Convergent validity of CR100-based session ratings of perceived exertion in elite youth football players of different ages

ABSTRACT

Purpose

To assess convergent validity of internal load measured with the CR100 scale in youth football players of three age groups.

Methods

Fifty-nine players, aged 12-17 y, from the youth academy of a professional football club were involved in this study. Convergent validity was examined by calculating the correlation between session-RPE load (sRPE) and Edwards' load, a commonly used load index derived from heart rate, with data originating from one competitive season. The magnitude of the relationship between sRPE and Edward's load was obtained with weighted mean correlations and by assessing the effect of the change of Edward's load on sRPE. Differences between individuals' intercepts and slopes were assessed by interpreting the SD representing the random effects (player identity and the interaction of player identity and scaled Edward's load). Probabilistic decisions about true (infinite-sample) magnitudes accounting for sampling uncertainty were based on one-sided hypothesis tests of substantial magnitudes followed by reference Bayesian analysis.

Results

Very high relationships exist between sRPE load and Edward's load across all age groups, with no meaningful differences in the magnitudes of the relationships between groups. Moderate to large differences between training sessions and games were found in the slopes of the relationships between sRPE and Edward's load in all age groups. Finally, mostly small to moderate differences were observed between individuals for the intercepts and slopes of the relationships between sRPE and Edward's load.

Conclusions

Practitioners working in youth team sports can safely use the CR100 scale to track internal load.

INTRODUCTION

Session ratings of perceived exertion (sRPE) have been used extensively in team sports to measure internal load, which is defined as the subjective responses to an external load [1]. While the validity of sRPE to measure load has been demonstrated in adults, the results of studies conducted in youth are inconsistent [2,3,4,5]. This may be due to the fact that children may have difficulties with understanding the written anchors used in scales such as the original CR10® [6] or the 0-10 scale modified by Foster [7]. However, the CR100® scale [8] may overcome some of the limitations associated with previous scales [9].

We have recently demonstrated that sRPE obtained with the CR100 scale is valid when compared to heart rate-based internal load measures in elite youth football players of 15 ± 1 years of age [10]. It has also been shown that ratings of perceived exertion obtained with the CR100 scales are interchangeable with the ones obtain with the older CR10 scale in players of approximately 18 years of age [11].

However, no information exists regarding the extent to which the validity of CR100-based sRPE load is influenced by the age of players in football. Therefore, the aim of the study was to assess the convergent validity of the CR100 scale to measure the internal training load in youth football players of three different age groups, the differences in individual player intercepts and slopes, and the differences between types of sessions (training vs games).

METHODS

Participants

Fifty-nine players from the youth academy of a professional football club were involved in this study. Players trained and competed for three teams, namely U20 (n = 22, age = 16.9 ± 0.4 y, range 15.3-16.7 y), U18 (n = 19, age 15.0 ± 0.4 y, range 14.1-15.6 y), and U15 (n = 18, age 13.2 ± 0.7 y, range 12.1-14.5 y). All players and parents were informed of the aims and risks associated with this study and provided written consent to participate. The study was approved by the authors' institutional human research ethics committee.

Overview

Training and game data were collected during one season (preseason: October-February; competitive season: February-September), during which players usually participated in four training sessions and one game per week.

The construct validity of the CR100 scale to measure internal training load was examined by assessing its correlations with Edwards' load, a commonly used load index derived from multiplying the time an individual spends in different heart rate zones by a linearly-increasing coefficient. Heart Rate data were collected through wearable technology devices (Team Pro; Polar Electro Oy, Kempele, Finland) and analysed via a Microsoft Excel customized spreadsheet.

CR100 anchoring

An anchoring session was performed during the Yo-Yo intermittent recovery test level 1, which was also used to obtain peak HR. The anchoring sessions consisted of two parts, a verbal anchoring and a physical anchoring. Firstly, before the commencement of the test, the official CR100 instructions were read out to players. These instructions contain an explanation of the aims of the scale, followed by a description of the ratings usually associated with the numbers 0, 6, 25, 45, 70, 90, and 100. Players were then asked to complete the Yo-Yo intermittent recovery test level 1 and provide staff with a rating from the CR100 scale after each shuttle run (physical anchoring). As players were already familiar with this scale, having used either the

CR10 or CR100 scales for at least one season, no further familiarisation was conducted. Anchoring was conducted approximately every six weeks after the initial session.

Heart rate load measurement

Edward's load was calculated by multiplying the duration (in minutes) of exercise in each of five heart rate zones by a coefficient ranging from 1 to 5, detailed as follows:

$$\text{Edwards' load} = \text{Time at each HR zone (min)} \cdot \begin{cases} \text{Zone 5; 90-100\% peak HR} = 5 \\ \text{Zone 4; 80-89\% peak HR} = 4 \\ \text{Zone 3; 70-79\% peak HR} = 3 \\ \text{Zone 2; 60-69\% peak HR} = 2 \\ \text{Zone 1; 50-59\% peak HR} = 1 \end{cases}$$

Only individual session files in which players had completed at least 45 minutes of training or game time were considered for the analysis. This criterion was utilised to make sure no data from substitutes would be included in the final sample.

Statistical analysis

Analyses were performed with the Statistical Analysis System (University edition of SAS Studio, version 9.4, SAS Institute, Cary NC) to assess the convergent validity between sRPE and Edwards' load. The main outcome measure was Pearson's correlation coefficients between these two variables, calculated for each individual and presented as a weighted mean correlation via the Fisher transformation. Magnitude thresholds for these correlations were assumed to be those of usual population correlations: <0.1, 0.1, 0.3, 0.5, 0.7 and 0.9 for trivial, low, moderate, high, very high and extremely high, respectively [12]. Uncertainties (compatibility limits) for the mean correlation and for the comparison of mean correlations between training and games are difficult to estimate because of interdependence of the players' data, which come from the same training sessions and games. The magnitude and uncertainty of the relationship between sRPE and Edward's load were therefore assessed with two general linear mixed models realized with Proc Mixed, which accounted for the interdependence. In both models, the dependent variable was the sRPE. In the first model, which evaluated the relationship with training and games combined, the fixed effect was the Edward's load (numeric, rescaled to a mean of zero for each individual and a mean within-player SD of 0.5, for ease of estimation of this effect). This fixed effect provided the mean within-player effect of two within-player SD of Edward's load (the change in sRPE between a mean player's mean -1 SD and mean +1 SD of Edward's load). This approach allows assessment of the relationship between Edward's load and sRPE load as a change score, effectively treating the slope of the relationship as a change in means, and the effect of two SD of a numeric linear predictor is appropriate to assess the magnitude of the predictor [12]. The magnitudes of effects were evaluated by standardization with the residual from the mixed model, which represents the typical within-player change in sRPE from session to session. The magnitude thresholds for the fixed effects were <0.2, 0.2, 0.6, 1.2, 2.0 and 4.0 for trivial, small, moderate, large, very large and extremely large, respectively [12]. The random effects in this model allowed for individual differences in the intercepts and slopes (effectively allowing for individual differences in the correlations), and an unstructured covariance matrix was specified to allow these effects to be correlated, as required for such "random intercepts and slopes" models. In the second model, which evaluated comparisons of training and games, a fixed effect was included for the type of session (two levels, training and matches, to estimate mean differences at the mean Edward's load) and Edward's load (numeric) interacted with type of session (to estimate different slopes corresponding to different correlations for training and games). The random effects allowed for separate individual differences in intercepts and slopes for training and games, with an unstructured covariance matrix. Separate residuals were specified for training and games and used to standardize the separate effects for training and games. Standardization for comparison of the means for games and training was performed with the harmonic mean of the SDs derived from the two residuals (ref.). Magnitude thresholds for the SD representing individual differences were half those for standardized mean effects [13].

Ref: A spreadsheet to compare means of two groups Will G Hopkins, Sportscience 11, 22-23, 2007

Uncertainty in the estimates of effects is presented as 90% compatibility limits. Probabilistic decisions about true (infinite-sample) magnitudes accounting for the uncertainty were based on one-sided hypothesis tests of substantial magnitudes [14]. The p value for rejecting an hypothesis of a given magnitude was the area of the sampling t distribution of the effect statistic with values of that magnitude. Hypotheses of substantial decrease and increase were rejected if their respective p values were less than 0.05. If one hypothesis was rejected, the p value for the other hypothesis was interpreted as evidence *for* that hypothesis, since the p value corresponds to the posterior probability of the magnitude of the true effect in a reference Bayesian analysis with a minimally informative prior [15,16]. The p value is reported qualitatively using the following scale: 0.25-0.75, possibly; 0.75-0.95, likely; 0.95-0.995, very likely; >0.995, most likely [12]. If neither hypothesis was rejected, the magnitude of the effect was considered to be unclear, and the magnitude of the effect is shown without a probabilistic qualifier. Effects with sufficient probability of a magnitude (at least very likely) were deemed clear.

RESULTS

The descriptive statistics, the weighted mean correlations and the magnitude of the relationships between sRPE and Edward's TL for each age group are shown in Table 1 and 2. The average within-player SD of Edward's used for the assessment of the magnitude of the relationships between sRPE and Edward's TL were 68 for U15, 92 for U18, and 90 for U20.

** Table 1 and 2 near here **

Session RPE was higher in games than training sessions when the intercepts were compared at the mean Edward's load, with clear large effects for U15 (1.55 ± 0.15), U18 (1.37 ± 0.13) and U20 (1.88 ± 0.19). Also, the differences in the magnitude of the relationship between sRPE and Edward's TL when assessed only in games vs. only in training sessions, for each group, are shown in Table 3.

** Table 3 near here **

Finally the individual differences in the intercept and slopes of the correlations between sRPE and Edward's TL are shown in Table 4.

** Table 4 near here **

DISCUSSION

Two main results were observed in this study.

Firstly, very high correlations exist between sRPE load and Edward's TL across all age groups, with no meaningful differences in the magnitudes of the relationships. This means that the

CR100-based sRPE has good convergent validity to track HR-based internal load in athletes as young as twelve, provided that the ratings are obtained following the correct instructions and with anchoring performed at regular intervals. This result is consistent with the level of validity of CR10-based sRPE encountered in youth athletes of other sports [4,17]

** Figure 1 near here **

Secondly, moderate to large differences were found in the slopes of the relationships between sRPE and Edward's TL when assessed only in training sessions or games, in all age groups. Figure 1 highlights how the games slopes are typically shallower than the training ones, signifying that for a given change in heart rate load, the change in sRPE is not the same if a player rates the effort originating from a game or a training session. This result is consistent with previous research highlighting differences in the validity of sRPE in competitive vs. non-competitive training sessions [4]. Important practical implications must be considered when sRPE is used as the primary variable to inform decisions in load management, return to play etc. Similar implications can exist in regards to individual differences within each group, as mostly small to moderate differences were observed between individuals for the intercepts and slopes of the relationships between sRPE and Edward's TL.

PRACTICAL APPLICATIONS

Based on the results of this study practitioners can be confident in using the CR100 scale to assess load in young athletes. However, care must be exercised when interpreting changes in sRPE load originating from a combination of training sessions and games; likewise, practitioners must be careful when applying the same considerations regarding the changes in load to different individuals.

CONCLUSION

Session-RPE obtained with the CR100 scale is a valid tool to assess internal training load in elite youth football players of age varying from 12 to 17 years.

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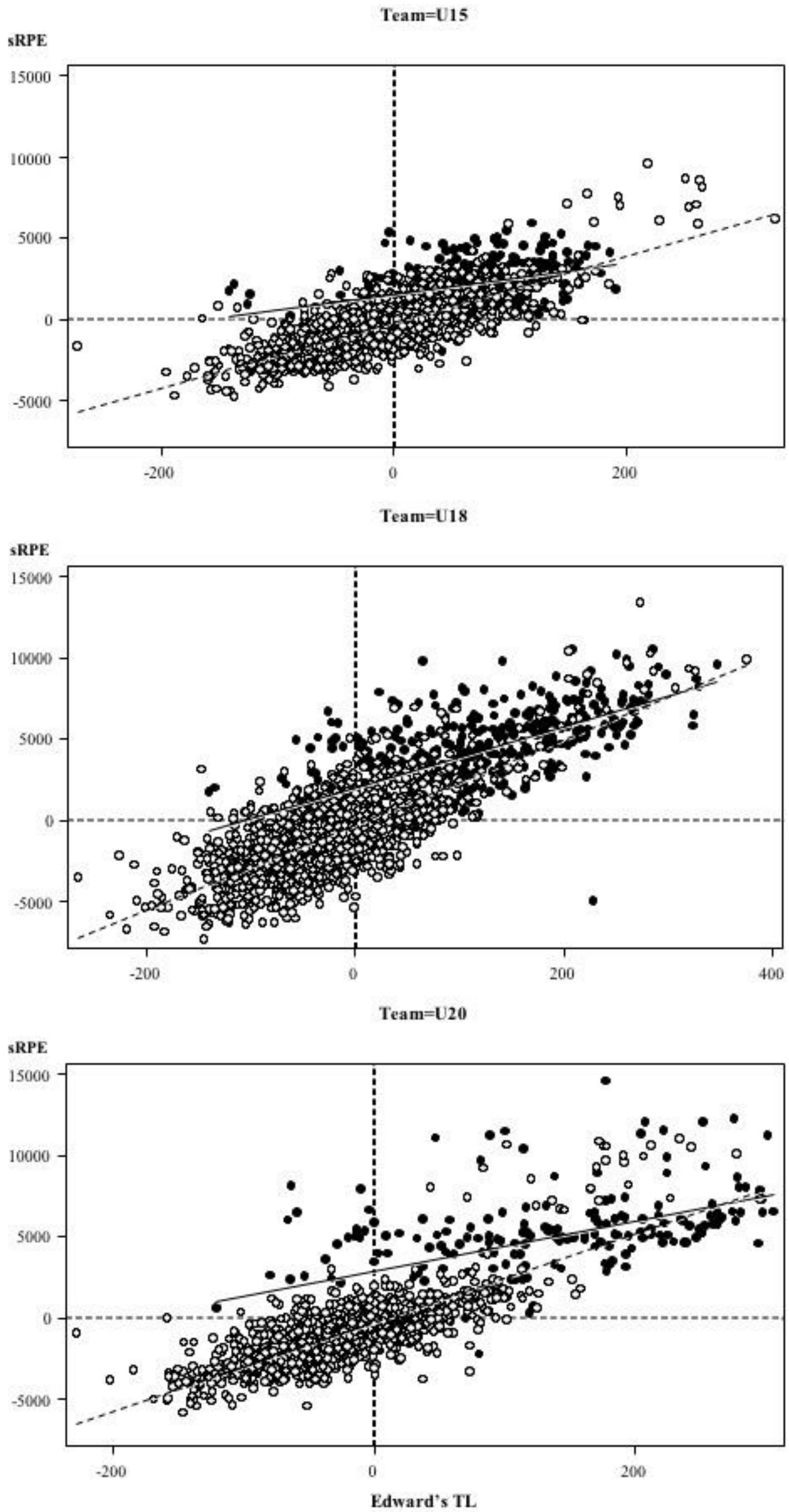
Team=U15
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Edward's TL

Table 1. Descriptive statistics for sRPE and Edward's load in elite youth football players o three different age groups.

Group (n. players; observations)	sRPE (Mean ± SD)	Edward's load (Mean ± SD)
U15 all sessions (18; 1802)	6700 ± 1900	257 ± 72
U15 games only (18; 338)	8900 ± 1400	320 ± 63
U15 training only (18; 1482)	6200 ± 1700	243 ± 67
U18 all sessions (19; 2001)	7700 ± 3300	272 ± 96
U18 games only (18; 405)	11700 ± 2900	381 ± 99
U18 training only (19; 1596)	6600 ± 2500	245 ± 74
U20 all sessions (20; 1237)	7800 ± 3200	255 ± 93
U20 games only (20; 203)	12500 ± 3000	378 ± 101
U20 training only (22; 1034)	6800 ± 2300	230 ± 70

sRPE = session RPE load

Table 2. Weighted mean correlations (via Fisher transformation) and magnitude of the relationships between sRPE and Edward's load in elite youth football players of three different age groups. All session types combined (games and training sessions).

Group (n. players; observations)	Weighted mean correlation (Mean ± SD)	Magnitude (ES, ±90% CI); decision
U15 (18; 1822)	0.78 ± 0.08	3.14, ±0.14; v.large****
U18 (19; 2073)	0.83 ± 0.05	3.29, ±0.17; v.large****
U20 (20; 1279)	0.84 ± 0.08	3.90, ±0.16; v.large****

sRPE = session RPE load
ES = effect size; CI = compatibility interval
The magnitude of the relationship between sRPE and Edward's load was obtained by assessing the effect of two within-player SD of Edward's load on sRPE.
**** = most likely substantial difference.

Table 3. Weighted mean correlations (via Fisher transformation) and differences in the magnitud of the relationships between sRPE and Edward's load, when assessed only in games vs. training sessions, in elite youth football players.

Group	Weighted mean correlation (Mean ± SD)		Difference in the slopes (ES ± 90% CI; decision
	Games	Training	
U15	0.46 ± 0.25	0.77 ± 0.05	-1.46 ± 0.28; large****
U18	0.72 ± 0.17	0.76 ± 0.07	-0.42 ± 0.28; small**
U20	0.59 ± 0.20	0.80 ± 0.08	-1.42 ± 0.45; large****

sRPE = session RPE load
ES = effect size; CI = compatibility interval
For clear effects, the likelihood that the true effect was substantial and/or trivial is indicated as follows: * = possibly; ** = likely, *** = very likely, **** = most likely.

Table 4. Individual differences in the intercept and slope of the correlation between sRPE an Edward's load, in elite youth football players of different age groups.

Group	Individual differences (SD ± 90% CI; decision)			
	Intercepts		Slopes	
	Games	Training	Games	Training
U15	0.58 ± 0.31; moderate***	0.57 ± 0.18; moderate****	0.38 ± 0.36; unclear	0.26 ± 0.12; small***
U18	0.67 ± 0.23; large***	0.67 ± 0.20; large****	0.42 ± 0.37; unclear	0.42 ± 0.20; moderate***
U20	0.46 ± 0..49; unclear	0.60 ± 0.20; large***	0.19 ± 0.42; unclear	0.30 ± 0.34; unclear

sRPE = session RPE load
SD = standardised random effects as standard deviations; CI = compatibility interval
For clear effects, the likelihood that the true effect was substantial and/or trivial is indicated a follows: * = possibly; ** = likely, *** = very likely, **** = most likely.