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ORIGINAL INVESTIGATION

Use of the CR100 Scale for Session Rating of Perceived Exertion in Soccer and Its Interchangeability With the CR10

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Purpose: To examine the construct validity of the session rating perceived exertion (s-RPE) assessed with the Borg CR100 scale to measure training loads in elite soccer and to examine if the CR100 is interchangeable and can provide more-accurate ratings than the CR10 scale. ***Methods:*** Two studies were conducted. The validity of the CR100 was determined in 19 elite soccer players (age 28 ± 6 y, height 180 ± 7 cm, body mass 77 ± 6 kg) during training sessions through correlations with the Edwards heart-rate method (study 1). The interchangeability with CR10 was assessed in 78 soccer players (age 19.3 ± 4.1 y, height 178 ± 5.9 cm, body mass 71.4 ± 6.1 kg) through the Bland–Altman method and correlations between change scores in different sessions. To examine whether the CR100 is more finely graded than the CR10, the proportions of responses corresponding to the verbal expressions were calculated (study 2). ***Results:*** Individual correlations between the Edwards method and s-RPE were large to very large (.52–.85). The mean difference between the 2 scales was –0.3 ± 0.33 AU (90% CI –0.41 to –0.29) with 95% limits of agreements (0.31 to –0.96 AU), Correlations between scales and between-changes scores were nearly perfect (.95 and .91–.98). Ratings corresponding to the verbal anchors were 49% in CR10 and 26% in CR100. ***Conclusions:*** The CR100 is valid for assessing the training load in elite soccer players. It can be used interchangeably with the CR10 and may provide more-precise measures of exercise intensity.

Keywords: RPE, Borg scale, football, training load, heart rate

The rating of perceived exertion (RPE) is a measure of exercise intensity and it is commonly used to calculate the session-RPE (s-RPE) training load (TL).[1] The s-RPE method is a well-established and validated method to quantify the internal TLs in sport.[2] The training process is the systematic repetition of physical exercise that is implemented to elicit internal responses (ie, psychophysiological stresses) that ultimately improve performance. This process can be monitored using measures of both external and internal TLs. External TL is defined as the activity prescribed to the athlete and the internal TL has been defined as the physiological effect imposed by the external TL accordingly with the individual athlete characteristics.[3] Therefore, a similar external TL can result in different internal-TL responses providing different stimuli for individual athletes and consequently different training outcomes.[3]

The s-RPE is calculated as the product of the athlete's perceived intensity and the duration of the session. This method was initially validated as an internal-TL indicator for endurance sports.[2] Later, it was validated by many studies as a measure of internal TL in soccer.[4,5] These studies have shown its validity through assessing its relationship with various heart-rate-based measures of TL.[4,5] The validity of s-RPE as a measure of TL in youth soccer players was first determined by showing significant correlations between s-RPE and heart-rate-based methods (.50–.85).[4] Afterward, when either heart rate or blood lactate was measured, a multiple-regression analysis showed that a significantly greater variance in RPE (58%) was explained by heart rate and lactate together than alone, showing RPE as a good indicator of exercise intensity.[5] These findings have been confirmed in soccer players of different levels, ages, and gender.[6–8] In addition, there are few studies that examined the relationship between s-RPE and indicators of external TL.[6,8] Indeed, s-RPE values have been shown to correlate with total distance; low-, high-, and very-high-speed activities; and Player-Load (.43–.80) measures derived from portable microtechnology devices in professional male soccer players.[6] The s-RPE values showed large correlation with total distance and Player-Load (.74 and .76, respectively) in semiprofessional male players.[8]

The s-RPE method was originally assessed with the Borg CR10 scale; however, later a new scale (ie, the CR100) was proposed that could improve the quality of TL data[9] and reduce the tendency of using whole numbers corresponding to the verbal anchors. The Borg CR100 scale, also called the centiMax scale, is a category ratio scale (similar to the CR10) that has verbal anchors and numbers (starting at absolute zero and equidistant steps) but with values of 0 to 100 arbitrary units (AU).[9] The Borg CR100 scale has been validated for monitoring training loads in team sport (ie, Australian football) comparing the scale with other measures of exercise intensity, including heart rate and various physical activity measures as the criteria for construct validity.[10] However, Australian football may provide different exercise stimulus than other team sports, which may result in different relationships between TLs measured with s-RPE and heart-rate-based methods.[10] At present there are no studies confirming the validity of the CR100 scale to assess internal TLs in soccer players. In addition, there are no studies evaluating the s-RPE in top-level soccer players, where the appropriate control of TL is considered essential to allow

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appropriate recovery and physiological stress to achieve optimal physical performance.

While the CR10 is widely used in research and practice, the new CR100 scale may be used in its place, especially if it is shown to be more sensitive than the CR10. Previous studies that have examined healthy participants during cycling activity reported that the 2 Borg CR scales operate in a similar way. For example, the CR10 and CR100 scales have a similar exponent in the power function,[11] and they also showed a significant correlation in the assessment of breathlessness and leg fatigue (.96 and .95, respectively).[12] In addition, the CR100 has been suggested to be more finely graded due to its wider numerical range,[11] and therefore it may provide more accurate ratings due to its larger numerical range (0–100 AU). However, at present, the interchangeability of the CR10 and CR100 to measure internal TL in soccer has not been verified.

The aims of this study were to examine the CR100's construct validity in the assessment of internal TL in soccer (ie, internal TL as construct) and to assess the interchangeability between the CR10 and CR100 to monitor TL during soccer activity. If the 2 scales are interchangeable their ratings should show agreement and changes in the same direction, providing large correlations between change scores. We hypothesized that the CR100 would be valid to assess internal TL in soccer, and we expected large correlations with other indicators of internal TL (ie, heart rate). We also expected the CR100 scale to be interchangeable with the CR10 and more finely graded than the CR10.

Methods

Subjects and Design

To examine the construct validity of the Borg CR100 scale and its interchangeability with CR10, 2 separate studies on 2 different cohorts of players were designed. Players were highly familiarized with both scales. Instructions for correct use were provided to all teams at the start of the season, and s-RPE was used to monitor daily TL throughout the entire season. The studies were approved by the ethics committee of the University of Verona and conformed to the Declaration of Helsinki.

Study 1

Nineteen Italian top-level (Serie A) professional players (age 28 ± 6 y, height 180 ± 7 cm, body mass 77 ± 6 kg) were involved in the study. Training data were collected during the competitive season from October to March, in which the team participated in the National Championship (Italian Serie A), Europa League Tournament (UEFA to the quarterfinals), and National Cup (TIM Cup).

Study 1 examined the construct validity of the CR100 to measure internal TL by assessing its correlations with heart-rate-based methods (ie, indicator of the reference construct). Since the internal TL was defined as the physiological demands induced by exercise,[3] we used heart rate as a construct indicator of exercise intensity. This approach was used in most previous s-RPE validation studies.[4,7,8]

Heart rate was measured with a telemetric system (Polar Electro Oy, Kempele, Finland). All data were downloaded onto a personal computer and exported to Excel software (Microsoft Corp, Redmond, WA, USA) for further analyses. Since the Edwards method[13] is the most commonly used in similar validation studies,[4,8,14] we used this method to assess internal TL (ie, Edwards TL) with the heart-rate data expressed as percentage of peak heart rate (%HR). Specifically, we calculated the product of the accumulated training duration (minutes) in 5 %HR zones by a coefficient relative to each zone (50–60%HR = 1, 60–70%HR = 2, 70–80%HR = 3, 80–90%HR = 4, 90–100%HR = 5) and then summed the results. Peak heart rate was measured during an incremental test performed on a treadmill at the start of the preseason during the training camp. The treadmill was set at 1% gradient, and the protocol started at a running speed of 9 km/h with stepwise increments of 1 km/h every minute until exhaustion. The test was terminated when the players were not able to run at the selected speed. Consistent verbal encouragement was given to participants by the team's fitness coach. The s-RPE was determined by multiplying the training duration (minutes) by the intensity perceived (ie, RPE)[2] and measured with the CR100 (ie, RPE100). The RPE100 referring to the overall session was collected within 20 minutes after the training session.

Study 2

Seventy-eight soccer players (age 19.3 ± 4.1 y, height 178 ± 5.9 cm, body mass 71.4 ± 6.1 kg) from 4 different teams (1 junior Swiss team, 1 semiprofessional Italian team, and 2 junior professional Italian teams) participated in the study during the last month of the regular season.

Study 2 compared the RPE collected with the CR100 and CR10 (RPE100 and RPE10, respectively) to examine whether they are interchangeable. To investigate the interchangeability between Borg's CR scales, the players reported their ratings using- both the scales in a randomized order at the end of each training session, with a 20-minute period between the 2 assessments. When RPE was collected after 20 minutes, players were asked to think about the perceived exertion (ie, intensity) experienced and not the rating already given.

Statistical Analysis

Data are presented as mean ± SD. To examine the construct validity of the CR100, the individual relationships between s-RPE and Edwards TL were analyzed using Pearson product–moment correlation. The magnitude of the correlations was determined as follows: $r < .1$, trivial; .1 to .3, small; .3 to .5, moderate; .5 to .7, large; .7 to .9, very large; >.9, nearly perfect; and 1, perfect. Interchangeability was examined using the Bland-Altman plot and Pearson product–moment correlation. In study 2 the RPE collected with the CR100 scale was divided by 10 (RPE100/10) to facilitate comparison with the CR10 scale. The Bland–Altman plot and 95% limits of agreement (95% LOA) were used to visually represent and compare RPE10 and RPE100/10. The 95% LOA were calculated as the mean difference ± 1.96 SD of the differences. The mean difference (bias) between the 2 scales was reported with the corresponding 90% confidence intervals (CI). An identity plot was used to present the theoretical relationship of equality between the 2 variables. The Pearson product–moment correlation was calculated both between the 2 scales and between the change scores determined as the RPE absolute differences between training sessions (with high shared variance between changes scores indicating interchangeability). To avoid the influence of individual players with more data points having a greater influence on the correlation coefficient for the interchangeability correlations, we used the corresponding mean value from all sessions (but not for the correlations of the change scores). To compare the association between ratings and verbal anchors in the 2 scales, the numbers of responses given at the level of verbal expressions were compared with the total numbers of ratings given for each scale and expressed as a percentage.[11] Using the same method adopted in a previous study,[11] the scales were divided into 3 zones: A from 0 to weak (weak included), B from above weak to strong, and C above strong to the upper limit. The percentage of rating corresponding to each verbal anchor was calculated for each zone. Statistical analyses were performed using SPSS software (SPSS Statistics 17.0, SPSS Inc, Chicago, IL).

Results

Study 1

Data were collected on 544 training sessions. The mean peak heart rate reached during the incremental running test by the players was 189 ± 7 beats/min. The mean Edwards TL and s-RPE for all the players were 166 ± 55 and 2659 ± 998 AU, respectively. Individual correlations were determined from a minimum of 20 to a maximum of 41 data sessions and are presented in Table 1 (r = .52–.85). The percentages of correlations considered large and very large were 37% and 63%, respectively.

Study 2

Data were collected on 327 training sessions. The mean RPE10 and RPE100/10 were 4.2 ± 1.0 and 3.9 ± 1.0 AU, respectively. The mean difference was –0.3 ± 0.33 AU (90% CI –0.41 to –0.29 AU) (Figure 1). The 95% LOA were 0.31 and –0.96 AU, respectively (Figure 1). The Pearson correlation coefficient between RPE10 and RPE100/10 was nearly perfect, and the linear regression for calculating the RPE100/10 from the RPE10 is shown in Figure 2. The correlation coefficients between change scores in CR10 versus CR100 were nearly perfect, ranging from .91 to .98 (P < .0001).

Table 1 Individual Correlations Between Edwards Training Load and Session Rating of Perceived Exertion (CR100)

Player	Number of sessions	Pearson correlation, r (P)
1	22	.70 (<.0001)
2	34	.78 (<.0001)
3	34	.77 (<.0001)
4	20	.58 (.008)
5	25	.64 (.001)
6	23	.68 (<.0001)
7	31	.64 (<.0001)
8	37	.81 (<.0001)
9	28	.75 (<.0001)
10	23	.74 (<.0001)
11	25	.60 (.001)
12	29	.73 (<.0001)
13	39	.52 (.001)
14	25	.80 (<.0001)
15	23	.76 (<.0001)
16	26	.85 (<.0001)
17	22	.79 (<.0001)
18	41	.78 (<.0001)
19	37	.76 (<.0001)

The ratings corresponding to the verbal anchors were 49% when players used the CR10 and only 26% when using the CR100 (Figure 3). The ratings corresponding to the verbal anchors for each zone were zone A, 7% and 2%; zone B, 34% and 17%; and zone C, 8% and 7% for the CR10 and CR100 scales, respectively.

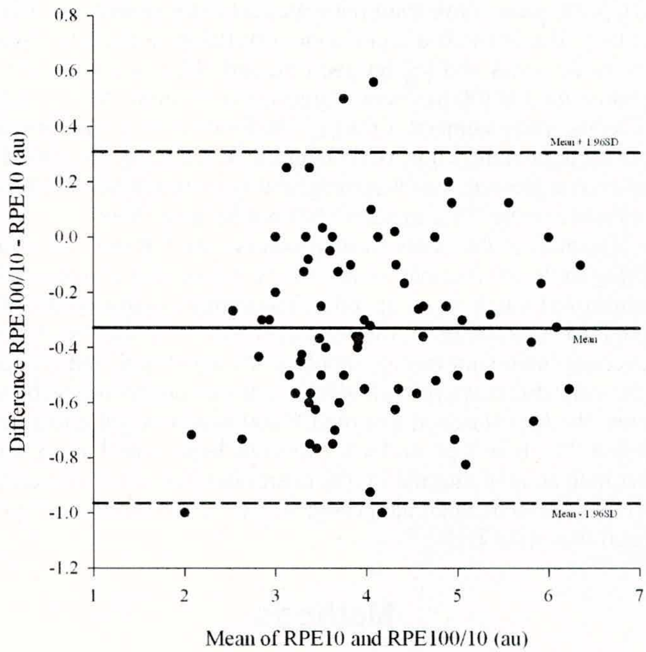

Figure 1 — Interchangeability between RPE10 and RPE100/10, Bland–Altman plot and 95% limits of agreement.

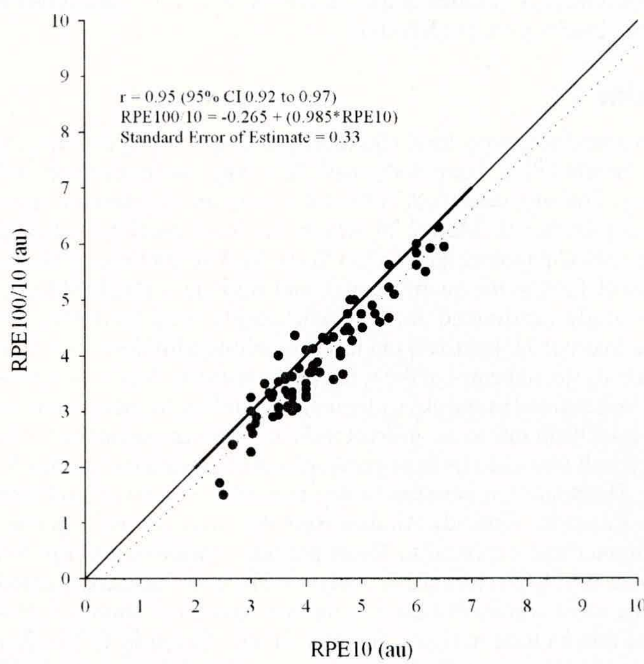

Figure 2 — Identity plot between RPE10 and RPE 100/10.

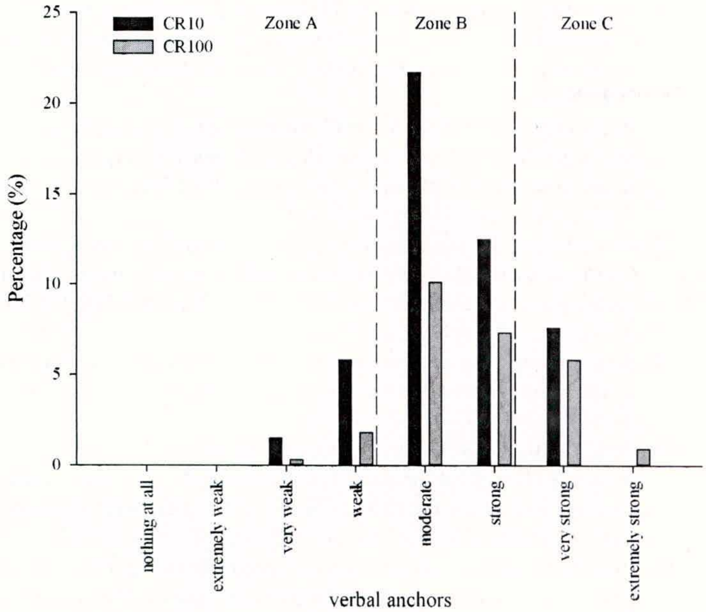

Figure 3 — Percentage of ratings clustered at the positions corresponding to verbal anchors in CR10 and CR100 assessments.

Discussion

The current results showed that the s-RPE determined with the Borg CR100 scale is a valid measure of internal TL in top-level soccer players. We also found the CR100 scale to be interchangeable with the CR10 scale. These results showed that the CR100 may be preferable to the CR10 scale, as it is more finely graded over a wider numerical range and has less clustering of ratings around verbal anchors than the CR10 scale.

Our results are consistent with previous studies using the CR10 to assess s-RPE in different populations of soccer players. For example, Impellizzeri et al[4] reported significant individual correlations between s-RPE- and heart-rate-based methods in young soccer players (.50–.85). Coutts et al[5] found significant correlations between RPE (.60) and lactate (.63) with heart rate in amateur soccer players, with higher correlations observed when heart rate and lactate were considered together (R^2 = .58). More recently several groups have reported large correlations (.57–.85) between various heart-rate-derived TL measures (ie, Edwards TL, Bannister TRIMP) in elite youth,[7] semiprofessional male,[8] and elite male[6] and female[14] professional soccer players. The current study also confirms the results of Scott et al,[10] who reported very large correlation (.81) between the CR100 scale s-RPE and Edwards TL during skill-based training sessions in professional Australian football players. However, since the correlation reported by Scott et al[10] was determined from pooled data, this analysis may be limited. Indeed, while this approach is commonly used in RPE validation studies, when the number of observations is different between subjects using a pooled correlation, the relationship may be influenced by data from individuals with more data points. For this reason individual correlation is preferable. Nonetheless, while the CR100 appears to be a valid measure to assess internal TL in soccer and Australian football, further studies should be useful to definitively validate the scale in other team sports.

The current results showed the Borg CR100 to be interchangeable with the Borg CR10, with a high between-scales correlation coefficient (.95). Nonetheless, both the identity and Bland–Altman plots showed a bias with the RPE100/10 giving lower values (0.3 AU) than the RPE10 (Figure 1). However, this difference was very low and unlikely to be practically meaningful (3.3 AU on a 0-to-100 scale). Moreover, since the LOA were narrow (±0.6 AU) and the between-scales correlations for both the absolute and change scores were nearly perfect (indicating that a change in the scores between scales had similar meaning), these findings suggest that the 2 scales are quite interchangeable. The current findings agree with the results of Borg et al,[12] who found similar correlation between the 2 CR scales in the assessment of breathlessness and leg fatigue (.96 and .95, respectively) in healthy participants. Therefore, since many coaches have likely collected years of data using the CR10 scale, we have provided the regression equation that can be used to translate these data to CR100 data. Alternatively, the data collected using the CR100 could be divided by 10 to provide data similar to those of the CR10 scale.

A notable finding from the current study was that the CR100 scale demonstrated a lower clustering of the ratings around the verbal anchors than the CR10 (26% vs 49%, respectively) during soccer activity. These results are consistent with previous findings on bicycle-ergometer exercise[11] where 25% of the RPE values corresponded to the same location of verbal anchors when using the CR100 scale compared with the 37% with the CR10.[11] One possible explanation for the proportional differences in the clustering of responses around the verbal anchor points in the current study may be the different number of verbal anchors in the 2 scales (9 and 11 in CR10 and CR100, respectively). However, countering this suggestion, the greatest differences (34% vs 17% in CR10 and CR100) were observed in zone B (weak to strong), where there are 2 verbal anchors for each scale. As suggested previously,[11] the difference in visual design or construction of the scales might also affect this clustering of responses. The current results confirm that the CR100 is more finely graded than the CR10, suggesting that players could provide more sensitive ratings of perceived effort, and this may also improve the statistical properties of the data.

Practical Applications

The popularity of the RPE in both research and practice for assessing internal TL is largely due to its simplicity and scientific validity. The current study has shown that the CR100 is valid and can also be used to determine the s-RPE in top-level soccer players. In addition, we have shown that the CR100 and CR10 scales are interchangeable. Moreover, and important from a practical point of view, we have also shown that the data collected with the previous CR10 scales can be appropriately converted to a CR100 score (or vice versa). The advantage of adopting the CR100 scale for assessing internal load is that the responses tend to be less clustered around the verbal anchors, suggesting that this scale provides a more accurate measure of training intensity than the CR10. Finally, the CR100 has also the advantage of providing associations to a percentage scale,[11] which makes it more logical to use with athletes. As a consequence it appears that the CR100 scale is an improvement on the earlier CR10 scale, so we recommend it for monitoring the training process in soccer.

Conclusions

The validity of the Borg CR100 for measuring TL has been demonstrated in elite soccer players by correlation with heart-rate-based measures of TL. The current findings extend this research to show that the CR100 is interchangeable with the CR10 scale, which allows comparison with session-RPE data collected with the 2 scales. However an advantage of the CR100 scale is that it measures training intensity in a more finely graded manner than the CR10 scale. Therefore, we recommend the CR100 scale for monitoring the TL in team sports.

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