MASTEROPPGAVE

MKØ210

Simen Raaen Sandmæl

Analysis of physical load during small-sided games in training. Will physical performance during small-sided games meet the physical performance demands in competitive matches for elite male soccer players?

Analyse av fysisk belastning ved kortbanespill under fotballtrening for mannlige elitespillere. Vil kortbanespill overbelaste de fysiske prestasjonskravene som stilles i kamp?

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Abbreviations

Acc	Accelerations
ATP	Adenosine triphosphate
ATT	Attacker
CD	Central defender
CM	Central midfielder
CP	Creatine phosphate
ED	External defender
EM	External midfielder
GPS	Global positioning system
HIR	High intensity running
HRmax	Maximal heart rate
PL	Player Load
SSG	Small-sided games
TDC	Total distance covered

Abstrakt

Fysisk prestasjonsevne hos fotballspillere kan ved hjelp av sporingssystemer måles underveis i trening og kamp. En bedre forståelse av fysisk prestasjonsevne hos fotballspillere i trening vil være viktig for å optimalisere treningsutbytte og identifisere tretthet. Denne studien ønsket å undersøke i hvilken grad spillernes fysiske prestasjon underveis i kortbanespill-trening møtte de fysiske prestasjonskravene under kamp. Videre ønsket studien å undersøke i hvilken grad tretthet på de fysiske faktorene oppstår underveis i treninger med kortbanespill. Deltakerne i studien var 26 mannlige fotballspillere der alle spilte for et norsk lag i eliteserien. Studien undersøkte spillerne i atten kamper og elleve treningsøkter, hvorav fire økter med 4mot4 (56 kamper) og sju økter med 6mot6 (28 kamper). ZXY Sport Tracking System ble brukt for å måle antall akselerasjoner (Acc), høy-intensiv løpsdistanse (HIR), total distanse (TDC) og spillernes akselerometermålte belastning (Player Load (PL)). Spillernes antall Acc og PL i 4mot4 var signifikant høyere enn den høyeste 5-minutters perioden i kamp, mens i 6mot6 var de samme variablene signifikant lavere enn de høyeste periodene i kamp ($P<0,05$). HIR distanse under kortbanespill (4mot4 og 6mot6) var signifikant lavere enn gjennomsnittsverdien av en kamp ($P<0,05$). Ingen tretthet ble funnet for hverken Acc, HIR, TDC eller PL gjennom treningsøkter med kortbanespill. Kortbanespill med 4mot4 på trening gir en overbelastning på Acc og PL sammenlignet med de mest intensive periodene i kamp. Likevel ga ikke treningsøktene noen tegn på tretthet på disse variablene. Dette er trolig et resultat av at pausetiden var tilstrekkelig for nok restitusjon i periodene mellom kortbanekampene. HIR under kortbanespill møter ikke de fysiske kravene fra kamp og viser dermed heller ingen tegn på tretthet underveis i treningsøktene.

Abstract

The physical performance of soccer players during training and matches can be measured by sport tracking systems. Knowledge about the physical performance among players in training may be helpful for coaches in terms of optimize training and identify fatigue. The aim of this study was to investigate to what extend players physical performance during small-sided games meet the physical demands that are experienced during match play. Another purpose was to examine to what extend fatigue would occur on physical factors during small-sided games in training. The subjects of this study were 26 male soccer players, all playing for a Norwegian top division team. The players were monitored during 18 matches and eleven training sessions of small-sided games (SSG), whereas four sessions of 4vs4 (56 games) and seven sessions of 6vs6 (28 games). ZXY Sport Tracking System was used to measure the players' number of accelerations (Acc), high intensity running (HIR) distance, total distance covered (TDC) and player load (PL). The players Acc and PL during 4vs4 were significantly higher than 5-minute peak in match, while the same variables were significantly lower than peak in 6vs6 ($P<0,05$). SSG with 4vs4 in training creates an overload on Acc and PL when comparing with the most intense periods of the match. No fatigue was found on Acc or PL between periods of SSG, indicating that the recovery time between SSG-periods is sufficient. HIR distance was significantly lower than mean match for both 4vs4 and 6vs6 in training ($P<0,05$). No fatigue was found in HIR between periods of SSG, which is most likely is due to a lack of overload on this variable.

Introduction

Physical demands in soccer

Soccer is a very diverse and dynamic sport. Typically, a game of soccer consists of 1200 different actions with a change of activity every 3-5 seconds, including 30-40 sprints, more than 700 turns and 30-40 tackles or jumps [1]. Elite players will often cover a total distance of 10-14 km during a 90-minute game. In an acyclic and interval embossed pattern the work will consists of 2500-2800 meters in running (>14.4 km·h^{-1}). Within this, around 800 meters is counted as high-intensity running (HIR)(19.8 km·h^{-1}), whereas about 300 meters is sprinting (≥25.2 km·h^{-1}) [2]. A study done by Dalen et al. (2016) have reported that players during a 90 minutes match, in average perform 76 ± 22 Acc, 847 ± 349 meters of HIR, and cover a TDC of 11046 ± 1015 meters [3].

The frequent change in intensity makes it physiological demanding because there is required to frequently switch between different energy systems [4]. The acyclic types of work in soccer form the need of adenosine triphosphate (ATP) production from both the aerobic and anaerobic energy system [5]. During a 90-minutes game the contribution of energy is primary given from the aerobic energy system (with oxygen) and consists of more than 90% of the total energy production. Players with a good developed aerobic fitness will have the prerequisite to perform well at periods with high intensity, and also have the ability to recover quickly in between [1]. Therefore, the respiratory systems capability to transport adequate amount of oxygen to the working muscles mitochondrial is essential when it comes to production of ATP, and thus to influence the fitness level and performance [6]. Studies have shown that modern elite soccer have increased high intensity actions with 30% during the recent years, and the number of sprints performed has increased with 85% in the same period [7]. However, the total distance covered in a game has virtually remained unchanged. Therefore, modern soccer seems to require a greater importance of a quickly development of force and power [7]. Nevertheless it is important to consider in what extend the measuring devices used several years ago are reliable in terms of comparing today's measurements on physical performance, knowing that the evolution and improvements of measuring devices in soccer have been significant during the recent years. The physical demands in soccer can be classified as; a) physical performance over time (endurance), b) physical performance during high intensity periods, c) sprinting performance, and d) physical performance of quickly development of force and power (e.g. jumps, accelerations etc.) [8]. The physical demands in soccer will however in high extend vary among players due to the different physical demands between playing positions.

Positional differences

Each player's position is characterized by its own activity profile, and physical performance is therefore based on the positions distinctive demands [9]. For instance will attackers perform a greater amount of sprints and HIR than defenders when own team are in possession of the ball [1]. The activity profiles differences will lead to various demands for energy production and players primarily source for energy will be taxed on the basis of positional demands and individual differences [9]. Studies by Bloomfield et al. (2007) showed significant differences in physical demands based on playing position in the English Premier League, suggesting that physical training in soccer should be highly individualized. They found that midfielders will often be superior to the defenders and attackers when it comes to total distance covered (TDC) and HIR covered during a game, which could argue a greater importance of aerobic fitness [9].

Further on Bloomfield et al. points out that defenders and attackers typically will perform a larger number of sprints than midfielders and therefore in greater extend depends on anaerobic fitness [8, 9]. Gonçalves et al. (2014) showed virtually no differences in TDC covered during match among playing positions [10]. More specifically, numerous of studies have shown that players in external positions perform the highest intense actions during a match [11-13]. HIR-distance of external midfielders (EM) seems to be superior to all others positions, and the recovery time between high intensity runs is found to be shortest for central midfielders (CM) and EM [13]. The findings are supported by studies conducted by Di Salvo et al. (2010) were EM, attackers (ATT) and external defenders (ED) are superior to central defenders (CD) in frequency of explosive sprints, of which EM were shown to be significant superior to the CM. Further on did EM performed considerable higher than any other positions in frequency of leading sprints [12]. Carling et al. (2012) share a similar discovery when investigating performance of high-speed bouts among playing positions, showing that ED, EM and CM perform at a higher frequency than CD and ATT [11].

Too much of a generalization of the positional demands however may be inappropriately in terms of highlighting physical demands for each position, knowing that strengths and weaknesses for each individual impact their way to solving different tasks [9, 14]. Mallo, J., et al (2015) showed that CM have the highest TDC during a game but were inferior to the external players when it came to HIR and sprints. In fact, ED and EM were shown to be superior to the CM in both HIR, sprinting and acceleration (Acc) performance [14]. The differentces in physical demands and physiological stress that are exposed between playing postions will therefore lead to a varying physical performance and development of fatigue among players.

Fatigue in soccer

Fatigue can be defined as a reduction in the muscles ability to create force and power [4], or failure to maintain the required or expected power output [15]. The physical complexity that exist in soccer causes difficulties in terms of limiting fatigue, and argues that soccer specific exercises require an appropriate use of both aerobic and anaerobic energy systems. Meaning that their ability to work together and interact within another will be essential when it comes to physical performance and to avoid fatigue [4, 7, 16].

The physical demands in soccer will often result in deterioration of physical performance and is highly influenced by the interaction of energy system contribution. Energy contribution during short high intensity work will mainly be received from the anaerobic energy system (without oxygen). By performing a sprint lasting for 3 seconds the aerobic energy system will only have a contribution consisting of 3% [17]. The aerobic energy system will primarily be dominated in working periods lasting longer than 60 seconds, which will be the longer periods with lower intensity, but also periods demanding repeated high intensity actions [16]. Players will typically experience temporarily fatigue during a game of soccer do to the frequent change of intensity, where acyclic maximal effort will interfere with the muscular homeostasis, reducing the concentration of muscle creatine phosphate, elevating levels of muscle lactate, and lowering the muscle pH [1, 18]. Players with a good aerobic fitness will therefore experience less interference from the anaerobic energy system during longer periods with high intensity, which will be beneficial in terms of saving and recreate adenosine triphosphate in the working muscles [16]. When it comes to HIR during a game, studies have shown that the most intense 5-minute period leads to a significant reduction in the next following 5 minutes, also referred to as temporarily fatigue [19]. The acyclic and intermittent pattern of actions with high intensity will demand a quickly contribution from the anaerobic energy system. In actions demanding immediate energy contribution, such as Acc and sprints, the anaerobic alactic system delivers already stored energy in form of ATP and creatine phosphate (CP) for instant and maximal work [20]. The involvement from the alactic system will though decrease when the action exceed 2-4 seconds. Studies has shown that the contribution of stored ATP and CP is respectively taxed 10% and 55% during a 3 second sprint, whereas 32% of the energy will be provided from the glycolysis anaerobic system [17].

The glycolysis anaerobic system has the ability to quickly create ATP in the cells cytoplasm, and contribute already during the commencement of maximal actions. The glycolysis anaerobic system will however increasingly subsidize when the activity exceed 6 seconds[17], suggesting that temporarily fatigue may be due to low concentration of CP in the working muscles. This is enhanced by studies showing that the decrease in muscle CP is significantly correlated with impairment in sprint ability [4, 18, 21]. Evidence of fatigue in high intensity actions has previously been explained by substitutes covered more HIR-distance compared to mean for all the remaining players at the same time period [22]. This fact limits the speculations according to if the decline could be because of some tactical element, score line etc. Also, recent findings suggest little or no differences in match running performance in all players between matches of critical or low importance, or if the match were competitive, heavy won or heavy lost [22]. This supports the assumption that a reduction in physical performance in the time course of the match, is because of exercise – induced homeostatic perturbation responsible for the decline. This might indicate that ATP stores only are partially restored, resulting in compromised performance during successive high intensity actions. Several studies have shown that players normally have a decrease in HIR and sprinting performance during a 90-minutes game, whereas the amount of HIR and sprints performed in the last 15 minutes of the game is reduced substantially [8, 19, 23]. Also, there is a wide consensus that acceleration performance seems to drop considerable towards the end of a game, arguably due to fatigue [24]. Fatigue that occur in the end of a game has been shown to be related to lower contribution of muscle glycogen which is an important contributor for production of ATP during long term intermittent exercise [25, 26]. Studies conducted by

Mohr (2003) has displayed that only 3% of the players perform their most intense period in the last 15 minutes of the game, and more than 40% have their least intense period in the last 15 minutes [19]. Periodic decline in intensity is therefore apparently due to fatigue [4]. Nevertheless, other studies have reported no decrease, or evidence of end-game fatigue regarding HIR or sprinting performance in the last 15 minutes of play [13, 27-29]. The differences of the findings may be linked to playing positions, and also the time spent by the team in ball possession [30]. A critical view on identifying fatigue will therefore be of great importance on the basis of the many factors influencing the physical performance during a game of soccer. Positional differences, as much as individual differences argue that comparison of means for all players together may be inappropriate to identify fatigue, knowing that the physical capacity and the physiological exertion among players may be highly different [30].

Physical performance in small-sided games

Small-sided games (SSG) in elite soccer are used as a soccer-specific training method to enhance player performance, meaning a positive impact on technical, tactical and physical components [31]. Previous studies have suggested that SSG in soccer is a good indication for performance at full size (11vs11), and helpful in terms of identify players that are capable of performing well at a bigger format [32, 33].

Studies done by Moreira et al. (2016) have shown a decrease in physical performance during SSG in training, where the study was consisting of four quarters of play with duration of four minutes of each period of play. Results showing a reduction in TDC (~22%), number of Acc (~41%), and number of sprints performed (~42%) from the first to the fourth and last period of play, which probably is related to fatigue [31]. However, there was no impairment in physical performance shown in TDC and Acc variables from the second till the third period, suggesting that fatigue is influenced by duration, quantity and recovery time between periods [31, 32]. The findings shares many similarities with end game fatigue were the physical performance is shown to drop significantly in the last quarter of the game [4, 19, 25, 26], arguing that SSG in training correspond with physical performance and development of fatigue during match play. However, the phenomenon about end game fatigue is shown to be complex and questioned with different opinions among authors [12, 13, 27-29]. The physical demands and development of fatigue in SSG will though vary with changes in the external conditions, such as number of players and pitch size [34]. A comparative study of 4vs4 and 8vs8 play conducted by Rebelo et al. (2016) have shown a increase in HIR distance and sprinting distance when changing from 4vs4 play to 8vs8 [34]. On the other hand were Acc count and TDC shown to be higher during 4vs4 play. The findings are in contrast to studies that found no differences in physical performance between 4vs4, 6vs6 and 8vs8 play [35-37]. Only looking at the number of players a-side in training is therefore apparently not sufficient in terms of manipulate the training load during SSG, arguing that external conditions (e.g. pitch size and duration) is essential for tailoring an appropriate SSG format [31, 37].

Temporarily fatigue in soccer will often occur as a result of periodic overload, which also is expedient in terms of creating a positive training effect [20, 31]. An increase in physical capacity demands a training load that exposes a higher load than earlier, where the phase of recovery can contribute to overcompensation. Overcompensation is a state were the working capacity and ability is increased as a result of the training load that the player is exposed to [38]. SSG in soccer is a method to manipulate training sessions, were the desirable outcome is an improvement of physical capacity, as much as technical and tactical aspects. The external conditions, such as length and quantity of periods, will in this term be measurements of the external training load [31, 39]. The physiological stress that the players will experience during SSG, such as heart rate and lactate threshold, is measurements of the internal training load. The internal load will apply different between players on the basis of individual differences [9, 39], meaning that an appropriate integration of the external and internal training load in soccer will be crucial for the training outcome [39]. An internal overload during SSG may lead to an impairment of physical performance (fatigue) and may be caused by a reduction of muscle CP, increase of muscle lactate, a lowering of the muscle pH, or imbalance in the muscular homeostasis [1, 18]. The physiological stress that occur will identify fatigue during SSG, but also be necessary in terms of create an overcompensation and benefit from the overload that are applied [38].

Dellal et al. (2012) reported a higher TDC and HIR per minute during SSG in training compared with average performance per minute during match play, arguing that SSG leads to a physical overload for the players. Similar findings appears in studies on Acc, were players is shown to perform a greater number per minute during match play. Furthermore, other studies have shown that players are exposed for a higher heart rate and blood lactate level when competing 4vs4 rather than 6vs6 [40, 41], but other investigations have also reported no differences in the two formats of play [37].

To our knowledge, there is a lack of studies showing differences between formats of SSG in comparison with the most intense periods of matches. Due to the intermittent change in intensity during match play [1, 8, 34], and also evidence regarding temporarily fatigue in match [19, 30] it seems to be appropiate to investigate the players performance in the most intense period during match. The major periodically differences in intensity may argue that the average intensity of a soccer match is an inconvenient standard for SSG in training. An average performance during a 90-minutes match will not identify the “tops and lows” that occur, and it will therefore be in interest to investigate the physical load that is present in the most intense periods in match and then compare with the training load in SSG. Additionally will a further investigation of development of fatigue in different formats of SSG be useful in terms of planning and implementation sessions with the purpose of making the training stimuli similar and appropriate to the demands that actually are experienced during match.

Purpose of the study

The purpose of the present study was to investigate if the players’ number of accelerations, player load, high intensity running distance and total distance covered during small-sided games meets the physical demands that are experienced during match play. In addition we aimed to examine in what extend fatigue will occur on these categories from throughout periods of small-sided games in training.

Methods

Subjects and Sample

Data in this study was collected from soccer players competing in the Norwegian top division (n = 26, age = 24,9 ± 4,2), consisting of four central defenders (CD), five external defenders (ED), eight central midfielders (CM), five external midfielders (EM), and four attackers (ATT). Goalkeepers were excluded in the study. Physical performance variables were collected and analyzed from a total of 18 home league matches and eleven training sessions during the 2015 and 2016 season. The training sessions consisted of multiple small-sided games 4vs4 (n = 4sessions), and 6vs6 (n = 7 sessions) with duration of 3, 5 or 6-minutes for each game. The recovery time between each small-sided game was equivalent with the duration of the relevant game played, meaning 3, 5 or 6 minutes. Numbers of small-sided games in total were 56 and 28 for 4vs4 and 6vs6 respectively. All the games were played on standardized pitch sizes meaning 32x32 meters for the 4vs4, and 40x36 meters for the 6vs6 games. Pitch sizes during matches were 105x70 meters. All matches and training sessions were played on natural grass. The team won the Norwegian league both seasons and participated also in the group stages of the UEFA Europa League.

Methodical approach

Number of accelerations (Acc), Player Load (PL), High-intensity running distance (HIR) and Total distance covered (TDC) were investigated for every SSG conducted. Each of the players was categorized by playing position to investigate positional differences, and only players that completed the training session were included. The physical variables from matches were collected from the 5-minute peak period. The 90-minute matches were divided into 5-minute periods, of wich only the highest period of performance for each of the variables seperately (Acc, PL, HIR and TDC) were included in the study. Additionally, means for each variable during all 90 minutes of match play are also included. Only players that started the game and participated >60 minutes were included in the analyses. Results are presented as performance per minute of play, for both training and match data.

Measuring devices

To measure the physical variables of the players, an automatic sport tracking system based on RadioEye™ was used to investigate the players match activity (ZXY Sport Tracking AS, ChyronHego Nasdaq, Trondheim, Norway). The ZXY tracking system measured Acc, HIR, TDC and PL during training and match activity for each of the players that participated in the study. By using a body-worn sensor all of the movements conducted were captured. The measurements were transferred by microwave radio to RadioEye™ sensors mounted on the surroundings of the team's home arena and training facility [3]. The sensors around the pitch manage to locate the player's position on the field, and by frequently receiving positional transmitted data (20 Hz) from the players, the physical variables was measured. Previous studies published have reported a good reliability for the ZXY Tracking system [42, 43].

Procedures

Player Load: Player Load was measured by using a triaxial accelerometer sensor placed on player's lumbar spine, mounted in a specially designed belt wrap around their waist. The accelerometer registers data at 20 Hz with a sensitivity of 184 µg/LSB with a static noise of 1 mg [3]. The player load is defined as the square sum of the high-passed filtered acceleration values for the mediolateral (X), anteriorposterior (Y) and vertical (Z) axes. For practical reasons the values are downscaled by dividing them with 800, leading to the following formula for the total player load: $(X^2 + Y^2 + Z^2)/800$ [3].

Accelerations: The ZXY Sport Tracking system defines accelerations by fulfilling four criteria: 1) to be registered, the acceleration have to reach the minimum limit of 1 $m \cdot s^{-2}$. 2) To be counted, the acceleration has to reach 2 $m \cdot s^{-2}$. 3) The acceleration must remain above the 2 $m \cdot s^{-2}$ for at least half a second, and 4) the duration of the acceleration have to last until it passes the minimum acceleration limit (1 $m \cdot s^{-2}$) [43].

Locomotion categories: The following categories were measured in the study: walking (0-7,1 $km \cdot h^{-1}$), jogging (7,2-14,3 $km \cdot h^{-1}$), running (14,4-19,7 $km \cdot h^{-1}$), high intensity running (19,8-25,2 $km \cdot h^{-1}$), and sprinting ($\geq$ 25,2)[1, 3]. TDC is the sum of distance covered regardless of velocity, and are together with HIR included in the results. The preset study share similarities with previous studies conducted on the topic [31, 37, 41].

Statistical analysis

All statistical analyses were done using IBM© SPSS© Statistics version 23 (New York, USA). To find means for 4vs4, 6vs6, mean match and peak match a comparison of means were performed. Performing a one-way ANOVA did further descriptive statistics, and were used to investigate differences between periods of SSG. A Bonferroni post hoc test with adjustment was performed to detect significant differences, and an independent sample t-test was used to find differences between playing positions. Results are presented as means ± standard deviation, and significance level was set to $P<0,05$

Results

SSG versus match

Acc during 4vs4 were 23% higher than 5-minute peak in match while PL was 12,6 % higher than peak in match during 4vs4 and 14,8 % lower than peak in match during 6vs6. Compared to 5-min peak in match, the HIR distance during SSG were respectively 80% lower during 4vs4 play, and 85% lower during 6vs6. HIR distance were also 54% and 68% lower than mean match during 4vs4 and 6vs6, respectively. TDC were 14% lower and 22% lower than the 5-minute peak in match during 4vs4 and 6vs6, respectively (Table 1).

Table 1. Number of accelerations, distance of high intensity running, total distance covered and player load per minute during 5-minute peak in match, 90-minute from match and different formats of small-sided games.

	Acc n/min	**PL** au/min	**HIR** m/min	**TDC** m/min
5-min peak match (n=154)	1,46 ± 0,34§	227,18 ± 38,58§	19,04 ± 5,51§	137,04 ± 11,53§
Mean match (n=154)	0,8 ± 0,19*	169,78 ± 23,59	8,14 ± 2,62	116,56 ± 10,55
4vs4 (n=350)	1,79 ± 0,76#§	255,80 ± 55,58#§	3,73 ± 4,41*$	118,41 ± 13,02*
6vs6 (n=271)	1,21 ± 0,56§	193,51 ± 63,81*	2,61 ± 2,42*$	99,94 ± 28,55*

Data are presented as mean ± standard deviation. Acc=Accelerations (numbers per minute), HIR=High-intensity running (meters per minute), TDC=Total distance covered (meters per minute), PL=Player Load (au. per minute). * = Significantly lower than 5-minute peak in match (P<0,05), # = Significantly higher than 5-minute peak in match (P<0,05), $ = Significantly lower than mean match (P<0,05), § = Significantly higher than mean match (P<0,05).

Furthermore, the players performed higher number of accelerations during all of the eight periods of 4vs4 in training (1,97 ± 0,69, 1,68 ± 0,58, 1,85 ± 0,93, 1,91 ± 0,81, 1,83 ± 0,70, 1,93 ± 0,81, 1,57 ±0,71, 1,64 ± 0,88) compared with 5-minute peak in match (Figure 1). Periods 1-4 of 6vs6 in training (1,25 ± 0,46, 1,24 ± 0,57, 1,16 ± 0,60, 1,16 ± 0,61) were lower than 5-minute peak in match, but higher than the mean of a full match. Period 5 in 6vs6 were higher than both mean of a full match, and also 5-minute peak in match (1,49 ± 0,37).

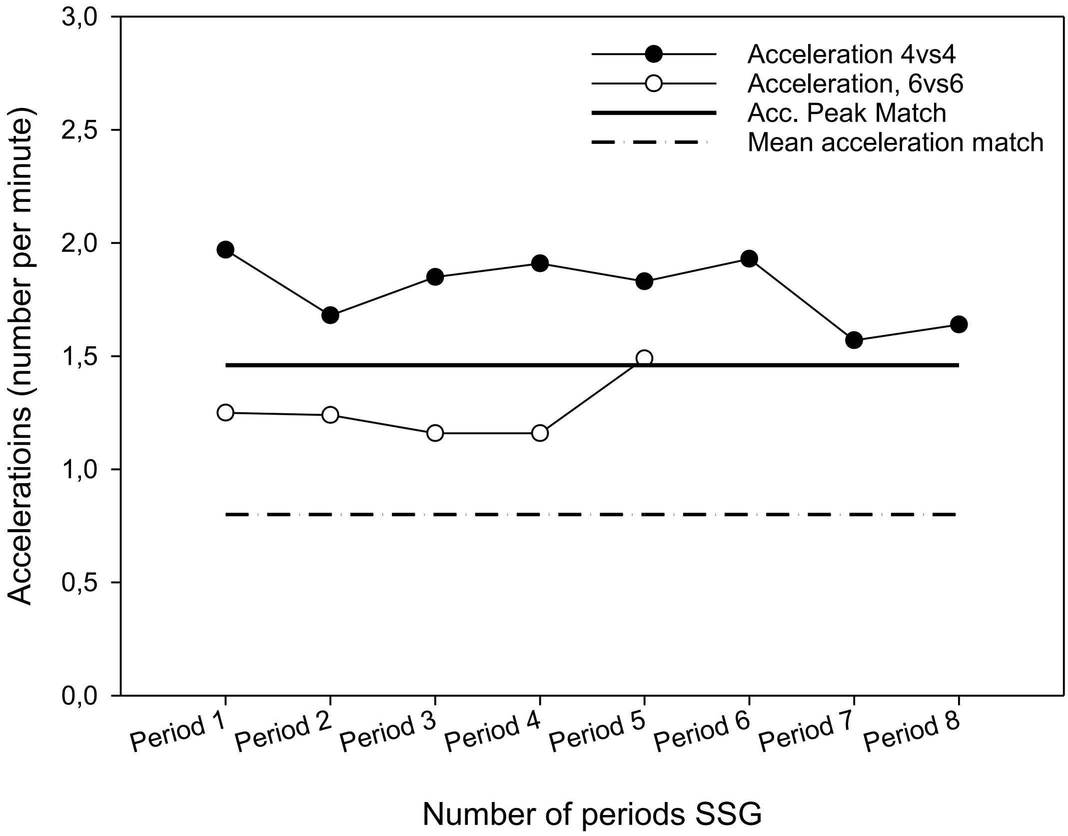

Figure 1. Number of accelerations per minute during 5-minute peak in match, 90-minutes match, 4vs4 and 6vs6 in training. Data are presented as mean ± standard deviation.

PL was significant higher during all eight periods of 4vs4 (266,96 ± 54,90, 262,55 ± 57,64, 271,02 ± 63,51, 244,71 ± 56,20, 263,60 ± 48,74, 250,83 ± 50,01, 239,49 ± 51,50, 247,48 ± 47,26) compared to the highest 5-minute peak in match (Figure 2). All of the five periods of 6vs6 in training (213,33 ± 37,05, 194,09 ± 72,00, 183,02 ± 66,16, 185,58 ± 72,81, 186,93 ± 29,57) however, were significantly lower than 5-min peak in match. Furthermore, periods of 4vs4 and 6vs6, and 5-minute peak from match were all superior to means of PL per minute during a full 90-minutes match.

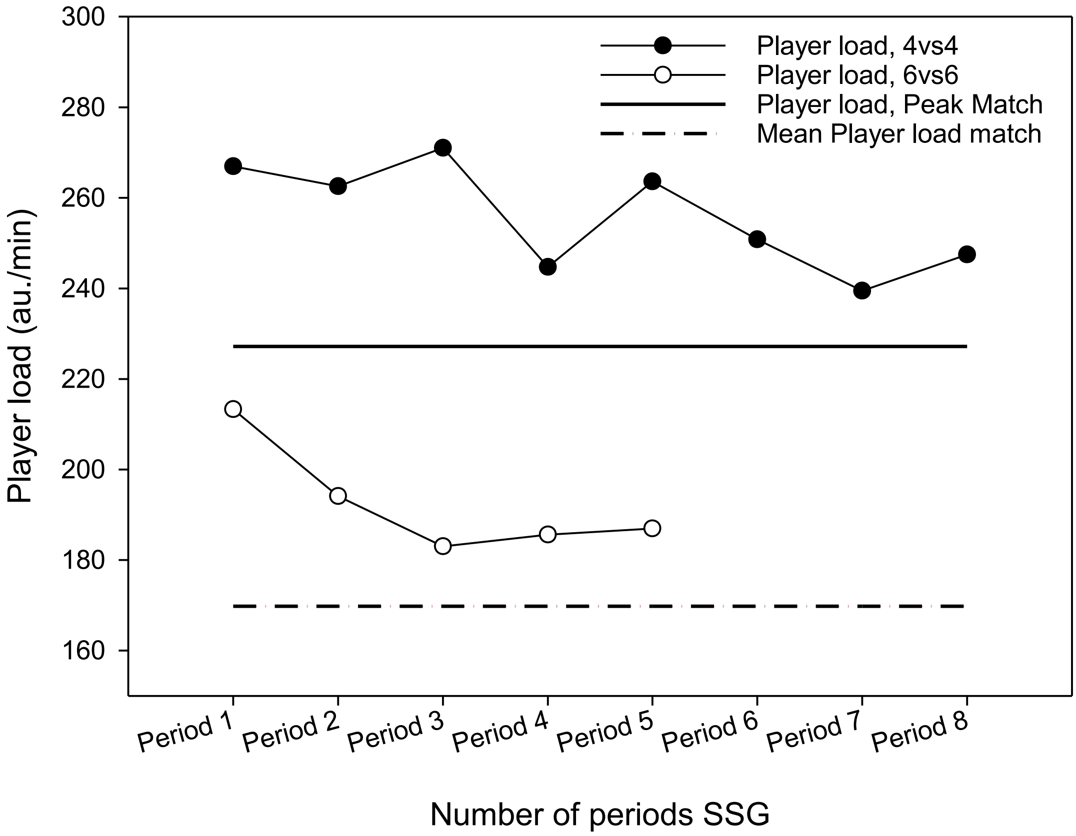

Figure 2. Player load per minute during 5-minute peak in match, 90-minutes match, 4vs4 and 6vs6 in training. Data are presented as mean ± standard deviation.

HIR were significantly lower than peak match during all of the eight periods of 4vs4 in training (3,51 ± 3,05 m, 3,22 ± 3,12 m, 3,97 ± 3,93 m, 3,06 ± 4,08 m, 4,12 ± 3,34 m, 5,70 ± 8,96 m, 3,65 ± 4,66 m, 3,73 ± 4,28 m), and also significant lower in all five periods of 6vs6 (2,80 ± 2,63 m, 2,64 ± 2,26 m, 2,59 ± 2,46 m, 2,33 ± 2,43 m, 2,89 ± 2,03 m) (Figure 3). Furthermore, all of the periods in both 4vs4 and 6vs6 in training were shown to be significant lower than means of a full match.

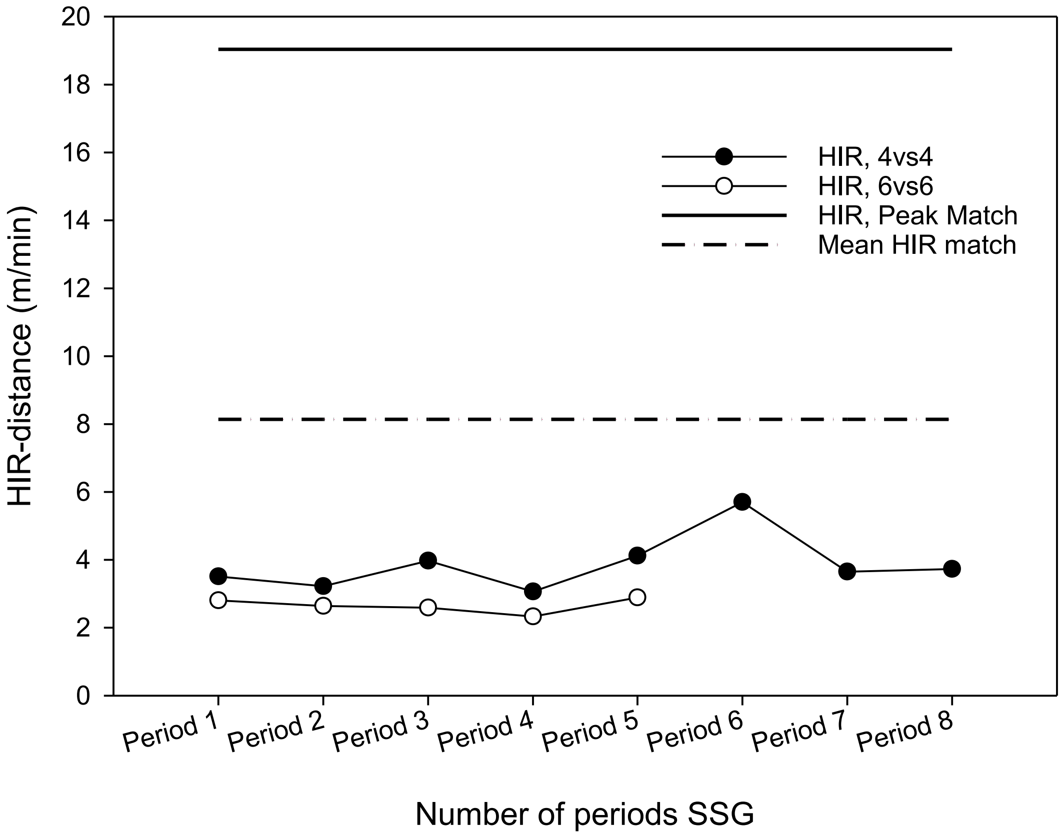

Figure 3. Meters of high intensity running per minute during 5-minute peak in match, 90-minutes match, 4vs4 and 6vs6 in training. Data are presented as mean ± standard deviation.

TDC was significantly lower during all of the eight periods of 4vs4 in training (122,18 ± 11,49 m, 116,37 ± 13,73 m, 122,76 ± 13,59 m, 115,03 ± 15,63 m, 121,39 ± 9,70, 115,61 ± 10,03 m, 115,43 ± 10,50 m, 117,96 ± 15,27 m) compared with 5-minute peak in match (Figure 4). Furthermore, all of the five periods of 6vs6 in training (108,16 ± 10,61 m, 97,81 ± 32,05 m, 95,57 ± 30,98 m, 97,46 ± 34,03 m, 110,28 ± 8,16 m) were significantly lower than 5-minute peak in match, and also significant lower than means of a full match.

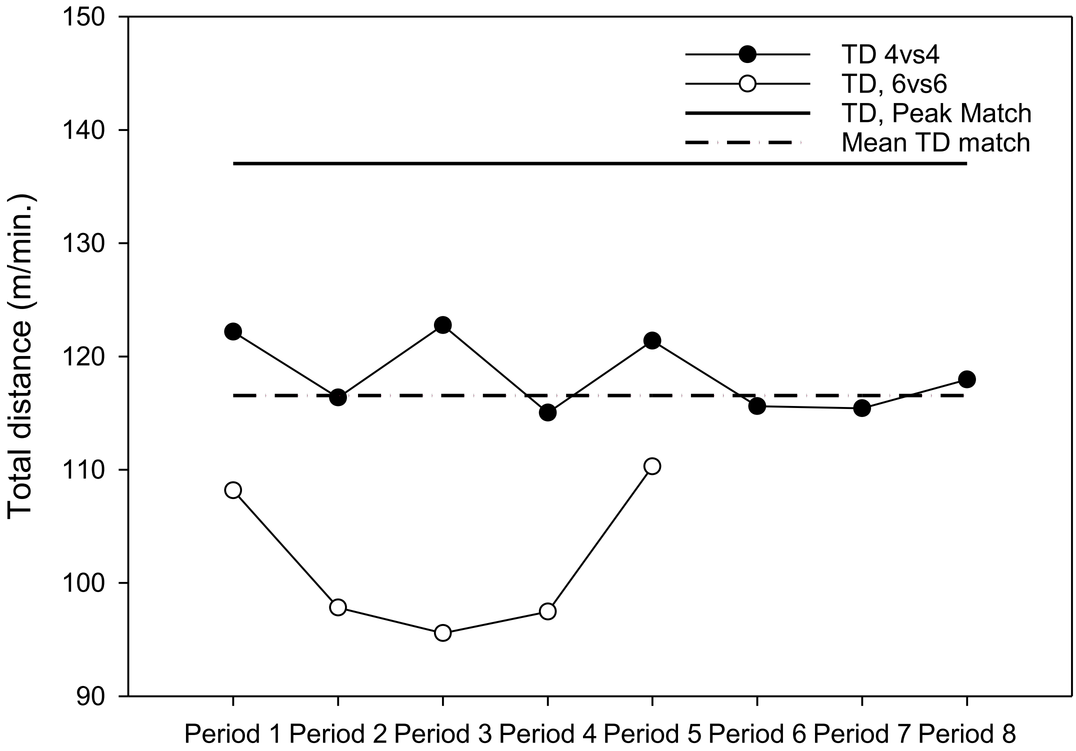

Figure 4. Meters of total distance covered per minute during 5-minute peak in match, 90-minutes match, 4vs4 and 6vs6 in training. Data are presented as mean ± standard deviation.

Finally, there were no significant differences in Acc, PL. HIR and TDC found in between periods of neither 4vs4 nor 6vs6.

Positional differences in SSG versus match

Table 2. Number of Acc, meters of HIR, PL and TDC per minute during 5-minute peak in match, 90-minutes match, 4vs4 and 6vs6 in training.

		ACC n/min	**PL** au/min	**HIR** m/min	**TDC** m/min
CD	*4vs4*	1,67 ± 0,77#	277,2 ± 65,63#	2,57 ± 3,25*	110,64 ± 7,84*
	6vs6	1,11 ± 0,38	201,19 ± 38,24	2,01 ± 1,92*	101,86 ± 7,84*
	Mean match	0,63 ± 0,09	174,7 ± 30,26	4,59 ± 1,23*	107,41 ± 5,22
	Peak match	1,18 ± 0,18	235,32 ± 47,36	13,37 ± 2,89	125,05 ± 5,34
ED	*4vs4*	1,81 ± 0,77#	234,93 ± 45,39#	4,81 ± 4,24*	120,44 ± 13,68*
	6vs6	1,23 ± 0,47	195,24 ± 21,06	3,33 ± 2,59*	107,19 ± 7,22*
	Mean match	0,71 ± 0,09	160,02 ± 13,7	8,72 ± 2,09*	114,43 ± 10,32
	Peak match	1,39 ± 0,27	220,75 ± 25,96	21,24 ± 5,15	135,9 ± 8,09
CM	*4vs4*	1,79 ± 0,73#	256,06 ± 52,48#	3,77 ± 3,75*	119,89 ± 11,18*
	6vs6	1,33 ± 0,44	215,99 ± 39,3	2,99 ± 2,62*	107,92 ± 9,25*
	Mean match	0,9 ± 0,18	176,68 ± 28,11	8,74 ± 2,47*	124,77 ± 10,47
	Peak match	1,55 ± 0,32	229,94 ± 45,92	19,88 ± 5,35	145,05 ± 12,39
EM	*4vs4*	1,83 ± 0,66#	256,27 ± 50,25#	2,89 ± 2,56*	116,62 ± 14,72*
	6vs6	1,14 ± 0,51	210,71 ± 69,08	3,36 ± 1,71*	99,5 ± 24,52*
	Mean match	0,93 ± 0,19	169,81 ± 16,69	9,76 ± 1.93*	114,43 ± 4,86
	Peak match	1,66 ± 0,33	228,65 ± 33,86	20,22 ± 4,91	137,86 ± 6,52
ATT	*4vs4*	1,92 ± 0,91#	256,9 ± 50,25#	4,32 ± 7,23*	122,18 ± 13,19*
	6vs6	1,31 ± 0,52	205,31 ± 38,56	2,74 ± 2,23*	112,74 ± 12,06*
	Mean match	0,81 ± 0,2	161,88 ± 13,03	8,22 ± 1,37*	115,45 ± 7,79
	Peak match	1,48 ± 0,45	214,01 ± 13	19,83 ± 4,74	135,22 ± 10,56

Data are presented as mean ± standard deviation. CD=central defenders, ED=external defenders, CM=central midfielders, EM=external midfielders and ATT=attackers. # = Significantly higher than 5-minute peak in match. * = Significantly lower than 5-minute peak in match (P<0,05).

Discussion

Accelerations and Player Load

A main finding of the present study was that players performed significant higher in accelerations and player load during 4vs4 in training than match play. The data from this study show that the numbers of Acc were significantly higher during 4vs4 in training than the mean performance in a 90-minute match, and also significant higher than the most intense periods of the matches. The finding share similarities with Castellano and Casamichana (2013) where the players performed more than twice as many accelerations during SSG compared to match play [44]. The authors was using GPS devices and tri-axial sensor accelerometers to monitor the players accelerations during SSG and matches, and like the measuring devices used in the present study, it have been reported with good validity and reliability [42, 43, 45]. However, the formats of SSG in their study are not in line with the formats of the present study where SSG consisted of 4vs4 and 6vs6 play with a relatively pitch size for each player at $128m^2$ and 120 m^2 respectively. Castellano and Casamichana (2013) investigated accelerations in three different format of SSG (3vs3, 5vs5 and 7vs7) with a constant relatively pitch size of $210m^2$ for each player. Due to the differences in SSG formats, such as number of players and pitch size in the two studies, the results may not be completely comparable. However, due to the results presented it may be reason to believe that the players preconditions to perform accelerations during SSG is increased when the relatively pitch size is increasing. This hypothesis is enhanced by the results of the present study showing that the acceleration count during 6vs6 (1,21 per min.) play is significant lower than 4vs4 (1,79 per min.).

Due to a smaller relatively pitch size it may therefore be discussed in what extend the players have the same preconditions to fulfill the four criteria of an acceleration on a smaller area, knowing that the acceleration need to reach a certain speed in a certain time over a certain duration. This assumption is supported in studies done by Moreira A et al. (2016) showing that players in average perform 3,6 accelerations per minute during SSG when playing 5vs5 on a relatively pitch size of each player at $276m^2$ [31]. However shows the results of the present study that the players perform lower on accelerations during match play (0,8/min) on a full size pitch with a relatively pitch size of $334m^2$ per player. This finding is similar to Dalen et al. (2016) and Ingebrigtsen et al. (2015) reporting that elite players in means perform respectively 0,84 Acc/min and 1 Acc/min on a full pitch size during match play [3, 43]. This strongly suggests that the size of the pitch alone is not evidence enough to explain the differences is accelerations performed in the different formats of play. This is further enhanced by the results of the present study, showing that also the acceleration performance during 5-minute peak from matches is significant lower than 4vs4 in training. However, it might be inappropriate to compare Acc performance between periods of SSG with match play, knowing that the continuous time of play during SSG is only up to 3-4 minutes, while the players during match have to play continuous for 45 minutes. It is therefore reason to believe that the player's performance of Acc per minute of play is decreasing when the continuous playing time is extended.

Furthermore are also the players PL shown to be significantly higher during 4vs4 compared with 5-min peak in match. Also, in this case there may be reason to believe that the higher PL is related to a smaller pitch size during SSG, causing a higher frequency of turns, jumps and tackles etc. Nevertheless is PL, in the same way as Acc, significantly lower during 6vs6 than 5-min peak in match. This fact makes it reasonable to assume that a high performance of Acc among players also causes a high PL. However, the author wants to clarify that this assumption needs further investigation. Bangsbo (1994) presented that the physical performance of quickly development of force and power is one out of four important categories measuring physical performance of soccer players. Due to the higher number of Acc and PL during 4vs4 than 5-min peak in match, the present study implies that SSG in training improves physical performance within this category [8]. This means that players are exposed for a high anaerobic turnover, where stored ATP and CP are important contributors, as much as the glycolysis anaerobic system [17]. The relatively higher number of Acc and PL during 4vs4 may be due to a higher neuromuscular fatigue and metabolic cost during match play [46]. Several studies have previously shown that players during SSG in training typically have an internal load consisting of 90-95 % of HRmax (maximal heart rate) [1, 47, 48].

Further, it is reasonable to assume that the players have higher load in a more diverse range of physical parameters during match play, such as sprinting, which is shown to be less relevant during SSG [49]. This is also supported by the relatively low HIR distance during SSG in the present study.

High intensity running

Players in this study showed a significant lower distance per minute of HIR during SSG in training compared with performance from matches. The finding conflicts with Dellal et al. (2012) where HIR were shown to be significant higher during 4vs4 in training compared to match play [33]. It may though be reason to question the player's motivation, due to the fact that Dellal et al. (2012) have collected the data from friendly matches and not competitive matches. The present study share great similarities with Dalen et al. (2016), showing that elite players perform 847 ± 349 (mean ± SD) meters in HIR during a 90-minute match. In addition are the measuring devices (ZXY Sport Tracking System) and the subjects participating in the study similar, but by excluding the high number of low intensity periods during a match HIR were in the present study measured much higher, and therefore caused great differences to the result. To our knowledge, the present study is the first to compare HIR during SSG with the most intense 5-minute period of match play.

The results in the present study may justify claims that SSG (4vs4 and 6vs6) is not a suitable training method to enhance performance of HIR. By not fulfilling the demands that are experienced during the most intense periods of match, it can be discussed in what extend SSG are appropriate in terms of influence physical factors in this category. The significant gap between physical performance in the 5-min peak in match and SSG may be due to several factors, and there is reason to believe that the training effect during SSG can be manipulated by facilitate the external conditions. Rebelo et al. (2016) have shown that players perform a higher amount of HIR when the size of the pitch is increased during SSG [34], while other authors also reporting a higher intensity during SSG when pitch size is increased[40, 50]. On the other hand are González-Rodenas, J., F. Calabuig, and R. Aranda (2015) not reporting any higher intensity when increasing the pitch size during SSG in training [37]. However is the results of the previous studies presented not unambiguously with HIR performance, meaning that a high intensity not neccesary means a high HIR performance. Although, it is reason to believe that the smaller pitch size during SSG in training may be a limiting factor in terms of fulfilling HIR that are experienced during 5-min peak in match play. The pitch size in the present study were 32x32 meters for 4vs4, while 6vs6 were played on a pitch 40x36 meters. It may therefore be questioned if the size of the pitch during SSG is sufficient to perform adequate distance of HIR, suggesting that players need a certain distance before reaching a speed high enough to be categorized as HIR. However, this hypothesis conflicts with the findings in the present study, where HIR during both 4vs4 and 6vs6 where significantly low, but HIR during 6vs6 slightly lower than 4vs4. This may argue that the technical and tactical aspect also plays an important role, or the fact that the relatively playing area for each player actually is decreased during 6vs6. The same argumentation can be used for TDC where the distance covered during 6vs6 is lower than 4vs4, whereas both formats are significantly lower than 5-min peak in match.

Furthermore, the major gap between HIR during 5-minute peak in match and SSG in training may be due to different demands of energy system contribution. The tighter and smaller pitch during periods of SSG may lead to a more continuous type of work on a relatively high intensity, as opposed to the highly periodic type of work that players experience during match play. The lack of sufficient time of recovery during periods of SSG may cause big challenges for the anaerobic alactic energy system in terms of restoring and reproduce CP and ATP for short high intensity actions [17, 20]. The frequency of short high intensity actions may therefore cause impairment in the ability to perform HIR during high intensity periods of SSG, causing lower "tops" of high intensity, and possibly in greater extend taxing the aerobic energy system [1, 8].

The present findings highlights the complexity of the game and does not necessary determine an unambiguously negative training effect on physical factors in SSG. However, it seems to be indisputable that SSG is not an optimal training method to fulfill the demands that are experienced for HIR during 5-min peak in match. SSG may still be an expedient training method for other physical factors, which may be reasoned by a higher player load during 4vs4 despite significant lower performance of HIR. Nevertheless, it is reason to argue whether a high load among players is desirable when performance of HIR is significant lower.

Fatigue during training

The findings showed no differences in performance in between periods of neither 4vs4 nor 6vs6 for any of the categories investigated, and therefore no fatigue was discovered. Previous studies done on fatigue have reported a temporarily fatigue during match, where the most intense 5-minute period of a match leads to a significant lower performance in the following 5-minute period [19, 30]. The "following 5-minute period" in the case of SSG will be when the players have breaks in between periods, and we can therefore not determine a relationship between temporarily fatigue in match and SSG in training. Furthermore have several studies reported fatigue on HIR that occurs in the end of matches [4, 19, 25, 26], which in high extend have been suggested to be caused by reduction of muscle creatine phosphate, an increase of muscle lactate, a lowering of the muscle pH, or that ATP stores only are partially restored. The reasons for the present findings may be due to a lack of overload on HIR during periods of SSG, which also the results from the first main finding support. The deficiency of overload does not cause any impairment in HIR arguing that the intensity during training is not high enough for this variable. Moreira, A., et al. (2016) presented fatigue from the first to the last quarter of play during SSG in training [31]. This finding share similarities with end-game fatigue that occur during matches, but are in conflict with the findings of the present study. The dissimarities may be due to the fact that Moreira, A., et al. (2016) was using youth players as subjects, and also that the HIR category was set to >18 $km \cdot h^{-1}$, and the present study was using >19,8 $km \cdot h^{-1}$.

Furthermore, are the results of the present study showing an overload of Acc and PL during periods of 4vs4 in training. Nevertheless, there is no evidence of fatigue on any of the two variables during periods of 4vs4. The lack of fatigue on Acc and PL may therefore imply that players have the possibility for physiological restoration in between periods, and therefore maintain the ability to perform in the upcoming periods as well. However is the recovery time between periods not evidence enough in terms of explaining the lack of fatigue, knowing that both HIR and TDC were significant lower than 5-min peak in match for all periods played for both 4vs4 and 6vs6, whereas Acc and PL where significantly lower during 6vs6. More apparently is 4vs4 and 6vs6 in the given formats not a sufficient training method with the purpose of high performance of HIR and TDC, and 6vs6 not suitable in terms of Acc and PL performance.

Perspectives

The results of the present study suggest that 4vs4 is a good training method to improve performance of Acc and PL. Acc and PL during 4vs4 are shown to create an overload when comparing to intense period of match play, and in light of this suggesting that 4vs4 is an good training method to improve performance of Acc and PL. Due to the significant lower HIR distance during both 4vs4 and 6vs6 vs match play it may be argued whether SSG is a good training method for this category. The lack of fatigue discovered in between periods of SSG and thus the lack of overload among players in HIR and TDC may prove that 4vs4 and 6vs6 is not an optimal training method in terms of improving the performance in these categories. The lack of fatigue in the Acc and PL suggest that the players have sufficient time to recover between periods of play in SSG. Although several studies have shown a positive training effect on a wide range of physical factors during SSG [1, 32, 37, 40, 41] it is essential to plan training sessions on the basis of which factors one wants to improve. Practical speaking meaning that coaches needs to be aware how different formats of play influence the physical factors differently. In light of the results of the present study, it can be argued that important physicals factors [8] in soccer are insufficient trained during SSG. The coaches' ability to manipulate training sessions on the basis on the prioritized physical factors will therefore be essential in terms of fulfilling the desired training effect. Previous studies show no consensus in what way pitch sizes affect physical factors during SSG, and the lack of consistency in formats of SSG (e.g. pitch size, pitch dimensions, number of players, rules and individual differences) makes it demanding to point out how only one factor may influence physical factors [32-34, 44]. A standardization of the external conditions during SSG among authors in the future will therefore be expedient in terms of getting a better understanding of the effects of SSG in training.

Finally, it is important to be aware that the technical and tactical aspect of the game plays an important role and may affect the physical performance among the players. Based on scoreline, formations, playing system etc. the need for physical performance is highly dynamic and should be taken into consideration among authors/readers.

Study limitations

The analyzed subjects in the present study were all playing for the same team, and therefore participating in the same league and cup competition. However it is reasonable to assume that the result presented in this study also may be applicable to other teams competing in leagues/competitions equivalent to the Norwegian top division or the UEFA Europa League, assumed that the teams that participate represents a relatively equivalent level of performance.

Conclusion

The player's performance of Acc and PL during 4vs4 SSG in training creates an overload when comparing with match play. Furthermore, SSG in training does not cause any fatigue during periods in training among players in Acc and PL. This is most likely is due to the fact that the recovery time between periods is sufficient. Physical performance of HIR during SSG however, does not meet the physical demands of HIR during different periods of match play. Finally, no reduction in HIR distance throughout different periods of SSG in training is most likely due to a lack of overload on this variable.

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