Full Title: The application of differential ratings of perceived exertion to Australian Football League matches

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Abstract

Objective: To investigate the application of differential ratings of perceived exertion for the examination of internal load during Australian Football League (AFL) matches.

Design: Single cohort, observational study.

Methods: Using the centiMax rating of perceived exertion (RPE) scale, 26 professional AFL players provided ratings for match exertion (RPE-M), along with differential ratings for breathlessness (RPE-B), leg exertion (RPE-L), and technical demand (RPE-T) following 129 matches (5.0 ± 1.6 matches per player). Global positioning satellite (GPS) and accelerometer measures were also collected. Data were analysed using magnitude-based inferences.

Results: RPE scores were 93.0 ± 8.2 AU (RPE-M), 89.0 ± 11.0 AU (RPE-B), 91.5 ± 9.8 AU (RPE-L), and 87.0 ± 10.0 AU (RPE-T). There was a most likely small difference between RPE-L and RPE-T (5.5%; ±90% confidence limits 1.9%), a likely small difference between RPE-L and RPE-B (3.5%; ±1.5%) and a possibly small difference between RPE-B and RPE-T (1.9%; ±1.9%). Within-player correlations between RPE and GPS measures were small for RPE-M (r=0.14-0.28), unclear to small for RPE-B (r=0.06-0.24) and unclear to moderate for RPE-L (r=0.06-0.37). Differential RPE's combined to explain 76% of the variance in RPE-M. For all RPE scores, within-player variability was moderate-high (typical error: 7.9-12.4%), and the thresholds for a likely between-match change were 8.8-13.7%.

Conclusions: As differential RPE's represent distinct sensory inputs, the collection of these scores facilitate the interpretation of internal match loads and therefore represent a valuable addition to match data collection procedures. Moderate to high within-player variability should be considered when interpreting between-match changes in all RPE scores.

Keywords: RPE; differential; monitoring; prescription

Introduction

Competitive team sport matches normally occur at the end of the training week and contribute a large percentage of the overall weekly dose of activity.[1] An understanding of the dose-response nature of competitive matches is required to inform post-match recovery and training strategies. While technological advances in physical activity measurement (e.g. GPS) have enabled sport scientists to accurately measure external loads,[2] the stimulus for exercise-induced adaptations is the internal load (e.g. physiological stress).[1] Accordingly, this places great importance on the measurement of the response to external match loads; however, the collection of physiological data in competitive team sport matches can be limited by restricted access to elite sports performers and the rules and regulations of competitions.[3]

Ratings of perceived exertion (RPE) provide a simple, noninvasive, inexpensive and valid method for measuring exercise intensity.[4,5] The limited available data demonstrate competitive match RPE's to be relatively stable measures in soccer players[6] and soccer referees[7] with between-match coefficients of variation (CV) of ~5%. This lack of variability, however, is observed despite high variability (between-match CV's 17-54%) for key measures of external load, in particular high-speed running and sprinting.[8,9] Therefore, while RPE provides a global measure of intensity, this gestalt could represent an oversimplification of the psychophysiological construct, which in turn could be insufficient to capture the whole range of exercise-related perceptual sensations.[10] The precision in scaling exertional signals during exercise may therefore be enhanced by differentiating perceptual reports according to their specific mediators[10] with "local" and "central" being regarded as the most important exertional signals in healthy persons.[11] Differential ratings of perceived exertion may therefore permit a more sensitive evaluation of internal load during competitive team sport matches.[2]

Professional Australian football (AFL) is a team sport characterized by a high-level of physical and tactical exertion.[12,13] The match performances of AFL players therefore provide an ideal vehicle for an investigation into the application of differential RPE during competitive team sport matches. Accordingly, the aim of our study was to examine the different dimensions of perceived exertion during AFL matches and to determine their association with external match load metrics. Furthermore, if RPE is to be used to help inform post-match recovery and training strategies, then a comprehensive understanding about the interpretation of meaningful change is required. As such, a further aim was to quantify the variability of the different dimensions of perceived effort during AFL matches and provide thresholds for the interpretation of meaningful between-match changes.

Methods

Thirty-seven professional AFL players (age: 22 ± 3 y; stature: 187 ± 7 cm; body mass: 84.4 ± 8.3 kg) were recruited for this study. The players' movements were tracked during nine consecutive matches over the course of the 2013 AFL season. Approximately 30 min[5] after each match, players' independently provided individual ratings regarding the degree of physical and technical exertion (details below). Players provided written informed consent to participate in the study, which was approved by an institutional ethics committee.

Using the centiMax scale (CR100),[14] the players were asked to differentiate between local (e.g. legs [RPE-L]) and central (e.g. breathlessness [RPE-B]) ratings of exertion.[15] Players also used this scale to provide ratings of overall match physical exertion (RPE-M), and overall match technical demand (e.g. technical [RPE-T]). Recent research has demonstrated the CR100 scale possesses good construct validity in AFL.[16] Players' were briefed on the correct use of the scales and the objectives of the study, before being familiarized with the procedures during field training sessions within the two weeks leading up to study commencement. To eliminate any potential order effect upon the differential RPE, players provided their ratings in a counter-balanced manner.

External load measures were derived from 10Hz GPS devices (MinimaxX S4, Catapult Sports, Melbourne, Australia) harnessed between the scapulae in customized undergarments. We exported the raw Doppler-derived velocity and acceleration data from GPS units and processed these data using R (Version 3.0.0, R Foundation for Statistical Computing, Vienna, Austria). We elected to discard data where either of the following criteria were met: 1) velocity > 36 $km \cdot h^{-1}$; 2) less than 6 satellites locked-on to the GPS unit; and 3) horizontal dilution of precision > 2.0. We also removed instances where Doppler-derived acceleration and deceleration values were > ± 6.0 $m \cdot s^{-2}$. Match files in which discarded data accounted for more than 2% of the playing time were not included in the analysis (n = 10). Players' total distance covered (m) and the proportion of that distance covered at high running speeds (HSR; ≥ 14.4 $km \cdot h^{-1}$) were collected over the course of the match, with data discarded from between-quarter rest periods and within-quarter benching's. Players were allocated the same devices in each game to attenuate between-unit variation. We applied a further inclusion criteria of, 1) a minimum of three matches per player where RPE and GPS match data were both recorded, and 2) at least 70-min of total playing time for these matches. This resulted in a final total of 129 match observations from 26 players (5.0 ± 1.6 matches per player; range 3 to 8 matches).

Because distances covered in discreet locomotor categories are insensitive to the metabolically taxing nature of acceleration and deceleration activities, recent work has adopted a conceptual model developed to estimate the combined energetic costs of constant-speed running and acceleration.[17] The so-called "metabolic power" approach is derived from a model to estimate the energetic cost of linear acceleration on a horizontal plane, which is assumed equivalent to gradient running at a constant speed, where the angle of trunk flexion relative to the running surface is associated with the acceleration magnitude.[18] Direct validation of this approach is absent; it also neglects the impact of limb movement, eccentric muscle actions, and air resistance upon energetic demands, and relies on the accuracy of instantaneous velocity measurements. However, total energy costs calculated from this model are similar to those derived from physiological measures,[17] and its determination of the instantaneous metabolic cost has demonstrated concurrent[19] and construct validity.[20,21] Therefore, in this study we adopted the metabolic power approach to estimate total match energy expenditure (Energy Expenditure, $KJ \cdot kg^{-1}$) and average metabolic power (P_{met}, $W \cdot kg^{-1}$), together with the relative distance covered at a high instantaneous metabolic power (≥ 20 $W \cdot kg^{-1}$). Equivalent Distance (ED; m) was determined to represent the corresponding total distance covered for steady state running to match the estimated energy expenditure.

Since the metabolic cost of tackling, jumping and directional changes is not reflected in either the traditional speed-category approach or the metabolic power model, we also examined the association between dimensions of perceived effort and external load using accelerometer data. Tri-axial accelerometer data are able to determine the mechanical loads incurred from changing direction, collisions, and jumps, which can not be quantified using GPS or pixel-tracking technology. To represent the totality of mechanical loads experienced by the players, we used tri-axial accelerometer data from a 100Hz piezoelectric linear sensor (Kionix: KXP94) encapsulated with the GPS device. A vector magnitude (PlayerLoad™, arbitrary units [AU]) was determined by raising the instantaneous accelerations detected in the anterior-posterior, medio-lateral, and vertical planes to the power of two, square-rooting the aggregate value and dividing by 100.[22] The within-device reliability (0.91-1.05% coefficient of variation [CV])[23] and test re-test reliability (5.9% CV) of PlayerLoad™ are high.[23]

Data are presented as the mean ± SD. Differential RPE data (RPE-B, RPE-L and RPE-T) were log transformed and standardised mean differences were calculated between the differential RPE scores, with uncertainty of estimates expressed as 90% confidence limits (CL). Inferences were subsequently based on standardised thresholds for small, moderate and large differences of 0.2, 0.6 and 1.2 of the pooled between-subject standard deviations.[24] The chance of the true effect being substantial or trivial was interpreted using the following scale: 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely.[24] A within-player design was used to determine if high RPE scores (RPE-M, RPE-B, RPE-L) were associated with higher GPS-derived external loads. This is the appropriate method as it permits the analysis of within-subject changes by removing between-subject differences.[25] Confidence limits (90%) for the within-player correlations were calculated as per Altman and Bland.[26] The following scale of magnitudes was used to interpret the magnitude of the correlation coefficients: <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.[24] Differential RPE scores and the GPS measures were then regressed on RPE-M. The magnitude of the effect of predictors was represented by the partial correlation with 90% CL's constructed using a bias corrected accelerated bootstrapping technique of 2000 samples with replacement from the original data (SPSS v.21, Armonk, NY: IBM Corp). Finally, for the assessment of meaningful between-match changes in RPE scores, the data were analysed using a mixed linear model (SPSS v.21, Armonk, NY: IBM Corp) with random intercepts to estimate the within- and between-player variability. Here, the within-player variability represented the typical error and 0.2 SDs of the between-player variability represented our reference for change (smallest worthwhile change). Using a custom-made spreadsheet[27] we calculated the minimum thresholds required for a change in RPE-M, RPE-B, RPE-L and RPE-T to be likely (75% chance), a very likely (97.5% chance), and almost certain (99% chance).

Results

Descriptive match data are presented in Table 1. Differences between the differential RPE were most likely small between RPE-L and RPE-T (5.5%; ±90% confidence limits ±1.9%), likely small between RPE-L and RPE-B (3.5%; ±1.5%) and possibly small RPE-B and RPE-T (1.9%; ±1.9%).

Within-player correlations for RPE-M, RPE-B and RPE-L with selected measures of GPS-measured external load are displayed in Table 2. Relationships between RPE and GPS measures were small for RPE-M, unclear to small for RPE-B and unclear to moderate for RPE-L. Regression analysis revealed that the differential RPE scores combined explained 76% of the variance in RPE_{match} scores (R=0.88, adjusted R-squared=0.76, SEE = 4.5%). Regression diagnostics revealed no degrading collinearity between the differential RPE scores, with tolerance levels of 0.477 (RPE-B), 0.544 (RPE-L), and 0.694 (RPE-T). Partial correlations were large for RPE-B (0.58; ±90% confidence limits 0.12) and RPE-L (0.53; ±0.12) and small for RPE-T (0.15; ±0.16). The addition of any of the GPS-derived external load measures did not improve the accuracy of our model.

Table 3 displays the within- and between-player variability for all RPE measures. Also presented in this table are the minimum thresholds for a likely change, a very likely change, and an almost certain change in RPE-M, RPE-B, RPE-L and RPE-T. The minimum threshold for a change in RPE scores was 8.8-13.7% for a likely change, 20.9-33.7% for a very likely change and 30.4-50.2% for an almost certain change.

Discussion

Ratings of perceived exertion (RPE) provide a valid measure of an individual's response to exercise[4,5] and could therefore help to inform post-match recovery and training strategies. A gestalt however, may lack sensitivity, which would limit its application for the interpretation of the internal load imposed by competitive team-sport matches. Differential RPE have the potential to overcome this limitation by permitting a more sensitive evaluation of internal load during competitive team sport matches.[2] The main findings of our study regarding the application of differential RPE scores for the interpretation of match internal loads were, 1) possibly to most likely small differences between the differential RPE suggesting that these measures represent distinct sensory inputs, 2) the associations between RPE and GPS-derived measures of external load were generally small, but strongest for RPE-L, 3) RPE-B, RPE-L and RPE-T combine to explain 76% of the total variance in RPE-M scores, and, 4) match RPE's display moderate to high within-player variability.

Differential ratings of exertion (legs, chest, arms) represent different dimensions of effort.[10] Given that the demands of team-sports are multifactorial, differential RPE may provide coaches and sports scientists with better understanding of the stress associated with competitive team sport matches than a single, gestalt measure.[2] We therefore believe that the small differences observed between our differential RPE provide the first piece of evidence that these measures represent distinct constructs during competitive team-sport as they are perceived differently during AFL matches. Of the differential RPE scores, RPE-L was scored the highest, a finding consistent with prior observations of peripheral sensations being perceived higher than central (chest) sensations during exercise.[10,15] Differential RPE, therefore, may represent a valuable addition to match intensity data collection methods as the scores will enhance precision in the measurement of perceived exertion, which in turn could help to better inform individualised post-match recovery and training sessions. For example, disassociations between RPE-B and RPE-L may highlight the need for specific training strategies (e.g., increased aerobic fitness for consistently higher RPE-B, improved leg strength, power, balance etc. for consistently higher RPE-L) and RPE-T scores may provide coaches with valuable information for the practice of skill training and the adherence to team tactics during matchplay. Further research on different cohorts over a larger number of matches is required, however.

Technological advances in activity measurement have provided sports scientists more options with regard to the measurement of external load.[2] Indeed, access to GPS-derived match activity is now commonplace in several team-sports and consequently there have many attempts to further understand internal load by examining its relationship with external load. Our GPS-derived measures of external load demonstrated only small to moderate correlations with match RPE scores. Nonetheless, the association between high-speed running (total and relative), relative total distance, total metabolic power and relative high power distance with RPE-L was moderate, which we believe provides further support for the discriminate validity of differential RPE's. The incorporation of both velocity and acceleration contributions to external load using the metabolic power approach did not strengthen associations with RPE ratings, which supports recent conclusions drawn by Coutts et al.[21] who suggested that metabolic power adds little information to external loading observations in AFL matchplay, perhaps due to the less congested nature of AFL versus Soccer[17,20] or Rugby League.[28] The unclear associations between accelerometer derived indices and RPE ratings may reflect the large between-subject variation in running mechanics.[23] Small to very large correlations between RPE (CR10) and GPS-derived measures of external load have previously been reported for training session data.[16,29,30] Further to this, Scott and colleagues[16] evidenced large to very large correlations between RPE (CR100) and GPS-derived measures of external load during skill-based Australian Football skill-based training sessions. It is, however, difficult for us to reconcile our internal-external associations with the work of others as our data were drawn from competitive matches, not training sessions, and we used RPE as a measure of intensity, not overall load. As such, our analysis was performed on RPE alone, whereas attempts to relate external load to internal load have been performed using RPE load (RPE*session duration).

Other authors[10] have reported that a single-item measure of exertion is insufficient to capture the whole range of perceptual sensations experienced during exercise. In the present study, 76% of total variance in RPE-M was explained by a combination of RPE-B, RPE-L and RPE-T. We consider our data to provide further support for the validity and usefulness of RPE as a gestalt measure of overall exertion as it captures the integration of several distinct inputs that are perceived differently and is therefore consistent with the measure being sensory-discriminative, cognitive-evaluative, and motivational-affective.[4] Our partial correlations provide information on how each of the distinct dimensions of exertion contributed to overall match exertion. Here, RPE-L and RPE-B made large contributions to RPE-M, whereas the contribution of RPE-T was small; thereby supporting recent observations that AFL is a physically and technically demanding team sport.[12,13,21] As such, we support the use of RPE as a global measure of internal match intensity but advocate the use of differential RPE to enhance our understanding of how different dimensions of exertion contribute to overall match exertion.

The practicality and validity of RPE as a measure of exercise-induced physiological stress advocates that the collection and interpretation of match RPE could be a valuable practice to help inform post-match recovery and training strategies. However, researchers and practitioners should establish the reliability of their data measurements, as understanding reliability assists with interpreting and applying data in practical settings.[28] With this in mind, we provide for the first time thresholds for the interpretation of between-match changes in all dimensions of RPE, with a threshold of ~10% for change to be likely. Such findings provide valuable information for interpreting meaningful between-match changes in the players' different dimensions of perceived exertion. Given the relatively small range of matches included in our study (3-8) we recognise that our thresholds for the interpretation of change may be an overestimation and acknowledge that further work in required in this area. Nonetheless, building on the work presented recently by Kempton et al.[28] we have provided researchers and practioners with a template for the calculation and subsequent interpretation of between-match changes in measures of internal match loads.

Conclusion

This is the first study to provide estimates of the different dimensions of exertion incurred by competitive matchplay in team-sports, namely AFL. Although the differences in differential RPE scores were small and our sample was drawn from one team over a relatively small cluster of matches, our data suggest that the scores represent distinct sensory inputs, thereby improving the precision in exertion scores and in turn providing a more accurate evaluation of match-imposed internal load. However, moderate to high within-player variability should to be accounted for when using the scores to inform post-match recovery and training sessions. The collection of match differential RPE scores therefore represents a useful addition to the match data collection procedures employed by sports scientists and practioners involved in team-sports.

Practical Applications

- Differential ratings of perceived exertion provide a more sensitive evaluation of overall match exertion, and may be a valuable tool to inform subsequent recovery and training protocols.
- Concurrent measures of match internal and external load are advocated to understand the true dose-response of team-sports matches.
- Overall and differential RPE scores were variable between matches, a 10% threshold is recommended to interpret between-match meaningful differences in individual players' perceptual ratings of intensity.

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Table 1. RPE scores and match GPS-derived measures (n=129).

Measure	Mean ± SD
RPE-M (AU)	93.0 ± 8.2
RPE-B (AU)	89.0 ± 11.0
RPE-L (AU)	91.5 ± 9.8
RPE-T (AU)	87.0 ± 10.0
Playing time (min)	104.4 ± 9.4
GPS-measures	
Accumulated player load (AU)	1413 ± 209
Player load 2D (AU)	895 ± 120
Low-speed running (m)	9071 ± 844
High-speed running (m)	3768 ± 1144
Total match distance (m)	12859 ± 1529
Relative high-speed running distance (m)	36 ± 10
Relative total match distance (m·min)	123 ± 12
High power distance (m)	3611 ± 981
Estimated energy expenditure ($KJ·kg^{-1}$)	66.6 ± 7.9
P_{met} ($W·kg^{-1}$)	10.7 ± 1.1
Equivalent distance (m)	14347 ± 1711
Total high power relative distance (m·min)	35 ± 9

Table 2. Within-player correlations (±90% confidence limits), for RPE-M, RPE-B and RPE-L with selected measures of GPS-measured external load.

	RPE-M	RPE-B	RPE-L
Player load (AU)	0.16; ±0.16	0.06; ±0.16	0.06; ±0.16
	Possibly small	*Unclear*	*Unclear*
Player load 2D (AU)	0.20; ±0.16	0.10; ±0.16	0.08; ±0.16
	Likely small	*Possibly small*	*Possibly trivial*
Low-speed running (m)	0.14; ±0.16	0.06; ±0.16	0.03; ±0.15
	Possibly small	*Unclear*	*Unclear*
High-speed running (m)	0.25; ±0.15	0.17; ±0.16	0.31; ±0.15
	Likely small	*Possibly small*	*Possibly moderate*
Total distance (m)	0.25; ±0.15	0.14; ±0.16	0.19; ±0.16
	Likely small	*Possibly small*	*Likely small*
Relative high-speed running (m·min)	0.21; ±0.16	0.19; ±0.16	0.34; ±0.14
	Likely small	*Likely small*	*Possibly moderate*
Relative total distance (m)	0.28; ±0.15	0.24; ±0.15	0.37; ±0.14
	Very likely small	*Likely small*	*Likely moderate*
High power distance (m)	0.24; ±0.15	0.15; ±0.16	0.29; ±0.15
	Likely small	*Possibly small*	*Very likely small*
Estimated energy expenditure ($kJ \cdot kg^{-1}$)	0.24; ±0.15	0.12; ±0.16	0.18; ±0.16
	Likely small	*Possibly small*	*Likely small*
P_{met} ($W \cdot kg^{-1}$)	0.26; ±0.15	0.22; ±0.15	0.36; ±0.14
	Very likely small	*Likely small*	*Possibly moderate*
Equivalent distance (m)	0.24; ±0.15	0.12; ±0.16	0.18; ±0.16
	Likely small	*Possibly small*	*Likely small*
Relative high power distance (m·min)	0.20; ±0.16	0.17; ±0.16	0.34; ±0.14
	Likely small	*Likely small*	*Possibly moderate*

Table 3. Within- and between-player variability for RPE-M, RPE-B, RPE-L, and RPE-T, along with the smallest worthwhile change for each measure and the threshold for determining the magnitude of change.

	Within-player CV (%; ±90%CL)	Between-player CV (%; ±90%CL)	Smallest worthwhile change (%)	Minimum threshold for …		
				Change to be 'likely'	Change to be 'very likely'	Change to be 'almost certain'
RPE-M	7.9; ±1.0	5.5; ±2.1	1.1	8.8%	20.9%	30.4%
RPE-B	12.4; ±1.5	7.9; ±3.4	1.6	13.7%	33.7%	50.2%
RPE-L	11.5; ±1.4	1.9; ±7.7	0.4	11.5%	29.7%	44.5%
RPE-T	11.0; ±1.3	6.2; ±2.5	1.2	11.9%	29.3%	43.5%

CV, coefficient of variation (%) with 90% confidence limits (CL)