

Heart Rate Responses during Small-Sided Soccer Games

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Abstract

The purpose of the present study was to examine the heart rate responses during small-sided games with different number of players. Sixteen professional soccer players were evaluated for body fat (%) using the skin fold thickness at three sites, VO_2 max and running velocity at the lactate threshold using an incremental treadmill protocol. %HRmax was measured during four-, five-, six-, seven-, and eight-a side soccer games. The four-a-side game showed significantly ($p < 0.05$) higher %HRmax in comparison to the other small-sided games. On the other hand, the %HRmax of the eight-a-side game was significantly lower ($p < 0.05$) than three-, four-, five-, six-, and seven-a-side game. The intensity of small-sided games decreases as the number of players increase. The monitoring of heart rate during small-sided games combined with laboratory VO_2 max tests is a possible way to define target training intensity zones.

Keywords: Soccer; Intensity; Small-sided games

Introduction

It is common during the daily soccer training to perform games with a limited number of players on each team in a smaller area of the pitch. These small-sided games develop physical abilities, as well as technical and tactical skills [1-3]. As far as physical condition is concerned, small-sided games develop aerobic capacity [1,4-6]. Small sided-games are an equally effective mode of aerobic training as interval running [1] and short duration intermittent running [4]. Other important characteristics of small-sided games training mode are environmental and competitive conditions similar to actual match-play [2,7].

An important research question is how the training intensity, as measured by heart rate (HR) responses, is differentiated among the small-sided games. Previous investigators have shown that the relative pitch size area per player, coach encouragement, the number of players on each side, the number of ball touches and the use of goalkeepers influence the intensity of small-sided games [3,7-9]. Although several studies have examined the effects of the above factors using soccer players of different ages, training experience, level of competition, divisions and National leagues, limited data exists on the influence of each of these factors separately on elite soccer players [1,2,7,9,10]. Elite soccer players present higher physical condition level compared to amateurs and other players from lower divisions, which may affect positively their physical effort during various small-sided games. The knowledge of physical effort during various small-sided games allows coaches and trainers to better control the training process, and develop effective daily and weekly training plan. In this context, it is necessary to develop a better understanding of the drill intensity on elite soccer players as the number of players differentiates the effects of small-sided games with different number of players at the physiological levels.

The purpose of the present study was to examine the heart rate responses during small-sided games with different number of players (four-, five-, six-, seven-, and eight-a-side) in elite professional soccer players. It is hypothesized that heart rate responses should decrease as the number of players increase, from four- to eight-a-side.

Methods

Participants

Sixteen elite Greek professional soccer players participated in the study. All participants belonged to the same club and they had similar

soccer training programs. All players were informed of the purpose of the study and gave their informed consent according to the Declaration of Helsinki.

Experimental design

A within subjects experimental design was used to examine the intensity of small-sided games with different number of players (four-, five-, six-, seven-, and eight-a-side) in soccer players. Although, the

number of the players, the duration, and the pitch dimensions were different among the five training drills that could affect the research design, this research approach compares the effectiveness of five small-sided games on heart rate responses. The within-subjects design helped to control for subject variability, such as anthropometric and physiological characteristics. Initially, participants were evaluated in endurance characteristics, such as VO_2 max, running velocity at the lactate threshold, and %HRmax at the lactate threshold using an incremental treadmill protocol. Then, their %HRmax was recorded during small-sided games with different number of players (four-, five-, six-, seven, and eight-a-side game) for four weeks.

Soccer players were trained through daily small-sided games with different number of players according to the training's goals (both physical and tactical). The in-season weekly training program included six training sessions in five days, an official match (usually on Sunday), and a free day after the match (on Monday) [11]. Technical staff organized the players into respective teams according to the tactical needs. Four-, five-, six-, seven, and eight-a-side games with the ball always replaced promptly when out of play [7]. Players participated in the small-sided games as part of their normal training and for this reason the order of games was not randomized. All small-sided

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games were played outdoors. The size of the pitch and the duration for each small sided game are presented in Table 1 and were according to previous studies [4,5,7]. In every training session, participants were informed of the aim of each small-sided game, and they encouraged maximum effort [7]. The limitations for all small-sided games were: two touches for each player, pass and sprint, and press the ball. The coach provided continuous encouragement during all small-sided games. All training sessions were conducted in the afternoon. No extreme environmental conditions (heat or cold) were observed during data collection. All small-sided games were performed after a 15 min warm-up. Warm-up was not standardized, but it was according to the goals of training. Participants were informed to maintain their normal diet, with emphasis on high fluid and carbohydrate intakes [2,7].

Heart rate was recorded every five seconds during each training session using downloadable, frequency coded heart rate watches (Polar S610, Kempele, Finland). After each training session, the heart rate data were downloaded to a PC, and were analyzed using POLAR software program by the same investigator. The mean percentage of maximum heart rate (% HRmax) of each small-sided game was calculated for each participant during each small-sided game. Each small-sided game was administered at least three times in a four week period. Maximal heart rate for each player was established using a VO₂ max test, as described below. No significant differences were observed in resting HR in all soccer players during the four week data collection period.

Laboratory measures

At the beginning of the first week, all participants were evaluated for body fat, VO₂ max, and running lactate threshold velocity.

Anthropometrics Characteristics: Height was measured to the nearest 0.1 cm using a stadiometer, and body mass was measured to the nearest 0.1 kg. Skin fold thickness was measured at right sites using a Harpenden skinfold calipers. Skin fold sites were chest, abdomen, and thigh. Body fat percentage (%) was calculated according to standard equations [12,13].

VO₂ max and lactate threshold: Expired gas analysis and blood lactate curve analysis were used for determination of VO₂ max and lactate threshold at fixed blood lactate concentration (4 mmol/L), respectively [14-16]. Warm up consisted of a 6 min run at 8 km/h (level treadmill grade) without gas analysis, where heart rate and blood lactate were measured. During this time, the metabolic cart (TrueMax 2400, ParvoMedics) was calibrated using known calibration gases, and volume also was calibrated with a 3-L syringe (Hans Rudolph). Then, the initial speed was set at 10 km/h and it was held constant for 3 minutes. Thereafter, speed was increased by 2 km/h for every 3 minutes until 16 km/h and then speed was increased 2 km/h for every 2 minutes until volitional exhaustion. During testing, expired gases were continuously analyzed using 30-s intervals and at the end of each stage, subjects stopped for 20 seconds for blood lactate determination (Accutrend lactate analyzer, Roche Diagnostics). Analyzers were calibrated each day using known standards. Running speeds (V-4mM) corresponding to fixed whole blood concentration of 4 mmol/l were calculated using linear interpolation [16,17]. Maximal oxygen uptake was determined by attaining at least 3 of the following 4 criteria: RER in excess of 1.10, maximal heart rate within +5% of age-predicted HRmax, a plateau in oxygen uptake despite increase in work rate, and max lactate concentration >8 mmol/l. The highest VO₂ value obtained during the test was considered as the VO₂ max. Heart rate was measured throughout the test using a Polar heart rate monitor.

Statistical analysis

Data was analyzed using the SPSS PC program (ver. 14.0) for windows. Mean ± SD were calculated. A repeated measures ANOVA followed by Bonferroni post-hoc test for pair-wise comparisons was applied to examine any differences in %HRmax of soccer players among the five small-sided games (four-, five-, six-, seven-, and eight-a-side). Statistical significance was accepted at p<.05.

Results

Anthropometric characteristics, VO₂ max, and running velocity at lactate threshold is presented in Table 2.

A repeated measures ANOVA revealed significant effect of the type of small-sided game (four-, five-, six-, seven-, and eight-a-side) on % HRmax (F_{4,60}=129.120, p<0.001, power = 1, η² = 0.896). Bonferroni's post-hoc test for pair-wise comparisons revealed that the four-a-side game led to significantly (p<0.05) higher % HRmax in comparison to the other small-sided games (Table 3).

Discussion

The determination of %HRmax in soccer drills is a popular approach to monitor the intensity of small sided game [2,3,6,7,10]. The present study focuses on the influence of different types of small-sided games (four-, five-, six-, seven-, and eight-a side) in the exercise intensity of elite Greek soccer players. The findings of the present study

Small-sided games	Size	Duration
4 vs 4	30m X 40m	4 set X 4 min, 2 min rest
5 vs 5	35m X 45m	4 set X 6 min, 3 min rest
6 vs 6	40m X 50m	3 set X 7 min, 3 min rest
7 vs 7	50m X 60m	3 set X 8 min, 3 min rest
8 vs 8	50m X 60m	3 set X 8 min, 3 min rest

Table1: Size and duration characteristics of small-sided games.

Endurance Characteristics	n=16
Age (y)	25 ± 5
Body Mass (kg)	75.7 ± 5.3
Height (m)	1.79 ± 0.06
Body Fat (%)	9.3 ± 2.1
VO ₂ max (mL/kg/min)	60.1 ± 2.8
HRmax (bpm)	186.4 ± 8.5
Running Velocity at the LT (km/h)	13.8 ± 0.3

VO₂ max indicates the maximal oxygen uptake; HRmax indicates the maximum heart rate; LT indicates the lactate threshold

Table2: Anthropometric and endurance characteristics of elite Greek soccer players (M ± SD).

Small-sided games	%HRmax (n = 16)
Four-a-side	93.5 ± 1.7*
Five-a-side	90.7 ± 2.5*#
Six-a-side	89.7 ± 2.1§
Seven-a-side	88.1 ± 3.1*§,†
Eight-a-side	85.3 ± 2.2*§,†

* p < 0.05 significant differences between 4 vs. 4 and 5 vs. 5, 6 vs. 6, 7 vs. 7, and 8 vs. 8 small-sided games

p < 0.05 significant differences between 5 vs. 5, and 7 vs. 7, 8 vs. 8 small-sided games

§ p < 0.05 significant differences between 6 vs. 6, and 7 vs. 7, 8 vs. 8 small-sided games

† p < 0.05 significant differences between 7 vs. 7 and 8 vs. 8 small-sided games

Table3: Percentage of maximum heart rate (% HRmax) during small-sided games with different number of players (M ± SD).

suggest that the intensity of small-sided games, as measured by the %HRmax, decreases as the number of players increase, from four- to eight-a-side.

The higher intensity among the small sided games was observed in four- a side small game compared to five-, six-, seven-, and eight-a side small game. Similarly, Rampinini et al. [7] have reported a significant increase in the intensity of a four- side small game compared to a six- a side small game. Other factors that may contribute to the change of the intensity in small-sided games are the field dimensions, coach encouragement, number of touches and goalpost, pressing, and the presence of goalkeepers [3,5-8,10].

In the present study, the percentage (%) of HRmax during the four-, five-, and six- a side game was 93%, 90% and 89%, respectively. Previous studies have reported lower % HRmax during all of these small-sided games [2,7]. Rampinini et al. [7] have reported 89.4%, 88.8%, and 87% of HRmax in four-, five-, and six-a-side small-sided game, respectively. Little and Williams [2] have found a 90.2%, 89%, 87.8%, and 88.5%, in four-, five-, six-, and eight-a-side small-sided games. It is possible the different results among the present and the previous two studies are attributed to the different training experience of participants [amateur in the study of Rampinini et al. [7]], the rules of the small-sided games [free number of touches in the studies of Rampinini et al. [7] and Little and Williams [2]] and the size of the field [Rampinini et al. [7] and Little and Williams [2]]. Recent studies [3,10] have confirmed these results. Dellal et al. [3] have reported that the number of ball touches authorized per possession affects the soccer player activity, whereas the same research group [10] has found that amateurs covered less total distance with respect to sprinting and high intensity running compared to international players. The field dimensions are an important factor affecting the intensity of small-sided games [6,7]. The higher %HRmax during four-, five- six-, and eight-a-side small-sided games compared to previous studies [Rampinini et al. [7] and Little and Williams [2]] might be attributed to the larger field dimensions used in the present study.

Important endurance parameters are the VO_2 max, the running velocity at the LT, and the %HRmax at the LT [16,18]. Helgerud et al. [19] have suggested that VO_2 max is related to the work rate in a soccer match. The current VO_2 max values (60.1 ml/kg/min) are comparable with VO_2 max values of soccer players from different National leagues [18,20]. Running velocity at the LT and the %HRmax at the LT are important endurance characteristics as well, because the average intensity of a soccer match is close to the anaerobic lactate threshold [21]. Previous studies have reported that the running velocity at the LT is a critical endurance factor among teams with different ranking in the championship [16]. Previous studies from other championships have reported higher running velocity at the LT (14.67 Km/h) in British professional youth soccer players [15], and lower (13 Km/h) in Spanish professional (1st division) soccer players [20].

Except to the evaluation of endurance performance characteristics from the laboratory VO_2 max tests, another significant purpose of them is the determination of individual HR- VO_2 relationship that may better analyze the metabolic demands of the sport specific exercises. Heart rate itself can be considered indicative of the physiological effort and can be used to define target exercise intensity zones. A previous study [22] has reported a practical link between the monitoring of %HRmax at small-sided games combined with the identification of HRmax, %HRmax at lactate threshold, from the laboratory VO_2 max measurements [22]. The validity of HR monitoring to determine the

metabolic demands during soccer exercises was high, especially in the range between 80% - 90% of HRmax [22]. So, coaches can monitor the daily training intensity of the soccer drills and can test the produced intensity for increasing endurance performance.

As far as intensity is concerned, the weekly pattern reaches a peak by mid-week and then tapers off in order to obtain peak performance in the match [23]. That is why in the present study high intensity small sided-games (4v4 and 5v5) were organized mid-week (Wednesday and Thursday), whereas lower intensity games were played at the beginning or by the end of the week. This ensures that soccer players were at top fitness level by the end of the week, before the official match.

In conclusion, the monitoring of %HRmax in soccer drills, using heart rate monitors, is a popular approach to determine the intensity of the small-sided game. The intensity of small-sided games, as measured by the %HRmax, decreases as the number of players increase, from four- to eight-a-side. The monitoring of %HRmax at small sided-games combined with the endurance characteristics may evaluate the training intensity of these soccer drills. The usefulness of monitoring the intensity of small-sided games for coaches is to determine the training intensity and to design and plan the daily and weekly training sessions.

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