Heart Rate Distribution during Training and a Domestic League Game in Swedish Elite Female Soccer Players

Anna Ohlsson1, Linda Berg2, Hanna Ljungberg2, Kerstin Söderman2 and Britt-Marie Stålnacke1*

1Department of Community Medicine and Rehabilitation, Rehabilitation Medicine, Umeå University, Sweden
2Department of Physiotherapy, Umeå University, Sweden

Abstract

Background: Soccer is a complex sport with high cardiovascular demands. Preparation for the demands of competition often involves game-simulation practice. This is supposed to improve the physiological adaptations. The main purpose of this study was to compare heart rate (HR) distribution among elite female soccer players during in-season training sessions and a game.

Methods: Fifteen players were observed during three regular training sessions, and at a domestic league game using Polar Team2 HR monitors. HR was categorized into HR zones to compare intensities of each activity observed.

Results: HR values were significantly higher during the game (HR mean: 168±9 beats per minute (bpm), HR peak: 189±8 bpm) than during training (HR mean: 134±11 bpm, HR peak: 183±9 bpm, p<0.001). Players spent 55% of the game and 11% of the total training time at high intensity (HR above 90% of HR peak, p<0.001). HR mean and HR peak were significantly higher in the first half compared with the second half of the game (p<0.05).

Conclusion: The present study demonstrates higher HR values and longer duration at high intensity during game play in comparison with training, which indicates higher demands on the players’ internal load during the game. Thus, the results suggest the need to include high intensity exercise sessions during training.

INTRODUCTION

Soccer is a popular sport played by both men and women all over the world. It is a complex sport where sport-specific skills, tactics, and the intermittent activity result in a high load on the cardiovascular system [1-7]. During an elite female soccer game, the players cover an average distance of 10km[3,4] with mean and peak heart rate (HR) values of 81-87% and 97-98% of maximum heart rate respectively [3-6]. The distance and the values are similar to those measured on male players. Numerous physiologically demanding activities are performed during a game such as sprinting, jumping, tackling and changing direction and pace [4,8,9]. Even though the average HR throughout the game is high, soccer players spend a relatively small proportion, less than 10% of the game, in high intensity running. However, this part seems to be an important factor for physical game performance [4,8].

Several studies, predominantly on male soccer players, have quantified the sport-specific skills and various physical elements that influence soccer performance and fatigue during game play and training [2,7,11,13-22]. Lately, due to the increased popularity of women’s soccer, researchers have started to examine and quantify the specific aspects of the female game [2-5,8-10]. It has been shown that elite players of both genders fatigue temporarily during a game and towards the end of the game. This could affect the game outcome since most goals are usually scored during the second half[10].

The individual physiological outcome of exercise is determined by the internal load during a training session. This is dependent on the duration and the intensity of the physiological stress on the players and is affected by their genetic background and training status [16]. To evaluate individual internal load during soccer play, HR monitoring can be used. A relationship...
between HR and oxygen uptake has been demonstrated both in a laboratory test and when measured during soccer play on the field [16]. A commonly used method to quantify the internal load is to define the time spent in different intensity zones based on percentage of HR\(_{\text{mean}}\) during a session [10,21,25]. HR monitoring has been found to be a simple and objective method for this purpose [14-16,20].

Due to the complexity of soccer, it seems important that players are well-prepared for the physical demands of a game and preparation is usually assumed to involve game simulation during practice. However, most studies of HR distribution during soccer play are based on game play while few studies have been published on HR in training sessions, especially as regards female soccer. Therefore it seems essential to study the HR distribution during both training and game play in order to select the training intensity needed to stimulate the cardiovascular system to fit the high intensity demands during a game.

The primary aim of this study was to compare the HR distribution among Swedish elite female soccer players during training and competitive game play. In addition, we aimed to evaluate time spent in the different HR intensity zones and to compare HR during the first and second half of the game.

MATERIALS AND METHODS

HR was individually monitored during three training sessions of a normal in-season training week and the following domestic league game.

Elite female soccer players (n=58), representing three different teams in the Swedish Premier League, were invited to participate in the study. Players who participated in three training sessions and at least 45 minutes of the actual game were included. Twenty of the invited players fulfilled these criteria. After HR collection, 5 players were excluded due to missing or insufficient data. Finally, data from 15 elite female soccer players (age 24±3 years, height 167±6 cm, and body mass 60±4 kg) were analyzed.

Participation was voluntary and before entering the study, the participants were informed, both verbally and in writing, regarding their commitment and the procedure of the study. Written consent was obtained from all participants. The personal data were coded before the data analysis to ensure confidentiality. Approval of this study was granted by the ethics committee of the Medical Faculty of Umeå University (Dnr 2010-332-31M).

The recorded games were played during the 2011 competitive season. The randomly chosen training sessions were part of a normal in-season training week and varied in duration, content, and intensity, without any influence by the authors. The training sessions consisted of intermittent shuttle with drills to improve footwork, running speed, short sided games and game simulation. The measurements included training sessions following a game as well as training in preparation for a game.

The HR was recorded individually with Polar Pro Team2 HR monitors (Polar, Electro Oy, Kempele, Finland) set to record at 1-second intervals. The team system allowed HR monitoring of several participants at the same time. A transmitter belt worn by each individual communicated via Bluetooth to a sideline software for display of multiple players’ HR. The transmitter belts were handed out to all participants just before the start of each of the four sessions and were then collected at the end of the training/game. The devices were checked for wear and tear and cleansed between each use. For each data collection, the players wore the same transmitter belt to prevent load differences. Polar Pro Team2 HR monitors have been used in a number of studies of HR in female and male soccer players [3-6] and HR monitoring has been validated as an indicator of aerobic demand during soccer activities [16].

During the training sessions and the game, each player’s real-time HR was shown on a monitor placed on the sideline of the field, which made it easy to quickly discover any interruption of the measurements. To ensure the correct registration of total game time, the beginning and end of the two halves were registered in the Polar Pro Team2 system. The HR data were processed both in the specific software, Polar Team2, and in electronic spreadsheets (Microsoft Excel 2007, 2010) in order to optimize the use of reliable values. Missing or unreliable data of a total of 14±7 minutes per player were observed and removed from the original data. This corresponded to 2.6-7.8% of the registered time. The missing data might have been a result of poor contact between the chest and the transmitter belt, cross-talk between equipment when the players stood too close to each other, or other unidentifiable disturbances. Warm up was recorded as part of the training sessions but not for the game since our measurements for the period included team activity. The measurements during training sessions included warm up as this was the time teams spent on practising technical drills. None of the teams dedicated time before practice for specific warm up drills as prior to a game. Prior to the game, warm up was individual and diverse among the players and was therefore excluded from the measurements.

HR\(_{\text{peak}}\) was defined as each individual’s maximum HR collected either during training or the game. HR values were divided into six intensity zones: >95%, 95-90%, 90-85%, 85-75%, 75-60%, and <60% of the individual HR\(_{\text{peak}}\) [2]. In this study, the exercise intensity at HR above 90% of HR\(_{\text{peak}}\) is defined as high intensity exercise in accordance with Castagna et al. [26]. HR\(_{\text{peak}}\), HR\(_{\text{mean}}\), total training time, game time, and percentage of the total training/game time in the different intensity zones were calculated for the whole game, each half separately, and for the three training sessions altogether. To adjust for minor differences in the amount of training and game data among the players, all averages are expressed as relative terms (the corresponding % HR\(_{\text{peak}}\) and % HR\(_{\text{mean}}\)).

STATISTICS

The processed data were analyzed using Predictive Analytics Software (PASW) Statistics for Windows version 18.0 (SPSS Inc., Chicago, IL, USA). Due to the difference in duration between the game and the training sessions, most analyses were made with relative HR values. A statistical data evaluation was performed with non-parametric tests as the sample was small and not normally distributed. Thus Wilcoxon Signed-Rank Test was used for related samples and bivariate correlations were calculated with Spearman’s correlation coefficients. The level of statistical significance was set at p<0.05. Descriptive statistics are
presented as mean±standard deviation (SD). Fifteen participants were estimated to provide a power of 80% with an α of 5% to detect a significant difference in the time spent over 90% of HRpeak between training and game playing. However, since we expected a large drop-out rate due to our strict inclusion criteria (i.e. completion of three full practice sessions and completion of at least 45 minutes of the game), we invited three teams with a total of 58 players to participate.

RESULTS AND DISCUSSION

The duration of the total training time (3 sessions) was 189±19 minutes with a HRmean and HRpeak of 134±11 and 183±9bpm respectively, corresponding to 71% and 97% of the individual HRpeak. The duration of the game was 90±8 minutes and the mean duration of playing time was 70 minutes with HRmean of 168±9 corresponding to 89%of HRpeak(Table 1).

Mean and peak HR values were significantly higher in the game compared with training (p<0.001). When comparing the time spent in the different intensity zones; we found an inverse relationship between training and the game. There were significant differences between the relative time spent in the different intensity zones in five of the six intensity zones. Significant higher values were found in each of the two lowest intensity zones, 75-60%, and <60% of HRpeak (p<0.05) during training, while significant higher values were presented during game in each of the three highest intensity zones 100-95%, 95-90% and 90-85% of HRpeak (p<0.001) (Figure 1).

The total time spent at high intensity HR>90% of HRpeak in the game was 49±14 minutes representing 55% of the game time and in training (3 sessions) 21±15 minutes corresponding to 11% of the training sessions. A positive correlation was found between the training sessions and the game when comparing the percentage of time spent at high intensity HR>90% of HRpeak (r=0.89, p<0.001) (Figure 2). Hence, the more time the players had spent in high intensity during training, the longer they could sustain at high intensity levels during the game.

The % HRmean and %HRpeak were significantly higher in the first half compared with the second half of the game (Table 1). The significant reduction occurred in the time spent in the intensity zone above 95% (p<0.05) (Figure 3).

This study shows a significant discrepancy between the cardiovascular demands during the game and practice with higher values in HRmean and HRpeak during the game situation than during the training sessions. The total time spent at high intensity was considerably higher during the game (54% of the

<table>
<thead>
<tr>
<th>Session</th>
<th>HRmean</th>
<th>%HRmean</th>
<th>HRpeak</th>
<th>%HRpeak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>134±11</td>
<td>71±5%</td>
<td>183±9</td>
<td>97±2%</td>
</tr>
<tr>
<td>Game</td>
<td>168±9</td>
<td>89±3%</td>
<td>189±8</td>
<td>100±0%</td>
</tr>
<tr>
<td>First half</td>
<td>169±9</td>
<td>90±3%</td>
<td>188±8</td>
<td>100±1%</td>
</tr>
<tr>
<td>Second half</td>
<td>167±9</td>
<td>89±3</td>
<td>186±8</td>
<td>98±2</td>
</tr>
</tbody>
</table>

a) Significant difference compared to the game (p<0.001) 
b) Significant difference compared to the second half (p<0.05)
The players spent the majority of time above 85% of HRpeak during the game in contrast to the training where they spent the majority of time below 85% of HRpeak. Although some previous studies have investigated HR during games [4,6] and training separately, to our knowledge, this study is the first to compare the HR distribution (intensity) of a competitive game with that of training in female elite soccer players.

Concerning the time spent at high intensity during the game, the players in the present study spent more time at high intensity when compared with previous results of Swedish female soccer players and also when compared with male players [18]. Yet, these studies were based on friendly games and not competitive games which may have affected the results. Several studies have focused on HR during training [21,26]. Our results of HR distribution seem to be in line with the results reported by Castagna et al. [26], who found that professional male players spent 8% at high intensity (>90% of HRpeak) during 6 weeks of pre-championship training. The authors speculated whether 8% at high intensity of the total training time is the amount of high intensity training that can be tolerated during a training period. Interestingly, this amount of high intensity during training has also been observed in elite cyclists [27], endurance runners, and cross-country skiers [28]. These studies emphasize the importance of studying the total internal load on players during a training period.

In addition to the differences in HR intensity between the game and training in the present study, a positive correlation was found between time spent at high intensity during the game and the training sessions. A possible explanation is that the effect of training at high intensity enhances the increase in aerobic physical capacity compared with exercise at lower intensities [14,18,26,29]. For example, Helgerud et al. [13] and Krustrup et al. [5], who have examined different aspects of female soccer players during game play, the authors point to the importance of focusing training on improving the ability to do repeated exercise at high intensity. Traditionally, a lot of time is spent on technical and tactical drills which are mainly low intensity activities. In the present study, the HRpeak during the training sessions was 134 bpm corresponding to 71% of the individual HRpeak which is clearly higher than that shown by Jeong et al. [21] who reported intensity differences between averages of pre-season training at 64% of HRpeak and in-season training at 58% of HRpeak. Furthermore, Eniseler [18] compared the average HRin male players between different sessions such as a soccer game (157 bpm), modified game (135 bpm), tactical training (126 bpm), and technical training (118 bpm), suggesting that there are also differences in intensity depending on the specific aim of the training. When compared with these values, the average HR value in our female players was higher during the competitive game (168 bpm).

It is difficult to generalize about the internal load during soccer training sessions when the number of sessions, aim, intensity, and content differ. With this in mind, we chose to measure multiple in-season training sessions during the same week to include several types of training aims that, in our opinion, could reflect the average of the internal load during a week.

Previous research has classified a large proportion of the activity during a soccer game as low intensity activity [3,4,8-10], such as standing, walking and jogging [11]. Although players are engaged in these types of low intensity activity during a game, our results show high HR values throughout the game. These observations are in line with the results reported by Dellal et al. [7], hypothesizing that recovery bouts during a soccer game are too short to lower HR. Their results explain high HR during the game with large energy costs and high anaerobic facilitation which is a physical state that over a prolonged period of time can lead to fatigue.

In the present study, HRpeak was significantly higher in the first half than in the second half of the game. This finding is in accordance with results in previous studies showing a tendency towards higher HR values in the first half compared with the second half [10]. Lower lactate concentrations have been documented in the second half both in female [5] and male players [30], suggesting a reduction in the number of high-intensity activities. Furthermore, the second half and especially the last 15 minutes of the game seem to be the critical point in time since studies have shown that during this time, the amount of intense running decreases and most goals are scored [3,4,8]. These are factors that are of great significance to the player and game outcome and several studies attribute them to fatigue [5,17,30]. Thus, in order to improve the capacity of playing at high intensity during the game, it seems important to include high-intensity activities during training.

To measure the internal load and the physical strain on the players, we used HR monitoring which has been shown to be a valid and simple method [13]. While no examination of each player’s HRpeak was made by the soccer team’s medical staff, we chose to use the individual HRpeak as the player’s maximum HR value since it has been shown that the HRpeak in a soccer game is approximately 97-98% of HRpeak [3-5]. This needs to be taken into consideration when interpreting the results from our study. However, the bpm values are easy to compare and the results of the bpm in our study during game play are in line with previous studies on female soccer players [3-5]. Some weaknesses with HR monitoring have been pointed out by MacArdle et al. [24]. The authors draw attention to individual variances in HR due to e.g. genetic differences, motivation, mental stress and day-to-day variances that need to be taken into consideration when interpreting the HR values. Furthermore, Bangsbo et al. [11] noted that tactical changes made during a game are also factors that might influence the variability of the HR values. In our study, we noticed that poor contact between the chest and the transmitter belt was probably one of the reasons for the missing and unreliable data of almost 15 minutes per player. However, since these data were removed, these values did not affect the results in our study. On the contrary, one significant advantage of the HR monitoring technique of team systems is that it makes it possible to register and study the response of several players taking part in exactly the same playing situation. This particular advantage of field-testing makes up for some of the disadvantages of using HR as a sole estimator of internal load during soccer play.
HR monitoring technology makes it possible to quantify the internal load during intermittent exercise in team sports. It can be a helpful tool for coaches to control the aim of the training and periodization strategies to keep players well-prepared for both training and games throughout the season. It is yet to be seen how much practice time athletes can sustain at high intensities for beneficial game qualities, avoiding overtraining, decreasing game injury rate, and improving stamina so as to last 90 minutes rather than 75 minutes of game time. In addition, vital information can be obtained to avoid overtraining or under-stimulation of the cardiovascular system during games and training.

Moreover, since the sample size in the present study was rather small, we can only generalize our results to a limited extent. However, we have described the strict inclusion process and the number of included players fulfilled the estimated number by the power calculation. In addition, the number of players seems to be consistent with other studies of HR in soccer players [4,6,16,21]. Although the time studied could have been longer, the three training sessions studied varied in time and content and included training in preparation for a game. In addition, we also studied a game. However, warm up was recorded only as part of the training sessions, since our measurements included team activity and teams were practising technical drills during warm up. Prior to the game, warm up was individual and diverse among the players and therefore excluded from the measurements.

The Polar Team 2 system has been used in a number of studies of both female and male soccer; however, we cannot rule out potential systematic distortions. In order to fully investigate the use of the Polar Team 2 system in future studies for monitoring exertion during performance testing, we may need to collect data over a longer period of time and in a sample with more players.

CONCLUSION

Our findings of higher HR values and longer duration at high intensity during game play in comparison with training indicate higher demands on the players’ internal load during the game. Players who had spent more time in high intensity during training could sustain longer at high intensities during the game. It therefore seems of importance to emphasize the need of including high intensity exercise sessions during training.

REFERENCES

1. Stålnacke et al. (2015)

Email: britmarie.stalnacke@rehabmed.umu.se


5/6


