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Abstract

Objectives: To examine the moderating effect of familiarisation on the relationship between external load and ratings of perceived exertion in elite youth soccer players**.** **Methods**: Thirty-five elite male youth soccer players were monitored over a thirty-one-week period. Players had no previous experience using the centiMax scale (CR100®) scale (arbitrary units; au). The final sample included familiarised (blackness test; n=20) and non-familiarised players (n=15) with the Borg CR100® scale. Players recorded a global rating of perceived exertion (RPE) and differential ratings (dRPE) for breathlessness (RPE-B), and leg muscle exertion (RPE-L) 15-30 minutes following training sessions and competitive matches. Separate multivariable-adjusted random-effects generalized additive models with restricted maximum likelihood quantified familiarisation *versus* no-familiarisation differences in actual perceived exertion score (au) by number of accelerations, decelerations, and high-speed running distance (m) as predictor variables, respectively. **Results**: Players improved their blackness test score from 39% to 78%. For explorations by number of accelerations, familiarisation effects were not practically relevant for the RPE and RPE-B variables. The width and sign of the effects for the RPE-L variable at 30 efforts of 10 au (95%CI, 4 to 16 au) suggested scores were lower for players who underwent familiarisation *versus* players who did not. Familiarisation effects were not practically relevant for any RPE variable irrespective of the number of deceleration efforts and high-speed running distance covered. **Conclusion**: Improved performance on the blackness test did not have a moderating effect on the relationship between proxy measures of external load and ratings of perceived exertion.

Key Words: training load, team sports, familiarisation, perceived exertion

Introduction

Ratings of perceived exertion (RPE) represents a simple, non-invasive, and valid means to monitor exercise intensity.[1,2] While RPE provides a global measure of intensity, it may lack sensitivity to cover the range of different exertion signals which arise during exercise.[3,4] To address this potential measurement shortcoming, recent investigations have centred on the use of differential ratings of perceived exertion (dRPE), which distinguish exertional scores between central respiratory and peripheral neuromuscular systems by providing separate ratings for breathlessness (RPE-B) and legs (RPE-L).[5-12] Given that dRPE measures represent unique sensory inputs, this could facilitate a more comprehensive understanding of the internal response induced by training and competition.[7]

Subjective measurement tools require formal psychometric appraisal, applied as intended (e.g., verbal anchors to obtain a numerical rating) and combined with education tools (e.g., Borg's blackness test) to obtain the best results for athletes and coaches.[2] Such processes, however, are rarely ascertained in the sports science literature. It may be assumed that, when different scores could be expected during sessions with disparate loading patterns, the absence of substantial differentiation in different dRPE scores could reflect differences in background education and familiarisation with the rating scale.[2,12] Comprehensive reporting of methodologies concerning RPE procedures including the degree of familiarisation may, therefore, improve the quality of perceived exertion data generally collected. For example, Macpherson et al.,[12] illustrated improvements in accuracy and precision of intensity ratings in team-sport coaches and players following familiarisation with exertional scoring using the blackness test. The blackness test serves as an educational instrument to enhance understanding of the CR10® [1] and CR100® [13] scales by providing participants with examples of a range of differing levels of blackness (0% = white; 100% = black), which are analogous to verbal anchors on the Borg CR intensity scales (i.e., 5% blackness corresponds with very easy; 15% blackness corresponds with easy etc.). Notwithstanding this, clinical research investigating the effects of familiarisation with RPE and dRPE challenged the notion of undergoing a formal learning trial prior to rating with RPE.[14] At moderate (50% $\dot{V}O_{2peak}$) to vigorous (70% $\dot{V}O_{2peak}$) exercise intensities determined on a maximal arm-cranking test, Hutchinson et al., [14] showed a 16-week period familiarisation with dRPE did not influence ratings of perceived exertion on the CR10® scale in adults with spinal cord injury compared to those who received no familiarisation. Nevertheless, no study to date explored the moderating effect of familiarisation with the CR100® scale on ratings of perceived exertion anchored against proxy measures of external load during training and matches in youth soccer.

With this in mind, we aimed to explore whether familiarisation with subjective ratings of perceived exertion moderates the relationship between proxy measures of external load and global RPE and dRPE over an extended period of training and match-play in elite youth soccer players.

Methods

Participants

The study sample thirty-five elite male youth soccer players (age 17.5 ± 1.1 years, body mass 68.8 ± 7.5 kg, height 1.77 ± 0.3 m) from an elite youth academy completed ~5 training sessions per week over a period of thirty-one weeks during the end of 2019-20 season plus phases of pre-season and start of 2020-2021 season. The sample included central defenders (n=6), wide defenders (n=7), central midfielders (n=10), wide midfielders (n=7) and strikers (n=5). Usual appropriate ethics committee clearance was not required as data was collected as a condition of employment and routine service provision.[15]

Design

Unavoidable study conduct modifications in response to the COVID-19 pandemic resulted in important design revisions.[16] By following and adapting a relevant sample of items from the CONSERVE (CONSORT and SPIRIT Extension for RCTs Revised in Extenuating Circumstances) guidelines, we sought to retain the quality, completeness, and transparency of reporting despite unforeseeable circumstances.[16] These modifications aimed to preserve the validity of the forethought research procedures and extended the original research purpose (Table 1). Accordingly, modifications to the original study design due to extenuating circumstances followed a re-adaptation of the CONSERVE guidelines[16] that resulted having two groups of players; these groups included players that did the familiarisation (n=20) and players that did not undergo the familiarization (n=15).

Table 1 about here

In this context, using an observational research design, data were collected following on-field training sessions (121 sessions) and competitive matches (18 matches) over a seven-week pre-season and eighteen-week in-season training period. Given the nature of our data collection process, we conducted sensitivity analyses to assess potential pre- versus in-season differences in training and match load with the trivial between-period differences suggesting pooling all measurements for our primary analyses. The team's typical weekly plan was based on a tactical periodisation model centred on overloading each of the three main fitness components (strength, endurance, speed) on a specific day alongside one competitive match. In a typical training week, Monday served as a recovery day with low-intensity, low-volume drills. Tuesday involved strength training sessions incorporating gym-based lower-body strength exercises together with high-intensity, moderate-volume field-based drills (1v1-5v5). Endurance training via moderate-intensity, high-volume field-based drills (6v6-11v11) was typically scheduled on Wednesday, with speed training via maximal-intensity, low-volume drills (max sprinting speed drills and tactical games) on a Thursday. Moderate-intensity, low-volume reaction drills together with set-pieces occurred on a Friday. Training and match data were only analysed for players completing the whole session, excluding rehabilitation or individual sessions.

Procedures

Familiarisation with dRPE

Players had not used the CR10® or CR100® scales previously. The first author of this study provided all players and coaches with a tutorial on the CR100® scale that explained each of the verbal anchors, the numbers, and the sensations each represented. Then, a group of players underwent a familiarisation process (n=20) in December 2019. The blackness test was provided to the players as a learning tool for the CR100® scale.[12,17] Players completed the blackness test on three occasions with three and seven days between test one and two and test two and three, respectively. The blackness test consisted of nine pictures with filled squares differing in blackness using the grey pre-set colours in Microsoft PowerPoint (5% to 95% blackness). Each picture was presented twice in a randomised order for 10 sec with blanks between each page. The task was to estimate how "strong" the player experienced the blackness of each filled square according to the CR100® scale.[17] The levels of blackness were closely linked to the verbal anchors on the CR100®

scale so players were asked to estimate how strong they experienced blackness on each image according to the CR100® (e.g., the 50% blackness square would represent the '*Strong*' verbal anchor on the CR100®).[12] Each answer was scored for accuracy (i.e., correct/incorrect) and level of precision (i.e., how many arbitrary units [au] away from the correct verbal anchor).[12]

Training Sessions

Player dRPE, along with a global rating for each session (RPE) were recorded 15-30 minutes post-session via a touch-screen tablet application (Iconia One 7 B1-750, Taipei, Taiwan: Acer Inc.) using CR100® scale, which was numerically blinded, labelled with the idiomatic English verbal anchors. Ratings were collected independently and confidentially for each player who was asked to login into the application via his shirt number. Coaches encouraged players how to provide ratings for overall session effort (RPE), breathlessness (RPE-B), and leg muscle exertion (RPE-L). Once players had provided their ratings using the touch-screen tablets, the application software uploaded each score as a number value to a cloud-based spreadsheet.

All training & match activity were monitored with a 10-Hz global positioning system (GPS; Catapult Optimeye S5, version 7.32) which represents a reliable and valid tool for monitoring locomotor activity.[18] To eliminate interunit variability, each player wore their own unit which was inserted into the manufacturer provided vest that holds the receiver tightly between the scapulae. The GPS devices were activated 15 minutes before data collection to allow for acquisition of satellite signals in accordance with the manufacturer's instructions. The average horizontal dilution was 0.74 ± 0.08 and the average number of satellites per unit was 14.3 ± 1.9. After recording, GPS data were downloaded to a computer and analysed using the manufacturer's software (Catapult Openfield Software, version 1.22.0).[18]

Statistical Analysis

Summary data for participants who completed familiarisation sessions were presented as median and interquartile range (IQR). Data from practices and opinions of practitioners from around the world informed the present study modelling framework, with number of accelerations, number of decelerations, and high-speed running distance selected as external load variables of interest.[19,20] Separate multivariable-adjusted random-effects generalized additive models with restricted maximum likelihood[21] quantified familiarisation *versus* no-familiarisation differences in perceived exertion at pre-specified values for each external load variable, respectively.[20] Models included the raw RPE score (au) as the response variable, familiarisation (0, no; 1, yes) as a categorical fixed effect, a smooth term for the external load variable set at 3,5,7, and 9 basis functions, a familiarisation × external load variable interaction term plus subject-specific and session duration random effects penalized by a ridge penalty.[21] An information-theoretic approach was adopted for optimal smooth model selection.[21] Post-estimation model diagnostics was conducted based on visual inspection of each model residuals using the *mgcViz* package.[22] Effects were summarised as estimated marginal means with 95% confidence interval (CI) presented using density strips to illustrate the degree of uncertainty surrounding the point estimates.[23,24] Familiarisation *versus* no-familiarisation effects in perceived exertion by external load were declared different if the location of the 95%CI for the mean estimate exceeded the predefined region of equivalence ranging from -4 au to +4 au (i.e., target value = 8 au) for all RPE scores.[7] Statistical analyses were conducted using R (version 3.6.3, R Foundation for Statistical Computing).

Figure 1 about here

Results

RPE familiarisation

For players who completed the blackness test familiarisation session (n=20), players answered 39% questions correctly with a median (IQR) level precision of 9 (IQR, 7 to 11 AU) on the first session (Figure 1). In subsequent sessions, players answered 64% and 78% correctly with a median level of precision of 5 (IQR, 4 to 7 AU) and 3 (IQR, 2 to 4 AU) in sessions two and three, respectively.

Table 2 about here

Table 3 about here

Table 4 about here

RPE and external load

Descriptive data for RPE and dRPE by number of accelerations, decelerations and high-speed running are presented in Tables 2-4. For explorations by number of accelerations, familiarisation effects were not practically relevant for the RPE and RPE-B variables (Figure 2). The width and sign of the effects for the RPE-L variable at 30 acceleration efforts of 10 au (95%CI, 4 to 16 au) suggested scores were higher for players who did not undergo familiarisation *versus* players who completed the familiarisation (Figure 2). Familiarisation effects were not practically relevant for any RPE measurement irrespective of the number of deceleration efforts (Figure 3) and high-speed running distance (Figure 4) covered, respectively. Analysis of the random-effects variance components indicated the proportion of differences in RPE and dRPE scores accounted for by between-player variability was minimal regardless of the proxy measurement of external load considered in the model.

Figure 2 about here

Figure 3 about here

Figure 4 about here

Discussion

In team sports, the use of perceived exertion scales has now become an established approach to gather proxy measurements of internal load during training and match-play.[6,7,8,12] Despite its widespread application, data collection procedures relevant to ratings of perceived exertion assessment remained under-explored. The present study provides novel information regarding the value of familiarisation on the relationship between proxy measures of external and internal load during training and match-play in youth academy soccer players. Notwithstanding improved ratings on the blackness tests in our sample of players following familiarisation, our study findings suggest the moderating effect of familiarisation on the internal-external load relationship was not meaningful.

With the objective to address current practices in youth soccer and the existing knowledge base, our study is the first to investigate how familiarisation with subjective measurement instruments of perceived exertion moderates the relationship between proxy measures of external and internal load over an extended period of training and match-play. Exertion scale data collection procedures may suffer from methodological limitations before (i.e., familiarisation) and/or during (i.e., non-validated scales) the period of data collection which may hinder the validity of the data.[25] In this context, modern psychophysiological theory suggests that specific strategies (e.g., standardised practices, education, and validated scales) are necessary to preserve the integrity of exertion data collection.[2,27] However, in the clinical realm, Hutchinson et al.,[14] challenged the notion of completing a formal learning trial prior to collecting valid RPE scores. Despite the different study sampling characteristics and use of the CR10® scale, our findings are consistent with this line of evidence. Conceptually, RPE principally reflects the central motor command and is deemed independent of afferent feedback).[25] Therefore, inability of familiarisation to alter the central motor command could provide a logical explanation for the lack of meaningful differences in dRPE between players who did and did not complete a prior learning trial in the present and previous studies. [14] In sport, Macpherson et al.,[12] first explored if preliminary familiarisation with ratings of perceived exertion enhanced an individual's ability to understand intensity estimation via the blackness test in semi-professional soccer. Participants improved the percentage of correct answers (39%, 78%, 83%) and precision of ratings (~7 au, ~8 au, ~1 au) over the course of three familiarisation sessions, respectively. [12] In the present study, the players had previously used unconventional, non-validated RPE scales. In line with Macpherson et al.,[12] and following the same methodological procedures, players from our study sample improved the percentage of correct answers (39%, 64%, 78%) and the precision of ratings (9 au, 5 au, and 3 au) throughout the familiarisation process. Collectively, our study investigation showed familiarisation procedures can enhance players' ratings with exertional scales, although confirming the lack of an influence when compared with players who were not familiarised.

Considering the general use of RPE amongst practitioners in the field,[2,19] we deemed it important to explore whether the lack of familiarisation hinders the integrity of perceived exertion data. While players education remains an important element of fundamental element of team sports monitoring strategies,[12] the present findings suggest that coaches and practitioners may be better served by allocating time to other aspects of their monitoring strategies rather than use their time to familiarise players with the exertional measurement procedures. It is important to note that the width and sign of the effects for the RPE-L variable at 30 efforts of 10 au (95%CI, 4 to 16 au) suggested scores were higher for subjects who did not undergo familiarisation *versus* subjects that completed the familiarisation process. The reasons for these differences are difficult to ascertain from the current study. Likewise, irrespective of differences in external load, the general consistency between dRPE scores (Table 2-4) is another aspect of our findings suggesting the collection of RPE, as opposed to dRPE scores, remains the most plausible measurement in soccer and deserves consideration. In soccer practices, RPE-L may better measure the peripheral load imposed on players during sessions with small-sided games due to high number of accelerations and decelerations.[28,29] The more precise nature of acceleration movements in small spaces may possibly be more difficult to gauge for the less familiarised players. Further work, however, is required to elucidate this using training scenarios which enable closer examination of the role of familiarisation processes on dRPE responses.

From a general standpoint, a key limitation of the present study stems from the description of familiarisation effects on dRPE scores without accounting for session type.[8,10] Training periodisation in soccer during the competition phase is typically centred around structuring the weekly micro-cycle to facilitate recovery whilst develop/maintaining the key physical components of strength, speed, and endurance. Future work examining the association between these session types and dRPE offers a way to further examine the utility of dRPE for monitoring internal intensity and load in football. Likewise, the interpretation of the differences we estimated against a pre-defined range of equivalence from -4 au to +4 au requires consideration since illustrated and generalised, for the first time, in a study involving youth female soccer players.[7] Also, the conceptual definition and elaboration of dRPE measurement scores in our investigation is another aspect deserving attention. While in keeping with existing literature in this field,[30] formal and distinct assessment of dRPE measurements rests on the assuming perceived exertion as a multidimensional construct that, by definition, can be measured using scales instruments on a reflective model framework basis. [30] In that context, the items are generally summed up.[30] Conversely, in a formative model, each item contributes a part of the construct, and *together* the items form the whole construct with different procedures available to derive sum-scores or overall scores. [30] Considering our study design and procedures, our exploratory investigation lends support to considering perceived exertion as a formative construct that, in samples of soccer players, can be assessed using conventional measurement approaches previously illustrated in the exercise physiology literature.[1]

Practical Applications

- Prior learning trials to familiarise players with a psychometric exertional scale improved RPE scoring.
- Despite the improvements on the blackness tests, familiarisation with dRPE did not influence ratings of perceived exertion on the CR100® scale in players who completed the learning trial compared to those who received no familiarisation.
- The practical outcomes of this investigation suggest coaches and practitioners involved in youth player development processes can quantify perceived exertion in training and match play with the CR100® irrespective of the player's prior experience with the scale.

Conclusion

Despite general recommendations concerning the implementation of education tools like Borg's blackness test to enhance awareness of athletes and coaches when using exertional scoring, our findings question the worthwhileness of this practice in elite youth academy soccer players. While players improved their ratings on the blackness test, this improvement did not translate to the practical environment as the internal-external load relationship was largely consistent for all RPE scores irrespective of familiarisation or no familiarisation. Therefore, we maintain practitioners can focus on other tasks that would potentially help them enhance their training load monitoring strategies rather than investing time and resources to familiarise their players with the exertional measurement procedures.

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Figure legends

Figure 1. Level of correctness during blackness familiarisation session.

Figure 2. Explorations by number of accelerations for familiarisation versus no-familiarisation effects in perceived exertion. Negative differences in sign (−) suggested higher perceived exertion in the familiarised group, whereas positive values (+) indicated higher perceived exertion in the non-familiarised group.

Figure 3. Explorations by number of decelerations for familiarisation versus no-familiarisation effects in perceived exertion. Negative differences in sign (−) suggested higher perceived exertion in the familiarised group, whereas positive values (+) indicated higher perceived exertion in the non-familiarised group.

Figure 4. Explorations by HSR distances covered for familiarisation versus no-familiarisation effects in perceived exertion. Negative differences in sign (−) suggested higher perceived exertion in the familiarised group, whereas positive values (+) indicated higher perceived exertion in the non-familiarised group.

Table legends

Table 1. Modifications to the original study design due to extenuating circumstances

Table 2. Descriptive data for RPE, RPE-C, and RPE-L by number of accelerations

Table 3. Descriptive data for RPE, RPE-C, and RPE-L by number of decelerations

Table 4. Descriptive data for RPE, RPE-C, and RPE-L by HSR (>20km/h) distance covered

Supplementary material

Supplementary File 1. R base code

Table 1. Modifications to the original study design due to extenuating circumstances

Context	*Sample of adapted CONSERVE items*
The original aim of this study was to explore the blackness test familiarisation as a training tool to assess a player's ability and understanding of intensity estimation following a repeated measures design [13]	• *Extenuating circumstance*: pre-planned data collection procedures were terminated due to the COVID-19 pandemic • *Impacts*: non-random change in study participants from the original sample (January to March 2020) following resumption of training and data collection (July to November 2020) • *Mitigating strategies*: revised study design to mitigate threats to the original study validity and extend research purpose • These are important modifications that had implications for study conduct and procedures

Table 2. Descriptive data for RPE, RPE-C, and RPE-L by number of accelerations

Effort (#)	Blackness familiarisation	RPE			RPE-B			RPE-L		
		mean	95% CI		mean	95% CI		mean	95% CI	
10	No	46	43	48	40	37	43	47	44	49
20		47	45	50	42	39	44	51	48	54
30		54	50	58	50	46	54	61	57	66
40		56	49	63	53	45	61	66	58	74
10	Yes	46	44	48	43	41	45	46	44	48
20		47	45	49	44	41	46	46	44	49
30		52	48	56	49	46	53	52	48	56
40		59	49	68	58	47	68	57	46	68

Abbreviations: RPE, session rating of perceived exertion; RPE-B, ratings of perceived exertion on breathlessness; RPE-L, ratings of perceived exertion on legs.

Table 3. Descriptive data for RPE, RPE-C, and RPE-L by number of decelerations

Effort (#)	Blackness familiarisation	RPE			RPE-B			RPE-L		
		mean	95% CI		mean	95% CI		mean	95% CI	
10	No	46	43	49	40	37	43	46	43	48
20		48	45	50	42	39	45	49	46	51
30		53	50	56	48	45	51	55	53	58
40		59	56	63	55	51	59	63	60	67
10	Yes	43	40	45	39	36	41	43	41	46
20		44	41	46	41	39	44	44	42	46
30		52	49	54	49	46	52	52	49	54
40		59	55	63	56	52	61	61	57	65

Abbreviations: RPE, session rating of perceived exertion; RPE-B, ratings of perceived exertion on breathlessness; RPE-L, ratings of perceived exertion on legs.

Table 4. Descriptive data for RPE, RPE-C, and RPE-L by HSR (>20km/h) distance covered

Distance (m)	Blackness familiarisation	RPE mean	RPE 95% CI		RPE-B mean	RPE-B 95% CI		RPE-L mean	RPE-L 95% CI	
500	No	47	45	49	41	39	43	49	47	51
1000		55	53	57	51	48	53	57	55	59
1500		63	60	66	59	56	63	65	62	68
2000		71	67	75	67	63	72	72	68	77
2500		79	74	84	75	69	81	79	73	85
500	Yes	42	40	44	39	36	41	44	42	45
1000		57	54	59	55	52	58	56	53	58
1500		66	62	69	65	61	69	66	63	70
2000		68	62	73	68	62	73	74	69	79
2500		74	66	81	74	67	82	81	73	88

Abbreviations: RPE, session rating of perceived exertion; RPE-B, ratings of perceived exertion on breathlessness; RPE-L, ratings of perceived exertion on legs.