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Factors influencing perception of effort (session-RPE) during elite soccer training

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ABSTRACT

Purpose: The aim of the present study was to identify the external training load markers that are most influential of session rating of perceived exertion (RPE) training load (RPE-TL) during elite soccer training. ***Methods:*** Twenty-two elite players competing in the English Premier League were monitored. Training load data (RPE and 10 Hz GPS integrated with a 100 Hz accelerometer) were collected during 1892 individual training sessions over an entire in-season competitive period. Expert knowledge and a colinearity $r<0.5$ were used initially to select the external training variables for the final analysis. A multivariate-adjusted within subjects model was employed to quantify the correlations between RPE and RPE-TL (RPE x Duration) and various measures of external training intensity and training load respectively. ***Results:*** Total high-speed running distance (HSR; $>14.4\ km{\cdot}h^{-1}$), number of impacts and accelerations $>3\ m{\cdot}s^{-2}$ remained in the final multivariate model ($p<0.001$). The adjusted correlations with RPE were $r=0.14$, $r=0.09$ and $r=0.25$ for HSR, impacts and accelerations respectively. For RPE-TL, the correlations were $r=0.11$, $r=0.45$ and $r=0.37$ respectively. ***Conclusions:*** The external load measures that were found to be moderately predictive of RPE-TL in soccer training were HSR distance, and the number of impacts and accelerations. These findings provide new evidence to support the use of RPE-TL as a global measure of training load in elite soccer. Furthermore, understanding the influence of characteristics impacting RPE-TL may serve to help coaches and practitioners enhance training prescription and athlete monitoring.

Keywords: RPE, Speed, Acceleration, Impacts, Metabolic Power, GPS

Introduction

Evaluating the physical demands of training requires accurate assessment of both the internal and external load. This is particularly important in team sports such as soccer since differences in individual physical and physiological responses to the same external workload arise.[1] Several methods have been used to quantify the internal training load.[2] In contrast, the multi-directional basis of sports such as soccer has previously made quantification of the external training load difficult to achieve. However, recent advancements in Global Positioning System (GPS) technology now enable the acquisition of a range of valid and reliable indicators of external load placed upon the athlete.[3,4,5,6,7]

The stimulus for training induced adaptation is the relative physiological stress imposed on the athletes (i.e. internal load).[2,8,9] In order to plan an effective training programme, coaches must therefore understand the internal response an external training load will elicit in each of their athletes.[10] Session rating of perceived exertion (RPE) is now increasingly used as a simple, non-invasive technique for monitoring the internal training load.[11,12,13] Derived from the RPE multiplied by session duration, RPE training load (RPE-TL) has previously shown to be highly correlated with HR based assessment of training load during intermittent team sports such as soccer.[1,11,14,15,16,17]

Understanding the influence of characteristics which influence RPE-TL is important when examining the response that a given external training load may induce in an athlete. In an attempt to subsequently examine the relationship between internal training load and different markers of external load, Lovell et al.[1] and Gallo et al.[10] examined the influence of external load derived from GPS on RPE-TL in elite rugby league and Australian Football players respectively. However, to date little attempt has been made to undertake similar analyses in soccer. Casamichana et al.[15] recently reported a large association between RPE-TL and total distance covered in semi-professional soccer players. However, the relationship between RPE-TL and the plethora of GPS and accelerometer derived estimates of external load has not been examined in elite soccer. Consequently, since differences exist in the physiological demands between team sports it is important to determine which markers of external load are most influential of the internal load within soccer. Therefore, the aim of this study was to identify the external training load markers that are most influential of RPE-TL during elite soccer training.

Methods

Subjects

Twenty-two soccer players competing in the English Premier League (age = 26 ± 6 years; height = 182 ± 7 cm; body mass = 79 ± 7 kg) took part in the study during the 2012-2013 in-season competition period (38 weeks). A total of 1892 individual training observations with a mean duration of 57±16 minutes were undertaken. The median observations per players was 86± 28 (range=25-120). Players with different position on the field were tested: 4 central defenders, 3 wide defenders, 6 central midfielders, 3 wide midfielders and 6 attackers. Goalkeepers were not included in the study. Only data derived from the team field-based training sessions was analysed, and no individual rehabilitation or individual fitness sessions were included for analysis. The warm-up period prior to each training session was not included for analysis. All sessions were performed on the same pitch. During the rest periods, players were allowed drink fluids "at libitum". All players were notified of the aim of the study, research procedures, requirements, benefits and risks before giving written informed consent. The study was approved by Liverpool John Moores University Ethics Committee.

Methodology

Each player's RPE was collected in isolation ~20 minutes after each training session using the CR-10 Borg scale. This ensured the perceived effort reflected the whole session and not the most recent exercise intensity. All the players were familiarised with use of the scale. The RPE training load (RPE-TL) was subsequently calculated by multiplying training duration (min) by the RPE as described by Foster et al.[2].

The players' physical activity during each training sessions was monitored using a portable non-differential 10 Hz global positioning system (GPS) integrated with a 100 Hz 3-D accelerometer, a 3-D gyroscope, a 3-D digital compass (STATSports Viper, Northern Ireland). This type of system has previously been shown to provide valid and reliable estimates of instantaneous velocity during acceleration, deceleration, and constant velocity movements during linear, multidirectional and soccer-specific activities.[3,4,6] A particular vest was tightly fitted to each player, placing the receiver between the scapulae. All devices were always activated 15-min before the data collection to allow acquisition of satellite signals in accordance with the manufacturer's instructions.[18] In addition, in order to avoid inter-unit error players wore the same GPS device for each training sessions.[18,19] After recording, the data were downloaded to a computer and analyzed using the software package Viper Version 1.2 (STATSports, 2012).

Based on GPS data total distance, high-speed (>14.4 $km \cdot h^{-1}$) and very high-speed (>19.8 $km \cdot h^{-1}$) running distance were calculated during each training session. Total, high-speed and very high-speed running distance covered were also divided by session duration (min) in order to obtain the intensity values "per min". Acceleration activity was measured on the basis of the change in GPS speed data and was defined as a change in speed for a minimum period of 0.5 s with a maximum acceleration in the period at least 0.5 $m \cdot s^{-2}$. The acceleration was considered finished when the player stopped accelerating. The classification of accelerations by zone is based on the maximum acceleration reached in the acceleration period. The same approach was used with regard to deceleration. The load and intensity measures were identified as total number of accelerations or decelerations (>3 $m \cdot s^{-2}$) and accelerations/min or decelerations/min, respectively.

Total energy expenditure (in $J \cdot kg^{-1} \cdot m^{-1}$) and average metabolic power (in $W \cdot kg^{-1}$) were estimated as previously described.[20,21,22,23] Total energy expenditure and average metabolic power were identified as load and intensity measures, respectively. Consequently, distance covered at metabolic power >25.5 $W \cdot kg^{-1}$ (high metabolic power) was analysed as an indicator of the high-intensity distance covered.[21,22,24] 25.5 $W \cdot kg^{-1}$ correspond to when a player is running at a constant speed of approximately 5.5 $m \cdot s^{-1}$ (i.e. 19.8 $km \cdot h^{-1}$) on grass or when they are performing significant acceleration or deceleration activity, for example if they are accelerating from 2 to 4 $m \cdot s^{-1}$, over 1 second (i.e. an acceleration equal to 2 $m \cdot s^{-2}$). The load and intensity measures were identified as high metabolic power distance and high metabolic power distance/min, respectively.

Player impact measures and body load were derived from triaxial accelerometers. Previous study has demonstrated an acceptable level of reliability for triaxial accelerometers both within and between units in team sports.[25] Impacts are a mixture of collisions and step impacts while running. Using the magnitude of the 3-D accelerometer values at any time point, impacts were identified as maximum accelerometer magnitude values above 2g in a 0.1 second period. The impacts were then totalled to give the number of impacts. The load and intensity measures were identified as total number of impacts and impacts/min, respectively.[1] In addition, the "dynamic stress load" was calculated as the total of the weighted impacts. Impacts were weighted using convex-shaped function (approximately a cubic function), an approach similar to the one used in the speed intensity calculation, with the key concept being that an impact of 4g is more than twice as hard on the body as an impact of 2g. The weighted impacts were totalled and finally scaled to give more workable values expressed in arbitrary units (AU). The load and intensity measures were identified as dynamic stress load and dynamic stress load/min, respectively.[1] Both speed intensity and dynamic stress load were calculated automatically using a custom algorithm included in the proprietary software provided by the manufacturers (Viper Version 1.2, STATSports, Northern Ireland).

Statistical Analysis

Data were analysed with general linear models, which allowed for the fact that data were collected within-subjects over time.[26] Recently, step-wise regression approaches have been criticised for reliable variable selection in a model.[27,28] Our added problem was the predicted high multicolinearity between the various independent variables in our study. Therefore, we used a combination of expert knowledge regarding which variables hold superior practical/clinical importance [27] and a multicolinearity correlation coefficient of >0.5 for initial variable selection. Total high-speed running distance and the number of impacts and accelerations (>3 $m \cdot s^{-2}$) were selected as the criterion measures of training intensity and load (independent variables) in the present study. We then quantified the relationships between the various predictors and outcomes using model I (unadjusted model) and model II (fully adjusted model from which partial correlation coefficients and associated 95% confidence intervals for each predictor could be derived). The following criteria were adopted to interpret the magnitude of the correlation (r) between test measures: <0.10 trivial, 0.10 to 0.30 small, 0.30 to 0.50 moderate, 0.50 to 0.70 large, 0.70 to 0.90 very large, and 0.90 to 1.00 almost perfect.[29] The level of statistical significance was set at $p<0.05$ for all tests.

Results

Mean load and intensity measures are presented in **Table 1**.

Within-individual correlations between the RPE-based measures of intensity and load and the three indicators of external training-intensity and load are presented in **Table 2**. Large to very large within-individual correlations were observed between RPE-TL and the external measures of TL (**Table 2**). In contrast, small within-individual correlations were noted between RPE and the external measures of intensity.

Partial correlations, 95% confidence interval and the level of significance of predictors are shown in **Table 3**. A small correlation was observed between high-speed distance and RPE-Load with moderate correlations noted between the number of impacts and accelerations and RPE-Load, respectively. Similar to the within-individual correlations, the partial correlations between RPE and high distance covered per minute, number of impacts per minute and number of accelerations per minute were trivial to small.

Discussion

The purpose of the present study was to determine the external training load markers that are most influential of RPE-TL in elite soccer players. The present findings indicate that a combination of different of external training load factors predict RPE-TL better than any individual parameters alone. These findings provide further evidence to support the use of RPE-TL as a global measure of training load in elite soccer. Furthermore, understanding the influence of characteristics impacting RPE-TL will serve to help coaches and practitioners enhance training prescription and athlete monitoring.

Recently, studies by Lovell et al.[1] and Gallo et al.[10] have investigated the relationship between internal and external load parameters in elite rugby league and Australian Football players respectively. Similarly, Casamichana et al.[15] examined such relationships relationship in sub-elite soccer players, however, the latter failed to account for the predicted high multicolinearity between the various independent variables[27]. In the present study, expert knowledge and a colinearity r<0.50 were used initially to select the external training variables for the final analysis. Consequently, total high-speed running distance (>14.4 $km \cdot h^{-1}$), number of impacts and accelerations (>3 $m \cdot s^{-2}$) remained in the final multivariate model (p<0.001).

The present findings demonstrate that RPE is significantly (p<0.001, **Table 2** and **Table 3**) related to several indicators of external physical load during training. In line with previous observations,[1] the magnitude of the within-individual correlations (**Table 2**) reduces substantially when adjusted for the effects of the other variables (**Table 3**, partial correlations). In both **Table 2** and **Table 3** the correlations between the RPE-TL and the three parameters taken into account resulted in higher correlations between the RPE and the same parameters expressed as "per minute".[1] This may reflect the fact that many additional factors may contribute to the perception of intensity in intermittent team-sport exercise.[1] Consequently, by multiplying the RPE by the session time, a more robust index is derived (i.e. RPE-TL).

In the present study, a small correlation was observed between RPE-TL and high-speed distance (r=0.114). Interestingly, significant emphasis has traditionally been placed upon this parameter when examining the physical demands of soccer training and match-play.[30] Recent works have shown that the high-intensity demands of soccer training are systematically underestimated by traditional measurements of high-speed running alone, especially during drills performed in small areas.[21,22] Soccer involves a number of acyclical changes in activity, each characterized by accelerations that further increase the energy demands placed on the athlete even when running within low speed thresholds. In line with such observations, a moderate correlation (r=0.37) was currently observed between RPE-TL and the number of accelerations during training. This supports the view that such indices are of significant importance when examining the overall physical demands of team sports such as soccer.[21,22] Indeed, high accelerations and decelerations frequently arise during soccer specific activities when the pitch dimensions or particular drill rules limit the degree of high-intensity running.[21,22,31] It should be noted that findings from the present investigation were derived from entire training sessions, however, training sessions frequently comprise drills which elicit different physical demands.[22,24] Future studies should therefore serve to evaluate the relationship between RPE-TL and the different external loading factors present across a range of soccer-specific training drills in order to derive a deeper understanding of the degree to which different factors affect RPE-TL.

Interestingly, similar to the number of accelerations, a moderate correlation was currently observed between the number of impacts and RPE-TL (r=0.45). These results are in line with those recently reported by Lovell et al. during rugby training (r=0.55).[1] Impacts, calculated from the 100Hz triaxial accelerometer not only includes impacts generated when running over the terrain but also takes into account jumps, tackles and collisions with the opponents. As such, the higher correlation observed in rugby likely reflects the high frequency of collisions inherent within the sport. The importance of impacts and accelerations on the internal load response is supported by studies that have evaluated the influence of different load parameters (e.g. body load, player load or dynamic stress load) computed from the combined number of impacts, accelerations and decelerations on RPE-TL.[1,13,15] For example, Lovell et al.[1] and Gallo et al.[10] demonstrated the high correlation between RPE-TL and accelerometer-derived measured of body/player load in Rugby league players (r=0.57) and Australian footballers (r=0.86), respectively. Interestingly, recent studies by Gaudino et al.[21,22] have also demonstrated that the estimated metabolic power (that take into account both speed and acceleration values) better represents the true demands of a training session when compared with traditional measurements of running speed alone. As such, whilst no criterion measure of external training load exists it seems that some combination of speed, acceleration and impacts are likely to be strong predictors of RPE-TL in soccer.

Practical implications

- RPE-TL may be used as a simple and reliable measure of TL in elite soccer training.
- High-speed running and the number of impacts and accelerations best predict RPE-TL during elite soccer training.

Conclusion

RPE-TL provided significant within-individual correlations with HSR distance and the number of impacts and accelerations during soccer training in elite players. These findings provide further evidence to support the use of RPE-TL as a global measure of training load in elite soccer. Furthermore, understanding the influence of characteristics impacting RPE may serve to help coaches and practitioners enhance training prescription and athlete monitoring.

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Table 1. Load and Intensity Measures for all Training Sessions, Mean ± SD, N = 1892

Measure	
Load	
RPE-TL (AU)	218 ± 102
Total Distance (m)	3545 ± 1038
High-Speed Distance (m)	426 ± 218
Very High-Speed Distance (m)	109 ± 95
Very High-Speed Runs (n)	10 ± 6
Impacts (n)	1898 ±730
Dynamic Stress Load (AU)	96 ± 57
Accelerations (n)	18 ± 10
Decelerations (n)	25 ± 11
Energy Expenditure (kcal)	372 ± 112
High Metabolic Power Distance (m)	519 ± 212
Intensity	
RPE (AU)	3.7 ± 1.1
Distance per minute (m/min)	63 ± 8
High-Speed Distance per minute (m/min)	7.5 ± 3.1
Very High-Speed Distance per minute (m/min)	1.9 ± 1.5
Very High-Speed Runs per minute (n/min)	0.2 ± 0.1
Impacts per minute (n/min)	63 ± 8
Dynamic Stress Load per minute (AU/min)	1.7 ± 0.8
Accelerations per minute (n/min)	0.3 ± 0.1
Decelerations per minute (n/min)	0.4 ± 0.2
Average Metabolic Power (W/kg)	6.0 ± 0.8
High Metabolic Power Distance per minute (m/min)	9.1 ± 2.5

Abbreviations: RPE, session rating of perceived exertion; TL, training load; AU, arbitrary units.

Table 2. Within-individual correlations (95 % CI) between RPE-TL and RPE with the external measures of training load and intensity.

	Within-Individual Correlation	**95% C.I.**	**Significance**
RPE-TL			
High-Speed Distance (m)	0.610	0.581-0.637	<0.001
Impacts (n)	0.729	0.708-0.749	<0.001
Accelerations (n)	0.631	0.603-0.657	<0.001
RPE			
High-Speed Distance per minute (m/min)	0.255	0.213-0.296	<0.001
Impacts per minute (n/min)	0.232	0.189-0.274	<0.001
Accelerations per minute (n/min)	0.297	0.256-0337	<0.001

Abbreviations: RPE, session rating of perceived exertion; TL, training load.

Table 3. Partial correlations (95% CI) and level of significance for predictors of RPE-TL and RPE.

	Partial Correlation	**95% C.I.**	**Significance**
RPE-TL			
High-Speed Distance (m)	0.114	0.069-0.158	<0.001
Impacts (n)	0.451	0.415-0.486	<0.001
Accelerations (n)	0.371	0.332-0.409	<0.001
RPE			
High-Speed Distance per minute (m/min)	0.141	0.097-0.185	<0.001
Impacts per minute (n/min)	0.095	0.05-0.139	<0.001
Accelerations per minute (n/min)	0.249	0.206-0.291	<0.001

Abbreviations: RPE, session rating of perceived exertion; TL, training load.