-122.

Magal, M., Smith, R. T., Dyer, J. J., & Hoffman, J. R. (2009). Seasonal variation in physical performance–related variables in male NCAA division III soccer players. *The Journal of Strength & Conditioning Research, 23*(9), 2555-2559.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences, 18*(9), 669-683.

Ritchie, J. D., Miller, C. K., & Smiciklas-Wright, H. (2005). Tanita foot-to-foot bioelectrical impedance analysis system validated in older adults. *Journal of the American Dietetic Association, 105*(10), 1617-1619.

Sporis, G., Jukic, I., Ostojic, S. M., & Milanovic, D. (2009). Fitness profiling in soccer: physical and physiologic characteristics of elite players. *The Journal of Strength & Conditioning Research, 23*(7), 1947-1953.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer. *Sports Medicine, 35*(6), 501-536.

Tønnessen, E., Hem, E., Leirstein, S., Haugen, T., & Seiler, S. (2013). Maximal aerobic power characteristics of male professional soccer players, 1989–2012. *International journal of sports physiology and performance, 8*(3), 323-329.

Taylor, H. L., Buskirk, E., and Henschel, A. (1955). Maximal oxygen intake as an objective measure of cardio-respiratory performance. J. Appl. Physiol. 8, 73–80.

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