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Differential training loads and individual fitness responses to pre-season in professional rugby union players

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ABSTRACT

We aimed to compare differentiated training loads (TL) between fitness responders and non-responders to an eight-week pre-season training period in a squad of thirty-five professional rugby union players. Differential TL were calculated by multiplying player's perceptions of breathlessness (sRPE-B) and leg muscle exertion (sRPE-L) with training duration for each completed session. Performance-based fitness measures included the Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1), 10-, 20-, and 30-m linear sprint times, countermovement jump height (CMJ) and predicted one-repetition maximum back squat (P1RM Squat). The proportion of responders (≥ 75% chance that the observed change in fitness was > typical error and smallest worthwhile change) were 37%, 50%, 52%, 82% and 70% for YYIRTL1, 20/30-m, 10-m, CMJ and P1RM Squat, respectively. Weekly sRPE-B-TL was very likely higher in YYIRTL1 responders (mean difference = 18%; ±90% confidence limits 11%), likely lower in 20/30-m (19%; ±20%) and 10-m (18%; ±17%) responders, and likely higher in CMJ responders (15%; ±16%). All other comparisons were unclear. Weekly sRPE-B discriminate between rugby union players who respond to pre-season training when compared with players who do not. Our findings support the collection of differential ratings of perceived exertion and the use of individual response analysis in team-sport athletes.

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KEYWORDS
Training load; differential RPE; individual responses; pre-season; athlete monitoring; team sports

Introduction

The frequent and substantial demands of intermittent team-sport competition require players to possess a broad range of well-developed fitness qualities (Iaia, Rampinini, & Bangsbo, 2009). Aerobic fitness, strength, power, speed and acceleration have previously been associated with match outcome (Gabbett, 2013; Gabbett & Gahan, 2016), match activities and physical performance (Gabbett & Seibold, 2013; Ross, Gill, Cronin, & Malcata, 2015; Smart, Hopkins, Quarrie, & Gill, 2014), skill characteristics (Gabbett, Kelly, & Pezet, 2007), competition standard (Gabbett, Kelly, Ralph, & Driscoll, 2009; Johnston, Gabbett, & Jenkins, 2015a), recovery and fatigue (Johnston et al., 2015a; Johnston, Gabbett, Jenkins, & Hulin, 2015b) and the likelihood of injury (Malone, Roe, Doran, Gabbett & Collins, 2017; Windt & Gabbett, 2017) in team-sport athletes. Maintenance or changes in these qualities are the consequence of functional adaptations to physiological and biomechanical systems elicited in response to various exercise stressors (Coffey & Hawley, 2007; Vanrenterghem, Nedergaard, Robinson, & Drust, 2017). The magnitude of such adaptations is, in the most part, explained by the combination of training volume and relative intensity (Coffey & Hawley, 2007) – otherwise referred to as internal training load (Soligard et al., 2016). The relationships between fitness changes and measures of internal training load may therefore be useful in examining the dose–response nature of team-sport training as well as the validity of specific internal measures (Akubat, Patel, Barrett, & Abt, 2012).

Session ratings of perceived exertion (sRPE) and heart rate (HR) are two commonly used measures of internal load in team-sport athletes (Akenhead & Nassis, 2016). While the relationships between HR-based measures of internal load and changes in aerobic fitness have received much attention to date (Jaspers, Brink, Probst, Frencken, & Helsen, 2017; Malone, Hughes, & Collins, 2017; Taylor et al., 2017), the associations between sRPE training load (sRPE-TL) and changes in fitness has received far less attention (Jaspers et al., 2017). This is perhaps surprising given the widespread use of RPE in both practice (Akenhead & Nassis, 2016) and research (Jones, Griffiths, & Mellalieu, 2017). This could be a consequence of the recent influx in wearable microelectrical mechanical systems technology (Malone, Lovell, Varley, & Coutts, 2017) and the associated interest between fitness and external load indicators (Jaspers et al., 2017), or publication bias occurring with non-significant, trivial or unclear findings, since scientists across most fields are encouraged to publish positive results (Halperin, Vigotsky, Foster, & Pyne, 2017).

Session RPE is an all-encompassing global measure of training intensity, mediated by many physiological exertion signals and non-physiological factors (Kinsman, Weiser, & Stamper, 1973; Robertson & Noble, 1997). While this brings many

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benefits to the measurement of internal load in team-sport athletes (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009; Impellizzeri, Rampinini, & Marcora, 2005), a gestalt measure such as sRPE-TL may lack sensitivity (Weston, 2013). The accuracy in measuring perceived exertion can be improved, however, by differentiating global sRPE into its specific psychophysiological mediators (McLaren, Graham, Spears, & Weston, 2016; McLaren, Smith, Spears, & Weston, 2017; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015). While differential ratings of perceived exertion (dRPE) may therefore have the potential to distinguish between specific cardiovascular and neuromuscular/musculoskeletal load–adaptation pathways (Jaspers et al., 2017; Vanrenterghem et al., 2017), research in this area is as yet limited and inconclusive (Gil-Rey, Lezaun, & Los Arcos, 2015; Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Mendez-Villanueva, 2015).

Although attention has been given to the measurement and quantification of the training "dose" (load) in team-sport athletes, a robust analysis of the training "response" (change in fitness) has been largely overlooked. Previous research has used conventional group-level analyses to examine the training response, which are impractical for monitoring performance changes in individuals (Buchheit, 2016). Conversely, interpretation of an individual's raw (observed) fitness change is naive since physiological measurements are always subject to random within-person variation (Atkinson & Batterham, 2015; Hopkins, 2015). It is therefore unclear as to whether the changes in fitness observed in previous dose–response studies have real-world value and are a true consequence of the training dose, or are simply the result of biological fluctuations. Individual responses can be appropriately assessed by quantifying the typical error of an outcome measure in a comparator sample or group over a similar duration to the period of intervention or interest (Atkinson & Batterham, 2015; Hopkins, 2000). The off-season training period could present an appropriate and feasible opportunity to quantify the typical error in fitness for team-sport athletes. Here, players may act as their own controls during a period of substantially reduced training load designed to mitigate fitness decay and the risk of subsequent injury during the return to higher-load training (Le Meur, Hausswirth, & Mujika, 2012; Mujika, 2010; Purdam, Drew, & Blanch, 2015). Such an idea is yet to be applied to team-sport athletes or the assessment of training dose–response, however. We therefore aimed to provide the first examination of individual fitness responses to pre-season training and compare dRPE training loads between responders and non-responders in a squad of professional rugby union players.

Methods

Experimental design

Using an observational longitudinal design, we monitored 35 professional rugby union players over an eight-week pre-season training period and an eight-week off-season training period. The pre-season period took part during the first eight weeks of the season and the off-season period took part in the eight weeks following the end of the competitive season. Players were assessed for a range of fitness measures before and after each training period. Session ratings of perceived breathlessness (sRPE-B) and leg muscle exertion (sRPE-L) were recorded along with training duration for each completed session. Training prescription, delivery and monitoring was undertaken by part of the research authorship (SJM and AS), who were also the club's physical performance support staff at the time of the study (sport scientist and strength & conditioning coach, respectively).

Participants

Players were senior first team squad members of an English Rugby Football Union Championship club (tier 2). Six players sustained an injury during the study period and were removed from all analyses. A further six players did not complete pre-season fitness testing and nine players did not complete off-season fitness testing. The final pre-season sample included 23 players (age: 24 ± 3 years, stature: 181 ± 17 cm, body mass: 100 ± 13 kg, body fat: 18.1 ± 5.1%) and the final off-season sample included 20 players (age: 23 ± 3 years, stature: 181 ± 19 cm, body mass: 100 ± 11 kg, body fat: 17.7 ± 4.7%). All players provided written voluntary consent to participate in this investigation and the study received ethical approval, conforming to The Declaration of Helsinki, from Teesside University's Research and Ethics Committee (School of Social Sciences, Humanities and Law).

Pre-season training programme (intervention period)

The pre-season training programme included both general- (week's 1–5) and specific- (week's 6–8) preparatory phases. The main goals of general preparation were to improve the execution of closed and semi-open skills, aerobic capacity, strength, maximum velocity and repeated effort ability. Training loads were programmed to increase linearly between weeks 1 and 3 before a taper and period of active recovery was applied throughout weeks 4 and 5. The main goals of the specific preparatory phase were to improve execution of open skills under fatigue, execution of team strategy, anaerobic capacity, power, acceleration and repeated effort ability. Training volume and frequency were reduced, with the goal of sustaining an average weekly training load that would be lower than the general preparation weeks but higher than the anticipated pre-competition and in-season phases. Detailed descriptions of the undertaken training typologies, including structure, volume, intensity and work-to-rest ratios, are described elsewhere (McLaren et al., 2017). Over the eight-week pre-season period, players completed 28 ± 2 training days and 67 ± 5 training sessions, with a total of 1546 individual sessions recorded.

Off-season training programme (control period)

The main goal of the off-season maintenance period was to provide a "minimum dose" training stimulus that would sustain current fitness levels and reduce the risk of injury on the return to higher-load training. This period took place at the end of the season, approximately eight months after the pre-season period, and included a mixture of player- and coach-lead sessions (i.e., unsupervised and supervised). We used a combination of previous research (Le Meur et al., 2012; Mujika, 2010; Purdam et al., 2015) and practitioner experience to prescribe running- and resistance-based training that would represent 40% to 60% of the pre-season training loads. Weekly training volume and frequency were reduced, with training loads and the bimotor focus programmed in a non-linear (daily- and weekly-undulating) fashion. Players typically completed 1 to 2 conditioning sessions (intermittent high-intensity running or cycling), 1 to 2 resistance training sessions (strength or power) and 1 technical-tactical or skills session per week. Over the eight-week maintenance period, players completed 22 ± 10 training days and 30 ± 15 training sessions, with a total of 605 individual sessions recorded.

Assessment of drpe training load

After each training session, players used a bespoke computer application (McLaren et al., 2017) running on a 7″ Android tablet (Iconia One 7 B1-750, Acer Inc., Taipei, Taiwan) to privately record their sRPE-B and sRPE-L. This application consisted of a touch-sensitive, numerically-blinded, centi-Max (CR100®) scale that stored RPE data in a cloud-based spreadsheet (Microsoft Excel 2013®, Microsoft Corp., Redmond, USA). The CR100® scale is an advancement to the more commonly employed CR10® RPE scale (Borg & Borg, 2001), with recent research suggesting that the scale's finer grading could allow for more sensitive sRPE responses in team-sport athletes (Fanchini et al., 2016). Scores were collected approximately 15 to 30-minutes following the end of each training session, with all scores typically recorded within a 10-minute period. This time frame represents a practically feasible window for collecting RPE data from large groups, which is unlikely to be influenced by post-session latency when the training intensity is distributed throughout the session (Fanchini, Ghielmetti, Coutts, Schena, & Impellizzeri, 2015). Compliance to RPE data collection was 100%. Differential training loads for breathlessness (sRPE-B-TL) and leg muscle exertion (sRPE-L-TL) were calculated by multiplying each RPE score by the session duration in minutes (Foster et al., 2001). The sum of all session training loads for a given training week represented the weekly training load (Foster et al., 2001).

Assessment of fitness and anthropometry

At the beginning of each training period and following the final week of training in each period, players completed a series of field-based fitness tests. Fitness tests were selected based on the key physical requirements of rugby union and their previously established relationships with match physical and technical performance (Smart et al., 2014). All four testing schedules were identical, with tests being performed on the same day and time of day at the same locations. All players were familiarised with the testing protocols prior to the study. Testing was carried out over a two-day period and was performed in an indoor sports hall facility. Players wore club issued clothing and their own footwear during all tests. Prior to all testing bouts, players completed a 15-min warm-up consisting of dynamic stretches, joint mobilisation, movement drills and muscle activation exercises.

On the morning of testing day 1, player's lower-limb explosive power was assessed via a bodyweight vertical countermovement jump (CMJ). During the CMJ, players held a 1 kg dowel in a high bar back squat position and were instructed to jump maximally in a vertical direction from a self-selected depth, without bending the knees during flight. Jump flight time was measured using a photocell jump system (Optojump Next, Microgate, Bolzano, Italy) sampling at 1000 Hz, with jump height (cm) subsequently estimated by proprietary software (Optojump Next, Version 1.3.20.0, Microgate, Bolzano, Italy). The highest jump height (cm; calculated to the nearest 0.1 cm) of three attempts was retained for analyses. Following jump testing, linear sprint testing was performed to assess speed and acceleration. The sprint lane was formed by four photoelectric timing gates (SmartSpeed, Fusion Sport, Queensland, Australia), placed approximately 2-m apart and at intervals of 0-, 10-, and 20- (forwards) or 30-m (backs). Sprints were initiated from a crouched, split-stance start position, with no countermovement, at a distance of 0.5-m behind the first timing gate. Each player performed three repetitions over their longest distance, with approximately 3-min passive rest between each trial. Players were instructed to sprint maximally "through" the end timing gate on every repetition. Test performance was measured as the time taken (s; recorded to the nearest 0.01s) to reach each split point marked by the timing gates from the start position (gate at 0-m), with the fastest overall time for each split used for the analyses. After two-hours rest, players' high-intensity intermittent running ability was assessed using the Yo-Yo Intermittent Recovery Test, Level 1 (YYIRTL1; (Krustrup et al., 2003), with test performance measured as the total distance covered (m). On the morning of testing day 2, maximum lower-body strength was assessed using the high-bar box squat. Details of the high-bar box squat protocol are described in detail elsewhere (Smart et al., 2014). Exercise technique was assessed by accredited strength and conditioning coaches (SJM and AS) and lifts were only considered valid when performed unassisted and unequipped with the correct technique. Predicted one-repetition maximum (kg; to the nearest integer: P1RM Squat) was calculated from the highest load lifted during a 2 to 3 repetition maximum lift using the Lander (1985) formula.

Statistical analysis

Visual inspection of histograms and Q–Q plots of raw data indicated no violation of normality assumptions. Raw data are therefore presented as the mean ± standard deviation (SD). All data were log transformed and subsequently back transformed following analysis to obtain effect estimates (fitness typical error, pre-season fitness changes, training load differences) as percentages. Uncertainty in these estimates was expressed as 90% confidence intervals (CI). Off-season fitness data were examined using mixed effects linear models (SPSS version 23, IBM Corp., Armonk, USA) with random intercepts to estimate the within- and between-player variabilities (SDs expressed as coefficients of variation [CV, %]; Hopkins, 2000). Thresholds for small, moderate and large changes in each fitness test were then calculated by multiplying the between-player variability with 0.2, 0.6, and 1.2, respectively (Hopkins, Marshall, Batterham, & Hanin, 2009). Typical error was calculated by dividing the SD of change scores by the square root of 2 (Atkinson & Batterham, 2015). Pre-season fitness changes were examined using paired samples *t*-tests, with mechanistic magnitude-based inferences (Batterham & Hopkins, 2006) subsequently applied (Hopkins, 2007). The chances of a clear effect being at least the observed magnitude or trivial was interpreted using the following scale of probabilistic terms: < 0.5% most unlikely; 0.5–5% very unlikely; 5–24.9% unlikely; 25–74.9% possibly; 75–94.9% likely; 95–99.4% very likely; ≥ 99.5% most likely (Batterham & Hopkins, 2006).

The magnitude of individual responses to pre-season was quantified as SDs by comparing SDs of the pre-season changes with SDs of the off-season changes (Hopkins, 2015). All SDs and the typical error in each fitness test were doubled before interpreting their magnitude against the usual thresholds for a mean change or difference (Smith & Hopkins, 2011). We then obtained the percentage chances that each player's observed change was greater than both the smallest worthwhile effect and the typical error (i.e., a true and substantial individual response; Atkinson & Batterham, 2015). These percentages were then interpreted via the above scale of probabilistic terms. A dichotomous cut-off value of ≥75% ("likely") was used to classify a player as being a responder or a non-responder in each fitness test.

Weekly differential training loads were examined using mixed effects linear models. First, sRPE-B-TL and sRPE-L-TL were modelled separately with a random intercept only to estimate within-and between-player variabilities. Subsequently, we specified RPE type (sRPE-B-TL, sRPE-L-TL) as a fixed effect (dummy coded: 0, 1, respectively) to compare the differences in weekly training loads. This model included a random intercept and slope for RPE type (unstructured covariance matrix) to estimate the interindividual variability (as an SD) of the difference between sRPE-B-TL and sRPE-L-TL. To compare differences in differential training loads between fitness test responders and non-responders we specified response (responder, non-responder) as a fixed effect (dummy coded: 0, 1, respectively) and included a random intercept only. Mechanistic magnitude-based inferences were then applied to all estimates, using standardized thresholds for small, moderate and large differences between sRPE-B-TL and sRPE-L-TL and the threshold for a small difference used to declare differential training loads as being higher or lower in responders when compared with non-responders. As previous, all SDs were doubled before evaluating their magnitude against the usual thresholds for small, moderate and large effects.

Results

Pre- and off-season differential training loads

Average weekly pre-season training loads were 18413 ± 2632 AU for sRPE-B and 20560 ± 1778 AU for sRPE-L. The overall difference between weekly sRPE-B-TL and sRPE-L-TL was likely moderate (10.1%; ±90 confidence limits 8.4%) and the SD representing interindividual variability of this difference was small (± 7.2%). Average weekly off-season training loads were 9387 ± 3391 AU for sRPE-B and 9078 ± 2749 AU; with no clear difference between the two load measures during this phase (4.8%; ±15.2%). The SD representing interindividual variability of this difference was large (± 17.6%).

Changes in fitness

Off-season (control assessment) fitness test performance, typical error and thresholds for substantial changes are presented in Table 1. Pre-season (intervention) fitness test performance and changes are presented in Table 2. The likely range of each player's individual change being true and substantial (> typical error and smallest worthwhile change) are shown in Figure 1. Data are displayed as the proportion (%) of individual responses that were true and substantially positive by each probability category. The proportion of responders in the YYIRTL1, 20/30-m, 10-m, CMJ and P1RM Squat were 37%, 50%, 52%, 82% and 70%, respectively.

Differences in differential training loads between fitness test responders and non-responders

Estimates of the average weekly sRPE-B-TL and sRPE-L-TL for fitness test responders and non-responders are presented in Figure 2. All within-player SDs were large. The differences in weekly differential training loads between responders and non-responders are presented in Table 3.

Disscussion

The application of differential RPE and individual response analyses has the potential to improve training monitoring and evaluation through a better understanding of specific cardiovascular and neuromuscular/musculoskeletal load–adaptation pathways (Jaspers et al., 2017; Vanrenterghem et al., 2017). The main findings from our investigation into the relationships

Table 1. Fitness test performance and the typical variability observed over the 8-week off-season maintenance (control) period (n = 20). Also presented are magnitude thresholds for important changes in each fitness test.

	Test performance (mean ± SD)		Typical error		Threshold (±%; ±90% CL) for a change to be...		
Test	Pre-maintenance	Post-maintenance	±CV (%; ±90% CL)	Magnitude	small	moderate	large
YYIRTL1 (m)	1704 ± 379	1845 ± 301	7.8; ± 2.6	moderate	4.4; ± 1.4	13.7; ± 4.7	29.2; ± 10.8
30-m^{B} (s)	4.35 ± 0.16	4.37 ± 0.13	1.5; ± 1.1	moderate	0.7; ± 0.5	2.0; ± 1.4	4.0; ± 2.9
20-m^{F} (s)	3.10 ± 0.11	3.13 ± 0.10	1.2; ± 0.6	moderate	0.7; ± 0.3	2.1; ± 1.0	4.2; ± 2.1
10-m (s)	1.78 ± 0.06	1.79 ± 0.08	2.1; ± 0.7	large	0.8; ± 0.3	2.4; ± 0.8	4.8; ± 1.7
CMJ (cm)	40.4 ± 6.5	40.3 ± 5.4	4.8; ± 1.9	moderate	3.1; ± 1.2	9.6; ± 3.9	20.1; ± 8.6
P1RM Squat (kg)	196 ± 31	204 ± 33	4.6; ± 2.2	small	3.2; ± 1.5	9.8; ± 4.8	20.6; ± 10.7

Abbreviations. 10-m: ten-meter linear sprint time; 20-m^{F}: twenty–meter linear sprint time (forwards only); 30-m^{B}: thirty-meter linear sprint time (backs only); CL: confidence limits; CMJ: countermovement jump height; CV: coefficient of variation; P1RM: predicted one-repetition maximum; SD: standard deviation; YYIRTL1: Yo-Yo Intermittent Recovery Test, Level 1.

Table 2. Fitness test performance and the changes observed over the 8-week pre-season training (intervention) period (n = 23).

Fitness Test	Test performance (mean ± SD) Pre-season start	Pre-season end	Pre-season mean change %; ±90% CL	Inference	Interindividual responses* CV (%); ±90% CL	Magnitude
YYIRTL1 (m)	1512 ± 443	1760 ± 440	17.5; ± 5.0	likely moderate ↑	3.6; ± 9.7	small
30-m[B] (s)	4.34 ± 0.11	4.22 ± 0.10	−2.7; ± 0.9	likely moderate ↓	−1.4; ± 2.2	trivial
20-m[F] (s)	3.13 ± 0.17	3.02 ± 0.14	−3.6; ± 1.6	possibly large ↓	2.5; ± 2.4	large
10-m (s)	1.79 ± 0.10	1.68 ± 0.07	−6.0; ± 1.4	likely large ↓	2.6; ± 2.9	large
CMJ (cm)	40.5 ± 5.2	42.3 ± 5.6	4.5; ± 2.5	likely small ↑	−3.8; ± 5.6	trivial
P1RM Squat (kg)	184 ± 23	205 ± 21	11.8; ± 3.2	likely moderate ↑	2.4; ± 6.4	small

*A negative value indicates more within-player variation for changes across the maintenance period when compared with changes across the pre-season period. The resulted magnitudes for pre-season individual responses are therefore truncated to "trivial".

Abbreviations. ↑: increase; ↓: reduction; 10-m: ten-meter linear sprint time; 20-m[F]: twenty-meter linear sprint time (forwards only); 30-m[B]: thirty-meter linear sprint time (backs only); CL: confidence limits; CMJ: countermovement jump height; CV: coefficient of variation; P1RM: predicted one-repetition maximum; SD: standard deviation; YYIRTL1: Yo-Yo Intermittent Recovery Test, Level 1.

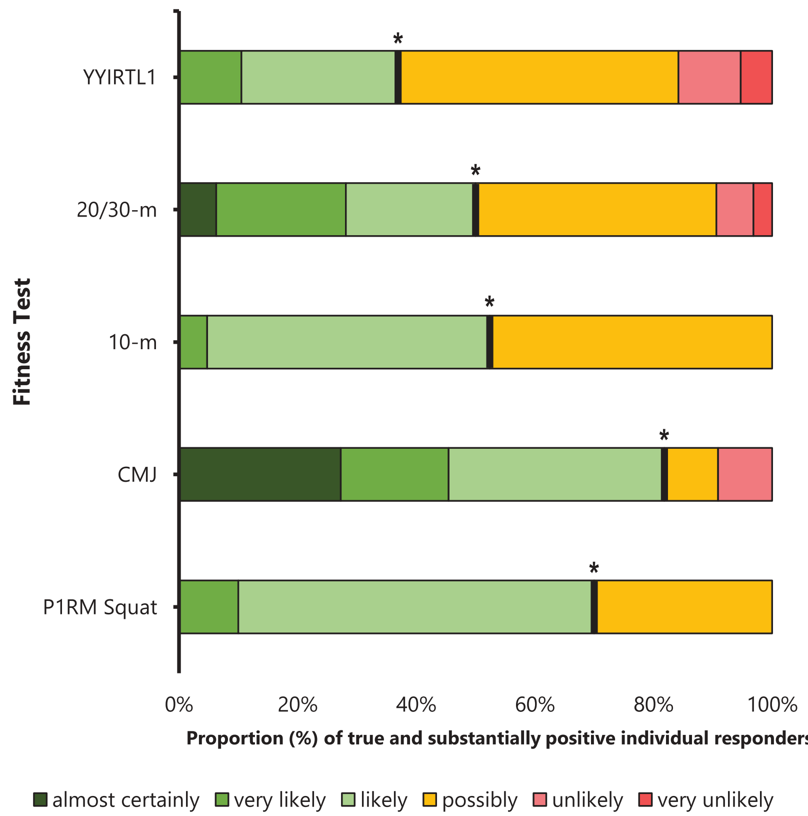

Figure 1. Individual fitness test responses observed over the 8-week pre-season training period. Data are shown as the proportion (%) of players who's individual responses were considered true and substantially positive (change > smallest worthwhile change and typical error) by each likelihood category. Thick black lines with an asterisk marks a dichotomous cut-off point for declaring responders and non-responders.

10-m: ten-meter linear sprint time; 20/30-m: twenty- or thirty-meter linear sprint time CMJ: countermovement jump height; P1RM: predicted one-repetition maximum; YYIRTL1: Yo-Yo Intermittent Recovery Test, Level 1.

between differential training loads and individual fitness responses to pre-season training in professional rugby union players were: 1) weekly sRPE-B-TL was higher in individual responders to the YYIRTL1 and CMJ, and lower in individual responders to 20/30-m and 10-m sprint tests, 2) differences in sRPE-L-TL between fitness responders and non-responders were unclear, 3) moderate differences were evident between weekly sRPE-B-TL and sRPE-L-TL, and 4) the interindividual fitness responses to pre-season training were substantial.

We provide the first evidence to show a difference in weekly sRPE-B-TL between responders and non-responders in the YYIRTL1 following pre-season training, such that weekly sRPE-B-TL was very likely higher in responders when compared with non-responders. Large to very large associations between average weekly sRPE-B-TL and changes in aerobic fitness indicators have previously been reported in soccer players (Gil-Rey et al., 2015; Los Arcos et al., 2015), demonstrating that players with higher average weekly sRPE-B-TL also tended to have greater fitness improvements. Interestingly, these investigations also report similar correlation magnitudes with average weekly sRPE-L-TL, yet we found no clear differences between YYIRTL1 responders and non-responders for this differential load measure. A plausible explanation could be the smaller differences between average weekly sRPE-B-TL and sRPE-L-TL reported in previous research (Los Arcos et al., 2015: ~3%, trivial; Gil-Rey et al., 2015: ~7%, small) in comparison with our present investigation (~10%, moderate). Nonetheless, the positive and substantial association between

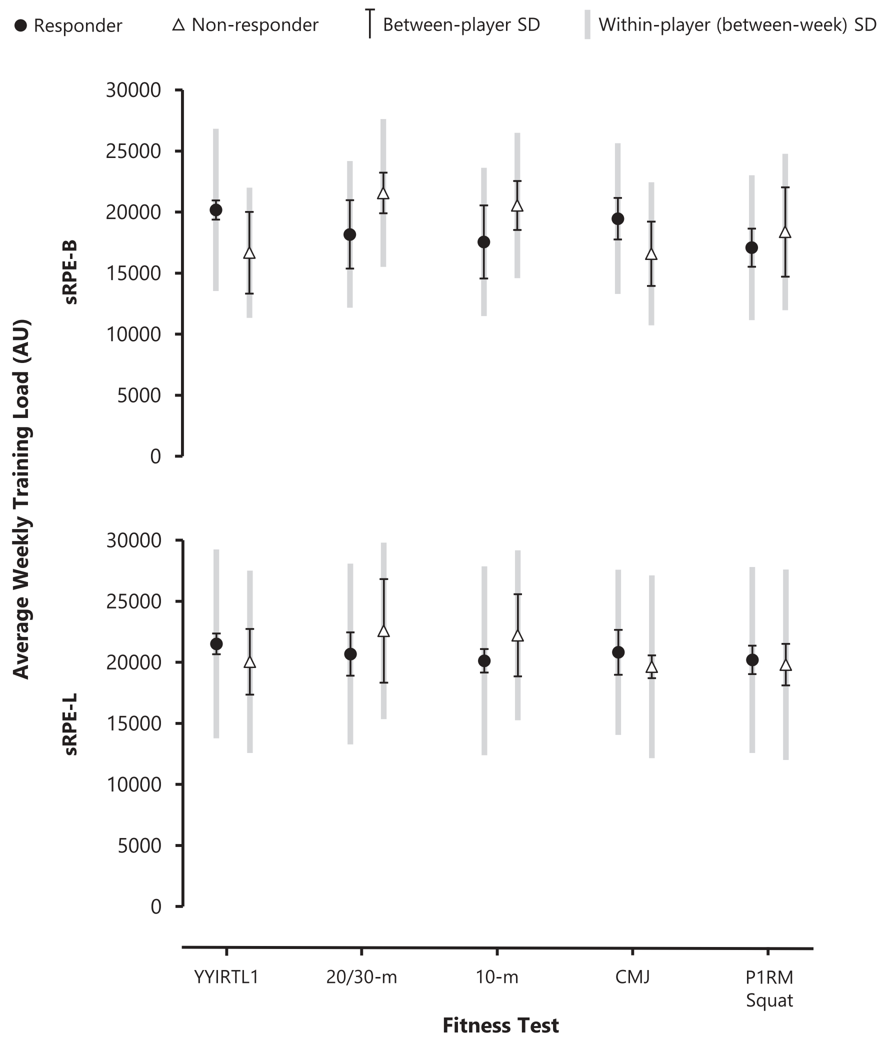

Figure 2. Weekly differential training loads across the eight-week pre-season period for responders and non-responders in each fitness test. Data are presented as estimates of the mean weekly training load with between- and within-player SDs.

10-m: ten-meter linear sprint time; 20/30-m: twenty- or thirty-meter linear sprint time; AU: Arbitrary unit; CMJ: countermovement jump height; P1RM: predicted one-repetition maximum; sRPE-B-TL: training load cumulated from session ratings of perceived breathlessness; sRPE-L: training load cumulated from session ratings of perceived leg muscle exertion; YYIRTL1: Yo-Yo Intermittent Recovery Test, Level 1.

Table 3. Differences in weekly differential training loads between fitness test responders and non-responders.

		Difference in weekly load between responders and non-responders	
Fitness Test	Load Measure	%; ± 90%CL	Inference
YYIRTL1	sRPE-B	**18; ± 11**	**very likely higher in responders**
	sRPE-L	8; ± 12	unclear
20/30-m	sRPE-B	**19; ± 20**	**likely lower in responders**
	sRPE-L	7; ± 17	unclear
10-m	sRPE-B	**18; ± 17**	**likely lower in responders**
	sRPE-L	12; ± 14	unclear
CMJ	sRPE-B	**15; ± 16**	**likely higher in responders**
	sRPE-L	7; ± 28	unclear
P1RM Squat	sRPE-B	7; ± 19	unclear
	sRPE-L	3; ± 15	unclear

weekly sRPE-B-TL and changes in cardiorespiratory fitness indicators seems intuitive given that an athlete's post-exercise perception of breathlessness should be reflective of cardiorespiratory stress – inclusive of elevated oxygen consumption and cardiac output (Bolgar, Baker, Goss, Nagle, & Robertson, 2010). Practically, this could indicate that team-sport athletes with higher weekly sRPE-B-TL are more likely to show substantial improvements in cardiorespiratory fitness during periods of intensified training by comparison to those with typically lower weekly sRPE-B-TL. When coupled with previous findings (McLaren et al., 2016, 2017), we feel that this provides evidence for the discriminant validity of sRPE-B-TL as an indicator of cardiorespiratory training load in team-sport athletes.

Interestingly, we observed higher weekly sRPE-B-TL in CMJ responders, which is somewhat counterintuitive to principles of stress and adaptation specificity. Although speculative, a plausible explanation for such a finding could be our inclusion of certain pre-season training modes (e.g., repeated-sprint training) that have shown to induce small to moderate improvements in CMJ (Taylor, Macpherson, Spears, & Weston, 2015) whilst also incurring substantial cardiovascular session responses (Taylor, Macpherson, McLaren, Spears, & Weston, 2016). Nonetheless, we found no clear differences in weekly sRPE-L-TL between responders and non-responders to sprint, jump and lower-limb strength tests in our current investigation. Despite previous work reporting the associations between sRPE-L-TL and similar neuromuscular-based fitness tests to range from trivial to small (Gil-Rey et al., 2015), a re-analysis of these data (Hopkins, 2007) indicates that the relationships were unclear (r = −0.21–0.25, chance of the true relationship being the inverse direction = 6–30%). Los Arcos et al. (2015) also report unclear relationships between sRPE-L-TL and changes in 5- and 15-m sprint performance, yet these authors found clear and possibly large, negative, associations between average weekly sRPE-L-TL and changes in countermovement jump height. Our current findings and that of previous work would suggest that the associations between sRPE-L-TL and changes in neuromuscular fitness are largely unclear at present, thus warranting further research. While this may question the sensitivity of sRPE-L-TL in relation to fitness test performance, it is plausible that the performance-based fitness outcomes used in our investigation and by others lack sensitivity to detect changes in important neuromuscular characteristics. For example, two athletes may have a very similar countermovement jump height or linear sprint times, but they may differ in the way performance is achieved, such as muscle activation patterns and maximal lower-limb force production, extension velocity or mechanical power output (Coffey & Hawley, 2007; Morin & Samozino, 2016). If a test outcome is not specific to the targeted training-induced adaptations, then an unclear link between its changes and a measure of training load may be of little surprise.

We report for the first time a moderate difference between weekly differential training loads during the pre-season training phase in professional rugby union players, with sRPE-L-TL being greater than sRPE-B-TL and the interindividual variability of this difference being small (i.e., relatively consistent between players). Despite previous research not reporting the magnitude of the difference between weekly differential training loads, it is evident that our findings are in agreement with substantial differences observed in soccer players during the pre-season training period (effect size calculated from descriptive data = 0.28, small; Los Arcos et al., 2015). Interestingly, we found no difference between weekly sRPE-L-TL and sRPE-B-TL during the off-season training period and this is again in agreement with Los Arcos et al. (2015; effect size calculated from descriptive data = −0.08, trivial) but not Gil-Rey et al. (2015; effect sizes calculated from descriptive data = 0.33 [sub-elite] & 0.44 [elite], small). Such a finding might suggest that the difference between sRPE-L-TL and sRPE-B-TL is moderated by the magnitude of load and the goals of training – with higher cumulative training loads during periods targeting adaptation resulting in more pronounced differences between the two measures. Nonetheless, the pre-season differential training load differences in our investigation are consistent with greater sRPE-L when compared with sRPE-B observed following soccer (Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014) and Australian Rules Football (Weston et al., 2015) match-play. Our findings, therefore, support that team-sport athletes recognise a substantial disparity between their feelings of central and peripheral exertion during training (McLaren et al., 2017) and competition (Weston et al., 2015), with the perception of leg muscle exertion often being the most dominant psychophysiological signal. Since global RPE is mediated by perceptual signal dominance (Bolgar et al., 2010; Robertson & Noble, 1997), our findings highlight the usefulness of adopting dRPE to training monitoring in team-sport athletes.

The magnitude and direction of our group (mean) pre-season fitness changes (small to large improvements) are comparable to those previously reported in professional northern hemisphere rugby union players with similar baseline pre-season fitness levels (Bradley et al., 2015; Roe, Darrall-Jones, Jones, & Till, 2016). A novel aspect of our investigation was the ability to specify the typical error in each fitness measure over an eight-week period designed to maintain fitness levels through the prescription of a "minimum dose" training load. The eight-week typical errors in our fitness measures ranged from small to large, with coefficients of variation being similar to those reported over shorter-term periods (3 to 10 days) in professional rugby union players (Darrall-Jones, Jones, Roe, & Till, 2016; Smart, 2011). Subsequently, we quantify and report for the first time the likely range for the true interindividual responses in fitness to pre-season training, as well as the probability that each player's observed change was true and substantial. This novel method identifies true responses by accounting for both the typical error and smallest worthwhile change (responder: change > SWC and typical error), rather than inappropriately interpreting the observed difference in isolation (Atkinson & Batterham, 2015; Hopkins, 2015). Our data indicate that interindividual differences in the fitness response to pre-season training range from trivial to large – with 18 to 63% of players showing no meaningful changes above what is observed during periods of fitness maintenance. Such a finding may suggest that analysis of group-level changes or using observed change scores with no consideration for typical error is highly misleading and could lead to erroneous conclusions when interpreting data on individuals or from research. We therefore recommend that practitioners and researchers adopt the individual response method as a robust means of analysing their data. Furthermore, we believe that follow-up studies are warranted to explore the characteristics of responders and non-responders to the pre-season training period in team sports. Such factors may include, but are not limited to: training frequency, load, volume or intensity, age, pre-training level of phenotype (starting fitness level) and genetic background (Coffey & Hawley, 2007; Impellizzeri et al., 2005).

A limitation to our current study is the sole use of performance-based fitness constructs – albeit ones that are relevant to rugby union (Smart et al., 2014). When assessing the dose–response relationships between fitness qualities and training load, it would also seem important to examine isolated physiological and biomechanical qualities, since load–adaptation pathways may be specific to the manner in which an athlete achieves their physical performance rather than the performance per-se (e.g., a shift in force–velocity profile or the anaerobic speed reserve, etc.). Another plausible limitation of our present work could be the calculation of differential training load using the session RPE method (RPE score × total session time in minutes; Foster et al., 2001). While this allowed us to build on previous work, such a method may not necessarily have direct transfer to dRPE given that central and peripheral perceived exertion are not proportionate constructs (Bolgar et al., 2010). This is not to say that the current approach is wrong; rather, there may yet be a better alternative. It does, however, present issues of mathematical coupling in the calculation of load (i.e., both sRPE-B-TL and sRPE-L-TL include the same volume constant), which prevented us from examining the dose–response effects of one measure while controlling for the other despite the fact that sRPE-B and sRPE-L are unlikely to be mutually exclusive (Green et al., 2009). As with previous investigations (Jaspers et al., 2017), our dose–response analysis represents a retrospective between-athlete comparison drawn from observations that may not necessarily be applicable to tracking the same individuals over multiple time points or the prognostic value of specific training doses. Given the practical relevance of such a topic, we recommend that future dose–response investigations aim to examine the within-athlete relationships between training load and changes in fitness as well as the effects of manipulated and pre-programmed training doses (e.g., pre–post parallel-groups design) while appropriately controlling for the many non-load–related mediators of the training response.

Conclusions

This is the first study to report the differences in differential training loads between fitness responders and non-responders to pre-season training in team-sport athletes. We demonstrate that weekly sRPE-B-TL is able to distinguish between players who show true and substantial changes in a range of performance-based fitness measures following intensified training when compared with players who do not. Substantial and consistent differences between sRPE-B-TL and sRPE-L-TL further indicate that ratings of central and peripheral exertion are perceived to be disparate psychophysiological constructs by professional rugby union players. Although the discriminant validity of sRPE-L-TL in relation to training outcomes requires further understanding, our findings support the collection of dRPE in team-sport athletes.

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No potential conflict of interest was reported by the authors.

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