DISTANCES COVERED ABOVE AND BELOW THE ANAEROBIC THRESHOLD BY PROFESSIONAL FOOTBALL PLAYERS IN DIFFERENT COMPETITIVE CONDITIONS

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Abstract. In modern endurance training information about an athlete's performance below and above the anaerobic threshold is crucial. The aim of the present study was a comparative analysis of the total distance covered by football players in two rounds of the 2013/1014 playing season. Furthermore, the study also assessed the performance of elite Bundesliga players during competitive matches, above and below the running speed of 4 $m \cdot s^{-1}$, corresponding to the level of anaerobic threshold (AT). The players' mean body height was 183.00 ±6.44 cm, body mass 78.19 ±7.42 kg, and mean age was 27.99 ±3.47 years. The analysis was carried using the Impire AG motion analysis system on the basis of official match reports from the Deutscher Fußball-Bund (DFB). The study revealed that the total distance covered by the players in match-play was significantly shorter in the second round of the playing season. The distance covered by the players below the AT is significantly shorter in the spring round than in the autumn round, while the distance covered above the AT shows a reverse, although non-significant tendency. In the spring round the volume of players' work performed above the anaerobic threshold is greater than the volume of exercise performed below the AT.

Key words: football, autumn round, spring round, covered distance, anaerobic threshold, Bundesliga

Introduction

Association football is the most popular sport in the world. Football dynamics and popularity have given rise to numerous research studies into motor skills of football players (Meylan and Malatesta 2009; Mujica et al. 2009; Requena et al. 2009). Present-day training of elite football players requires coaching staffs to know and use

state-of-the-art match analysis technology in their practice. One of the football coach's key tasks is the proper selection and implementation of individualized loads for players' motor training. This individualization allows for optimal use of players' technical-tactical skills in the conditions of incremental fatigue (Rampinini et al. 2009).

Actions with and without the ball executed by football players during a match are diverse and multidirectional. Bishop and Girard (2013) emphasize that football players are required to perform multiple repetitions of actions with the maximal or nearly maximal intensity (accelerations, frequent changes of running pace and direction, sprints, jumps), interrupted with short rest breaks (standing, jogging or actions with low or moderate intensity). The acyclical character of football actions and the high variability of situations during a match make football players utilize both aerobic and anaerobic energy from different energy sources.

A modern football player should display high levels of endurance, speed, strength and coordination skills. A practical measure of evaluation of players' endurance skills is the length of covered distance during a match. Elite football players cover a total mean distance of 10–12 km at 80–90% of maximum heart rate (Strøyer et al. 2004; Di Salvo et al. 2007). One of the most important indices of players' physical fitness is maximal oxygen uptake. The VO_2max ranges from 58 to 65 ml·kg·min^{-1} in elite players (Helgerud et al. 2001), which permits attainment of a high intensity level of exercise and covering longer distances during a game.

A crucial indicator of players' aerobic fitness is the anaerobic threshold, often referred to in exercise physiology as the 4 mmol·l^{-1} onset of blood lactate accumulation (OBLA). It corresponds to the highest workload intensity level at which a balance is still maintained between lactate production and lactate clearance with no changes in blood pH (Keul et al. 1981). The 4 mmol·l^{-1} OBLA is reached at 55–75% of VO_2max and 75–90% of HRmax.

The anaerobic threshold is most often marked using an analysis of blood lactate concentration during exercise of increasing intensity. The main criteria of threshold exercise intensity include running speed, power, or % VO_2max. In sport, the threshold workload is considered to be a running speed at 4 m·s^{-1}. After exceeding this value a rapid increase in blood lactate can be observed, which leads to an acid-base imbalance, and in consequence, to increasing fatigue. The performance of short, intensive actions by football players in match-play may cause a rise in the blood lactate level up to 14 mmol·l^{-1} (Bishop and Girard 2013).

It has been assumed that after crossing the anaerobic threshold the rate of incremental fatigue has a negative effect on players' psychomotor performance Chmura and Nazar (2010) proved that after crossing the AT (4 mmol·l^{-1}) a player's psychomotor performance can improve for even 10.1% until reaching the psychomotor fatigue threshold. It is after crossing the psychomotor fatigue threshold due to increasing fatigue that players' performance efficiency and analytical and decision-making skills become greatly impaired.

From the practical point of view, changes in players' lactate threshold during the football competitive season constitute an interesting research subject. Radzimiński et al. (2010) revealed that the running speed at the AT was significantly greater at the end of the spring round of the season than at the beginning of the preparatory training period, but it hardly differed in comparison with the beginning of the autumn round. Jastrzębski et al. (2011) noted that at the start of the preparatory training period football players reached lower AT values than after its completion. According to Chmura and Nazar (2010), in the same period, a 6-week training cycle, brought about a shift of the anaerobic threshold toward higher workloads for 6.9%. Moreover, Silva et al. (2007) concluded in their study of Brazilian elite football players that the threshold running speed in a 12-week training cycle increased from 3.7 m·s^{-1} to 4.1 m·s^{-1}.

The aim of the present study was a comparative analysis of the total distance covered by football players in two rounds of the 2013/1014 playing season. Furthermore, the study also assessed the volume of players' performance above and below the running speed of 4 $m \cdot s^{-1}$, corresponding to the anaerobic threshold in elite Bundesliga players during competitive matches.

Methods

All 35 matches of the 2013/2014 playing season were analyzed. The analysis encompassed 480 observations of 41 players (including 13 members of the Germany national team and other national teams) from two top Bundesliga teams. Only players who played the entire length of the match were selected for the study. The players' mean body height was 183.00 ±6.44 cm, body mass 78.19 ±7.42 kg, and mean age 27.99 ±3.47 years. The study was approved by a local ethics committee.

The analysis was carried using the Impire AG motion analysis system (Tiendemann et al. 2011) with records of all movements of players in all the 34 matches. These records were then transformed into quantitative data. The analysis was carried out on the basis of official match reports from the Deutscher Fußball-Bund – DFB.

The study examined the total distance covered by the players in match play, and distances covered below and above the threshold running speed. Following the official Impire AG match reports the threshold running speed was accepted as 4 $m \cdot s^{-1}$ (14.4 $km \cdot h^{-1}$), which in professional literature corresponds to workloads at the anaerobic threshold (Śliwowski et al. 2013). Data from both rounds (spring and autumn) of the competitive season were then compared.

All statistical analyses were conducted with the use of Statistica 10.0. All variables were checked for their conformity with normal distribution. The normality of distribution was evaluated with the Shapiro-Wilk test ($p \leq 0.05$). Arithmetic means and standard deviations were calculated. To compare the mean values of the examined variables a single-factor ANOVA was applied. Fisher's least significant difference (LSD) method was used to verify pairwise differences. To measure correlations between the variables Pearson's correlation was used. In all statistical analyses the levels of statistical significance was set at $p \leq 0.05$, $p \leq 0.01$ or $p \leq 0.001$.

Results

The analysis of the total distance covered by elite Bundesliga players in the 2013/2014 season revealed that in the autumn round the players covered the distance of 11181 ±790 m, and in the spring round the distance of 10997 ±842 m. The differences between these distances were statistically significant ($p \leq 0.01$) (Figure 1).

The mean distance below the AT covered by the studied players was significantly shorter ($p \leq 0.001$) in the spring round matches than in the autumn round matches. The difference was 255 m, i.e. 2550 m for all outfield players on a team (Table 1). The mean distance covered above the AT was 72 m longer in the spring round than in the autumn round. The difference was, however, statistically non-significant (Table 1).

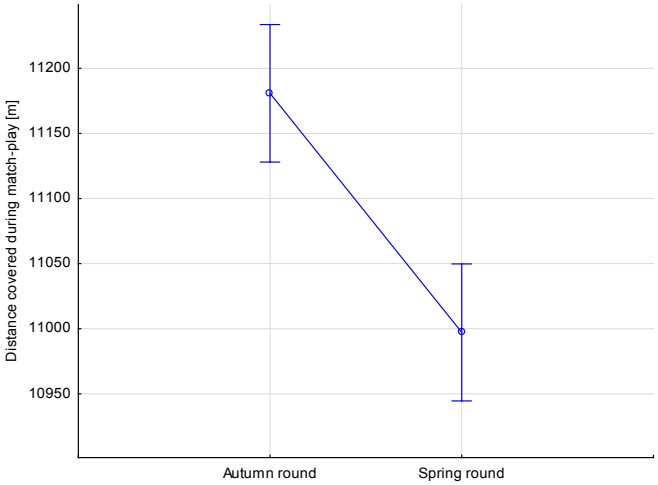

Figure 1. Total distance covered by players during match-play in two different rounds of the playing season

Table 1. Distance covered by elite football players below and above the anaerobic threshold

Round	Autumn	Spring	
Covered distance	x ±SD		p
Below AT [m]	8663 ±510	8408 ±498	0.001***
Above AT [m]	2518 ±537	2590 ±581	0.164

Statistically significant ***(p ≤ 0,001).

In the autumn round matches the distance covered above the AT amounted to 22.5%, and in the spring round to 23.5% of the total covered distance. The correlation coefficient between the total distance covered by players and the volume of the work performed below the AT was r = 0.739 (p ≤ 0.001), while it amounted to r = 0.781 (p ≤ 0.001) above the AT.

Discussion

Data on the amount of physical exercise performed by players below and above the anaerobic threshold is crucial in modern endurance training. The covered distance in match-play reflects players' level of aerobic fitness and anaerobic fitness after crossing the threshold. The results of the present study indicate that elite Bundesliga players covered significantly shorter total distances and distances below the AT in the spring round matches than in the autumn round matches. A different tendency can be observed in the length of covered distance above the AT. In the spring round the examined players performed greater exercise loads above the running speed of 4 $m \cdot s^{-1}$ than in the autumn round.

The studied players covered a significantly shorter distance below the AT in the spring round (8408 ±498 m) than in the autumn round (8663 ±510 m). These results correspond to 76.5% and 77.5% of total distance covered

in match play, respectively. These results confirm the aerobic character of match-play exercise (Gibson et al. 2013; Manzi et al. 2014). The lower amount of work performed below the AT results primarily from the shorter total distance covered in match-play and longer distance above the AT in the spring round. It can also be a result of lower emphasis on aerobic endurance development in players during the pre-competitive training session, and/or the use of use of specific training loads or recovery periods of insufficient length during the competitive season. This might also be related to the high frequency of league and domestic and European cup matches.

In sport training theory and methodology workloads at the AT can be used for aerobic fitness training. Janssen (2001) and Bunc and Psota (2001) show that exercise performed near the AT is most effective for development of aerobic fitness. A practical marker of development of aerobic endurance above threshold HR is the lactate threshold running speed, which ranges from 3.4 to 4.2 $m \cdot s^{-1}$, and in some extreme cases may even reach 4.7 $m \cdot s^{-1}$ (17 $km \cdot h^{-1}$). According to Kindermann et al. (1993) elite football players should be able to reach the threshold running speed at 4 $m \cdot s^{-1}$. Thus this value was accepted in the present study as the threshold value, especially since the mean intensity of match-play exercise in elite players remains near the anaerobic threshold (Stølen et al. 2005).

After crossing the running intensity threshold (4 $m \cdot s^{-1}$) the player's energy metabolism becomes anaerobic in character (Bangsbo et al. 2006; Krustrup et al. 2006). It involves a dynamic rise in lactate accumulation in muscles and, in consequence, increasing fatigue. The length of the covered distance can be indicative of the player's tolerance to increasing fatigue, and on the other hand, of the player's anaerobic endurance. The results of the study show that the distance covered above the threshold in the spring round was longer (72 m) than in the autumn round, which points to an increase in players' anaerobic endurance level. This could be also caused by the reduced level of aerobic endurance, as illustrated by the shorter distance below the anaerobic threshold in the spring round.

Thomassen and Halvari (2007) reveal that playing matches at the intensity level close to the AT is highly significant for sport performance. Thus an analysis of the length of distance covered by the elite Bundesliga players below and above the AT is necessary for setting up a level to be reached by other players. Often excessive motivation may lead to the crossing of the AT and a dramatic drop in fitness and performance effectiveness. However, according to Chmura and Nazar (2010) players' psychomotor performance still increases after crossing the AT until reaching a specific intensity level. This means that despite a considerable acid-base imbalance and increasing fatigue, players' performance efficiency improves until reaching the psychomotor fatigue threshold.

The observed decrease in the total distance length covered in the spring round matches can be a result of increasing fatigue during the season. On the one hand, it may lower the AT and decrease the amount of exercise performed below it, but on the other hand, it may also lead to better adaptation to exercise of high intensity. Studies show that the total distance covered by players in a match is highly correlated with VO_2max (Thomas et al. 2006; Karakoç et al. 2012). This is confirmed by the present study which also revealed a high correlation between the total covered distance and distance below the AT ($r = 0.739$) and above the AT ($r = 0.781$). Kozłowski and Nazar (1999) also point to correlations between players' AT level and ability to perform intense exercise ($r > 0.90$), aerobic performance of skeletal muscles, percentage of slow-twitch muscle fibers and capillary density.

In sport, the threshold running speed is accepted as the upper limit of exercise intensity, at which aerobic performance can still be carried out. To put it simply it can be assumed that a distance covered until reaching the running speed of 4 $m \cdot s^{-1}$ is a measure of players' aerobic endurance. Football coaches regard this measure as an important criterion of assessment of the body's response to specific workloads. A higher AT means that a player can perform with higher intensity without incremental fatigue and that he can also recover more quickly. Kalapotharakos

et al. (2011) and Ziogas et al. (2011) state that the anaerobic threshold is a more sensitive measure of physiological workload that VO_2max. The periodization of sport training and related changes of threshold loads in particular training cycles directly affect the players' level of exercise adaptation.

The discussed characteristics of players' match performance point to the significant role of players' pre-season endurance preparation in modern football. In the preparatory training period before the spring round of the playing season it is recommended that coaches and motor preparation trainers place a particular emphasis on aerobic training to help their players sustain the length of total covered distance in match-play and, in consequence, cover longer distances above the anaerobic threshold. This issue stilly requires further research.

Conclusion

1. The present study revealed that the total distance covered by football players in match-play is significantly lower in the second round of the competitive season.

2. The distance below the anaerobic threshold run by football players is significantly shorter in the spring round than in the autumn round. However, the distance covered above the anaerobic threshold displays a reverse tendency, but the difference is non-significant.

3. During the spring round of the playing season the amount of exercise performed above the anaerobic threshold increases and exercise below the AT decreases.

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Cite this article as: Chmura P., Konefał M., Kowalczuk E., Andrzejewski M., Rokita A., Chmura J. Distances Covered above and below the Anaerobic Threshold by Professional Football Players in Different Competitive Conditions. Central European Journal of Sport Sciences and Medicine. 2015; 10 (2): 25–31.