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7 AUTHORS, INCLUDING:

Paolo Gaudino

Liverpool John Moores University

Giampietro Alberti

University of Milan

Warren Gregson

Liverpool John Moores University

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Factors Influencing Perception of Effort (Session Rating of Perceived Exertion) During Elite Soccer Training

Paolo Gaudino, F. Marcello Iaia, Anthony J. Strudwick, Richard D. Hawkins, Giampietro Alberti, Greg Atkinson, and Warren Gregson

Purpose: The aim of the current study was to identify the external-training-load markers that are most influential on session rating of perceived exertion (RPE) of 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 collinearity $r < .5$ 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 of RPE and RPE-TL (RPE × duration) with various measures of external training intensity and training load. ***Results:*** Total high-speed-running (HSR; >14.4 km/h) distance and number of impacts and accelerations >3 m/s^2 remained in the final multivariate model ($P < .001$). The adjusted correlations with RPE were $r = .14$, $r = .09$, and $r = .25$ for HSR, impacts, and accelerations, respectively. For RPE-TL, the correlations were $r = .11$, $r = .45$, and $r = .37$, 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 affecting RPE-TL may help coaches and practitioners enhance training prescription and athlete monitoring.

Keywords: rating of perceived exertion, speed, acceleration, impacts, metabolic power, GPS

Evaluating the physical demands of training requires accurate assessment of both the internal and external loads. 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 multidirectional nature of sports such as soccer has previously made quantification of the external training load difficult. 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 on the athlete.[3–7]

The stimulus for training-induced adaptation is the relative physiological stress imposed on the athletes (ie, internal load).[2,8,9] To plan an effective training program, coaches must therefore understand the internal response that 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, noninvasive technique for monitoring internal training load.[11–13] Derived from the RPE multiplied by session duration, RPE training load (RPE-TL) has previously shown to be highly correlated with heart-rate-based assessment of training load during intermittent team sports such as soccer.[1,11,14–17]

Understanding the influence of characteristics that 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 semiprofessional 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 there are differences in the physiological demands between team sports, it is important to determine which markers of external load are most influential on the internal load in soccer. Therefore, the aim of this study was to identify the external-training-load markers that are most influential on RPE-TL during elite soccer training.

Methods

Subjects

Twenty-two soccer players competing in the English Premier League (age 26 ± 6 y, height 182 ± 7 cm, body mass 79 ± 7 kg) took part in the study during the 2012–13 in-season competition period (38 wk). A total of 1892 individual training observations with a mean duration of 57 ± 16 minutes were undertaken. The median observation 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 were analyzed,

Gaudino, Strudwick, Hawkins, and Gregson are with the Research Inst for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK. Iaia and Alberti are with the Dept of Biomedical Sciences for Health, University of Milan, Milan, Italy. Atkinson is with the Health and Social Care Inst, Teesside University, Teesside, UK. Address author correspondence to Paolo Gaudino at paolo.gaudino@hotmail.com.

and no individual rehabilitation or individual fitness sessions were included for analysis. The warm-up period before 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 ad 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's 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 that the perceived effort reflected the whole session and not the most recent exercise intensity. All the players were familiarized 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 session was monitored using a portable nondifferential 10-Hz GPS integrated with a 100-Hz 3-dimensional accelerometer, a 3-dimensional gyroscope, and a 3-dimensional 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, holding the receiver between the scapulae. All devices were always activated 15 minutes before the data collection to allow acquisition of satellite signals in accordance with the manufacturer's instructions.[18] In addition, to avoid interunit error, each player wore the same GPS device for each training session.[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, high-speed (>14.4 km/h), and very high-speed (>19.8 km/h) 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) to obtain the intensity values per minute. 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 second with a maximum acceleration in the period at least 0.5 m/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/s^2) and accelerations or decelerations per minute, respectively.

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

Player impact measures and body load were derived from triaxial accelerometers. A previous study 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-dimensional accelerometer values at any time point, impacts were identified as maximum accelerometer magnitude values above 2 *g* in a 0.1-second period. The impacts were then totaled to give the number of impacts. The load and intensity measures were identified as total number of impacts and impacts per minute, 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 4 *g* is more than twice as hard on the body as an impact of 2 *g*. The weighted impacts were totaled 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 per minute, 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 analyzed with general linear models, which allowed for the fact that data were collected within subjects over time.[26] Recently, stepwise regression approaches have been criticized for reliable variable selection in a model.[27,28] Our added problem was the predicted high multicollinearity between the various independent variables in our study. Therefore, we used a combination of expert knowledge regarding which variables hold superior practical or clinical importance[27] and a multicollinearity correlation coefficient of >.5 for initial variable selection. Total high-speed-running distance and the number of impacts and accelerations (>3 m/s^2) were selected as the criterion measures of training intensity and load (independent variables). We then quantified the relationships between the various predictors and outcomes using model 1 (unadjusted model) and model 2 (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: <.10 trivial, .10 to .30 small, .30 to .50 moderate, .50 to .70 large, .70 to .90 very large, and .90 to 1.00 almost perfect.[29] The level of statistical significance was set at $P < .05$ 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 3 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 intervals, and the level of significance of predictors are shown in Table 3. A small correlation was observed between high-speed distance and RPE-TL with moderate correlations noted between the number of impacts and accelerations and RPE-TL, 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.

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

Measure	Value
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 (m) per minute	63 ± 8
high-speed distance (m) per minute	7.5 ± 3.1
very high-speed distance (m) per minute	1.9 ± 1.5
very high-speed runs (n) per minute	0.2 ± 0.1
impacts (n) per minute	63 ± 8
dynamic stress load (AU) per minute	1.7 ± 0.8
accelerations (n) per minute	0.3 ± 0.1
decelerations (n) per minute	0.4 ± 0.2
average metabolic power (W/kg)	6.0 ± 0.8
high metabolic power distance (m) per minute	9.1 ± 2.5

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

Table 2 Within-Individual Correlations (95% CI) Between RPE-TL and RPE and the External Measures of Training Load and Intensity

	Within-individual correlation	95% CI	Significance
RPE-TL			
high-speed distance (m)	.610	.581–.637	<.001
impacts (n)	.729	.708–.749	<.001
accelerations (n)	.631	.603–.657	<.001
RPE			
high-speed distance (m) per minute	.255	.213–.296	<.001
impacts (n) per minute	.232	.189–.274	<.001
accelerations (n) per minute	.297	.256–0337	<.001

Abbreviations: CI, confidence interval; RPE, 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% CI	Significance
RPE-TL			
high-speed distance (m)	.114	.069–.158	<.001
impacts (n)	.451	.415–.486	<.001
accelerations (n)	.371	.332–.409	<.001
RPE			
high-speed distance (m) per minute	.141	.097–.185	<.001
impacts (n) per minute	.095	.05–.139	<.001
accelerations (n) per minute	.249	.206–.291	<.001

Abbreviations: CI, confidence interval; RPE, rating of perceived exertion; TL, training load.

Discussion

The purpose of the current study was to determine the external-training-load markers that are most influential on RPE-TL in elite soccer players. The findings indicate that a combination of different external-training-load factors predict RPE-TL better than any individual parameter 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 affecting RPE-TL will help coaches and practitioners enhance training prescription and athlete monitoring.

Recently, Lovell et al[1] and Gallo et al[10] 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 in subelite soccer players; however, the latter failed to account for the predicted high multicollinearity between the various independent variables.[27] In the current study, expert knowledge and a collinearity $r < .50$ were used initially to select the external training variables for the final analysis. Consequently, total high-speed-running distance (>14.4 km/h) and number of impacts and accelerations (>3 m/s^2) remained in the final multivariate model ($P < .001$).

The current findings demonstrate that RPE is significantly ($P < .001$; Tables 2 and 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 3 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 (ie, RPE-TL).

In the current study, a small correlation was observed between RPE-TL and high-speed distance ($r = .114$). Notably, significant emphasis has traditionally been placed on 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 = .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 current investigation were derived from entire training sessions; however, training sessions frequently comprise drills that elicit different physical demands.[22,24] Future studies should therefore evaluate the relationship between RPE-TL and the different external loading factors present across a range of soccer-specific training drills to derive a deeper understanding of the degree to which different factors affect RPE-TL.

Notably, similar to the number of accelerations, a moderate correlation was currently observed between the number of impacts and RPE-TL (r = .45). These results are in line with those recently reported by Lovell et al[1] during rugby training (r = .55). Impacts calculated from the 100-Hz triaxial accelerometer not only include impacts generated when running over the terrain but also take 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 in the sport. The importance of impacts and accelerations on the internal-load response is supported by studies that evaluated the influence of different load parameters (eg, 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 = .57) and Australian footballers (r = .86), respectively. Notably, recent studies by Gaudino et al[21,22] also demonstrated that the estimated metabolic power (that takes into account both speed and acceleration values) better represents the true demands of a training session than traditional measurements of running speed alone. As such, while there is no criterion measure of external training load, it seems that in some combination, 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

Rating of perceived exertion (RPE) of training load (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 affecting RPE may help coaches and practitioners enhance training prescription and athlete monitoring.

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