

MEASURES OF EXERCISE INTENSITY DURING SOCCER TRAINING DRILLS WITH PROFESSIONAL SOCCER PLAYERS


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ABSTRACT. Little, T., and A.G. Williams. Measures of exercise intensity during soccer training drills with professional soccer players. *J. Strength Cond. Res.* 21(2):367–371. 2007.—Recent evidence supports the use of certain soccer drills for combined technical and physical training. Therefore, it is important to be able to accurately monitor training intensity during soccer drills intended for physical development to allow the optimization of training parameters. Twenty-eight professional soccer players were assessed for heart rate (HR) and rating of perceived exertion (RPE) responses to 5 commonly used soccer training drills (2v2 to 8v8 drills). The responses of both HR and RPE differed significantly ($p < 0.05$) between the drills, generally showing an elevated response to drills involving lower player numbers. However, the 2v2 drill showed a significantly ($p < 0.05$) lower HR response (mean \pm SD: $88.7 \pm 1.2\%$ HRmax) than 3v3 ($91.2 \pm 1.3\%$ HRmax) and 4v4 drills ($90.2 \pm 1.6\%$ HRmax). There was no significant correlation between the HR and RPE responses to the various drills ($r = 0.60$, $p = 0.200$). This poor relationship is probably because during the 2v2 drill, RPE was higher than during any of the other 6 drills, whereas HR was only fourth highest of the 6 drills. This demonstrates that HR and RPE are only poorly related during the intense drills used in this study, and that HR underestimates the intensity of the 2v2 drill. Heart rate demonstrated lower intersubject variability (1.3–2.2%) than RPE (5.1–9.9%). However, unlike HR, Borg 15-point RPE appears to be a valid marker of exercise intensity over a wide range of soccer training drills by maintaining validity in all drills and demonstrating acceptable intersubject variability. A combination of both HR- and RPE-based training load calculations appears optimal for use in soccer training.

KEY WORDS. football, heart rate, perceived exertion

INTRODUCTION

occer performance is dependent on a multitude of factors. Of these, technical skill and the physical capacity of players are known to exert a major influence on match performance. If both these capacities could be trained simultaneously using soccer games, it would be an extremely effective use of training time and physical load. Nevertheless, a number of presuppositions have meant that endurance capacities of soccer players have traditionally been trained using running drills without a ball. Principally, soccer games were not believed to provide sufficient exercise intensity to effectively improve the physiological mechanisms important in soccer endurance (16, 27). However, numerous authors (2, 4, 16, 21, 26) have now observed training intensities deemed appropriate for endurance training (8) during various small-sided soccer games. Also, comparable improvements in endurance performance were observed following a 6-week program of a small-sided soccer games program and a running program (25). As movements during soccer drills

are sporadic and difficult to control externally, there was also a concern that variability in work rate between players may be relatively high, increasing the risk of some players training at inappropriate intensities. However, recently Little and Williams (21) observed a number of soccer training drills that exhibited low variability of relative heart rates (HRs) across players and on repetition of a drill.

If soccer training drills are to be used increasingly as a method of physical training, it is important that we are able to accurately monitor training intensity. Accurate evaluation of training intensity allows us to better tailor training to prevent undertraining or overtraining and to ensure that players are in peak condition for competition. Heart rate monitoring is an increasingly common method of monitoring training load in soccer. There was concern that factors inherent in soccer training, such as emotion, high tensile strain, and intermittent activity, may lead to HRs that represent a higher intensity than actual workload (5). Ogushi et al. (23) reported that $\dot{V}O_2$ estimated from HR was 25% higher than actual $\dot{V}O_2$ during a 90-minute simulated friendly game, but the use of heavy Douglas bags, short gas collection times, and only two subjects makes interpretation of their results difficult. On the contrary, comparison of $\dot{V}O_2$ -HR relationships during laboratory conditions on an incremental treadmill test and during 5-a-side soccer games (10, 17) and a soccer-specific circuit (14) indicated that HR monitoring is a valid indicator of metabolic expenditure during soccer activities. Furthermore, Drust et al. (12) reported similar average HR and $\dot{V}O_2$ during intermittent exercise reproducing a soccer game and continuous running at the same average speed. However, in soccer training drills that have a high anaerobic component, evidence suggests that HR monitoring may underestimate the intensity of the drill. Aroso et al. (2) found that altering a training game to induce more intense conditions produced increases in blood lactate levels without concomitant increases in HR.

Rating of perceived exertion (RPE) is a simple and cheap method of monitoring exercise intensity. The literature indicates that RPE is strongly correlated with other measures of exercise intensity, such as HR, lactate, and $\dot{V}O_2$ (11). Impellizzeri et al. (18) monitored 479 soccer training sessions and concluded that RPE was a valid indicator of training load, based on correlations with HR-derived training loads. Their results also suggest that RPE may give a more reliable measure of exercise intensity than HR when both anaerobic and aerobic systems are appreciably activated, as they are in the majority of soccer drills. Drust et al. (12) found a similar $\dot{V}O_2$ and HR during intermittent exercise on a treadmill simulating

soccer match activities compared to continuous exercise at the same mean intensity, although ventilation and RPE were significantly higher during the intermittent protocol. The authors suggest that this may be because of the greater contribution of anaerobic energy during the intermittent protocol.

No published studies have examined different methods of monitoring exercise intensity during varied soccer training drills with professional players. Therefore, the current study aims to monitor physiological responses of professional soccer players during several soccer training games (21) using HR and RPE. The data will be used to evaluate the concurrent validity of HR compared to RPE as a measure of intensity in various types of soccer training drills. It is hypothesized that HR will underestimate the intensity of soccer drills that involve near-maximal intensity. Therefore, it is hypothesized that Borg RPE will give the most accurate overall reflection of exercise intensity over a range of soccer drills of varying intensities. The soccer training drill intensities will also be analyzed to evaluate whether they result in physiological responses suitable for soccer endurance training based on current recommendations in the literature (17).

METHODS

Experimental Approach to the Problem

Professional soccer players were assessed for HR and perceived exertion responses to a range of soccer training drills. All soccer drills and structures (exercise periods) were chosen from pilot work and a previous study (21), with the intention of producing a moderate to high exercise intensity. The exercise intensity of each drill was also compared to current recommendations in the literature regarding suitability for soccer endurance training.

Subjects

Twenty-eight professional soccer players from an English Division One club (the second highest of 4 fully professional leagues in England) volunteered for the study. Mean (\pm *SD*) age, height, body mass and percentage body fat (skinfold method of Jackson and Pollock [19]) were 24 (5) years, 182.6 (\pm 7.8) cm, 80.2 (\pm 5.8) kg, and 8.1 (\pm 1.9)%. Mean (\pm *SD*) performance characteristics of the subjects were vertical jump 43.2 (\pm 5.2) cm, 10-m acceleration 1.77 (\pm 0.06) seconds, and 20-m flying sprint 2.28 (\pm 0.08) seconds (for more detail of the procedures used here only for descriptive purposes, refer to Little and Williams [20]). All participants gave their informed consent and the Sport, Health, and Exercise ethics committee at Staffordshire University approved the study. Participants were familiar with all procedures used prior to the study.

Procedures

All participants performed 6 training drills as part of their normal training within the middle 3 months of the 9-month competitive phase of the annual cycle. The specific training drills used for the study were chosen from a suite of training drills used regularly at the club, after consultation with the club management. The soccer training drills used (shown in Table 1) involve a moderate to high work intensity and have been shown to produce consistent HR responses in professional soccer players (21). Participants were informed of the drill structure and the simultaneous aims of skill and fitness training in order to encourage maximum effort. Coaches were present and provided encouragement during all drills. As is usual in

TABLE 1. Structures of the soccer drills used in the study.

Drill	Structure	Pitch size (yd)
2v2 game	4 \times 2 min, 2 min rest	30 \times 20
3v3 game	4 \times 3.30 min, 1.30 min rest	43 \times 25
4v4 game	4 \times 4 min, 2 min rest	40 \times 30
5v5 game	4 \times 6 min, 1.30 min rest	45 \times 30
6v6 game	3 \times 8 min, 1.30 min rest	50 \times 30
8v8 game	4 \times 8 min, 1.30 min rest	70 \times 45

6
7 – Very, very light
 8
9 – Very light
 10
11 – Fairly light
 12
13 – Moderately light
 14
15 – Hard
 16
17 – Very hard
 18
19 – Very, very hard
20 – Exhaustion

FIGURE 1. Borg 15-point rating of perceived exertion scale.

professional football clubs, no vigorous training drills were utilized within 24 hours of competition. All drills were conducted in the morning as the first part of training, following an initial warm-up. Participants were asked to maintain their normal diet, which emphasized high fluid and carbohydrate intakes.

Heart rate was monitored telemetrically using 5-second intervals during the drills (Polar Electro, Kempele, Finland). All subjects were instructed to regularly check that their monitors were functioning correctly, and investigators were on hand to deal with any problems that arose. Mean percentage of maximum HR (% HR_{max}) during the working periods was calculated for each participant during each drill. Rest periods between exercise bouts were excluded from the analysis. Maximal HRs for each player were established using an incremental maximum HR field test and were confirmed with a maximal incremental endurance test (Yo-Yo Intermittent Recovery Test), both described by Bangsbo (6).

Subjects' RPE was assessed using the Borg 15-point scale (Figure 1). Meta-analysis of the literature indicated that this method of measuring perceived exertion gave the most valid indication of exercise intensity (11). For a period prior to testing, subjects were educated and familiarized with the use of the Borg 15-point scale in theory and practical lessons that included anchoring of the scale to levels of exercise intensity. Subjects' RPE was recorded on an individual basis following completion of each drill.

Statistical Analyses

Repeated measures analysis of variance and Newman-Keuls post hoc tests were used to identify differences in

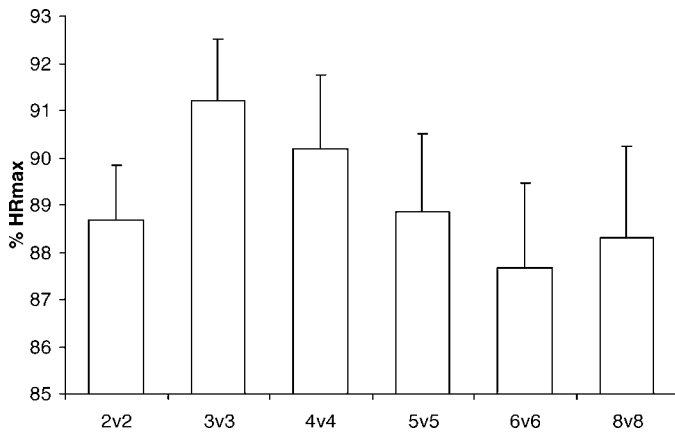


FIGURE 2. Percentage of maximum heart rate (% HRmax) for the various soccer drills ($n = 28$). Bar heights are mean values, and error bars are *SD* values. The only nonsignificant comparisons were 2v2 and 5v5, 2v2 and 8v8, and 6v6 and 8v8.

the physiological responses between the different training drills. Pearson correlation was used to determine the relationship between the HR and RPE responses to the soccer drills. The correlation was calculated using the mean values (that is, all subjects were combined to provide 6 mean HR values—1 for each drill). Interindividual variability of the different measures of exercise intensity for each drill was quantified using the coefficient of variation (COV; *SD* divided by the mean, expressed as a percentage). To assess the influence of the type of soccer drill on the interindividual variability in exercise intensity, the COV results were also correlated with the number of players per side in the soccer drills. All data analyses were performed using SPSS (version 11.5.0; SPSS, Inc., Chicago, IL). Statistical significance was accepted at $p \leq 0.05$.

RESULTS

Heart Rate

Heart rate responses for the different soccer training drills are illustrated in Figure 2. There were significant differences ($p < 0.05$) between all training drills except for just 3 of the 15 post hoc comparisons (2v2 and 5v5, 2v2 and 8v8, 6v6 and 8v8). There was generally an increased HR response to the drills using fewer players, although the 2v2 game showed a significantly lower response than 3v3 and 4v4. The HR responses in the present study are typically higher than previous studies (2, 4, 17).

Rating of Perceived Exertion

Subjects' RPE following the different soccer training drills is shown in Figure 3. There were significant differences ($p < 0.05$) between the different training drills with only 3 of the 15 post hoc comparisons (3v3 and 4v4, 5v5 and 8v8, 6v6 and 8v8) not demonstrating significant differences. There tended to be increased RPE in response to the drills that involved fewer players.

Correlation Between Heart Rate and Rating of Perceived Exertion Responses

The correlation between HR and RPE was $r = 0.60$ ($p = 0.200$) and this non-statistically significant relationship is shown in Figure 4. The clear outlier at 88.7% HRmax and 16.2 RPE represents the responses to the 2v2 drill.

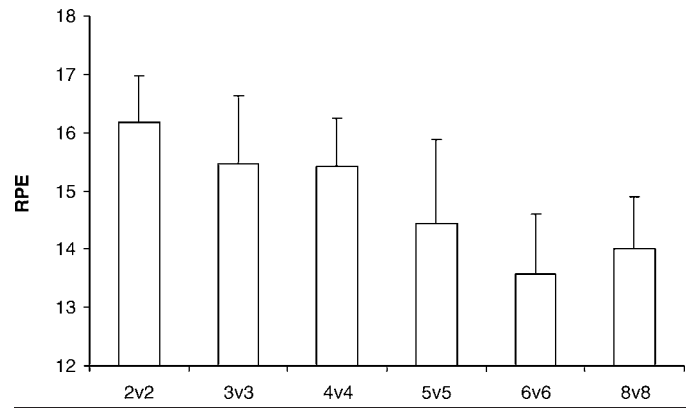


FIGURE 3. Borg rating of perceived exertion (RPE) scores for the various soccer drills ($n = 28$). Bar heights are mean values and error bars are *SD* values. The only nonsignificant comparisons were 3v3 and 4v4, 5v5 and 8v8, and 6v6 and 8v8.

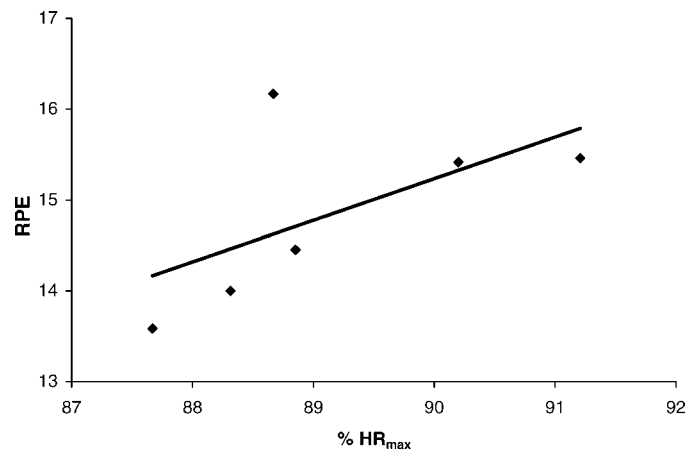


FIGURE 4. Relationship between mean percentage of maximum heart rate (% HRmax) and mean rating of perceived exertion (RPE) using the 6 mean values derived from all 28 subjects. $r = 0.60$, $p = 0.200$.

TABLE 2. Coefficients of variation (%) for the heart rate (HR) and rating of perceived exertion (RPE) responses to the different soccer drills.

	2v2	3v3	4v4	5v5	6v6	8v8
HR	1.3	1.4	1.7	1.9	2.0	2.2
RPE	5.1	7.6	5.4	9.9	7.5	6.4

Coefficient of Variation

The COV values of both HR and RPE measures of intensity are illustrated in Table 2. The COV values for both HR and RPE results are low, and showed a general trend of increasing as the number of players in the soccer drill increased. Indeed, HR COV showed a significant correlation ($r = 0.98$, $p = 0.001$) with the number of players in the soccer drill, although the COV for RPE showed only a weak, nonsignificant relationship with the number of players ($r = 0.25$, $p = 0.632$).

DISCUSSION

Recent evidence suggests that certain soccer training drills are appropriate for combined technical and soccer-specific endurance training. Therefore, it is important that sport scientists and coaches are able to accurately gauge the intensity of soccer drills to enable the appli-

cation of optimal training parameters and periodization strategies. The results from the present study suggest that HR is generally a valid method of monitoring training intensity in soccer games but may have limited usefulness in shorter, more intense drills. Borg 15-point RPE appears to be a valid marker of exercise intensity over a range of soccer training drills.

Both measures of intensity follow the same basic pattern across the different soccer drills. Significant differences exist between the responses to the drills in each measure of intensity in that HR and RPE responses both tend to decrease as the number of players in the drill increases. However, Figure 4 shows a clear outlier relative to the linear regression line (showing a high RPE:HR ratio compared to the other drills) and this point represents the 2v2 drill. This would suggest that HR had underestimated the intensity of the 2v2 drill. The 2v2 drill involved only 2-minute work periods, as pilot studies had indicated that severe fatigue ensues after such periods because the drill involves continual high-intensity work. Heart rate responses to sudden changes in intensity are not immediate (1), and during maximal intensity drills, the short duration means that a significant proportion of the exercise time is spent with the HR transcending to a steady-state level. Furthermore, the relationship between HR and energy expenditure becomes nonlinear at very high intensities (3). Therefore, mean HR may underestimate exercise intensity in short-duration, maximal-intensity soccer drills. For mean HR to be a valid measure of intensity, soccer drills may need to be of sufficient duration to produce steady-state HR levels for a significant portion of the exercise period. Varying methods of determining exercise intensity from HR in very-high-intensity drills may have to be adopted, such as using peak HR or analyzing the last portion of the exercise period. This area requires further research.

RPE appears to be a valid marker of exercise intensity for all the soccer drills tested. It is quick, noninvasive, and cheap, and an RPE-based training load system (15) has been validated for soccer training (18). One potential limitation to the use of RPE is that players may perceive the same physiological stimulus differently as a consequence of their psychological state (9). This can be useful as a potential marker of overtraining (15), but may lead to inappropriate training intensities because of temporary alterations in mood.

Although the use of HR monitoring appears to be limited in very-high-intensity drills and is not always feasible because of issues such as technical expertise and cost, its benefits remain considerable. Modern telemetric systems allow rapid and precise analysis of the whole exercise period, and there are several validated methods of calculating training loads from HR (7, 13, 22). Also, real-time feedback is possible, so appropriate adjustments to intensity can be made immediately rather than retrospectively. Many endurance training methods are defined by target HRs. Although RPE can be associated with certain training zones, HR provides a more objective and definitive method of prescribing and assessing training intensity. Furthermore, as approximately 90% of energy during soccer competition is derived from aerobic sources (6), a significant proportion of soccer training drills are aerobically based, so HR will be a valid indicator of exercise intensity for the vast majority of training.

We did in fact also measure the capillary blood lactate response to the 6 soccer training drills in a small subgroup of 4 athletes. However, we did not report these data

earlier in this paper because of the low sample size for this variable. Nevertheless, there tended to be an increased blood lactate response to the drills that involved fewer players, thus suggesting a similar pattern to the HR and RPE responses. However, even in this small subgroup of athletes, we observed very large interindividual variations in blood lactate—especially in drills that involved a greater number of players, such as the 8v8 drill that showed a COV of 36.7%. As player numbers increase, activity becomes more intermittent and sporadic as the proportion of direct involvement in play decreases. Therefore, mean blood lactate responses may be misrepresentative of individual exercise intensities, especially during the more intermittent soccer training drills. This topic could be investigated further using a greater sample size.

Based on HR, all the soccer drills tested in the present study produced intensities deemed appropriate (16, 24) for developing aerobic properties important to soccer endurance (17). Based on the high RPE responses to the 2v2 drill, this drill may be more suited to developing anaerobic energy pathways. The COV for HR showed a significant correlation with the number of players in a soccer drill. This was probably because of the smaller-sided drills requiring more continuous involvement in play and less tactically-based movement, so activity for all players during those drills was probably more homogenous. When training groups of players, as in soccer drills, it is important that all players work at similar intensities so that they all receive the optimal training loads. Therefore, soccer drills with a moderate number of players are probably more appropriate when using soccer drills for combined technical and endurance training.

PRACTICAL APPLICATIONS

Heart rate monitoring and Borg 15-point RPE both appear to be valid measures of exercise intensity during many soccer training drills. Although HR monitoring probably is the most advantageous method of monitoring exercise intensity, it appears to underestimate intensity in soccer drills that have shorter duration and induce fatigue rapidly. Therefore, strategies need to be adopted to account for this. A combination of HR- and RPE-based training load calculations may be optimal.

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