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Examining Physical and Physiological Requirements of Experienced Soccer Players during Competition: A Review

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Abstract* – *Soccer is the most popular sport in the world with nearly 200 million practitioners. Match analysis of the physical demand have revealed that the game is characterized by the mix of short-duration sprints, high-intensity running, jumps, duels, tackles, directional changes, backwards, and walking and standing episodes with an average game intensity ranging from 80 to 90% of maximal heart rate (HRmax). For instance, top-level players require developing specific physical capacities such as an elevated aerobic power and the ability to perform repeated HIR (including sprinting) with limited rest period, to be able to cope with the game demands. The utilization of glycogen stores during a football match was suggested to be 155 – 160 g from the muscle glycogen stores, with an estimated 600 kcal of energy provided, while blood glucose derived from the liver may account for approximately 210 kcal of energy during the game. In accordance, the endogenous CHO stores are suggested to supply ~55% of the energy requirements of match-play, and a substantial utilization of lipids and proteins must also be taken into account.

The running demands of professional soccer match-play are widely established, with players performing various high-intensity actions interspersed with periods of low-intensity activity. However, the demands of in-season training sessions, and how closely they relate to match-play, remain largely unknown. The purpose of this study was to investigate the running demands of professional soccer players during in-season field-based training sessions and matches, and to examine whether the demands of training are similar to those of competition.

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INTRODUCTION

Performance analysis of invasion games has received much attention in recent years. The analysis of performance is vital in soccer if the individual/team is to be successful.

For many coaches the information gained from performances will not only form the basis of weekly training programmes, but also may act as the primary source for the scheduling of seasonal plans (Ali & Williams, 2009).

Over the last two decades, there has been a growing interest in match-analyses of soccer (Bangsbo, et. al., 2006, Barbero, el. al., 2007, Bloomfield, el. al., 2007, Bravo, el. al., 2008, Castagna, el. al., 2003) Match analysis refers to the objective recording and examination of behavioral events occurring during competition. Probably the main aim of match analysis is to identify the strengths of one's team, which can then be further developed, and its weaknesses, which suggest areas for improvement. Similarly, a coach analyzing the performance of an opposition side will use the data to identify ways to counter that team´s strengths and exploit its weaknesses (Ali & Williams, 2009, Ekblom, 1986). In this respect, matchanalysis has been helpful in identifying the physiological demands of one particular event (Reilly, 2000).

Understanding the physiological load imposed on toplevel soccer players according to their positional role during competitive matches (activity profile, distance covered, intensity, energy systems and muscles involved) is necessary to develop a sport specific training protocol. Especially in elite athletes, the most important form of training is that which matches energy use and biomechanics of an intended competitive performance. Therefore, match-analyses are helpful to develop a specific training program that mimics the physiological conditions imposed by the game.

As in every collective sport, in soccer the planning of training loads is a fundamental parameter to improve player performance. This is due to the long length of competitive periods, which usually cover an entire season, including the pre-season and some interspersed tournaments. Therefore, a deeper understanding of trainings physical demands, would make possible a more thorough planning with more specific and appropriate sessions.

Although physical and physiological variables have been widely studied during the competition, their effects in training sessions have rarely been studied, which makes their study more interesting (Barbero et al., 2007). It is clear that a greater control over training loads will enable the improvement of performance and it will ensure that training loads may or may not be appropriate. Besides, it should be stressed that the vast majority of studies and research are focused on adult soccer players of absolute categories, remaining outside categories of training, mainly younger age categories such as under 8's age group and under 10's age group. Although at this age specific physical preparation is not necessary, since players are in a period of full-on growth, it is very interesting to analyse training loads in these categories to compare them with other players, categories and methodologies.

Therefore, the study of analysis of physical and physiological demands in categories of training can be an interesting subject due to the importance of trainings in players' development. However, the absence of studies upon this subject greatly impedes the comparison of analysis and results. Furthermore, the recent addition of the new technologies into the world of sport makes possible the use of tools, which enable to monitor and record players' performance (Barbero et al., 2007). For this reason, it is of crucial importance to take advantage of these tools to analyse physical and physiological aspects, as without these tools it would be impossible to analyse players' external and internal load. Specifically, satellite tracking devices (GPS) and heart rate monitors are being used in research with the aim of recording heart rate (internal load), distance travelled and speed (external load). It must be emphasized that the use of heart rate as a variable is much more practical and economic than other methods, such as oxygen consumption (Mújika, 2006).

For soccer training to be effective, it must specifically relate to the demands imposed by match-play (30). Several contemporary time-motion investigations have detailed the physical demands of professional soccer players during competition (26-28). Research has established that professional players cover a distance of approximately 8500-13000m at varying movement intensities during a 90-minute match (35), including 1000-1400 unpredictable changes in locomotor activity, which occur every 3-6 s (26,31). As a result, it is widely accepted that training for professional players should focus on improving both aerobic and anaerobic capacities, as well as enhancing the ability to perform repeated bouts of intense exercise and to recover rapidly between these bouts (5). The challenge for soccer and strength and conditioning coaches is to ensure that appropriate training strategies are implemented to train for these demands. In order to achieve this, it is important that strength and conditioning staff examine the efficacy of training methods by monitoring players during practice, so as to ensure they are being applied a suitable and specific training stimulus.

Analysis of player movement patterns using global positioning system (GPS) technology has become increasingly popular in intermittent team sports (4). While it should be acknowledged that the reliability of GPS devices may decrease when resolving distance covered at high speeds (10), the portability and simple analysis of data make this technology an attractive monitoring tool for strength and conditioning staff. GPS-derived measures have been recently used to quantify the external-training load of professional soccer players during in-season field-based training (33), and can provide a simple means to quantify the running demands of players during training. While these training-based data provide coaches with practical information detailing the physical stimulus applied within a training session, to the authors' knowledge, no research has compared the physical demands of field-based training sessions for soccer with matchplay data.

While the physiological and time-motion characteristics of various training drills and small-sided games have previously been investigated (17,18), the relationship between the demands of in-season field-based training sessions and competitive match-play remains unclear. Therefore, the aims of the current study were to investigate the running demands of professional soccer players during in-season field-based training sessions and matches, and to examine whether the demands of training are similar to those of competition. It is hypothesised that in-season field-based training sessions will be characterised by greater time spent and distance covered at low speeds, and less at high speeds, than during competitive match-play. While it is expected that the demands of training and matches during the completive season will be dissimilar, the results of this study have important implications for soccer strength and conditioning staff. This study will detail how the inherent nature of in-season training can affect the training stimulus provided to players, and highlight the need for comprehensive understanding of this training stimulus in conjunction with weekly match-play.

HIGH-INTENSITY INTERMITTENT IN SOCCER

Soccer is a high-intensity intermittent sport which is normally played over 90 min, split into two 45 min halves that are separated by a 15 min half-time period.

The speed and accuracy with which players completed soccer-specific skills were significantly affected after a 45-min period of intermittent shuttle running replicating one half of a soccer match. Finally, soccer skill performance measured by the time taken to complete a passing test, including penalty time accrued for inaccurate passing or poor control, declined during the final 15 min of exercise within a

90-min intermittent running test (Ajmol Ali & Williams, 2009). Changes in arousal, decreased neuromuscular and cognitive function, glycogen depletion and dehydration are possible candidate factors for impaired skill-related performance during and/or towards the end of such exercise. While a decline in physical performance was observed during the second half and the final third of games, this was not accompanied by a drop in skill-related performance. In addition, unlike high-speed running performance, skill-related measures were not affected in the 5-min period following the most intense 5-min period of high-speed exercise. In contrast, a reduction in the distance covered in high-speed exercise was accompanied by a drop in the frequency of some skill-related variables during the final 5 min of games. None of the physical or technical measures of performance were affected when competing in three successive matches within a short time-frame (<7 days).

Intermittent high-intensity endurance and the ability to repeatedly sprint within relatively short time intervals (RSAs) are deemed relevant fitness prerequisites in competitive soccer players. Consequently, intermittent training and testing protocols have been proposed to improve soccer player's fitness and guide talent selection (Bravo et al., 2008). Recent studies reported that high intensity intermittent endurance and RSA are both influenced by anaerobic and aerobic metabolism. Additionally, training studies showed that RSA training positively affects intermittent high-intensity performance.

METABOLIC DEMAND IN SOCCER PLAYER

Early assessments of metabolic demand, which were conducted through measurements of body temperature, demonstrated that the average metabolic load of a soccer player is close to 70% of VO2max. In addition, HR recordings do not yield information on high-intensity bouts. Likewise, direct measurement of oxygen uptake is not suitable to provide data on high intensity exercise, and its use during training sessions or competitions is not feasible. Overall, all these methods show that the total estimated energy expenditure during a match ranges from 1200 to 1500 kcal. The studies conducted so far on anaerobic energy expenditure are rather scant; furthermore, the current procedures are not applicable to official matches and are definitely not suitable for continuous recordings. An example of this approach is the study by Krustrup and et al 2006, which measured creatine phosphate concentration on biopsies taken from muscular tissue of athletes immediately after high-intensity exercise bouts during a soccer match. Blood lactate concentration (LA) has also been considered as a marker of anaerobic energy expenditure by several researchers; the results of these studies show that its level during matches ranges from 2 to 10 mmol.L-1.

In accordance, it was indicated that both the aerobic and anaerobic energy systems contribute to the physiological demands of the game. The total duration of active play in football is typically 90 minutes, indicating that the primary energy source during the game is supplied via aerobic glycolysis, with an average maximal oxygen uptake (VO2max) of around 70 – 80% during the match. The mean and peak heart rates of players were estimated to be around 85 and 98, respectively.

The utilization of glycogen stores during a football match was suggested to be 155 – 160 g from the muscle glycogen stores, with an estimated 600 kcal of energy provided, while blood glucose derived from the liver may account for approximately 210 kcal of energy during the game (36). In accordance, the endogenous CHO stores are suggested to supply ~55% of the energy requirements of match-play, and a substantial utilization of lipids and proteins must also be taken into account.

MUSCLE GLYCOGEN UTILIZATION DURING A SOCCER MATCH

Saltin observed that the muscle glycogen stores were almost depleted at half time when the prematch levels were low (~45 mmol/kg wet weight). In that study, some players also started the game with normal muscle glycogen levels (~100 mmol/kg wet weight), and the values were still rather high at halftime but below 10 mmol/kg wet weight at the end of the game. Others have found the concentrations to be 40 to 65 mmol/kg wet weight after a game, indicating that muscle glycogen stores are not always depleted in a soccer game. Analyses of single muscle fibers after a game, however, have revealed that a significant number of fibers are depleted or partly depleted at the end of the game.

The intense exercise periods during a soccer game lead to high anaerobic-energy turnover with an associated accumulation of lactate and lowering of pH in the exercised muscles. These factors are probably not, however, the main factors in the temporary fatigue that occurs during a game, which is probably caused by a complex interplay between a number of factors. Recent data from human studies support an old theory about accumulation of potassium in muscle interstitium and a concomitant change in muscle-membrane potential playing an important role in the development of fatigue during intense exercise.

METHODOLOGY

Participants -

Thirty players of soccer 8 from under 10's age group (9.93±0.25 years; 141±0.05 cm. and 37.5± 5.3 kg.) belonging to "A" teams of three clubs, which participate in under 10's age group. The participants trained two times a week, played a competition match once a week and some tournaments.

Two players were analysed in each of the 15 training sessions in which global methodology was used. Sessions lasted one hour and fifteen minutes and were structured in three parts: a warmup (displacement with joint movement, games with a ball and ball handling exercises), a main part (matches with modified dimensions, possession games, competitive games and matches with modified rules) and a restoration of order (static stretching and games with low-intensity coordinative actions).

For the valuation of the pattern of activity we have established a series of categories of displacement for players of these ages: 1ª. 0-0.4 km/h (standing), 2ª. 0.5-3 km/h (walking), 3ª. 3.1-8 km/h (low-intensity running or jogging), 4ª. 8.1-13 km/h (medium-intensity running), 5ª. 13.1-18 km/h (high-intensity running), 6ª. >18.1 km/h (maximum intensity or sprint). Medium heart rate and peak heart rate reached during training were analysed as physiological parameters and indicators of cardiovascular stress. Peak heart rate has been considerated as maximum. Furthermore, overall distance travelled, average speed (distanced travelled per minute), maximum speed (peak), distance travelled in every category, percentage with respect to the overall, number, distance and sprints duration were analysed to determine the pattern of activity. Comparisons by specific posts were also affected.

Measures -

Players bore a GPS receiver called SPI Elite. It is a GPS receiver device, which integrates the reception of satellite signal with a triaxial accelerometer and a chip for heart rate record.

This device weighs approximately 75 grams and can record (one record per second) time, position, speed, distance, height, direction and heart rate data (this one requires a thoracic band). Data can be manipulated according to researcher's interests. It enables a detailed and customized analysis of physical activity. Besides, data can be exported to Excel to perform the required statistical treatment.

Procedures -

Before beginning every training session, investigators put a little padded bag (harness) on player's back. There was a GPS SPI Elite device inside. This harness was adjusted so that it couldn't move or disturb players during the 75 minutes of game. At the end of the training, data was downloaded in a laptop computer to effect the treatment of variables, subject of study.

Statistical Analyses -

Data are presented as average, average standard deviation and ranges. The mean values for displacement categories between matches were compared using analysis of variance (ANOVA), taking as signification values $p < .05$.

RESULTS -

Distance and speed -

The average distance travelled during the 75 minutes of training was 3837.8±1045.14 m. (2391.8–7143.6 m.). If we analyse it according to the positions, defenders travelled 3355.77±677.91 m. (2391.8-4244.5 m.), midfielders 4220.87±1438.31 m. (2430–7143.6 m.) and forwards 3936.76±811.82 m. (2915.9-5315.5 m.), with no significant difference for every position (p>.05).

These values amount to an average speed of 54.01±13.2 m. (31.8-86.4 m/min). According to players' positions, average speed of defenders was 42.74±7.81 m/min (31.8-53.74 m/min), midfielders' one of 60.64±14.24 m/min (40.87-86.4 m/min) and forwards' one of 58.66±9.63 m/min (46.81-71.43 m/min). The coefficient of variability in relation to the overall distance travelled was 18.27% in defenders, 23.48% in midfielders and 16.42% in forwards.

Pattern of activity -

Pattern of activity based on the distance travelled for every established category is reflected. A great similarity is observed in all positions, finding significant differences in distance travelled in high intensity (13.1-18 km/h).

Heart rate -

Heart rate during the training was 157.62±19.28 lpm. (122-201 lpm.), these values amount to 70.16±6.29 % (58.9-84.45 %) of the maximum obtained in the training and whose average value was 224.24±12.26 lpm.

CONCLUSION

The main findings of the present study were that effective playing time should be taken into account when analyzing the physical demands of elite soccer player., and variations on the workload of the players could be not only linked to fatigue but also to the strategic management of the playing time.

The results obtained in the present study show that in under 10's age group (9.93±0.25 years) training session of 75 minutes applying the global methodology, the average distance travelled is 3837.8 meters. The average speed of every player is 54.01 m/min. The player who travels more meters in a medium speed higher than other players is the midfielder, though there are no significant differences between the game different positions regarding these two variables.

The physiological exigency (heart rate) of trainings based on the global method, supposes that players are working in a heart rate of 157.62 lpm., though according to players' positions significant differences between the players have been observed. Forward is the player who works in a higher medium heart rate.

In this method of training, the player is most of the time (68.88 %) in less than 80 % of maximum heart rate obtained during the accomplishment of the session, which has been of 224.24 lpm. According to games positions, there have been significant differences during the time a player is in less than 70 % and in more than 95 % of his maximum heart rate.

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