Variation in the correlation between heart rate and session rating of perceived exertion based estimations of internal training load in youth soccer players

Abstract:

Purpose: When exposed to the same external load, players receive different internal load resulting in varied adaptations in fitness. In adult soccer, Internal Training Load (ITL) is measured using Heart Rate (HR) and session Rating of Perceived Exertion (sRPE) scale, but has been under-utilised in youth soccer. This study investigated the in-season variation in correlation between HR and sRPE estimations of training load for adolescent soccer players. *Method:* Fifteen male professional adolescent players were monitored for 7 months. Within-participant correlations and Bland-Altman agreement plots for HR and sRPE were calculated for each month to analyse the variation over the season, and for individual players to analyse the validity of the scale. *Results:* The monthly correlations ranged from r=0.60 to r=0.73 (p<0.05) and the overall correlation was r=0.64 (95%CI 0.60-0.68; p<0.001). Bland-Altman plots showed an agreement of methods. *Conclusion:* Results showed consistently large correlations for all months. sRPE is a consistent method of measure of internal training load for the entire season. Validity analysis found no bias in sRPE measurements when compared to HR for all players in the study.

Key words: perceived exertion, heart rate, adolescents, youth soccer, training load

Introduction:

The professional youth soccer season typically runs for ten months from July to April. The high demand and long duration of professional soccer puts coaches under pressure to produce results, maintain match fitness and allow sufficient time for recovery (5). With limited time, staff resources, and competitive matches each week, coaches often conduct training in groups, focusing on multiple aspects of the sport within a training session (2, 5). The organisation of the training for team sports makes group sessions essential for appropriate match related and developmental adaptations. Consequently, this makes it difficult to design training sessions to cater to each individual player's requirements, leading to varied inter-player responses (6). While the External Training Load (ETL) for all players is the same, individual characteristics like baseline fitness, illness, weather, nutrition, cause different adaptations among players (16). For the same ETL (training drills), players experience different internal training loads (response to ETL). Players with higher levels of fitness often do not receive sufficient stimulus to improve their fitness levels during group training sessions (14) while players with lower fitness levels show increased stress, fatigue and potential risk of injury (2). To ascertain appropriate load on each player throughout the season, it is important to monitor the training load on individual players.

Research has shown that rather than the ETL, it is the player specific internal response to the external load that causes changes in fitness (5, 14, 16). With the demand for consistent performance throughout the season, teams commonly use measures of ITL as markers of match fitness and fatigue levels (13, 16). ITL is quantified as the product of exercise intensity and duration of the exercise (Eq. 1);

$$\text{Internal training Load (AU)} = \text{exercise intensity (AU)} \times \text{duration of exercise (min)} \quad \text{(Eq.1)}$$

Thus, the duration is the same for all the players, whilst the intensity varies. The most commonly used methods to monitor ITL in soccer are HR based estimations and perception of effort based estimations (21). HR is a non-intrusive measure of physiological response and is monitored using HR transmitter belts worn by the players (23). HR demonstrates a nearly linear relationship with VO_2 over a wide range of steady-state submaximal exercise intensities and is considered a reliable measure of aerobic exercise intensity (11). In soccer, various methods based on the analysis of HR such as Banister's training impulses, Edwards' Training Load, or Lucia's Training Load are used to measure HR training load (1, 2, 5). However, previous research has revealed HR estimations have poor sensitivity at high intensities (1, 5) and have limited applicability in soccer, where the training load includes short bursts of high intensity activity, comprising higher contributions of anaerobic metabolism (17). Furthermore, the apparatus required to monitor HR for a whole youth squad can be expensive and requires considerable time for staff analyses. Hence, individual player data needs the expertise of the sports science staff to analyse and interpret any training effects (17, 14).

An alternative method to quantify ITL is the session-Rate of Perceived Exertion (sRPE) which was first proposed for team sports by Foster et al. (11). This method measures the psychological response of the player to training load (20, 21), measured on a scale from 0 to 10, where 0 represents rest and 10 represents maximal effort. This method is easy to implement and provides a cost-effective and efficient alternative to HR measures (12, 21, 22).

Many studies have investigated the use of sRPE scale as a measure of ITL in soccer

(1, 2, 5-9, 15, 17, 21, 22). These studies measured the correlation between HR and sRPE over different types of training sessions, such as technical and tactical development, resistance training, physical conditioning (2, 5), position specific (17) and average weekly load (1, 14). The studies found correlations between Heart Rate Training Load (HRTL) and sRPE Training Load (sRPETL), which ranged between $r=0.17$ (21) to $r=0.84$ (17). Only two studies (17, 22) analysed the data using within participant correlations. Within participant correlations, where the longitudinal dataset is modelled as a whole, are associated with higher levels of statistical power and corrected degrees of freedom (17, 22). While Fanchini et al. (9) stated that the Borg CR10 scale has been validated against HR in soccer (9), this validation is limited in its interpretation. The studies validating the scale (1, 2, 5, 7, 15) merely correlate the two measures. While correlations indicate the strength of relationships between measures, they do not fully explain any biases or trends that may influence the correlation (3). Despite high correlations there may be a significant bias in one of the measures, which can be quantified using Bland-Altman plots of agreement (3). However, no study has analysed the HR and sRPE data for this bias using Bland-Altman plots of agreement. Though studies support the use of sRPE as a global indicator of training load in soccer, they have cautioned on the interchangeability of the two methods. This is because using sRPE explains between 12-70% of the variation in HR (1, 2, 5-9, 15, 17, 21). Since the precise reason for the large variation is unknown, it is difficult to accurately estimate the correlation for a session.

To the best of the author's knowledge, only five studies analysing the correlation between HR and sRPE in adolescents and children have been conducted, and consist of durations ranging from 6 to 16 weeks. Strong correlations were found for professional adolescent boys (age=17±1 years; $r=0.75$; $p<0.02$) (1), amateur adolescent boys (age=17±0.7 years; $r=0.54\text{-}0.78$; $p<0.01$) (15), (age=17.2±0.8 years; $r=0.72$) (22) and elite adolescent girls (age=19.3±2 years; $r=0.52\text{-}0.82$; $p<0.01$) (2), whilst Rodriguez-Marroyo and Antonan (21) found a small and non-significant correlation (age=11.4±0.5 year; $r= 0.17$, $p>0.05$) in children aged between 11 and 12 years. The only study on professional adolescent boys (age= 17±1 years) was statistically underpowered as players were excluded due to poor compliance (1). Thus, the strength of correlations may not be representative as these studies (1, 2, 15, 21) have been conducted only for a few weeks during the season, mostly at the start of the season (1, 15), reflecting a relatively small portion of the season.

Since sRPE is receptive to cumulative fatigue and stress (15), for the same training session that may be conducted in August and January, the load may be markedly different due to the training schedule, home or away games, or play-offs. While adult professionals are more experienced to handling the stress of professional soccer, adolescent players are still in their developmental phase and may respond differently (10, 18, 21). Moreover, professional adolescent players are more susceptible to non-functional overreaching and overtraining compared to recreational players (19). The Long-Term Athlete Development model (LTAD) classifies players aged 16 to 18 years as in the "training to compete" phase of development with highly structured training (10, 18). At this age, players are still developing their physical attributes and cognitive skills specific to the sport (18). The response to training load and recovery will therefore be markedly different to adult professionals who have greater developed physical attributes specific to soccer and where training is predominantly on maintaining and improving physical attributes and performance (10, 18). Hence, results from studies on adult players are not generalizable to children and adolescent players. Further research is required to understand these relationships for adolescent players. Data collected over the entire season will reflect the training load for a season rather than just a selected portion. Hence, a longitudinal study will provide a larger data set yielding results with higher sensitivity and power.

Therefore, the aim of this study is to observe the in-season variation in the relationship between HR and sRPE based estimations of training load in professional youth soccer players over an entire season. Since sRPE is sensititve to cumulative fatigue (15), towards the end of the season, we assume the athlete's perception to training load to be weakened. It was, therefore, hypothesised that the correlation will be stronger at the beginning of the season compared to the end of the season. A secondary aim was to examine the validity of the scale for each player over the duration of the season.

Methods:

Participants:

Fifteen male professional youth players (age: 16.7±1.0 yr.; stature:176.3 ±5.3 cm; body mass: 69.9 ±6.9 kg) were monitored over a competitive season for 7 months from October 2016 to April 2017. Data from 160 training sessions were collected and analysed. All players were contractually registered as part of an under-18 team competing in the English Football League Youth Alliance League. All players and parents were fully informed of the aims and procedure of the study and written consent was provided. This study was approved by the Institutional Ethics Committee. Goalkeepers were excluded from the study as goalkeepers training load is very different from the training load of the outfield players. Players on trial were also excluded as these players usually attend only a few training sessions, thus using their data would introduce a bias in the study

Data Collection:

The training week typically consisted of 7 training sessions and one match. A general training week consisted of two technical sessions on Mondays, strength training on Tuesday, resistance training on Wednesday, one speed and one technical session on Thursday and match preparation on Friday. Matches were played on Saturdays. Sundays were rest days. Weeks where matches were on both Saturday and Wednesday, training load was adjusted as match preparation on Tuesday and rest on Thursdays. In order to maintain consistency, data for all sessions was collected for the training session only, not the warm-up or cool-down.

Heart Rate Training Load (HRTL):

For this study, HRTL was used as the criterion measure of ITL (14, 17). Each player was assigned a specific HR monitor from Polar Team 2 HR Monitors from October to mid-November and a specific HR monitor from Polar Pro HR Monitors (Software version 1.3.1) from mid-November to April. Player HR was recorded at 1 second intervals throughout the training session. The data was downloaded onto a PC using Polar Team Pro web service application (Software 1.0.7). This study used Edwards' method of calculating heart rate based training load (17). This method is easy to implement, non-intrusive and has been found to be a reliable measure of HR based training load in soccer (1, 5, 14). For each player, HRTL for each session was quantified as:

$$\text{HRTL(AU)} = \sum [\text{time (min) spent in zone x numerical factor of zone}]$$

The numerical factor was calculated as a percentage of HR_{max} as 50-59%[HR_{max}] = 1, 60-69%[HR_{max}] = 2, 70-79%[HR_{max}] = 3, 80-89%[HR_{max}] = 4, 90-100%[HR_{max}] = 5.

HR_{max} was predicted as:

$$HR_{max} = 220 - \text{Age of player.}$$

This was adjusted where players regularly exceeded their HR_{max}. Where a player regularly exceeded this value, the mean recording of HR_{max} was used.

Session Rating of Perceived Exertion Training Load (sRPETL):

sRPETL is the primary outcome measure for this study. sRPE was collected about twenty minutes after the end of the training session to reflect the entire training session rather than the most recent activity (11). While studies have collected sRPE data 30 minutes after the end of the session (1, 5, 6, 15), few studies have analysed the effect of time on the measurement of sRPE. Christen et. Al (8), found no significant effect of post exercise time on sRPE value. We, therefore, infer that 20-min post training will be sufficient time to reduce the influence of the last exercise on sRPE. The inclusion of cooldown does affect the sRPE value (8), however, since in the current study the players reported sRPE about 10 mins after cooldown (assuming average cooldown time to be 10 mins) there should be no effect of last exercise on sRPE reporting. The players answered the question “How would you rate the intensity of your session?” using the Borg CR 10 scale with a number from 0 to 10, with 0 being rest and 10 being maximal effort (4). Players were familiarised with the scale for a month during pre-season. The sRPE data was collected in isolation via a Google Forms questionnaire on their smartphones in the changing room at the end of each session. The data was monitored by the sports scientists to avoid peer pressure and coach’s opinion influencing the players’ reporting. sRPE training load was quantified as:

sRPE training load (AU) = sRPE x duration of session (min)

Data Processing:

All training sessions and match data over the 7-month period were collected for the study. Sessions or matches where either HR or sRPE data were missing, due to either HR monitors not working or players forgetting to fill in the sRPE data, were excluded from the analysis. Sessions where players trained with either the first team or the under 21 team were excluded from analysis. Rehabilitation sessions were also excluded from the analysis. All data was processed by the same trained individual.

Statistical Analysis:

Data are expressed as means ± Standard Deviation (SD). Relationships between variables were analysed using Pearson's correlation coefficients. Significance level was set at $p<0.05$. The magnitude of correlation between the variables was interpreted using the following criteria: $r < 0.1$, 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; $r=1$ perfect (17). Data were analysed using SPSS statistical analysis software for Mac (version 23.0, SPSS Inc., Chicago, IL, USA).

Monthly Variation:

To examine the monthly variation, HRTL and sRPETL were correlated using within participant Pearson's correlations. This method quantifies the correlation, and 95% Confidence Intervals (CI), between the covariate (HR) and outcome (sRPE) while accounting for the within-participant nature of the study design. Data was pooled for the month, not for individual participants, providing higher degrees of freedom and statistical power than for individual participants. To understand the difference between the correlations, Fisher's r-to-z transformation was used. To investigate the trends or biases in the data Bland-Altman plots of agreement and 95% Limits Of Agreement (LOA) were plotted for each month using standardised scores (z-scores) of HR and sRPE training loads (3). The 95% LOA were calculated as: mean difference ±1.96xSD of differences. Coefficient of determination (R^2) were calculated to investigate percentage of variance in HRTL estimations explained by sRPETL for each month.

Validity of scale :

To examine the validity of the scale individual player correlations between HRTL and sRPETL were calculated. Data were pooled by individual players for the entire period of the study. Validity of the scale was analysed by Bland-Altman plots of agreement and 95% LOA. Coefficient of determination (R^2) were calculated to investigate percentage of variance in HRTL estimations explained by sRPETL for each player.

Results:

Monthly Variation:

The mean HRTL and sRPETL across the observed sessions was 259±96AU and 398±180AU respectively. A total of 863 data points (36.9% of total data) were analysed and 1477 (63.1%) were not included due to the following reasons: 88 rehabilitation data points (3.8%), 929 data points (39.7%) because only one measure was recorded/reported and finally 460 data points (19.7%) were lost since neither measure was reported/recorded. The changes in HRTL and changes in sRPETL, over the entire period of the study, showed large correlations (r=0.64; 95% CI 0.60-0.68; $p<0.001$). Monthly correlations, number of sessions for each month, average HRTL and sRPETL for each month and R^2 are shown in Table 1. There was no statistically significant difference between the monthly correlations between any months when analysed using Fisher's r-to-z transformation.

PLACE TABLE 1 ABOUT HERE

The agreement of methods was consistent through the months with a bias of 0.0 to -0.0002 between the methods. Figures 1A and 1B shows the Bland-Altman agreement plot for each month with 95% LOA.

PLACE FIGURES 1A and 1B ABOUT HERE

Validity of scale:

Individual player correlations, total number of sessions for each player and R^2 are shown in Table 2.

PLACE TABLE 2 ABOUT HERE

Figures 2A, 2B and 2C shows the Bland-Altman agreement plots with 95% LOA for individual players over the entire duration of the season. The methods showed consistent agreement with a bias range of 0.0 and -0.59.

PLACE FIGURES 2A, 2B AND 2C ABOUT HERE

Discussion:

The aim of this study was to observe the in-season variation in the correlation between HR and sRPE based estimations of training load in professional adolescent soccer players over an entire season. As shown in Table 1, HRTL and sRPETL showed large to very large correlations for all the months, ranging from r=0.60 to r=0.73. These results are consistent with previous studies on senior professional men (5, 9, 17), senior semi-professional men (6) and elite women (2). They are also supportive of findings in one study of professional (1) and a second study of amateur adolescent players (14), but extend the findings by establishing the relationship over a longer period of time.

The LTAD classifies players aged 16 to 18 years to have transitioned from the “training to train” phase into the “training to compete” phase of development with highly structured training (10, 18). Players in this phase are still developing their metabolic conditioning, endurance strength and power specific to soccer, with lower performance pressure as training is still focused around “training to compete” rather than “training to win” (18). The response to training load and recovery will therefore be markedly different to adult professionals who have fully developed physical attributes specific to soccer and where training is predominantly on maintaining and improving physical attributes and performance (10, 18). The weaker strength of correlations found in this study, compared to Kelly et al. (17), where $r= 0.75,$ on adult professional players, may be due to the difference caused by the age and training status of the players.

The correlation was strongest in October (r=0.73) and weakest in April (r=0.60) showing a possible influence of time on the strength of correlation (Table 1). However, the relatively weak correlation in April may be because the number of sessions analysed were fewer in April compared to other months. On analysis of the 95% CI there appears a clear overlap of range of correlations for each month. Moreover, when analysed using Fisher’s r-to-z transformation, there was no significant difference in the correlations between the months. The hypothesis that the correlation is stronger at the beginning of the season compared to the later parts of the season was rejected. There seems to be no effect of time on the strength of correlation. These results show that sRPE is a reliable measure when compared to HR throughout the season. The players can perceive the training load through the season with reasonable accuracy. Any changes that may occur in training load seem to be accounted for in both measurement methods.

Since correlations are compared over the whole range of data, high correlations are often reported despite biases in the method. This implies that the methods may relate but may consistently over or underestimate the measurement (3). Bland-Altman agreement plots were plotted to observe the trends and biases in the data. This is the first study to use this statistical approach between HR and sRPE measures, providing a better understanding of the spread of the data. The Bland-Altman agreement plots (Figures 1A and 1B) for each month show a bias of 0.00 to -0.0002 demonstrating that the methods agree and sRPETL estimates the internal training load with similar accuracy as HRTL.

The diagonal patterns visible in the data are due to the discrete nature of the sRPE data. The sRPE training load takes values as the product of 0 to 10 on the scale and session duration which typically ranges from 60-120 minutes. The sRPETL values are distinct and repetitive, for example each score on the sRPE scale represents a HRTL range and not a specific value. Thus, the sensitivity of sRPE to changes in training load is weaker than HR, which is on a continuous scale with more precise values. Therefore, over a certain range of HRTL values, the player's sRPE scale representation will be the same, which causes the diagonal patterns in the Figures 1 and 2. Moreover, the sRPETL reflects the average session training load and does not provide continuous data for the duration of the session. For a more detailed training load, coaches can measure the load during different specific drills or components of the training session. However, multiple monitoring of the intensity and progressions within the training session is unlikely to be practical given the limited resources of many academies, hence a single global estimation is more pragmatic.

The secondary aim of the study was to examine the validity of the scale for individual players. While interpreting the data for each month, it is important to note that individual players may bias the overall result. For practical use, it is crucial that the scale be valid for all players. Therefore, individual player analyses were completed. The individual correlations ranged from large (*r*=0.54) to very large (*r*=0.88), consistent with individual correlations as reported by Impellizzeri et al. (15) and Alexiou & Coutts (2). The large variation in individual correlations may be due to varying number of sessions analysed for each player and their different response and recovery to ITL. Players with less game time may have lower levels of cumulative fatigue since match load accounts for a significant portion of the weekly training load (14, 17). Individual and team performance may also psychologically affect the stress perception among athletes. Better performance increases psychological wellbeing which may reduce perceived effort.

Players were often selected to play for the under-21 or senior team which would imply a higher workload compared to their peers in the under-18 team. These sessions, while excluded from analysis, may influence the training load in the subsequent sessions with the under-18 team. It has been reported that 72 hours after an intense training session or match, players have elevated levels of fatigue, tiredness, muscle soreness, which may influence sRPE in the subsequent sessions (5).

Research has shown (2, 5) that the strength of correlation may be dependent on the training session type since the aerobic and anaerobic components vary significantly between resistance, endurance, technical, tactical and speed sessions. In this study, the variation in correlations may be due to types of sessions being grouped together. Varied levels of player compliance resulted in the number of sessions analysed for each player to vary significantly. Since the nature of training sessions analysed within this varying data set for each player is unknown, the different correlations could be possibly associated to the proportional influence of different session types. The Bland-Altman agreement plots for each player (Figures 2A, 2B and 2C) show a bias of 0.00 to -0.59 supporting the use of sRPE as a valid measure of ITL for all the players. These Figures 2A, 2B and 2C show that there is no bias in the data. This is the first study to look at the spread of the data for individual players. This supports the use of sRPE as a measure of ITL in soccer. Coaches can thus confidently incorporate the use of sRPE for ITL monitoring for their players. Though sRPE is not as precise as HR monitoring, it will provide coaches with immediate and reliable information regarding the ITL of the session.

Limitations and future research:

Since the current study initiated data collection two months into the season due to logistical constraints, findings were restricted to the concluding seven months. Furthermore, the number of sessions analysed for each month varies significantly due to variable player compliance. Future research must increase the monitoring of player data to increase strength of analysis. Another limitation in the study is that the HR monitors were changed mid-November. However, since both HR monitors were from the same brand and showed same levels of sensitivity, this change did not affect the data. sRPE is a subjective measure of ITL and while we controlled for peer pressure and coaches' influences on the players' report, in practice, it is impossible to eliminate external influences.

Future research should establish base-line HR values corresponding to the sRPE scale using laboratory tests of field techniques at the start of the season to analyse the validity of the scale more accurately. Studies have varied in their understanding of the different strengths of correlations suggesting it may be the nature of training type

(2, 5), age (21), time point in the season or duration of study that affect the correlation. Coutts et al. (7) found that measuring blood lactate, as well as sRPE, explained an increased 14.7% in total variance of HRTL compared to sRPE alone. A more comprehensive longitudinal study analysing different session types and including more extensive measures of ITL throughout the season may explain the variability in the correlations. Comparisons between age groups may be difficult due to different external loads, however studies across different age groups must be conducted for universal use of the scale in soccer.

Conclusion:

To the best of the author's knowledge, this is the first study on professional youth soccer players to be conducted for the entire season. The large data set collected and higher statistical strength of this study may provide a more accurate representation of training load in youth professional soccer. This is the first study to examine the agreement of HRTL and sRPETL in youth soccer. The large to very large correlations between HRTL and sRPETL found in this study show that sRPETL is a reliable measure of ITL for the entire duration of the season, with small variations, which may be due to number of sessions analysed, type of session, away or home game load. Individual player analysis supports the use of sRPE as a valid measure of ITL when compared to HR with little bias between the two methods of measures.

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Figures:

Figure 1A. Bland-Altman Agreement plots between HRTL and sRPETL from October to January

Figure 1B. Bland-Altman Agreement plots between HRTL and sRPETL from February to April

Figure 2A. Bland-Altman Agreement plots between HRTL and sRPETL for individual players (Player 1 to Player 5)

Figure 2B. Bland-Altman Agreement plots between HRTL and sRPETL for individual players (Player 6 to Player 10)

Figure 2C. Bland-Altman Agreement plots between HRTL and sRPETL for individual players (Player 11 to Player 15)

Tables:

Table 1. Within participant monthly correlation and R^2 between HRTL and sRPETL. *Significant at $p<0.05$

Months	**Number of sessions analysed (N)**	**Average HRTL (AU)**	**Average sRPETL (AU)**	**Correlation (r) with 95%CI**	**R^2**
October	53	222.40	416.32	0.73 (0.55; 0.85) *	0.53
November	190	248.12	416.73	0.70 (0.61; 0.77) *	0.49
December	107	263.06	429.95	0.63 (0.49; 0.77) *	0.40
January	186	264.14	388.04	0.64 (0.54; 0.73) *	0.41
February	177	256.67	392.54	0.67 (0.58; 0.74) *	0.44
March	114	273.38	369.96	0.70 (0.61; 0.79) *	0.49
April	36	285.11	352.50	0.60 (0.31; 0.82) *	0.35

Table 2. Individual player correlations and R^2 between HRTL and sRPETL.

*Significant at $p<0.05$

Participant	**Number of sessions analysed (N)**	**Correlation (r)**	**R^2**
1	35	0.81*	0.65
2	125	0.69*	0.48
3	40	0.54*	0.29
4	37	0.79*	0.63
5	85	0.70*	0.49
6	59	0.69*	0.47
7	49	0.76*	0.57
8	28	0.67*	0.44
9	42	0.74*	0.55
10	53	0.64*	0.42
11	50	0.65*	0.43
12	76	0.64*	0.41
13	37	0.58*	0.33
14	55	0.88*	0.78
15	92	0.59*	0.35