Original Article

Performance assessment in elite football players: field level test versus spiroergometry

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ABSTRACT

Broich H, Sperlich B, Buitrago S, Mathes S, Mester J. Performance assessment in elite football players: field level test versus spiroergometry. *J. Hum. Sport Exerc.* Vol. 7, No. 1, pp. 287-295, 2012. The purpose of this study was to demonstrate that elite football players with the same anaerobic threshold calculated from the lactate performance curve during a field level test may have substantially different values describing endurance performance capacity determined from spiroergometric laboratory tests. A group of 28 male elite football players underwent a field level test and a spiroergometric laboratory test. A subgroup of players with the same anaerobic threshold was selected, and the endurance performance capacity obtained from spiroergometric measurements during treadmill level tests were compared descriptively within this subgroup. Among the three players with the same anaerobic threshold, test duration for the treadmill level test and consequently also the maximal lactate value achieved during the test varied substantially. The tests were aborted after 5 min at 4.4, 4.8 and 4.0 $m \cdot s^{-1}$ for players 1, 2 and 3, respectively. VO_2-values at V4 were 87 %, 75 % and 96 % of their personal VO_2-peak, respectively. Maximum lactate concentrations were 8.8, 9.2 and 5.3 $mmol \cdot L^{-1}$, respectively. Peak relative VO_2 values were 55.0, 61.6 and 59.7 $ml \cdot min^{-1} \cdot kg^{-1}$, respectively. The result of this study clearly show that conventional field level tests yield insufficient information on underlying physiological and metabolic mechanisms of endurance performance capacity. Taking result of spiroergometric tests into account is critical for designing and evaluating player-specific training programs aimed at optimizing each player's performance. **Key words**: ENDURANCE PERFORMANCE TEST, LACTATE CONCENTRATION, ANAEROBIC THRESHOLD, SOCCER, OXYGEN CONSUMPTION, EXERCISE TEST.

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INTRODUCTION

Excellent endurance performance capacity has long been recognized as important prerequisite for on-field performance of football players (Bangsbo et al., 2006; Ekblom, 1986; Reilly, 1997). For instance, a player's aerobic endurance capacity facilitates performance retention, which is limited by endurance, throughout a 90-120 min-game. In addition, it influences the regeneration capabilities following high-intensity games and training units and the recovery following brief high-intensity exercise spurts during games or training units. Further, well-established anaerobic endurance capacity is important for explosive and maximum execution of such high-intensity game situations (Ekblom, 1986; Reilly, 1997; Reilly et al., 2008).

Because of the importance of players' aerobic and anaerobic endurance capacity, maximizing this capacity is the central element of conditioning training in football players. Performance control and the design of player-specific training regimens aimed at performance optimization rely on diagnostic methods for the assessment of individual player's (sometimes not fully utilized) potentials and capacities. Maximal oxygen consumption (VO_{2max}) and anaerobic threshold are the main parameters used to describe aerobic performance capacity and basic aerobic endurance, respectively (Hoff, 2005; Hoff & Helgerud, 2004; Impellizzeri et al., 2005; Mader et al., 1976). The anaerobic threshold is usually calculated from the lactate performance curve using a field level test, an organizationally, time and financially efficient test for large groups of players. In contrast, determining other relevant measures of endurance performance capacity, such as VO_2, requires complex instrumented laboratory-based tests conducted by trained personnel (Rognmo et al., 2004) and has not been widely implemented by professional German football team. Because of this lack of appropriate methods for performance diagnostics, training programs used by professional German football teams are generally broad and time-consuming.

The lactate performance curve is in part based on the ratio of maximal anaerobic and maximal aerobic capacity (VO_{2max}) (Bangsbo & Mizuno, 1988). Hence, players with different metabolic capacity can have the same lactate performance curve and anaerobic thresholds. In addition, if training programs are based solely on the anaerobic threshold, players with different metabolic capacities might undergo the same training resulting in suboptimal training and consequently suboptimal performance. Further, individuals may react differently to the same training impulses (same resistance, different intensity), and hence performance evaluation solely based on the lactate performance curve may not be sufficiently sensitive to possible shifts and other training-related adaptations.

In contrast to most German professional and national football teams, professional leagues and national teams of other nations routinely use spiroergometric assessments as standard tool for endurance diagnostics despite of higher time-requirements and costs (Arnason et al., 2004; Hoff et al., 2002; Hoff, 2005). Spiroergometric data combined with a laboratory-conducted treadmill level test provides detailed information regarding specific metabolic capacities of the athletes, and additional indirect calorimetric analyses can be used to obtain information on energy expenditure and substrate metabolism (e.g. carbohydrates, fats) at different performance levels (Frayn, 1983). However, to date a direct comparison of parameters describing a football player's performance capacity obtained using the field level test with those obtained using spiroergometry and the treadmill level test is lacking.

The purpose of this study was to demonstrate that elite football players with the same anaerobic threshold calculated from the lactate performance curve during a field level test may have substantially different measures of endurance performance capacity determined from spiroergometric laboratory tests.

MATERIAL AND METHODS

Experimental approach to the problem

In this descriptive study, a group of elite football players underwent a field level test and a spiroergometric laboratory test. From this group, a subgroup of players with the same anaerobic threshold calculated from the lactate performance curve during a field level test were selected. Measures of endurance performance capacity obtained from spiroergometric laboratory tests were compared among players in this subgroup.

Subjects

Twenty-eight professional male football players (age: 22.7±3.8 years; body mass: 79.0±7.2 kg; height: 183.1±7.5 cm) of a team of the top German national league (1st Bundesliga) volunteered for this study after providing written consent. The study was approved by the institutional review board and was conducted in accordance to the Declaration of Helsinki. Each athlete completed an endurance test to determine their endurance capacity as part of a performance diagnostics examination at the beginning of the preparations for the 2008-09 season.

Procedures

The endurance diagnostics assessments were carried out at the beginning of an eight-week preparations period. As part of a newly established expanded performance diagnostics concept, the tests were carried out under standardised laboratory conditions on the treadmill rather than in the field. The level tests followed the specifications by Mader et al. (1976) (initial speed: 2.8 $m \cdot s^{-1}$; level increase: 0.4 $m \cdot s^{-1}$; treadmill incline increment: 1 °; level duration: 5 min; rest between levels: 30 sec), and the anaerobic threshold was derived. During a 30-second break between levels, 20 µL of capillary blood was extracted from the athlete's earlobe, and the lactate concentration was determined. In addition, the players were attached to an aeroplethysmograph (ZAN 600 USB, ZAN Messgeräte GmbH, Oberthulba, Germany) during the entire test, and respiratory parameters were registered breath by breath. Heart rate was also continually recorded throughout the treadmill level test. The players were asked to perform at their maximum effort.

Endurance performance parameters

Data obtained breath by breath with the aeroplethysmograph were used to determine VO_{2max}. A level test with level durations of 5 min does not allow for a direct measurement of VO_{2max} because the generally applied measurement criteria (Australian Sports Commission, 2000) are not met. Although the difference between VO_{2max} and the maximum VO_2 value during a level test in football players may be up to 10 %, the maximum VO_2 value during a level test is a good estimate of a player's maximal aerobic capacity.

Traditionally, the field level test is considered as being a submaximal test with the primary goal to identify the anaerobic threshold, and hence, the athlete should not be pushed until maximum exertion is achieved (Weineck, 1992). In this study, measurements recorded using spiroergometry were monitored to ensure that selected exertion criteria (respiratory exchange ratio (RER) > 1.1; ventilatory equivalent for VO_2 (EQ O_2) > 30; breathing frequency (BF) > 60/sec) were met before aborting the test. The lactate performance curve was determined from measured lactate concentration in the blood samples. The anaerobic threshold was calculated according to Mader et al. (1976) where the anaerobic threshold coincides with the maximal lactate steady state (maxLaSS). According to Mader et al. (1976), maxLaSS corresponds to the velocity at which the lactate concentration levels off at 4 $mmol \cdot L^{-1}$. The following relevant parameters for training control and planning were derived: V4 (in this case maxLaSS); oxygen intake (VO_2) at each load level, at V4 and maximal oxygen intake (VO_{2peak}); heart rate (HR) at the end of each level, at V4 and maximal heart rate (HR_{max}); and maximal lactate concentration. The individual metabolism profiles of football players can then be used to develop player-specific training programmes and guidelines.

Data analysis
To demonstrate differences in individual metabolism profiles between players, three players with the same V4 value were selected from the subject pool. Parameters describing metabolic and physiological capacities of these three players were compared descriptively.

RESULTS

Exemplary case results
Three players (S1, S2, S3) from the subject pool had a V4 value of 3.8 m·s^{-1} (Table 1). In addition, the lactate performance curves for these three subjects were very similar (Figure 1). However, the test duration for the treadmill level test and consequently also the maximal lactate value achieved during the test varied substantially between these three subjects.

Table 1. *Anthropometrical data of the players (S1, S2, S3) as well as performance diagnostic data from the V4 and the maximal values of the level test.*

	Height	Mass	v_4	HR_4	$VO_{2\ rel.\ 3mmol}$	La_{max}	HR_{max}	$VO_{2\ rel.}$
unit	cm	kg	m·s^{-1}	L·min^{-1}	mL·min^{-1}·kg^{-1}	mmol·L^{-1}	L·min^{-1}	mL·min^{-1}·kg^{-1}
S1	182	76.0	3.8	168	47.7	8.8	186	55.0
S2	182	65.0	3.8	168	46.2	9.2	195	61.6
S3	191	84.0	3.8	172	57.5	5.3	173	59.7

v_4=velocity at 4mmol lactate; HR_4=heart rate at 4mmol lactate; $VO_{2\ rel.\ 3mmol}$=relative oxygen consumption at 3mmol lactate; LA=lactate; HR=heart rate, relative; VO2rel=oxygen consumption.

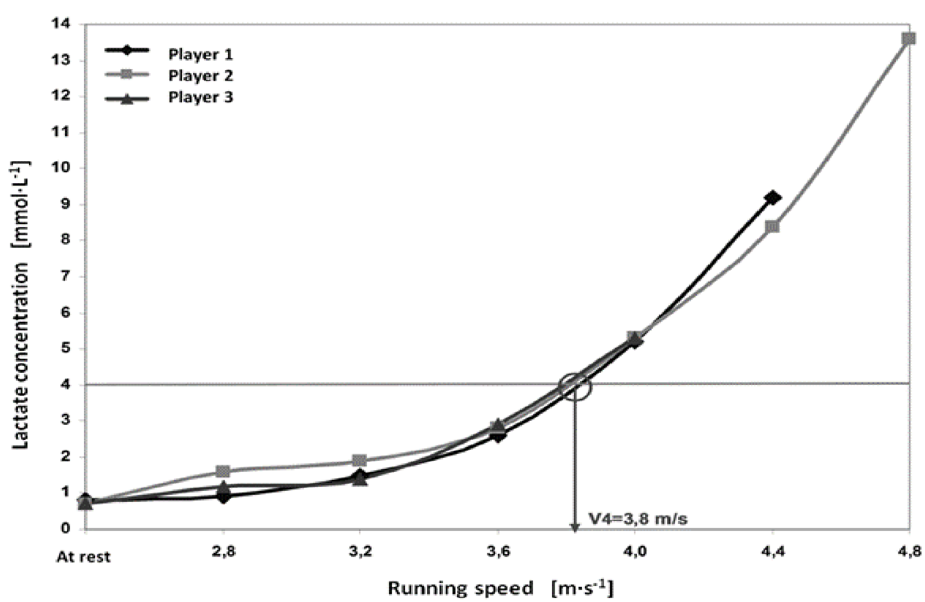

Figure 1. *Lactate concentration for three players in the field level test.*

A more detailed analysis of the data showed that for S1, S2 and S3 their VO_2-values at V4 were 87 %, 75 % and 96 % of their personal VO_{2peak}, respectively. While S3 used a larger portion of his aerobic capacity without lactate build-up than S1 and S2, S3 had to abort the test already after 5 min at 4.0 $m \cdot s^{-1}$. In contrast, S2 reached V4 already at 75 % of his VO_{2peak} but was able to continue the test beyond V4 and aborted the test after 5 min at 4.8 $m \cdot s^{-1}$.

While S2 had a much lower VO_2-value at V4 compared to S3, VO_{2peak} for these two players were very similar (S2: 61.6 $mL \cdot min^{-1} \cdot kg^{-1}$; S3: 59.7 $mL \cdot min^{-1} \cdot kg^{-1}$). However, S2 had a much greater maximal lactate value than S3 (9.2 $mmol \cdot L^{-1}$ versus 5.3 $mmol \cdot L^{-1}$).

S1 completed one additional load level compared to S3 (abortion after 5 min at 4.4 $m \cdot s^{-1}$) but had a lower VO_{2peak} and a lower aerobic exhaustion (VO_2 at V4: 87 % of VO_{2peak}). While S1 had a higher anaerobic capacity than S3 enabling him to longer maintain the specified performance at a load level with the same lactate accumulation. Nevertheless, the performance of S1 was lower than that of S2 (VO_{2peak}: 55.0 $mL \cdot min^{-1} \cdot kg^{-1}$ versus 61.6 $mL \cdot min^{-1} \cdot kg^{-1}$).

DISCUSSION

The purpose of this study was to compare results of performance assessment using the field level test with those obtained using spiroergometry in elite football players. The results of this study showed that spiroergometric measurements provide important metabolic information on an individual's endurance capacity that cannot be captured using standard field level tests. In particular, similar lactate concentration and the same V4 values parameters that are typically obtained in a field level test can result from different combinations of metabolic and physiological capacities. Three players from the subject pool had the same V4 value and similar lactate performance curves but substantially different test durations for the treadmill level test and maximal lactate values achieved during the test. These results indicate that while these three players have the same basic endurance as typically assessed in a field level test, their individual endurance capacity is based on different metabolic patterns.

Individual results obtained in this study suggest that players may utilise their aerobic capacities at different levels. For instance, one subject (e.g. S1) may be able to exhaust a larger portion of his aerobic capacity without lactate build-up corresponding to a better basic endurance but may be able to perform less work, and hence, his total test performance would be sub-optimal. For other players (e.g. S2), their V4 may be a relatively small percentage of their VO_2-peak that may go along with a higher lactic capacity reflecting a different metabolic pattern. These exemplary differences in metabolic patterns underlying endurance capacity cannot be revealed using field level tests. In addition, if endurance training would be designed merely based on V4, then these three players would complete the same program. However, taking into account information on VO_2 and the resulting relationship between aerobic and anaerobic capacities would facilitate the design of player-specific training programs with different training focuses and intensities and presumably optimize each player's endurance performance.

Currently, mainly two methods are used by coaches and scientists for determining training intensity. In the first method, the anaerobic threshold is determined from the lactate performance curve and used as a reference point for determining different training intensity indicated as percentage of the anaerobic threshold (Bangsbo & Mizuno, 1988; Borrie et al., 2002; Ekblom, 1986; Hashimoto & Brooks, 2008). The second method is based on spiroergometric examinations and intensity standards are presented predominantly as fixed percentages of VO_{2max} or maximal heart rate (HF_{max}) (Hoff et al., 2002; Hoff, 2005;

Hoff & Helgerud, 2004). However, Bleicher et al. (1998) previously criticised that performance diagnostics based on the determination of lactate concentration do not provide sufficient information about differences in energy metabolism. The metabolic performance profile of an athlete should undergo a detailed analysis that necessitates spiroergometric measurements during treadmill level lests and the determination of VO_{2max} using a maximal test (Bleicher et al., 1998). In addition, other football-specific studies suggested that spiroergometrically collected VO_{2max}, running economics, anaerobic threshold and anaerobic capacities are determining factors in endurance performance capability (Bangsbo et al., 2006; Bleicher et al., 1998; Hoff et al., 2002).

Blood lactate concentration is widely considered as representation of the balance of lactate production and lactate elimination in musculature, heart and liver (Stallknecht et al., 1998; Stegmann et al., 1981). Findings of recent years broadened the knowledge on lactate in terms of its functions, effects (Gladden, 2004) and kinetics (Gladden, 2008; Juel & Halestrap, 1999a). For instance, lactate is transported between different compartments (muscle - plasma - erythrocytes) or within the same tissue (between muscle fibres) (Juel & Halestrap, 1999b). Hence, training-related changes of the anaerobic threshold may not only result from a change in lactate production but may also reflect upon an increased activity of lactate transport. Consequently, the use of lactate measurements for designing and evaluating training programs should be reconsidered. For instance, lactate is believed to be mainly a product of the anaerobic metabolism where increased concentrations originate from increased build-up of acidity and lead to muscle fatigue (Robergs et al., 2004). While to date it is unclear if lactate accumulation contributes to fatigue, and other factors have been shown to be relevant for muscle fatigue. In addition, lactate acts as fuel for the heart and brain (Chatham, 2002) and for the working muscles and as signal molecule that can stimulate growth and regeneration of biological tissues including vessels and tissue fibres (Philp et al., 2005).

Consequently, high lactate concentrations as observed after high-intensity exercise are not necessarily harmful or primarily responsible for a drop in performance. Recent studies showed that the initial adaptations observed in aerobic systems and performance improvements during a conventional, extensive endurance training can be achieved using high-intensity training (HIT) (Burgomaster et al., 2008; Gibala et al., 2006). A major advantage of HIT is the substantially reduced time-effort of only 10-30 % of that of conventional training programs. The results of these previous studies raise the question of a connection between the specificity of adaptation and specific impulses (Hawley, 2008). However, some studies included only untrained persons (Burgomaster et al., 2008) examined only few parameters describing the aerobic metabolism (Burgomaster et al., 2008; Gibala et al., 2006), and the training interventions investigated lasted only two to eight weeks (Burgomaster et al., 2008; Gibala et al., 2006). To date, scientific evidence on the sustainability of the effects of HIT and on the adaptations over a longer period of time is lacking. Nevertheless, the observations reported on the effect of HIT are especially interesting for the sport of football: because football players require a multitude of skills and capabilities, a more efficient training program for endurance capacity would free up time to concentrate on other relevant core aspects of pre-season training.

Because of the lack of scientific evidence for the efficacy of HIT in sport, restructuring the methodology in endurance training complete is not yet justified. However, in diseases such as type 1 diabetes and lung and coronary heart diseases (Hsieh et al., 2007; Rognmo et al., 2004), HIT led to an improvement of the glucose regulation of the aerobic metabolism (Rognmo et al., 2004) and respiratory indicators (Hsieh et al., 2007), and the effects achieved with HIT were significantly higher than those achieved with extensive training (Hsieh et al., 2007; Rognmo et al., 2004). The results of these studies are promising, and the potential of using HIT as an efficient training program in professional football should be further investigated.

In summary, compared to field level tests, spiroergometric examinations provide critical information that allows for a more precise description and profile compilation of a player's endurance capacities. Individually optimized and differentiated training methodology measures can be taken based on a well-founded metabolism performance profile using spiroergometry and lactate analysis. Therefore, spiroergometry for performance diagnostics should be established in German high performance football ideally already in youth teams as shown in teams abroad and in other sports. Additional efforts should be put on earlier translation of scientific knowledge to training practice especially in German football.

PRACTICAL APPLICATIONS

The results of this study emphasize the need for detailed measurement of performance capacity for the design and evaluation of training programs especially in elite football players. Coaches of youth, development and elite teams should consult and collaborate with exercise physiology specialists. Regular laboratory testing of players is critical for achieving each player's optimal performance. While these additional tests will place a financial burden on the team, individualised training programs based on these test results will most likely result in improved performance.

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