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Relationships Between Rating-of-Perceived-Exertion- and Heart-Rate-Derived Internal Training Load in Professional Soccer Players: A Comparison of On-Field Integrated Training Sessions

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Purpose: To describe the internal training load (ITL) of common training sessions performed during a typical week and to determine the relationships between different indicators of ITL commonly employed in professional football (soccer). ***Methods:*** Session-rating-of-perceived-exertion TL (sRPE-TL) and heart-rate- (HR) derived measurements of ITL as Edwards TL and Stagno training impulses ($TRIMP_{MOD}$) were used in 9 players during 3 periods of the season. The relationships between them were analyzed in different training sessions during a typical week: skill drills/circuit training + small-sided games (SCT+SSGs), ball-possession games + technical-tactical exercises (BPG+TTE), tactical training (TT), and prematch activation (PMa). ***Results:*** HR values obtained during SCT+SSGs and BPG+TTE were substantially greater than those in the other 2 sessions, all the ITL markers and session duration were substantially greater in SCT+SSGs than in any other session, and all ITL measures in BPG+TTE were substantially greater than in TT and PMa sessions. Large relationships were found between HR >80% HR_{max} and HR >90% HR_{max} vs sRPE-TL during BPG+TTE and TT sessions ($r = .61–.68$). Very large relationships were found between Edwards TL and sRPE-TL and between $TRIMP_{MOD}$ and sRPE-TL in sessions with BPG+TTE and TT ($r = .73–.87$). Correlations between the different HR-based methods were always extremely large ($r = .92–.98$), and unclear correlations were observed for other relationships between variables. ***Conclusion:*** sRPE-TL provided variable-magnitude within-individual correlations with HR-derived measures of training intensity and load during different types of training sessions typically performed during a week in professional soccer. Caution should be applied when using RPE- or HR-derived measures of exercise intensity/load in soccer training interchangeably.

Keywords: heart rate, TRIMP, football, quantification

The intensified competitive demand of contemporary professional football (soccer) players challenges coaches' ability to ensure an appropriate balance between training stimuli and recovery.[1] With limited training time and the need to perform at the highest possible level at least every weekend, coaches typically prioritize on-field integrated training sessions where match-specific tactical, technical, and physical elements are blended. The obvious need to use group training drills often results in marked interplayer differences in physiological responses.[2] That is, for a given training drill or session players can receive completely different training stimuli. While the between-players differences in training stimulus are actually expected when integrated training is performed (eg, different tactical roles will demand different movement patterns and associated physiological responses), knowledge on the internal and external training loads is necessary to ensure that optimal load and recovery needs are met.

Monitoring training load (TL) helps one determine the individual responses of athletes in different training sessions.[3] Measurements of the internal TL (ITL) assess physiological stress endured by the athlete, and measurements of the external TL (ETL) quantify physical stimuli performed. The result of training is the consequence of both stimuli, and the analysis of ETL and ITL can provide useful information to assess the effects of training.[4,5] However, it seems that only the magnitude of the ITL supported may ultimately be the main determinant of improvements in fitness.[6] For this reason, methods based on the analysis of heart rate (HR) as the measurement of Banister's training impulses (TRIMP),[7] Edwards' training load,[8] or Stagno's adaptation to team sports[9] are used to monitor the ITL in soccer. Apart from top-level soccer teams, the routine use of HR-based methods is not always feasible.[10] An alternative low-cost and practical strategy to quantify ITL is session rating of perceived exertion (sRPE),[11] which has been extensively shown as a valid and reliable load-monitoring tool in football and other team sports.[10]

Despite large- to very-large-magnitude correlations having been reported between sRPE and HR-derived measurements of ITL in soccer training sessions,[10,12,13] some researchers have suggested that the magnitude of those correlations can vary depending of the session training topics.[12] In this regard, large correlations ($r = .82$) were found between sRPE and Edwards TL in relatively low-intensity, predominantly aerobic sessions (ie, technical session type), while low-magnitude associations ($r = .25$) were reported in more neuromuscular types of sessions (ie, resistance session type) in female soccer players.[12] These findings appear to suggest that the sRPE method might be unable to reflect the underlying HR-inferred physiological stress arising from some of the sessions typically performed by soccer teams. This might be related to the nature of the tasks assessed: very short, high-intensity, intermittent

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exercise interspersed with periods of passive recovery in which HR is unlikely to reflect the intensity of the task.[10] However, virtually no information is currently available on the ITL responses to specific football training sessions carried out during a typical week to prepare players for the weekend game in professional football.[13] Accordingly, the focus of the current study was to describe the ITL of common training sessions performed during a typical week (ie, with a game every 7 d) in professional football players. In addition, we aimed to determine the relationships between different indicators of ITL commonly employed in football (sRPE, Stagno $TRIMP_{MOD}$, Edwards TL) in different types of training sessions.

Methods

Experimental Design

The study was conducted over a full competitive season. The competitive season began in the last week of August (wk 6, after the preseason) and continued until the first week of June. The team typically performed 5 training sessions and 1 match per week. Training sessions in this period had a duration of ~90 minutes (ranging from 60 to 105 min) with a typical structure as shown in Figure 1. Training practices were conducted on 3 different fields (all natural grass) in the same facility on a rotational basis. Moreover, once a week the team trained in the stadium where official games were played. The coaching staff decided pitch usage and rotation.

Three assessment periods were established in the study (July, November, and March) to assess the intermittent performance with the Yo-Yo Intermittent Recovery Test (Yo-YoIR1).[14] During the test, the maximum HR (HR_{max}) of each player was obtained[14] using an HR monitor (Polar Team 2). In players whose HRs were higher in the course of the training than obtained HR_{max} in the Yo-YoIR1, the HR_{max} values shown during the training were retained and used in the analysis. Six weeks after each assessment, the ITL of every training session was monitored. Training sessions were classified into the following categories depending on the activities covered:

- *Skill Drills/Circuit Training + Small Sided Games*. After the warm-up, players performed, at high intensity, 6 to 12 series of 30 to 45 seconds of explosive drills (SCT) (eg, accelerations, changes of direction, jumps) combined with technical skills. These drills were followed by 3 to 6 sets of 5-versus-5 to 8-versus-8 small-sided games (SSGs) with goals and goalkeepers, played on an individual area of ~85 m^2 per player. SSG duration ranged from 3 to 5 minutes with 2-minute recovery periods.
- *Ball-Possession Games + Technical and Tactical Exercises*. After the warm-up, the players performed ball-possession games (BPGs) (without goalkeepers). The main attacking principle of those BPGs was to "play fast" (with few touches), while the main defensive principle was to quickly press after losing possession. BPGs were organized as 5-versus-5 up to 8-versus-8 on an individual area ranging from 35 to 45 m^2 per player. Two to four sets of 4 to 8 minutes with recovery periods of 2 minutes were performed. After the BPGs, a session of technical and tactical exercise (TTE) was performed (11-versus-11 exercises with the aim of training game situations).
- *Tactical Training*. After the warm-up period, players performed tactical-related practices (TT). Typically, those practices included 11-versus-11 exercises with the objective of training game situations related to the upcoming game.
- *Prematch Activation*. The day before the match, finishing actions executed at maximum speed were performed (PMa). After this, players performed 10 to 15 minutes of 11-versus-11 match play on a 70 × 65-m area. The session typically ended with 15 minutes of set pieces.

Only the sessions in which the players participated in full were retained for further analysis.

Participants

Nine professional soccer players (mean ± SD age 26.7 ± 4.5 y, height 176.5 ± 6.8 cm, body mass 74.5 ± 5.7 kg, % body fat 10.1% ± 0.8%) participated in this study. All players belonged to the same team (2nd division Spanish La Liga) and had an average experience in professional football of 4.5 ± 4.1 years. All players signed an informed written consent before participating in the study. The current study was approved by the institutional review ethics committee and follows the recommendations of the Declaration of Helsinki.

Exercise Intensity and ITL

HR was recorded every 1 second using a telemetry system (Polar Team 2) during all training sessions. Mean HR (HR_{mean}), HR_{max}, and percentage of total playing time spent in 80% to 100% during the sessions was determined. The ITL was quantified via 2 different methods based on the monitoring of HR and 1 based on the RPE.

ITL calculation was performed as proposed by Edwards,[8] which includes the total volume of training intensity, considering 5 zones of different intensity. The calculation was performed for each session by multiplying the accumulated duration in each HR zone (min) for a value assigned to each intensity zone (90–100% HR_{max} = 5, 80–90% HR_{max} = 2, 70–80% HR_{max} = 3, 60–70% HR_{max} = 2, 50–60% HR_{max} = 1) and then adding the results.

$TRIMP_{MOD}$ calculation was also performed as proposed by Stagno et al,[9] with 5 established intensity zones with a weighting factor obtained by studying the fractional rise in HR and lactate concentration relationship. Thus, the ITL is determined by calculating the result of multiplying the training duration (min) at each of the current zones for the weighting factor for each zone (93–100%

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Postmatch recovery session or COMP-TL	Rest	Skill drills/circuit training + SSG session	Ball-possession games + technical-tactical exercises	Tactical training	Prematch activation	Official match

Figure 1 — Weekly working structure during the competitive season. Abbreviations: SSG, small-sided games; COMP-TL, compensatory training load (only for players who did not participate in the match or played less than 45 min).

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HR_{max} = 5.16, 86–92% HR_{max} = 3.61, 79–85% HR_{max} = 2.54, 72–78% HR_{max} = 1.71, 65–71% HR_{max} = 1.25) summing the results.

Finally, the ITL was quantified by analyzing the RPE of each session. Each athlete's sRPE was collected 30 minutes after each training session using the Borg Scale-10,[15] with which all athletes were previously habituated. Afterward, RPE value was multiplied by the total duration of training (min), according to Foster et al,[11] to estimate the RPE-derived ITL (sRPE-TL). A total of 288 individual training sessions met all requirements and were included in the analysis.

Statistical Analysis

Variables are shown as mean ± SD. Precision of estimates is indicated with 90% confidence limits (CL). In addition to the analyses for statistical significance (ie, paired *t* tests), possible differences between periods and training sessions were analyzed (pairwise comparisons) for practical significance using magnitude-based inferences.[16] The data were log-transformed before analysis to reduce nonuniformity of error. The effect size (ES) was determined, and the threshold values for Cohen ES statistics were trivial (0.0–0.19), small (0.2–0.59), moderate (0.6–1.1), large (1.2–1.9), and very large (>2.0).[17,18] Magnitude-based inferences were also used to assess possible differences between duration, HR, and ITL indicators during different types of sessions using the following qualitative probabilities (QP): <1%, almost certainly not; <5%, very unlikely; <25%, unlikely/probably not; 25% to 75%, possibly/possibly not; >75%, likely/probably; >95%, very likely; >99%, almost certainly. A substantial effect was set at >75%.[17,19,20] Pearson correlation coefficient was used to examine the relationships between different ITL measurements. The threshold values were small (.1–.2), moderate (.3–.4), large (.5–.6), very large (.7–.8), and extremely large (≥.9).[18]

Results

Yo-YoIR1 performance in July (preseason) was substantially lower than in the November (ES = 0.68 ± 0.18, QP = 100/0/0) and March (ES = 0.75 ± 0.30, QP = 100/0/0) assessments (2609 ± 312 vs 2849 ± 320 vs 2880 ± 374 m, respectively), while there were no differences in the HR_{max} attained during the test (184 ± 8 vs 184 ± 12 vs 185 ± 10 beats/min, respectively).

HR and ITL measures are shown in Table 1. HR values obtained during SCT+SSGs and BPG+TTE were substantially greater than in the other 2 sessions. All the ITL markers and session duration were substantially greater in SCT+SSGs than in any other session. All ITL measures in BPG+TTE were substantially greater than in TT and PMa sessions (Table 1).

Mean (90% confidence limits) within-individual correlations between sRPE-TL and HR recorded during different types of sessions are shown in Table 2. Large relationships were found between HR >80% HR_{max} and HR >90% versus HR_{max}-sRPE-TL during BPG+TTE and TT sessions (*r* = .61–.68). All the other correlations were unclear.

Mean (90% confident limits) within-individual correlations between ITL and intensity markers in the different training sessions are presented in Table 3. Very large relationships were found between Edwards TL and sRPE-TL and between $TRIMP_{MOD}$ and sRPE-TL in sessions with BPG+TTE and TT (*r* = .73–.87). Correlations between the different HR-based methods were all extremely large (*r* = .92–.98) (Table 3). Unclear correlations were observed for other relationships between variables.

Discussion

Careful planning and periodization of the weekly training topics and sessions is an important aspect of sustainable performance during the long competitive season in professional football. Thus, the aim of the current study was to examine the internal loads associated with training sessions typically prescribed during a standard week (with a game every 7 d) by coaches in professional football. The current results seem to confirm that training sessions carried out at the beginning of the week were characterized by greater ITL than those performed at the end of the week (when the game is closer). A secondary aim was to determine the relationship between different indicators of ITL commonly employed in football. Relationships across different sessions revealed variable-magnitude strength (from very large to small and unclear) of correlations between HR-based TL methods and sRPE-TL.

ITL measures determined from sRPE were highest for SCT+SSGs, followed by BPG+TTE, which were perceived harder than both TT and PMa (Table 1). There is very limited literature describing the internal load associated with different types of training sessions in professional male soccer players.[13] Jeong et al[13] reported the physical training sessions (7 ± 1 au) to be of similar intensity to SCT+SSGs and BPG+TTE. Furthermore, technical/tactical training (4 ± 1 au) and physical and technical/tactical training (4 ± 1 au) were of intensities lower than any of the sessions investigated in the current study. Previously, Jeong et al[13] reported mean HR for physical training sessions (72% ± 3% HR_{max}) to be of similar intensity to SCT+SSGs and BPG+TTE but with substantially less time spent >90%HR_{max} (0.4% ± 1.0%). Moreover, mean HR during technical/tactical training (60% ± 5%) and physical and technical/tactical training (59% ± 3%) and time spent >90%HR_{max} (0.6% ± 1% and 0.2% ± 1%) were lower than currently reported for any session category (Table 1).

Despite substantial perceptual differences between SCT+SSGs (7.4 ± 0.7 au) followed by BPG+TTE (6.9 ± 1.4 au), there were no substantial differences in any HR measure (HR_{mean}, peak HR, >80%HR_{max}, or >90%HR_{max}) between these 2 different types of training sessions. However, mean training duration in SCT+SSGs (87.0 ± 11.1) was substantially longer than in BPG+TTE (73.8 ± 13.5), suggesting that sRPE might not be considered a "pure" measure of training "intensity" and that exercise duration should also be taken into consideration. Apart from this discrepancy between sRPE- and HR-derived ITL markers in these 2 kinds of sessions, there were clear trends for the sessions performed at the beginning of the week (ie, SCT+SSGs and BPG+TTE) to be characterized by the greater internal load (RPE and HR) than the sessions performed the 2 days immediately before the week's match (ie, TT and MPa). This supports the idea that coaches deliberately reduced the load in the days preceding matches.[21,22]

An important finding of the current study was the variable magnitude of the within-individual correlations between the various markers of ITL and intensity in the different training sessions (Table 2 and 3). A previous study[12] in women's soccer found very large correlations between sRPE-TL and Edwards TL in technical-type sessions (*r* = .82) and small correlations between sRPE-TL and Banister TRIMP in resistance-type sessions (*r* = .25). The current data show that HR-derived measures of intensity (Table 2) and ITL (Table 3) are substantially correlated with sRPE-TL in most, but not all, training sessions. Notably, the training session perceived as harder and with the RPE-derived higher ITL (ie, SCT+SSGs) showed the overall weaker correlations with HR measures of both

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Table 1 Comparison of Duration, Recorded Heart Rate (HR), and Internal-Training-Load Indicators During Different Types of Sessions, Mean ± SD

	Session length (min)	Intensity					Training Load		
		RPE	Mean HR (%HR_{max})	Peak HR (%HR_{max})	>80%HR_{max}	>90%HR_{max}	$TRIMP_{MOD}$	Edwards TL	sRPE-TL
SCT+SSGs	87.0 ± 11.1*	7.4 ± 0.7*	70.5 ± 3.8†	95.4 ± 2.8†	26.2 ± 8.0†	9.0 ± 6.6†	132.9 ± 34.7*	226.2 ± 37.5*	642.4 ± 108.6*
BPG+TTE	73.8 ± 13.5	6.9 ± 1.4†	71.2 ± 4.4†	94.8 ± 3.7†	24.1 ± 8.3†	9.4 ± 7.3†	119.6 ± 38.6†	197.7 ± 47.1†	516.8 ± 178.0†
TT	74.2 ± 11.4	4.8 ± 1.7	66.2 ± 4.9	91.4 ± 4.1	14.5 ± 10.7	2.2 ± 3.7	85.1 ± 37.6	166.0 ± 51.4	370.5 ± 182.0
PMa	72.7 ± 8.1	4.5 ± 0.9	65.6 ± 3.3	92.3 ± 4.4	10.7 ± 4.8	2.7 ± 2.8	73.6 ± 22.3	156.2 ± 30.2	328.0 ± 82.7

Abbreviations: SCT, skill drills/circuit training; SSGs, small-sided games. BPG, ball-possession games; TTE, technical and tactical exercises; TT, tactical training; PMa, prematch activation; RPE, rating of perceived exertion; $TRIMP_{MOD}$, Stagno training load[9]; Edwards TL, Edwards training load[8]; sRPE-TL, session-RPE training load.[11]

*Substantial difference (was set at >75%) vs other training sessions; †Substantial difference (was set at >75%) vs TT and PMa training sessions.

Table 2 Within-Individual Correlations Between Intensity Measures of sRPE-TL and Heart Rate (HR) Recorded During Different Types of Training Sessions in Male Professional Football Players, Mean (90% Confidence Limits)

Sessions	Average HR (%HR_{max})	>80%HR_{max}	>90%HR_{max}
SCT+SSGs	–.06 (–.14;.25)	.23 (.04;.41)	.11 (–.09;.30)
BPG+TTE	.12 (–.08;.31)	.61 (.47;.72)	.62 (.48;.73)
TT	.39 (.21;.54)	.67 (.55;.77)	.68 (.56;.77)
PMa	.21 (.02;.39)	.34 (.15;.50)	.38 (.20;.54)

Abbreviations: sRPE-TL, session-rating-of-perceived-exertion training load[11]; SCT, skill drills/circuit training; SSGs, small-sided games. BPG, ball-possession games; TTE, technical and tactical exercises; TT, tactical training; PMa, prematch activation.

Table 3 Within-Individual Correlations Between Heart-Rate- and RPE-Derived Measures of Internal Training Load, Mean (90% Confidence Limits)

	$TRIMP_{MOD}$	Edwards TL	sRPE-TL
SCT+SSGs			
$TRIMP_{MOD}$	—	.93 (.90;.95)	.35 (.17;.51)
Edwards TL	—	—	.55 (.40;.67)
sRPE-TL	—	—	—
BPG+TTE			
$TRIMP_{MOD}$	—	.93 (.90;.95)	.73 (.62;.81)
Edwards TL	—	—	.87 (.81;.91)
sRPE-TL	—	—	—
TT			
$TRIMP_{MOD}$	—	.98 (.97;.99)	.78 (.69;.85)
Edwards TL	—	—	.80 (.72;.86)
sRPE-TL	—	—	—
PMa			
$TRIMP_{MOD}$	—	.92 (.88;.95)	.38 (.20;.54)
Edwards TL	—	—	.50 (.34;.63)
sRPE-TL	—	—	—

Abbreviations: RPE, rating of perceived exertion; $TRIMP_{MOD}$, Stagno training load[9]; Edwards TL, Edwards training load[8]; sRPE-TL, session-rating-of-perceived-exertion training load[11]; SCT, skill drills/circuit training; SSGs, small-sided games. BPG, ball-possession games; TTE, technical and tactical exercises; TT, tactical training; PMa, prematch activation.

intensity (Table 2) and ITL (ie, volume; Table 3), while BPG+TTE and TT sessions were typically largely to very largely correlated with both HR-derived measures of intensity and ITL. The reason for the poorer RPE-HR correlations in SCT+SSGs, indicating substantial individual responses, than in BPG+TTE and TT is unknown. It could be speculated that because SCT+SSGs are typically performed ~72 hours after the last match, important between-players differences in recovery status might be present, as it has been reported that 72 hours after a soccer match some players can still have elevated (ie, higher than prematch) physiological, neuromuscular, metabolic, and perceptual responses.[23,24] As both mental and physical feelings of fatigue, tiredness, and muscle soreness[23] can influence sRPE, such between-players differences in presession recovery status might substantially modify the relationships between the physiological load arising from the session and the players' perceived exercise intensity. On the contrary, as the week advances and players have more time to recover, pre-training-session between-players recovery status might be more even, which might, at least partly, explain the greater-magnitude correlation between HR-RPE observed in BPG+TTE and TT (both sessions are typically performed ~86 and 100 h after the game, respectively). Another possible explanation for the poorer RPE-HR correlations in SCT+SSGs is that these sessions usually include short high-intensity lifting efforts and, particularly in our case, heavy neuromuscular load. Previous studies have shown that HR-based TL methods reflected a low validity to quantify this type of exercise[10] and this could be another reason for these results.

Another finding of our study was that the sRPE-TL and $TRIMP_{MOD}$ relationships were similar to those between sRPE-TL and Edwards TL (Table 3). The $TRIMP_{MOD}$ method has been suggested to be a more accurate method than Edwards TL to estimate ITL in team sports.[9] In the current study, however, both methods yielded similar relationships with sRPE-TL.

Conclusions and Practical Applications

To summarize, sRPE provided variable-magnitude within-individual correlations with HR-derived measures of training intensity and load during different types of training sessions typically performed during a week in professional soccer. Caution should be applied when using RPE- or HR-derived measures of exercise intensity/load in soccer training interchangeably.

Due to the limited training time and the need to maintain high levels of physical fitness over the long competitive season in contemporary soccer, monitoring players' individual physiological and perceptual responses to different training sessions during the week appears critical. While a clear trend toward a greater physiological and perceptual load in sessions performed at the beginning of the week appears to be a conscious decision by the coaches, substantial between-players differences in the perceptual-physiological relationship were found in the current study in those sessions (ie, SCT+SSGs). Thus, care should be taken when monitoring those sessions. For example, further measures might be desirable in players showing divergent HR and sRPE results during such sessions.

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