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Article

THE WITHIN-PARTICIPANT CORRELATION BETWEEN PERCEPTION OF EFFORT AND HEART RATE-BASED ESTIMATIONS OF TRAINING LOAD IN ELITE SOCCER PLAYERS

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ABSTRACT

The measurement of relative physiological stress during training is important because this is the stimulus for the long-term adaptive response. Measurements of perceived exertion (RPE) have been reported to correlate with the heart rate during field-based training sessions. Nevertheless, there are few studies on how well RPE tracks with the heart rate over repeated training sessions in elite soccer players. Therefore, we aimed to quantify the within-participant correlations between variability in session-RPE (sRPE) and the heart rate in elite male soccer players, and to determine whether the playing position moderated these correlations. The field-based training of four central defenders, four wide defenders, six central midfielders, two wide midfielders and three attackers from an elite English Premier League squad were monitored over an entire in-season competitive period, giving a total of 1010 individual training sessions for study. Correlations between session-RPE and heart rates were quantified using a within-participant model. The correlation between changes in sRPE and heart rates was $r=0.75$ (95% CI: 0.71-0.78). This correlation remained high across the various player positions (wide-defender, $r=0.81$; central-defender, $r=0.74$; wide midfielder, $r=0.70$; central midfielder, $r=0.70$; attacker, $r=0.84$; $P<0.001$). The correlation between changes in RPE and heart rates, measured during a season-long period of field-based training, is high in a sample of elite soccer players.

KEY WORDS: *training intensity, team sports, elite, position*

INTRODUCTION

Exercise training is an adaptive process in response to the progressive manipulation of the training load. While there are many moderators and mediators of the training response, performance enhancement is generally achieved through a planned manipulation of the training load (a product of the volume and intensity of training) (Manzi et al., 2010). Consequently, the accurate assessment of an individuals training load is imperative for effective training prescription.

Training load can be quantified by recording both the internal and external loads imposed upon the individual player (Impellizzeri et al., 2004). The physiological strain resulting from the external training factors has been labelled the internal training load (Viru & Viru, 2000). Therefore, valid and reliable indicators of internal training load are essential to monitor the training process. Several approaches based on heart rates have been formulated in an attempt to quantify the internal training load across a range of sports (Banister, 1991; Edwards, 1993; Foster, 1998; Foster et al., 2001). While the heart rate represents a valid means through which the exercise intensity is measured in endurance sports (Åstrand & Rodahl, 1986), the method is questionable in team sports such as soccer, where the overall training load can comprise more short-term high load components (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Furthermore, full heart rate monitoring systems can be expensive for squads, there can be poor compliance by players to use the monitors and the transmitter belts cannot normally be worn during competition (Lambert & Borresen, 2010).

Session-RPE (sRPE) represents an easier to implement and cheaper alternative to heart rate systems for quantifying training loads (Foster et al., 2001). The sRPE has been reported to be a valid indicator of global internal load of training during both endurance type sports (Foster, 1998) and intermittent team sports such as soccer (Casamichana, Castellano, Calleja, San Roman, & Castagna, 2013; Impellizzeri et al., 2004). To date, studies in which the relationship between sRPE and HR-based estimations of training has been quantified in soccer have principally involved sub-elite level players monitored over a small number of training sessions under well controlled conditions (Alexiou & Coutts, 2008; Casamichana et al., 2013; Impellizzeri et al., 2004). To the present authors' knowledge, only one research group has quantified the correlation between the two methods in elite soccer players undertaking various forms of field based soccer-specific training over extended periods of time (Fanchini et al., 2015), which is important for generalisation to the 'real world' domain of elite-level soccer. However, it is also important in longitudinal studies of "tracking" to quantify within-participant correlations according to the most appropriate statistical approach, which models the longitudinal dataset as a whole using the correct degrees of freedom, rather than by calculating correlations for individual players (Atkinson et al., 2011; Bland & Altman, 1995; Lazic, 2010).

In elite players, marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in activity which is highly dependent upon aerobic metabolism (Bangsbo, 1994) compared to central defenders and strikers where a high proportion of activity is supported by anaerobic metabolism (Di Salvo et al., 2007;

O'Donoghue, 1998). Recent observations indicate a poorer relationship between sRPE and HR-based estimations of training load during training sessions which incorporate short-term high-intensity efforts (Campos-Vazquez et al., 2014). The limitations of using heart rates for monitoring the intensity of these types of efforts may extend to affecting the magnitude of the correlation between sRPE and heart rate-load during training. Therefore, the purpose of the current investigation was to quantify the within-participant correlation between the sRPE and heart rate methods for estimating training load in elite soccer players across a typical in-season competitive phase and to determine the influence of playing positions on the magnitude of this correlation.

METHODS

Experimental Approach to the Problem

Nineteen elite-level players were monitored during a full competitive playing season. Players were assigned to one of five positional groups: (central defenders (n = 4, wide defenders (n=4), central midfielders (n=6), wide midfielders (n=2) and attackers (n=3)). A total of 1010 individual training observations were undertaken on outfield players (goal-keepers were excluded) across the entire in-season competitive period (43 weeks) with a median of 55 training sessions per player (range: 21-102). Training observations for each positional category were: central defender ((n) = 179), wide defender (218), central midfielder (313), wide midfielder (76), and attacker (224)). Only data derived from team field-based technical and physical training sessions were analysed. Matches, individual rehabilitation sessions and individual fitness sessions were not included for analysis.

Subjects

Data were collected from 19 soccer players (mean ± SD: age 27 ± 5.1 years, body mass 78 ± 6.2 kg, height 181 ± 7.1 cm) competing in the English Premier League during the in-season competition period. All players were notified of the aim of the study, research procedures, requirements, benefits and risks before giving written informed consent. The Ethics Committee of Liverpool John Moores University approved the study.

Data Collection

sRPE training load: the sRPE training load was computed by multiplying training duration (min) by the sRPE as described by Foster et al. (2001) (Table 1). Each player's sRPE was collected in isolation where possible, to avoid the potential effects of peer pressure ~20 minutes after each training session. This ensured that the perceived effort reflected the whole session and not the most recent exercise intensity. All the players were familiarised with the use of the scale during the pre-season training phase.

<p style="text-align:center; color:red;">****Table 1. near here****</p>

Heart-rate training load*:* individual player heart rate was recorded every 1 s during each training session using individual coded heart rate monitors (Team^2, Polar Electro, Kempele, Finland). After each training session, the individual heart rate monitors were downloaded onto a PC using Polar Team^2 software (version 1.4.5). The individual heart rate data were subsequently exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U. S.). The current study utilised the

heart rate-based training load method proposed by Edwards (1993) as used by Foster (1998) to validate the use of sRPE training load to monitor endurance training. This heart-rate based method has also been employed as a criterion measure to examine sRPE in the non-steady state and prolonged exercise (Foster et al., 2001; Impellizzeri et al., 2004). The Edwards method (Edwards, 1993) was applied to heart rate data recorded during the 43-week in-season competitive phase. Internal training load was quantified by measuring the product of the accumulated training duration (minutes) of five separate heart rate zones by a numerical factor relative to each zone (50-59% [HR_{max}] = 1, 60-69% = 2, 70-79% = 3, 80-89% = 4, 90-100% = 5) and then summating the results.

Statistical Analysis

Data are expressed as means ± S.D. Within-participant correlations were calculated between sRPE load and heart rate-load (Bland & Altman, 1995). Rather than pooling all the data, or calculating correlations separately for individual participants, this approach quantifies the correlation, and associated 95% confidence interval (95% CI), between a covariate and outcome while taking into account the within-participant nature of the study design. This longitudinal modelling approach is based on the correct degrees of freedom, and is therefore associated with higher statistical precision than the averaging of Pearson's correlations for individual players. The latter approach also violates the assumption of case independence necessary for a Pearson's correlation. To interpret the magnitude of correlation between the two variables, the following criteria were applied: ($r < 0.1$) trivial, ($0.1 < r < 0.3$) small, ($0.3 < r < 0.5$) moderate, ($0.5 < r < 0.7$) large, ($0.7 < r < 0.9$) very large, ($r > 0.9$) almost perfect, and ($r = 1$) perfect (Viru & Viru, 2000). Statistical analyses were carried out

using the SPSS statistical analysis software for Windows (version 19.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The overall training load across the observed sessions was 229 ± 105 arbitrary units (AU) and 132 ± 57 beats/min for sRPE and heart rate-load, respectively. Overall, the changes in sRPE training load were highly correlated with the changes in heart rate-load (r=0.75; 95% CI 0.71-0.78; $P<0.001$). Playing positions had little influence on the correlations between measurement methods. Within-participant correlations between sRPE and heart rate-load were large and very large in magnitude for central defenders (r=0.74, $P<0.001$, 95 % CI 0.70-0.77; Figure 1), wide defenders (r=0.81, $P<0.001$, 95 % CI 0.78-0.84; Figure 2), central midfielders (r=0.70, $P<0.001$, 95 % CI 0.66-0.74; Figure 3), wide midfielders (r=0.70, $P<0.001$, 95 % CI 0.66-0.74; Figure 4) and attackers (r=0.84, $P<0.001$, 95 % CI 0.82-0.86; Figure 5).

****Figure 1. near here****

****Figure 2. near here****

****Figure 3. near here****

****Figure 4. near here****

****Figure 5. near here****

DISCUSSION

The purpose of the current study was to quantify the correlation between the variability in sRPE and a heart rate-based method for quantifying the internal training load in elite soccer players, encompassing both technical and physical field-based soccer drills during daily training sessions, and to determine the influence of playing position on the magnitude of this correlation. The large correlation (r=0.75; 95% CI 0.71-0.78; *P*<0.001) between the overall sRPE and heart rate-load observed in the present study compares favourably with the moderate-large associations (r=0.50 to r=0.85) observed in young amateur (Impellizzeri et al., 2004), semi-professional males (Casamichana et al., 2013) and elite female (Alexiou & Coutts, 2008) and male soccer players (Fanchini et al., 2015).

Previous attempts to quantify the correlation between sRPE and heart rate-load are limited to some extent by suboptimal statistical approaches, including pooling all of the data over time for calculation of single correlation with inflated degrees of freedom, or quantifying correlations for individual players and calculating a sample mean correlation, which lacks statistical power (Atkinson et al., 2011). The 'within-subjects' correlations employed in the current study, and large number of data sets collected on a daily basis from elite-level professional English Premier League players may therefore give a more accurate representation of the relationship between the two measured variables observed in elite-level soccer.

While the heart rate represents a valid means through which to measure exercise intensity in endurance sports (Åstrand & Rodahl, 1986), the method is questionable in team sports such as soccer where the overall training load frequently comprises

anaerobic components (Impellizzeri et al., 2004). Indeed, this may partly account for the failure to observe a higher correlation between sRPE training load and HR-derived training load in the current study, and in previous studies which have compared the two methods during activities involving a high anaerobic contribution (Casamichana et al., 2013; Fanchini et al., 2015; Impellizzeri et al., 2004). In line with such observations, Campos-Vazquez and colleagues (2014) recently reported that the magnitude of the relationship between sRPE and HR-based estimations of training load was dependent upon the type of training session undertaken. Moderate correlations (r=0.35 to 0.55) were observed between the two methods during high-intensity sessions involving explosive drills (e.g., accelerations, changes of direction, jumps) and small side games (5 *vs.* 5 to 8 *vs.* 8) compared to very large correlations (r=0.73 to 0.87) during tactical based sessions (e.g. 11 *vs.* 11) incorporating a higher proportion of aerobic activity. Players observed in the current study were regularly exposed to a variety of training drills. These were in the format of pre-training activation type drills, small-sided games, which were varied according to organisational parameters enforced by the coaches (ranging from 4 *vs.* 4 to 9 *vs.* 9 formats), high-intensity running drills and speed endurance training. The anaerobic conditioning component inherent with these types of drills may therefore have reduced the magnitude of the correlations between sRPE and heart rate-load observed in the current study.

Marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in low to moderate-intensity aerobic activity compared to central defenders and strikers who are characterised to a greater extent by short, high-intensity

anaerobic bouts (Di Salvo et al., 2007; O'Donoghue, 1998). Given the limitations inherent in using the heart rate for monitoring the intensity of anaerobic exercise, differences in the aerobic and anaerobic contribution to energy provision between playing positions may influence the magnitude of the correlation between sRPE and heart rate-load. A further aim of the present study therefore was to examine whether these differences in physical demands between different positions influences the magnitude of the correlation between session-RPE and heart rate-load. Playing positions had little influence on the magnitude of the relationship with the within-individual correlation ranging from large (r = 0.70) in central and wide midfielders to very large (r =0.74 to 0.84) in the remaining positions. These findings may, to some extent, reflect a lack of position-specific training undertaken as part of the methodology implemented by the coaches in the present team. As noted above, a high proportion of small-sided games (4 *vs.* 4 to 9 *vs.* 9) were employed which reduce the degree to which players participate in 'set' positions on the field of play. These drills were supplemented with both position-specific and non-position-specific high-intensity running and speed endurance drills (with and without the ball) in order to prepare players for the most critical and/or intense periods of the games. Since match data was not included in the current study and 11 v 11 type drills formed a relatively small proportion of the weekly training time (e.g. pre-game day) it is possible that the degree of position-specific training was not sufficient enough to influence the correlation between session-RPE and heart rate-load. Further work is needed in order to determine whether the magnitude of the correlation between session-RPE and heart rate-load is influenced by playing position during training drills which demand a position-specific focus.

PRACTICAL APPLICATIONS

The present study findings indicate that session-RPE shows promise as a simple and practical global indicator of individual training load in elite-level soccer players irrespective of playing position. Session-RPE and heart rate-load are highly correlated and do reflect the internal training load stressors elicited on individual players.

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Table 1. Category ratio rating of perceived exertion (RPE) scale utilised in the current study(CR-10 scale) Foster et al. (2001).

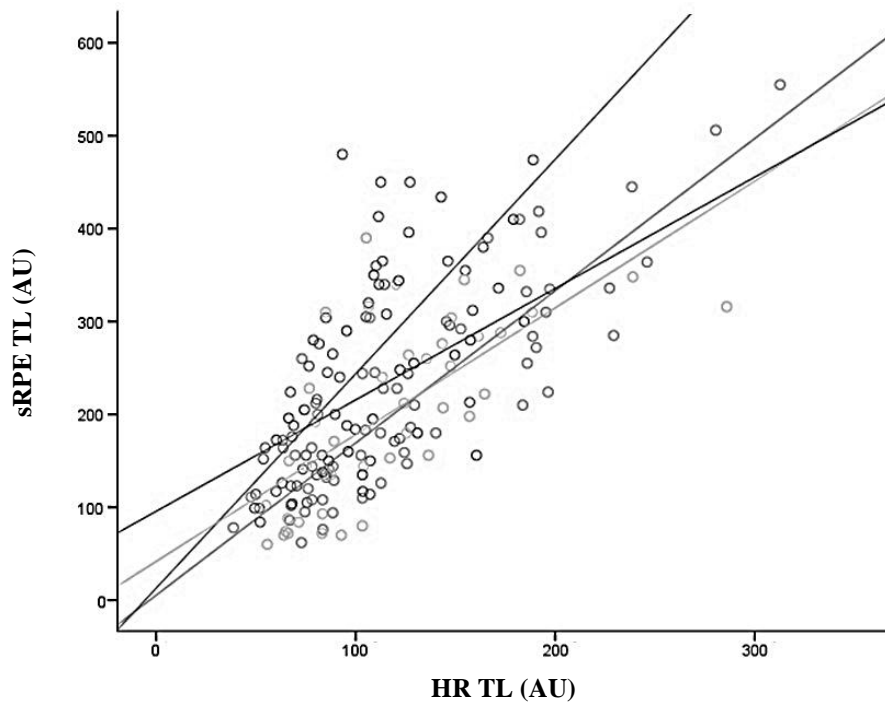| Rating	Descriptor
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal

Figure 1. Relationship between the sRPE TL and HR TL for *central defenders* (r = 0.74; *p*<0.001).

Figure 2. Relationship between the sRPE TL and HR TL for *wide defenders* (r = 0.81; *p*<0.001).
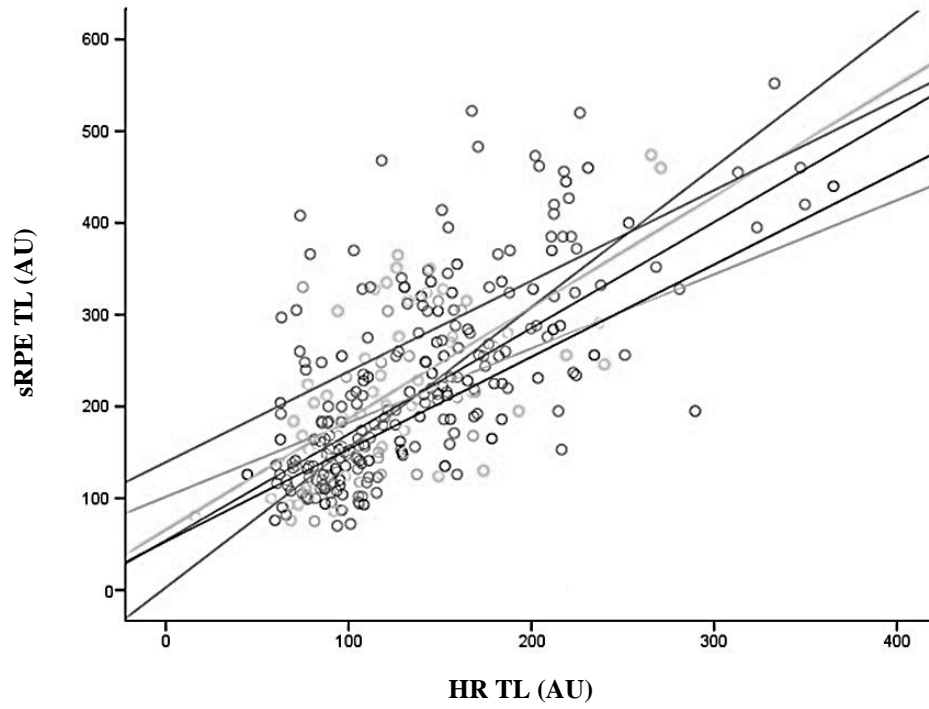
Figure 3. Relationship between the sRPE TL and HR TL for *central midfield* players (r = 0.70; *p*<0.001).
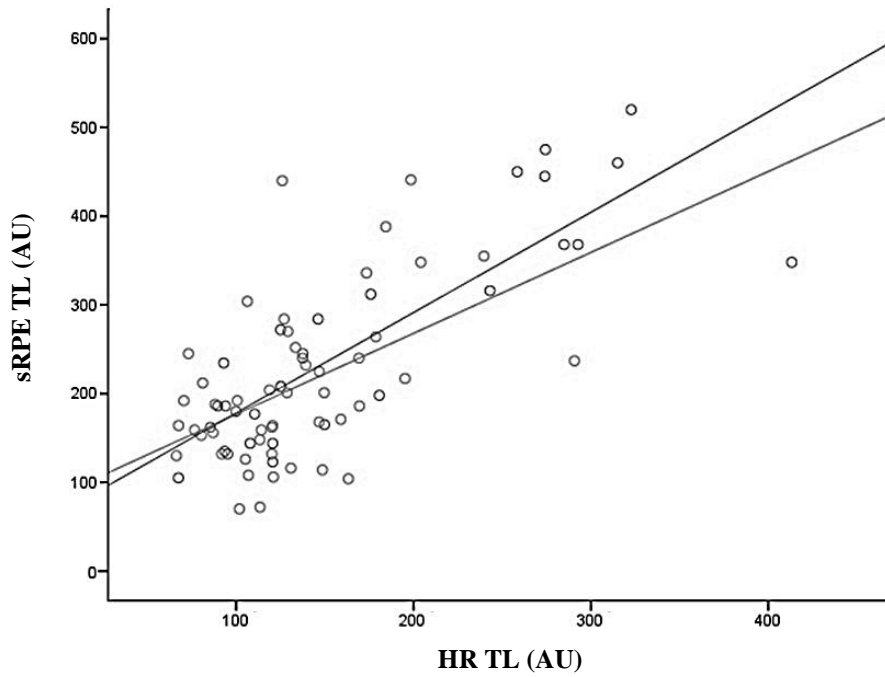
Figure 4. Relationship between the sRPE TL and HR TL for *wide midfield* players (r = 0.70; *p*<0.001).
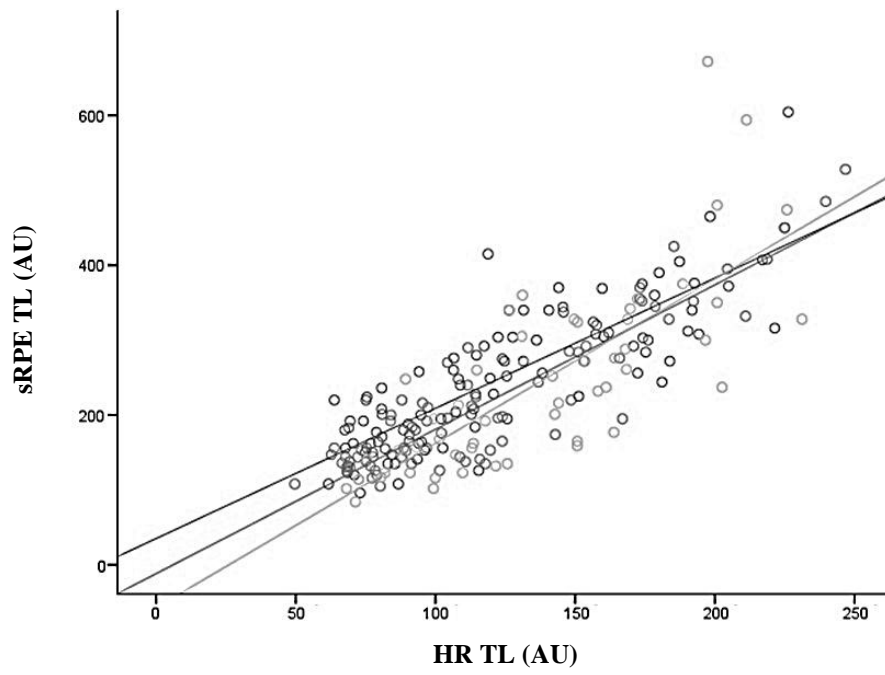
Figure 5. Relationship between the sRPE TL and HR TL for *attackers* (r = 0.84; $p<0.001$).