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Article Title: The Sensitivity of Differential Ratings of Perceived Exertion as Measures of Internal Load

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Abstract

Purpose: To investigate the sensitivity of differential ratings of perceived exertion (dRPE) as measures of internal load. ***Methods:*** Twenty-two, male, university soccer players performed two maximal incremental exercise protocols (Cycle, Treadmill) on separate days. Maximal oxygen uptake ($\dot{V}O_{2max}$), maximal heart rate (HR_{max}), peak blood lactate concentration ($B[La]_{peak}$) and the post-pre protocol change in countermovement jump height (ΔCMJ_H) were measured for each protocol. Players provided dRPE (CR100®) for breathlessness (RPE-B) and leg exertion (RPE-L) immediately upon exercise termination ($RPE\text{-}B_0$, $RPE\text{-}L_0$) and 30-minutes post-exercise ($RPE\text{-}B_{30}$, $RPE\text{-}L_{30}$). Data were analysed using magnitude-based inferences. ***Results:*** There were clear between-protocol differences for $\dot{V}O_{2max}$ (Cycle 46.5 ± 6.3 vs Treadmill 51.0 ± 5.1 $ml \cdot kg^{-1} \cdot min^{-1}$, mean difference -9.2%; ±90% confidence limits 3.7%), HR_{max} (185 ± 13 vs 197 ± 8 $b \cdot min^{-1}$, -6.0%; ±1.7%), $B[La]_{peak}$ (9.7 ± 2.1 vs 8.5 ± 2.0 $mmol \cdot L^{-1}$, 15%; ±10%) and ΔCMJ_H (-7.1 ± 4.2 vs 0.6 ± 3.6 cm, -23.2%; ±5.4%). Clear between-protocol differences were recorded for $RPE\text{-}B_0$ (78 ± 12 vs 94.7 ± 9.5 AU, -18.1%; ±4.5%), $RPE\text{-}L_0$ (92.6 ± 9.7 vs 81 ± 14 AU, 15.3%; ±7.6%), $RPE\text{-}B_{30}$ (70 ± 11 vs 82 ± 13 AU, -13.8%; ±7.3%) and $RPE\text{-}L_{30}$ (86 ± 12 vs 65 ± 19 AU, 37%; ±17%). A substantial timing effect was observed for dRPE, with moderate to large reductions in all scores 30-minutes post-exercise when compared to scores collected upon exercise termination. ***Conclusion:*** dRPE enhance the precision of internal load measurement and therefore represent a worthwhile addition to training load monitoring procedures.

Introduction

The ultimate consequence of the training process is the relative physiological response to a given workload, that is, the internal load.[1] Accurate measures of internal load are therefore important for practitioners and coaches to prescribe and evaluate training dose-response.[2] Session ratings of perceived exertion (sRPE) are widely used as practical and effective means of quantifying internal training load and are able to capture a range of physiological and psychological sensations.[1,3] However, sRPE may lack sensitivity when measuring the varying external loads (e.g. high-intensity running, sprinting, collisions) associated with team sports.[2,4] Differential ratings of perceived exertion (dRPE) have the potential to overcome this issue by discriminating between discrete sensory inputs, such as central and peripheral exertion signals.[5,6] As such, dRPE may provide coaches and sports scientists with a better understanding of the dose-response nature of team-sport training loads and match loads.[6,7] Despite this, a detailed analysis of dRPE collected alongside objective physiological measures during contrasting exercise modes is absent. Further, in light of recent evidence suggesting no latency effect is evident on sRPE[8] or dRPE,[7] the influence of post-session timing when collecting dRPE scores warrants further examination. Our aim, therefore, was to investigate the sensitivity of dRPE as measures of internal load—with respect to objective physiological markers and the influence of post-session latency.

Methods

Twenty-two outfield, university, male soccer players (age: 23 ± 3 y; stature: 179 ± 7 cm; body mass: 76 ± 8 kg), volunteered to participate in this study. Written informed consent was provided from all players and the study received ethical approval via Teesside University’s ethics committee, in accordance with the Declaration of Helsinki.

Running and cycling are physiologically demanding tasks known to elicit dissimilar dimensions of central and peripheral exertion,[9] and therefore represent appropriate exercise modes to assess the sensitivity of dRPE in combination with objective, physiological measures of exercise intensity. Accordingly, players visited a physiology laboratory (temperature: 20.9 ± 1.3°C; humidity: 30.3 ± 5.4%; pressure 1018 ± 8 mm·Hg^{-1}) on two separate occasions and completed one of two, counterbalanced, maximal incremental exercise protocols on each visit (Cycle, Treadmill). During the Cycle protocol, players pedalled continuously on an electronically braked cycle ergometer (Lode Excalibur Sport, Lode BV, The Netherlands) at a cadence of 90 RPM, with the resistance of the ergometer (power; W) increasing linearly at a rate of 30 W·min^{-1} (i.e. 1 W every 2 seconds) until maximal volitional exhaustion. During the Treadmill protocol, players ran continuously on a treadmill (Woodway ELG70, Woodway Gmbh, Germany) at a 1% gradient, with the intensity of exercise (speed; km·h^{-1}) increasing by 1 km·h^{-1} every 3 minutes until maximal volitional exhaustion.

Throughout each protocol, oxygen uptake (ZAN 600 Oxigraf CPET, nSpire Health GmbH, Germany) and heart rate (Polar RS400, Polar Electro Oy, Finland) were continually measured, with maximal oxygen uptake ($\dot{V}O_{2max}$) and maximum heart rate (HR_{max}) extrapolated for analysis. Capillary blood samples were aspirated from the fingertip at the point of exercise termination and 5-minutes post exercise to determine peak blood lactate concentration ($B[La]_{peak}$; YSI 2300 Stat Plus, YSI UK Ltd., United Kingdom). The pre-post protocol change in countermovement jump height (ΔCMJ_H) was also measured (Optojump Next, Microgate, Italy). Using the centiMax scale (CR100®),[10] players provided sRPE as well as dRPE for breathlessness (RPE-B) and leg muscle exertion (RPE-L).[6] Scores were provided in a counterbalanced manner at the point of exercise termination ($sRPE_0$, $RPE\text{-}B_0$, $RPE\text{-}L_0$)

and 30-minutes post-exercise ($sRPE_{30}$, $RPE\text{-}B_{30}$, $RPE\text{-}L_{30}$).[3] Players were familiarised with the CR100® scale and the dRPE concept prior to participating in this study.

Raw data are presented as the mean ± SD. All variables were log-transformed and standardised mean differences (effect sizes) with 90% confidence limits (CL) were used to estimate the between-protocol differences in objective physiological markers of exertion and dRPE, as well as the differences in dRPE scores collected at exercise termination and 30-minutes post-exercise. Threshold values of 0.2, 0.6 and 1.2 represented small, moderate and large effects, respectively, with magnitude-based inferences subsequently applied.[11] Clear mechanistic effects (<5% chance of the CL overlapping both substantially positive and negative thresholds) were qualified as per Batterham & Hopkins.[11]

Results

Raw data and the between protocol-differences (Cycle versus Treadmill) in physiological measures of exertion and dRPE are presented in Table 1. The differences between $RPE\text{-}L_0$ and $RPE\text{-}B_0$ were possibly large following the Cycle protocol (19.4%; ±90% CL 4.6%) and likely large following the Treadmill protocol (-18.1%; ±4.5%). The differences between $RPE\text{-}L_{30}$ and $RPE\text{-}B_{30}$ were likely large following the Cycle protocol (23.2%; ±5.8%) and possibly large following the Treadmill protocol (-22.4%; ±7.4%). The effects of timing on dRPE and sRPE are presented in Table 2. All RPE scores were substantially lower at 30-minutes post exercise when compared to scores collected at exercise termination.

Discussion

Accurate measures of internal load enhance our understanding of the training process and therefore help to guide the prescription of recovery and subsequent training loads. Session ratings of perceived exertion are a reliable, valid and popular method of measuring internal training load, yet differential ratings could enhance the precision of internal load measurement by discriminating between central and peripheral perceived exertion.[6] The main findings of our investigation into the sensitivity of dRPE were that clear between-protocol differences in dRPE scores (moderate-large) were concurrent with clear between-protocol differences in objective measures of physiological load (moderate-large), clear and large differences between RPE-B and RPE-L at all time points indicate that dRPE represent different dimensions of effort, and a moderate to large latency effect is apparent on dRPE scores following maximal graded exercise.

The accuracy in measuring internal load may be enhanced by focusing perceptual reports on specific physiological mediators, thus isolating the sensory-discriminative dimensions of effort.[6] In our investigation, the between-protocol differences in $sRPE_0$ and $sRPE_{30}$ were moderate and small, respectively, yet the differences in the majority of physiological markers were moderate to large. The between-protocol differences in RPE-B and RPE-L scores were however, moderate to large; suggesting that dRPE can enhance the precision of internal load measurement. For example, RPE-B_0 and RPE-B_{30} were greater following the treadmill protocol when $\dot{V}O_{2max}$ and HR_{max} were greater, whereas RPE-L_0 and RPE-L_{30} were greater following the Cycle protocol in concurrence with higher $B[La]_{peak}$ and greater reductions in $CMJ_{H.}$ Further, the differences between RPE-B and RPE-L at the end of exercise and 30-minutes post-exercise were large. These data support previous notions that RPE-B and RPE-L represent dissimilar dimensions of effort,[6] where RPE-B appear reflective of central factors (e.g. uptake and transport of oxygen, central nervous system etc.), and RPE-L appear reflective of peripheral factors (e.g. neuromuscular, musculoskeletal and muscle metabolite characteristics).[9] This information may be useful to coaches and practitioners when designing specific interventions based on an individual's relative physiological response to training sessions or match-play.

Our data also shows a moderate-large latency effect on RPE-B and RPE-L. The dRPE scores (and sRPE) were substantially lower when recalled 30-minutes following maximal exercise in comparison with scores obtained at exercise termination and the magnitude of these reductions was dependent upon exercise mode. This is in contrast to recent research suggesting no substantial latency effect is evident between RPE scores collected near the end of exercise (i.e. 0-minutes[8] or 10-minutes[7] post-exercise) and 30-minutes post-exercise. These discrepant findings are no doubt a consequence of differences in exercise mode between our research and that of others (soccer training). For example, during maximally graded tests, the intensity peak occurs at the end of the protocol whereas in sport-specific training sessions, the intensity is distributed throughout the session.[8] The collection of RPE data 30-minutes post-exercise can be inconvenient, yet evidence surrounding the effects of time delay on psychophysiological scores is limited. While the latency effect appears to be dependent upon exercise mode and session type, more research is required to understand this paradigm. In the interim, practitioners should look to explore novel methods to overcome the inconvenience of obtaining 30-minute post-session RPE scores, which should remain the gold-standard procedure until proven otherwise.

Practical applications and conclusions

Accurate training load monitoring enhances knowledge of training response, aids training program design and provides a further avenue for communication between support staff and athletes and coaches.[12] While sRPE represent a practical, reliable and valid measure of physiological and psychological exertion (e.g. technical demand)[6], our data demonstrate that from a physiological perspective, dRPE can enhance the sensitivity of internal load measurement. We believe, therefore, that the collection of training and match dRPE represents a worthwhile addition to internal load monitoring strategies, but not a replacement of sRPE. An ever-increasing network of athlete support staff, when combined with on-going technological advances in activity measurement, serves to continually increase the number of data contact points between athletes and practitioners. Although adding dRPE to monitoring strategies will increase the number of such contact points, we consider that the improved sensitivity of the information obtained will outweigh the increased time commitment required to collect, analyse and interpret the data.

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Table 1: Raw data and the between-protocol differences (Cycle versus Treadmill) in objective physiological markers of exertion and dRPE

	Raw Data (Mean ± SD)		**Between-protocol Differences**	
	Treadmill	Cycle	%; ±90% CL	Qualitative Inference
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	51.0 ± 5.1	46.5 ± 6.3	-9.2; ±3.7	likely moderate
HR_{max} ($b \cdot min^{-1}$)	196.7 ± 7.8	185 ± 13	-6.0; ±1.7	likely large
$B[La]_{peak}$ ($mmol \cdot L^{-1}$)	8.5 ± 2.0	9.7 ± 2.1	15; ±10	possibly moderate
ΔCMJ_H (cm)	0.6 ± 3.6	-7.1 ± 4.2	-23.2; ±5.4	very likely large
$sRPE_0$ (AU)	92 ± 11	86 ± 12	-6.3; ±5.7	possibly moderate
$RPE\text{-}B_0$ (AU)	94.7 ± 9.5	78 ± 12	-18.1; ±4.5	very likely large
$RPE\text{-}L_0$ (AU)	81 ± 14	92.6 ± 9.7	15.3; ±7.6	possibly moderate
$sRPE_{30}$ (AU)	75 ± 15	81 ± 12	10; ±11	likely small
$RPE\text{-}B_{30}$ (AU)	82 ± 13	70 ± 11	-13.8; ±7.3	likely moderate
$RPE\text{-}L_{30}$ (AU)	65 ± 19	86 ± 12	37; ±17	likely moderate

SD: standard deviation; CL: confidence limits; $\dot{V}O_{2max}$: maximal oxygen uptake; HR_{max}: maximum heart rate; $B[La]_{peak}$: peak blood lactate concentration; ΔCMJ_H: pre-post protocol change in countermovement jump height; AU: arbitrary units; $sRPE_0$: session rating of perceived exertion at the point of exercise termination; $RPE\text{-}B_0$: rating of perceived breathlessness at the point of exercise termination; $RPE\text{-}L_0$: rating of perceived leg muscle exertion at the point of exercise termination; $sRPE_{30}$: session rating of perceived exertion 30-minutes post-exercise; $RPE\text{-}B_{30}$: rating of perceived breathlessness 30-minutes post-exercise; $RPE\text{-}L_0$: rating of perceived leg muscle exertion 30-minutes post-exercise.

Table 2: Effect of timing when collecting dRPE scores following maximal graded exercise (30-minute versus end-exercise)

	Raw Change (AU; ±90% CL)	**Percent Change (%; ±90% CL)**	**Qualitative Inference**
Treadmill			
sRPE	-17.0; ±5.3	-19.9; ±6.2	likely large
RPE-B	-13.0; ±5.5	-14.4; ±6.0	possibly large
RPE-L	-16.0; ±4.9	-21.7; ±6.7	possibly large
Cycle			
sRPE	-4.7; ±3.8	-5.7; ±4.4	likely small
RPE-B	-7.8; ±3.8	-10.0; ±4.9	possibly moderate
RPE-L	-6.2; ±3.4	-7.1; ±4.0	possibly moderate

AU: arbitrary units; CL: confidence limits; $sRPE_0$: session rating of perceived exertion at the point of exercise termination; $RPE\text{-}B_0$: rating of perceived breathlessness at the point of exercise termination; $RPE\text{-}L_0$: rating of perceived leg muscle exertion at the point of exercise termination; $sRPE_{30}$: session rating of perceived exertion 30-minutes post-exercise; $RPE\text{-}B_{30}$: rating of perceived breathlessness 30-minutes post-exercise; $RPE\text{-}L_0$: rating of perceived leg muscle exertion 30-minutes post-exercise.