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Article Title: Use of CR100 Scale for Session-RPE in Soccer and Interchangeability With CR10

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Abstract

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 compared to 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 Edwards heart rate method (study one). 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 Bland–Altman method and correlations between change scores in different sessions. To examine whether the CR100® is more fine graded than the CR10®, the proportion of responses corresponding to the verbal expressions were calculated (study two). **Results**: Individual correlations between Edwards' and s-RPE were large to very large (0.5**2** to 0.85). The mean difference between the two scales was -0.3 ± 0.33 AU (90% CI -0.41 to -0.29 AU) with 95% limits of agreements 0.31 to -0.96 AU. Correlations between scales and between changes scores were nearly perfect (0.95 and 0.91 to 0.98). 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.

Key words: rate of perceived exertion, Borg scale, football, training load, heart rate

Introduction

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 used to quantify the internal training loads in sport[2]. The training process is the systematic repetition of physical exercise which is implemented to elicit internal responses (i.e. psycho-physiological 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 characteristics of the athlete[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 the calculated as the product of the athlete's perceived intensity and the duration of the session. This method was initially validated as internal-TL indicator for endurance sports[2]. Later, it has been validated by many studies as 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 measure of TL in youth soccer players was first determined by showing significant correlations between s-RPE and heart rate-based methods (0.50 to 0.85) [4]. Afterwards, when either heart rate or blood lactate were 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 load [6,8]. Indeed, s-RPE values have been shown to correlate with total distance, low-speed, high-speed, very high-speed activities and Player-load™ (range 0.43 to 0.80) measures derived from portable micro-technology devices in professional male soccer players [6]. The s-RPE values showed large correlation with total distance and Player-load™ (0.74 and 0.76, respectively) in semi-professional male players [8].

The s-RPE method was originally assessed with the Borg CR10® scale, however later a new scale (i.e. CR100®) was proposed that could improve the quality of training loads 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®) which has verbal anchors and numbers (starting at absolute zero and equidistant steps) but with values between 0 to 100 arbitrary units (AU) [9]. The Borg CR100® scale has been validated for monitoring training loads in team sport (i.e. Australian football) comparing the scale to other measures of exercise intensity including heart rate and various physical activity measures as the criterions for the construct validity [10]. However, Australian Football may provide different exercise stimulus compared to other team sports which may result in different relationships between training loads 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 training load is considered essential to allow appropriate recovery and physiological stress to achieve optimal physical performance.

Whilst 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 two 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 the two CR scales also showed a significant correlation between in the assessment of breathlessness and leg fatigue (0.96 and 0.95, 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 to 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 1) to examine the CR100® construct validity in the assessment of internal-TL in soccer (i.e. internal-TL as construct) and 2) to assess the interchangeability between the CR10® and CR100® to monitor training loads during soccer activity. If the two scales are interchangeable their ratings should show agreement and changes in the same direction providing large correlations between change scores. We hypothesized the CR100® is valid to assess internal-TL in soccer**,** therefore we expected large correlations with other indicators of internal-TL (i.e. heart rate). In addition we also expected the CR100® scale to be interchangeable with the CR10® and more fine-graded compared to CR10®.

Methods

Subjects and design

To examine the construct validity of the Borg CR100® scale and its interchangeability with CR10® two separate studies on two 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 training load 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 one

Nineteen Italian top-level (Serie A) professional players (age 28 ± 6 years, 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, till quarterfinals) and National Cup (TIM cup).

Study one examined the construct validity of the CR100® to measure internal-TL by assessing its correlations with heart rate-based methods (i.e. 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 is used in most previous s-RPE validation studies [4,7,8].

The heart rate was measured with telemetric system (Polar Electo Oy, Kempele, Finland). All data were downloaded on a personal computer and exported to Excel software program (Microsoft Corporation, U.S.) 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 (i.e. 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 five %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 summated the results. The peak heart rate was measured during an incremental test performed on a treadmill at the start of the pre-season during the training camp. The treadmill was set at 1% gradient and the protocol started at a running speed of 9 $km \cdot h^{-1}$ with stepwise increments of 1 $km \cdot h^{-1}$ every min 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 fitness coach of the team. The s-RPE was determined by multiply the training duration (minutes) by the intensity perceived (i.e. RPE) [2] and measured with the CR100® (i.e. RPE100). The RPE100 referred to the overall session has been collected within 20 minutes after the training session.

Study two

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

The study two compared the RPE collected with the CR100® and CR10® (RPE100 and RPE10, respectively) in order to examine whether they are interchangeable. To investigate the interchangeability between Borgs' 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 min period between the two assessments. When RPE was collected after 20 min, players were asked to think about the perceived exertion (i.e. intensity) experienced and not the rating already given.

Statistical analysis

Data are presented as mean ± standard deviation (SD). In order to examine the construct validity of CR100®, the individual relationships between s-RPE and Edwards-TL were analysed using Pearson's product moment correlation. The magnitude of the correlations was determined using the modified scale by Hopkins (http://www.sportsci.org/resource/stats/2002): $r<0.1$, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; >0.9, nearly perfect; and 1 perfect. The interchangeability was examined using the Bland-Altman plot and Pearson's product moment correlation. In study two 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 was used to visually represent and compare RPE10 and RPE100/10. The 95% limits of agreement (95% LOA) were calculated as the mean difference ± 1.96 the SD of the differences. The mean difference (bias) between the two scales was reported with the corresponding 90% confidence intervals (CI). The identity plot was used to present the theoretical relationship of equality between the two variables. The Pearson's product moment correlation was calculated both between the two 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 two 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 percentage [11]. Using the same method adopted in previous study [11], the scales were divided in three 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 at each verbal anchor was calculated for each zone. Statistical analysis were performed using the software package SPSS (SPSS Statistics 17.0, SPSS Inc., Chicago, IL).

Results

Study one

Data were collected on 544 training sessions. The mean peak HR reached during the incremental running test by the players was 189 ± 7 beats·min^{-1}. The mean Edwards-TL and s-RPE for all the players was 166 ± 55 and 2659 ± 998 AU, respectively. Individual correlations were determined from a minimum of 20 to a maximum of 41 data sessions and presented in Table 1 (r=0.5**2** to 0.85). The percentage of correlations considered large and very large were 37% and 63%, respectively.

Study two

Data were collected on 327 training sessions. The mean RPE10 and RPE100/10 were 4.2 ± 1.0 and 3.9 ± 1.0 AU. 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 (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 showed in Figure 2. The correlation coefficients between changes score in CR10® vs. CR100® were nearly perfect ranging from 0.91 to 0.98 ($p<0.0001$). 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 every 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.

Discussion

The present 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 rating around verbal anchors compared to 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 (from 0.50 to 0.85). Coutts et al. [5] found significant correlations between RPE (0.60) and lactate (0.63) with heart rate in amateur soccer players, with higher correlations observed when heart rate and lactate were considered together (R^2=0.58). More recently several groups have reported large correlations (0.57 to 0.85) between various heart rate-derived training load measures (i.e. Edwards-TL, Bannisters TRIMP) in elite youth [7], semi-professional male

[8] and elite male [6] and female [14] professional **soccer** players. The present study also confirms the results of Scott et al. [10] who reported very large correlation (0.81) between 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, whilst 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, whilst 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 present results showed the Borg CR100® to be interchangeable with the Borg CR10®, with a high between-scale correlation coefficient (0.95). 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 1a). However, this difference was very low and unlikely to be practically meaningful (3.3 AU on a 0-100 scale). Moreover, since the limits of agreement were narrow (+/- 0.6 AU) and the between-scale 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 two scales are quite interchangeable. The present findings agree with the results of Borg et al. [12] that found similar correlation between the two CR scales in the assessment of breathlessness and leg fatigue (0.96 and 0.95, 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 similar data to the CR10® scale.

A notable finding from the present study was that the CR100® scale demonstrated a lower clustering of the ratings around the verbal anchors compared to the CR10® (**26**% vs. 49%, respectively) during soccer activity. These results are consistent with previous findings on bike-ergometer exercise [11] where 25% of the RPE values were corresponded to the same location of verbal anchors when using the CR100® scale compared to 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 present study may be due to the different number of verbal anchors in the two scales (9 and 11 in CR10® and CR100® respectively). However, countering this suggestion, greatest differences (34% vs. 17% in CR10® and CR100®) were observed in zone B (between weak to strong) where there are two 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 present results confirm that the CR100® is more "finely graded" compared to 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 RPE in both research and practice for assessing the internal-TL is largely due to its simplicity and scientific validity. The present study has shown that the CR100® is valid and can be also used for determining the s-RPE in top-level soccer players. In addition, we have shown that the CR100® and CR10® scales are interchangeable. Moreover, importantly 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 or training intensity compared to 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, therefore it is recommended for monitoring the training process in soccer.

Conclusions

The validity of the Borg CR100® for measuring training load has been demonstrated in elite soccer players by correlation with heart rate-based measures of training load. The present 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 two scales. However an advantage of the CR100® scale is that it more finely graded measures the training intensity compared to the CR10® scale. Therefore the CR100® scale is recommended monitoring the training load in the team sports.

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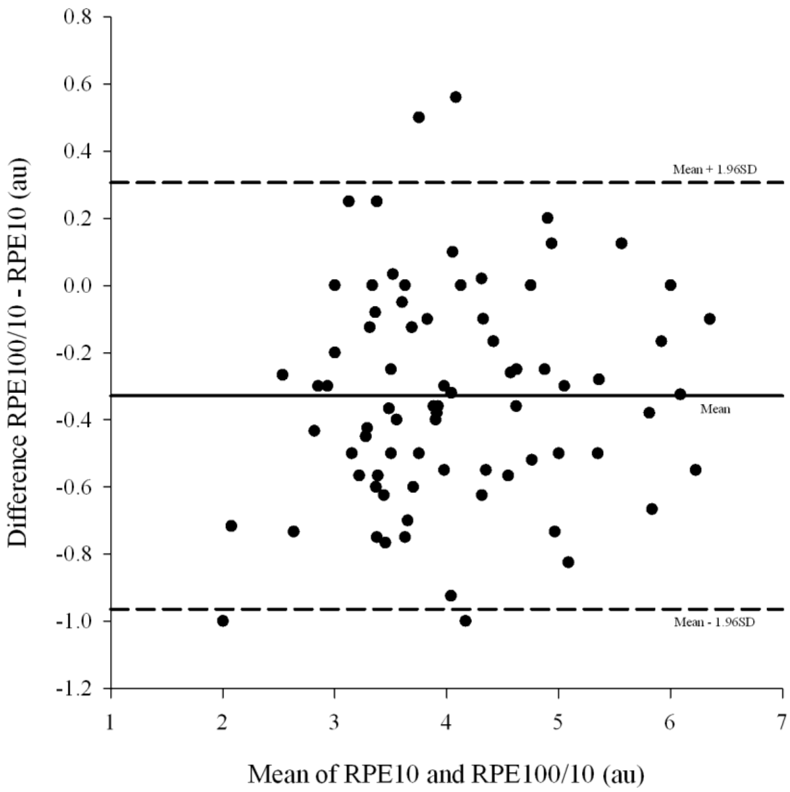

Figure 1. Interchangeability between RPE10 and RPE100/10, Bland & Altman Plot and 95% Limits of Agreement.

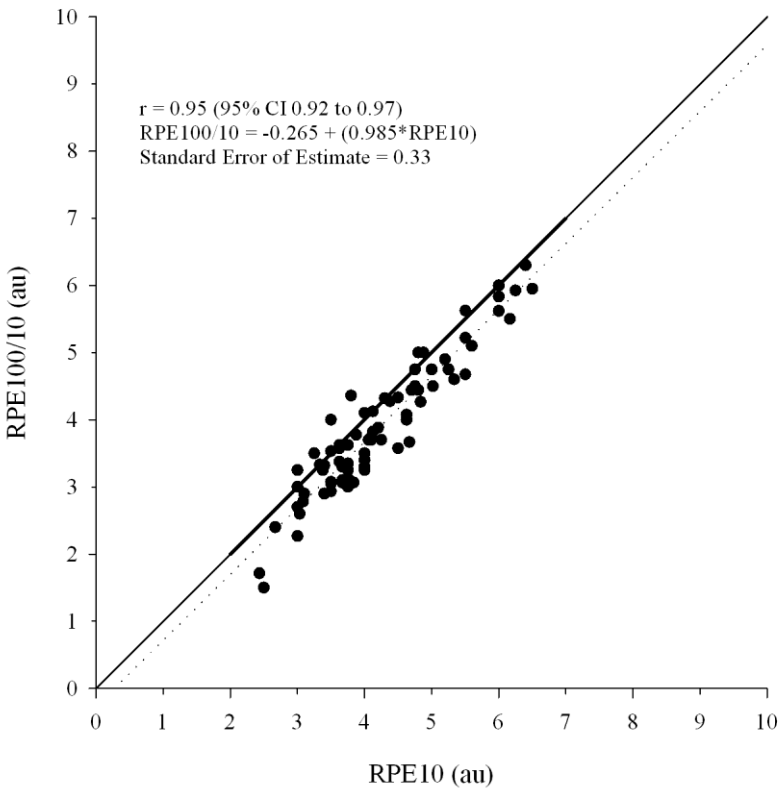

Figure 2. Identity plot between RPE10 and RPE 100/10.

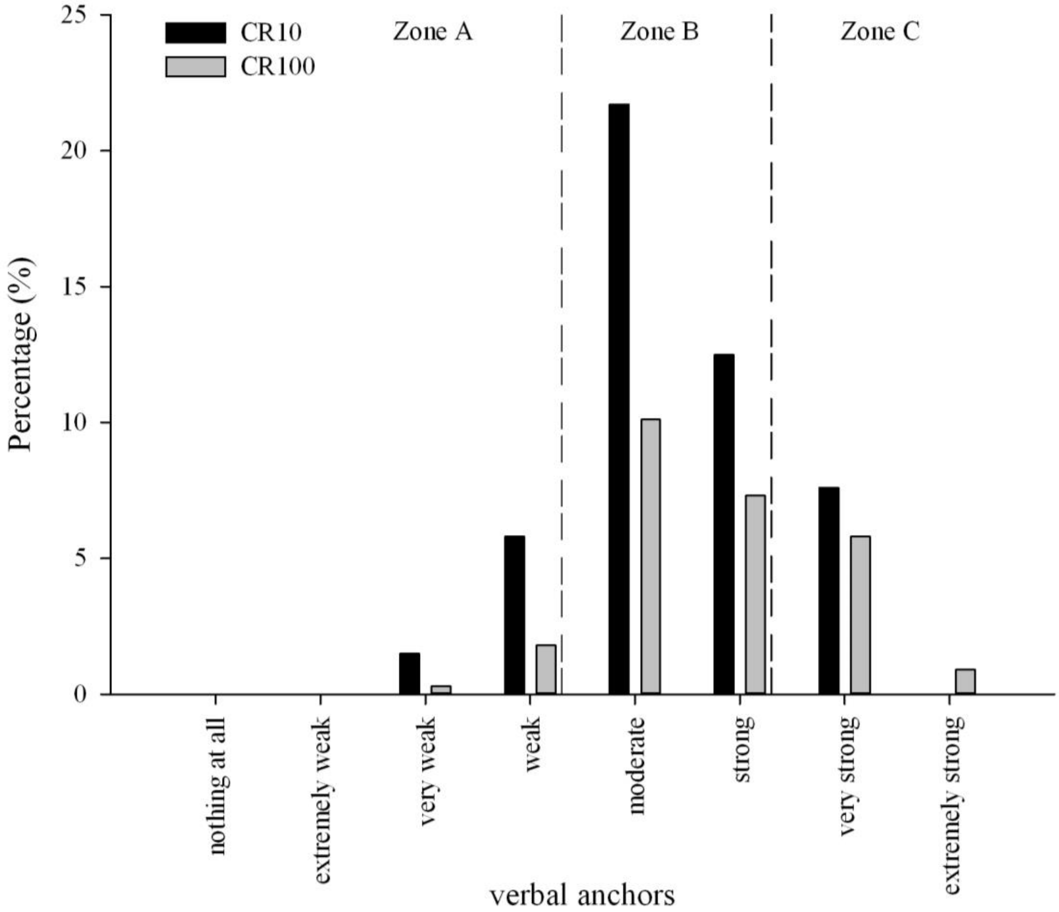

Figure 3. Percentage of ratings clustered at the positions corresponding to verbal anchors in CR10® (black histograms) and CR100® assessments (white histograms).

Table1. Individual correlations between Edwards-TL vs. session-RPE (CR100).

Player ID	N of Sessions	Pearson correlation *r (p level)*
P1	22	0.70 (< 0.0001)
P2	34	0.78 (< 0.0001)
P3	34	0.77 (< 0.0001)
P4	20	0.58 (0.008)
P5	25	0.64 (0.001)
P6	23	0.68 (< 0.0001)
P7	31	0.64 (< 0.0001)
P8	37	0.81 (< 0.0001)
P9	28	0.75 (< 0.0001)
P10	23	0.74 (< 0.0001)
P11	25	0.60 (0.001)
P12	29	0.73 (< 0.0001)
P13	39	0.52 (0.001)
P14	25	0.80 (< 0.0001)
P15	23	0.76 (< 0.0001)
P16	26	0.85 (< 0.0001)
P17	22	0.79 (< 0.0001)
P18	41	0.78 (< 0.0001)
P19	37	0.76 (< 0.0001)

Player ID: identifier