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Section III – Sports and Physical Activity

Analysis of Differential Perceived Training Loads in a Rugby Union Academy

by
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This study analyzed weekly training and match loads through respiratory and muscular ratings of perceived exertion (RPEres and RPEmus) and investigated the relationship between differential RPE-training loads (TL) and fitness changes in rugby union players. Twenty-eight males from the U16 and U18 teams of the same club completed a 10-week longitudinal observational study with testing sessions (i.e., a countermovement jump, a 10-m running sprint and a 1.2-km shuttle run) before and after the monitoring phase. No changes in physical fitness were observed after this period ($p > 0.05$). RPEres-TL and RPEmus-TL four days before the match-day (MD–4) were greater than on the MD–2 (RPEres-TL: $p = 0.004$, $d = 0.73$; RPEmus-TL: $p = 0.001$, $d = 1.02$) and on the MD (RPEres-TL: $p < 0.001$, $d = 0.90$; RPEmus-TL: $p < 0.001$, $d = 1.16$) in U16 players. In U18 players, RPEmus-TL was higher on the MD–4 than on the MD–2 ($p = 0.045$, $d = 0.73$), while the dRM-Index (respiratory/muscular ratio) was higher on the MD–2 than on the MD–4 ($p = 0.042$, $d = 0.55$). No significant differences were found between RPEres-TL and RPEmus-TL for any session ($p > 0.05$). The accumulated RPEres-TL ($p = 0.018$, $r = 0.59$) and RPEmus-TL ($p = 0.001$, $r = 0.76$) were positively correlated with changes in shuttle running test performance in U18 players. Differential RPE-TLs provide additional insights to analyze and differentiate weekly load distribution between categories, and partially indicates fitness changes: players who accumulated more perceived loads during the season tended to maintain endurance performance. This practical available monitoring approach can assist academy rugby union practitioners in further individualizing training and optimizing performance.

***Keywords**: team sports; youth sports; internal load; perceived effort; physical fitness*

Introduction

Monitoring players' training load (TL) has become commonplace in team sports (Impellizzeri et al., 2019) to optimize post-game recovery, avoid pre-game fatigue during competitive weeks (Douchet et al., 2024; Silva et al., 2018), and quantify its dose-response relationships with changes in physical fitness performance (Dudley et al., 2023; Jaspers et al., 2017). TL represents the exposure to an agent (or a factor) and includes two different, but related sub-dimensions: the external and the internal load (Impellizzeri et al., 2023). Since the internal TL determines the training outcome, it is recommended to use it as a primary measure when monitoring the athletes' load (Impellizzeri et al., 2019). In contrast to the external TL, the internal TL allows accurate comparisons between athletes with regard to their true responses to training (Impellizzeri et al., 2019). Predicting an individual's actual internal TL prior to training becomes more difficult in team sports than in individual sports. Team sports are

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characterized by the presence of teammates and opponents that induce decisional uncertainty (Martínez-Santos et al., 2020; Parlebas, 2013). This leads coaches to set up specific training situations full of affordances that players can resolve in different ways (Woods et al., 2019). The lack of control over players' responses to the practice increases the distance between the training loads expected/desired by coaches and the actual training loads experienced by players. Thus, the quantification of the internal TL is crucial in the monitoring of players' training responses to optimize performance in team sports.

Among the methods for quantifying psychophysiological response (i.e., internal load), the rating of perceived exertion (RPE) stands out for its simplicity (Borg, 1982), the lack of requirements for qualified professionals (Alexiou and Coutts, 2008), cost-effectiveness (Borg, 1982), time-efficiency, and validation as a non-invasive indicator of the internal TL (Foster et al., 2001; McLaren et al., 2018a). These advantages make it applicable in real-world settings, especially in youth sports academies where human resources (e.g., qualified coaches) and material resources (e.g., heart rate monitors or global positioning systems) are scarce. For these reasons, the RPE-based TL is the most common method to quantify TL in team sports, as in rugby (Comyns and Hannon, 2018; Loturco et al., 2024; Quarrie et al., 2017; Simmons et al., 2024). However, it has been suggested that a single-item measure of effort (i.e., global RPE) is insufficient to capture the whole range of perceptual sensations during training (Hutchinson and Tenenbaum, 2006). The deconstruction of the RPE gestalt has been proposed to quantify TL because the distinction between central (i.e., breathlessness, respiratory RPE [RPEres]) and peripheral (i.e., leg muscle exertion, muscular RPE [RPEmus]) perceptions (Ekblom and Golobarg, 1971) provides additional valuable information for training monitoring in team sports (Iglesias-Torres et al., 2024; Los Arcos et al., 2015; McLaren et al., 2018b). Nevertheless, to the best of our knowledge, RPEres and RPEmus examination in rugby union academies has been little investigated.

Studies in professional male rugby players have indicated that the differential RPE helps reflect and contemplate players' specific perceptual responses to the different training sessions throughout the competitive weeks (McLaren et al., 2017, 2018b). Those studies indicated sessional peripheral RPE-TL to be *moderately* greater than central RPE-TL. Furthermore, differential RPE-TL discriminated between players who experienced a positive change in fitness performance from those who did not (McLaren et al., 2017, 2018b). The quantification and assessment of differential RPE-TL helped to further detail the weekly TL (periodization unit in team sports) and analyze the accumulated TL dose-response relationship with physical performance changes in professional rugby union teams (McLaren et al., 2018b). Collectively, those findings support registering the differential RPE to monitor individual actual training responses in team-sport athletes. However, despite the satisfactory application of the differential RPE for sessional, weekly and accumulated TL monitoring in professional senior rugby union players (McLaren et al., 2017, 2018b), it has never been explored in youth athletes. Considering the limited resources in youth teams in comparison with the professional teams, investigating the applicability of the differential RPE for TL monitoring in rugby union academies deserves further attention.

Therefore, this study aimed to (1) analyze weekly training and match loads through respiratory and muscular ratings of perceived exertion (i.e., RPEres and RPEmus), and (2) investigate whether changes in physical fitness performance were related to RPEres-TL and/or RPEmus-TL in a dose-response manner in youth rugby union players. It was hypothesized that both training and match RPEmus-TL would be greater than the RPEres-TL, and that both differential RPE-TLs would partially explain changes in players' physical performance.

Methods

Participants

Thirty-three male rugby union players (U16: $N = 18$, body height: 1.70 ± 0.08 m, body mass: 71.3 ± 11.2 kg; playing experience: 5 ± 2 years; U18: $N = 15$, body height: 1.75 ± 0.07 m, body mass: 82.7 ± 17.7 kg; playing experience: 7 ± 3 years) from the same club participated in the study during the 2023/2024 season. The club's first team competed in the Spanish second division. Players were assigned to Tier 2: Trained/Developmental of the participant classification framework (McKay et al., 2022). Indeed, players identified rugby as their main sport, regularly trained for more than 150 min per week with a competitive purpose and competed in the autonomous league for their age group (i.e., Basque league). Participants, their parents/guardians, coaches, and club management were fully informed of the purpose and procedures of the study before written informed consent was obtained from parents/guardians and players agreed to participate. The study followed the ethical principles for medical research involving human subjects of the World Medical Association (Declaration of Helsinki, 2013) and was approved beforehand by the Ethics Committee for Research involving Human Beings (GIEB in Basque) of the University of the Basque Country UPV/EHU (protocol code: M10_2022_328MR1; approval date: 20 September 2022).

Design and Procedures

A longitudinal observational design was adopted to describe and assess the differential RPE-TL and its association with changes in physical fitness performance in U16 and U18 rugby union players from the same club. This study was conducted for 10 weeks, from October to December 2023. The study period included testing during week 1 (T1) carried out in the last week of the pre-competition period, an 8-week competition period, and testing 2 (T2) carried out during the 9th week of this period. Testing sessions included the evaluation of the jump (countermovement jump [CMJ]), sprint (5- and 10-m distances) and endurance (1.2-km shuttle running test [Bronco test]) performances. The training design and implementation were not interfered by the researchers at any time (Phibbs et al., 2018a). Each player declared their differentiated RPE, respiratory and muscular (Los Arcos et al., 2015; McLaren et al., 2016, 2018b) for the whole training or the match (Foster et al., 2001) for every session completed during the study.

Training Schedule

Players from both the U16 and U18 teams typically attended two 90-min training sessions per week (Tuesdays and Thursdays) and played an official match on Saturdays (match-day [MD]) during the competition. Thus, training sessions were performed on four (MD−4) and two days (MD−2) before the match. In total, there were 15 specific rugby training sessions and six official matches during the monitoring period. The typical weekly structure and session content are summarized in Table 1 and were similar for both U16 and U18 teams: the Tuesday's session (MD−4) consisted of physical conditioning and analytical technical drills (e.g., rucking, tackling or passing) performed collectively and position-specific drills for forwards and backs (e.g., scrummaging for forwards). Thursday's training (MD−2) consisted of small-sided games, position-specific drills (e.g., plays for backs) and tactical training focused on the team game system and overall game movements.

Measurements

Fitness assessment sessions were carried out at 6 p.m. in club facilities after two days of minimal physical activity (i.e., no rugby practice or game and no exercise). Sessions started with a standardized 12-min warm-up that included low-intensity running, two agility exercises and several acceleration-runs, jumps and sprints. Then, players performed neuromuscular tests in the same order (i.e., CMJ and sprint) in the club's indoor gym. After ten minutes, players performed the 1.2-km shuttle run test (Bronco test) on the club's natural grass field. Participants were vigorously encouraged to perform maximally in every test. Tests were overseen by the same experienced assessors who were proficient in the testing protocols. Participants were familiarized with all the test procedures: neuromuscular tests were included during the warm-up of several previous training sessions and players performed the Bronco test three weeks before T1.

Countermovement Jump

Players performed the CMJ test on an indoor court in accordance with the procedures of Bosco et al. (1983). Players carried out the jump with the hands fixed on the hips, went down to 90° knee flexion from an extended leg position and immediately performed a concentric action for maximal height. They were instructed to land on the contact platform in a position like that of the take-off. Players performed three attempts with a minimum of 20-s recovery between each repetition. Jumps were recorded by a contact platform (Microgate Opto Jump Next, Bolzano, Italy). The highest jumping height was retained for further analysis. Test reliability (intraclass correlation coefficients [ICCs]$_{3,1}$; Koo and Li, 2016) was > 0.96 and the intra-player coefficient of variation (CV) was 4.1 ± 2.7%.

Linear Running Sprint Test

The linear sprint test was carried out on an indoor court and consisted of three maximal sprints of 10 m. The rest interval between each sprint was 3 min. Running time was recorded with accuracy of 0.001 s using photocell gates (Microgate Polifemo, Bolzano, Italy) placed 0.5 m above the ground. The sprint was self-initiated from a standing start, 0.5 m behind the start line. The time was automatically activated when the participant passed the first gate at the 0-m mark, and split times were recorded at 5 (S5) and 10 (S10) m. The best time on each distance was selected for further analysis. Test reliability (ICCs$_{3,1}$; Koo and Li, 2016) was > 0.94 and > 0.97, and intra-player CVs were 2.9 ± 1.3% and 1.8 ± 0.8%, for S5 and S10, respectively.

Shuttle Run Test

The 1.2-km shuttle run test, also known as the Bronco test (Sella et al., 2021), is commonly used by practitioners to assess the endurance performance of rugby union players (Vachon et al., 2021). This was performed outdoors, on a natural grass field, using rugby boots. During on-field testing-sessions ambient conditions (temperature 9–14 ºC; humidity 76–92%) were measured and wind velocity (5 ± 7 $km \cdot h^{-1}$) was obtained from the nearest weather station. The test consisted of continuous 20-, 40-, and 60-m straight shuttle runs (i.e., 20 m forward and back, 40 m forward and back, 60 m forward and back) completed five times at the maximal possible speed (Sella et al., 2021). A handheld chronometer was used by the same trained experimenter to record Bronco test finish times, and these were used for analysis. The ICC for Bronco time was observed to be 0.99 (Brew and Kelly, 2014).

Training Load Quantification

Internal TL data collection started after T1 and finished with the last training session before T2. TL was quantified using the perceived TL method (Foster et al., 2001). Ten minutes after each training and match (Los Arcos et al., 2015; Zabaloy et al., 2025) and using the Foster's (2001) 0-to-10 scale, participants were asked by the same person (i.e., the fitness coach) on all occasions to rate their RPE separately for respiratory (RPEres) and leg musculature (RPEmus) efforts (McLaren et al., 2016, 2018b). They were familiarized with the scale after training and matches during the four weeks before T1. TL was calculated by multiplying each RPE value by the duration of the training session or the match (Foster et al., 2001). The duration of a training session was recorded for each player from the start to the end of the session, including warm-up and excluding cool-down activities, while the match duration excluded the warm-up and in-between half-time rest (Los Arcos et al., 2015). Only observations from players who completed the entire training session or the match were included in the weekly and session analysis (Gil-Rey et al., 2015). Therefore, the mean weekly RPEres-TL and RPEmus-TL values for each player were obtained by calculating the average of the training weeks in which the player completed all three sessions (MD−4, MD−2 and MD). The RPEres-TL/RPEmus-TL ratio (i.e., dRM-Index) was calculated by dividing RPEres-TL by RPEmus-TL.

Statistical Analysis

Descriptive results are presented as means ± standard deviations (SDs). Data were analyzed using parametric statistics following confirmation of normality and homoscedasticity. Paired *t*-tests were used to compare physical fitness performance from T1 to T2 and accumulated, weekly, and session RPEres-TL and RPEmus-TL. Repeated measures ANOVAs with Tukey post hoc tests were used to compare RPEres-TL, RPEmus-TL, and dRM-Index between sessions. Cohen's *d* effect sizes (*d*) were used to interpret the magnitude of the differences, with values < 0.2, 0.2–0.5, 0.5–0.8, and ≥ 0.8 considered *trivial*, *small*, *moderate*, and *large*, respectively (Cohen, 1988). Accumulated, weekly, and sessional TL variabilities between players were calculated by the CV. Pearson's product-moment correlation coefficients (*r*) were used to assess the direction and magnitude of the linear relationships between accumulated TL and changes in physical fitness performance. The accuracy of each linear regression was evaluated using the standard errors of the estimates (SEEs) and the 95% confidence intervals (CIs). Correlation magnitudes were interpreted according to the following threshold effects: *small* (0.1), *moderate* (0.3), *large* (0.5), *very large* (0.7) and *extremely large* (0.9). A p value < 0.05 was considered significant for analyses not requiring post hoc adjustments. Analyses were performed using jamovi software, version 2.3.2 for Windows (The jamovi project, 2023, retrieved from https://www.jamovi.org).

Results

One U18 player missed T2 due to an illness and four U16 players faced long-term (more than three weeks) injuries. Thus, 28 players (U16: $n = 14$, 6 backs and 8 forwards; U18: $n = 14$, 7 backs and 7 forwards) were finally included in the study.

Trivial to *moderate* non-significant ($p > 0.05$) differences were found from T1 to T2 in U16 and U18 players' physical fitness performance (Table 2).

Table 3 presents descriptive data and between-subjects CVs of the accumulated and weekly differential RPE-TL of youth rugby union players. Significant differences were not apparent ($p > 0.05$) between the accumulated RPEres-TL and RPEmus-TL for U16 ($d = 0.06$, *trivial*) nor U18 ($d = 0.00$, *trivial*) players. Significant differences were not found ($p > 0.05$) between weekly RPEres-TL and RPEmus-TL for U16 ($d = 0.03$, *trivial*) nor U18 ($d = 0.06$, *trivial*) players.

Figure 1 shows individual and teams' mean RPEres-TL and RPEmus-TL distribution along the week during the 10-week competitive period for both U16 and U18 teams. MD−4 RPEres-TL and RPEmus-TL were significantly greater than those from MD−2 (RPEres-TL: $p = 0.004$, $d = 0.73$; RPEmus-TL: $p = 0.001$, $d = 1.02$) and the MD (RPEres-TL: $p < 0.001$, $d = 0.90$; RPEmus-TL: $p < 0.001$, $d = 1.16$), while significant differences were not found ($p > 0.05$) between MD−2 and MD values (RPEres-TL: $d = 0.05$, RPEmus-TL: $d = 0.07$) in U16 players. In U18 players, MD−4 RPEmus-TL was significantly greater ($p = 0.045$, $d = 0.73$) than MD−2 RPEmus-TL, while the rest of comparisons between particular sessions showed non-significant differences ($p > 0.05$): MD−4 vs. MD−2, RPEres-TL: $d = 0.28$; MD−4 vs. MD, RPEres-TL: $d = 0.41$, RPEmus-TL: $d = 0.58$; MD−2 vs. MD, RPEres-TL: $d = 0.00$, RPEmus-TL: $d = 0.36$.

Figure 2 illustrates the individual and teams' mean dRM-Index along the week during the 10-week competitive period for both U16 and U18 teams. Significant differences were not found ($p > 0.05$) for the dRM-Index in U16 players (MD−4 vs. MD−2: $d = 0.05$; MD−4 vs. MD: $d = 0.00$; MD−2 vs. MD: $d = 0.05$). The MD−4 dRM-Index was significantly lower than the MD−2 dRM-Index ($p = 0.042$, $d = 0.55$) and significant differences were not found ($p > 0.05$) between the other sessions (MD−4 vs. MD: $d = 0.18$; MD−2 vs. MD: $d = 0.42$) in U18 players.

Significant correlations were not found between the differential RPE-TL and performance changes in the CMJ (RPEres-TL: $p = 0.75$, $r = 0.10$ [CI: −0.46; 0.60]; RPEmus-TL: $p = 0.87$, $r = 0.05$ [CI: −0.50; 0.57]), 5-m (RPEres-TL: $p = 0.38$, $r = 0.26$ [CI: −0.32; 0.69]; RPEmus-TL: $p = 0.38$, $r = 0.26$ [CI: −0.32; 0.69]) and 10-m sprints (RPEres-TL: $p = 0.28$, $r = 0.31$ [CI: −0.26; 0.72]; RPEmus-TL: $p = 0.22$, $r = 0.35$ [CI: −0.22; 0.74]), and Bronco test (RPEres-TL: $p = 0.16$, $r = 0.40$ [CI: −0.17; 0.77]; RPEmus-TL: $p = 0.18$, $r = 0.38$ [CI: −0.19; 0.76]) for U16 players.

There were no apparent correlations between the differential RPE-TL and performance changes in the U18 players' CMJ (RPEres-TL: $p = 0.30$, $r = -0.30$ [CI: −0.72; 0.27]; RPEmus-TL: $p = 0.22$, $r = -0.35$ [CI: −0.74; 0.22]), 5-m (RPEres-TL: $p = 0.43$, $r = 0.23$ [CI: −0.34; 0.68]; RPEmus-TL: $p = 0.48$, $r = 0.21$ [CI: −0.36; 0.66]) and 10-m sprints (RPEres-TL: $p = 0.15$, $r = 0.41$ [CI: −0.15; 0.77]; RPEmus-TL: $p = 0.22$, $r = 0.35$ [CI: −0.22; 0.74]). Significant, *large*-to-*very large*, and positive correlations were found between both the RPEres-TL ($p = 0.018$: $r = 0.59$ [0.09; 0.85]) and the RPEmus-TL ($p = 0.001$; $r = 0.76$ [0.38; 0.92]) and changes in Bronco test performance for U18 players (Figure 3).

Discussion

The primary aim of this study was to analyze weekly training and match loads through respiratory and muscular ratings of perceived exertion (i.e., RPEres and RPEmus) in rugby union academy players during the in-season period. The main findings were as follows: i) the highest RPEmus-TL was observed in the training session furthest (MD−4) from the match in both age groups, indicating a thoughtful effort to ensure optimal recovery and minimize fatigue during competition; ii) while the highest RPEres-TL also occurred in the MD−4 session for the U16 team, it remained similar throughout the week for the U18 team; iii) the dRM-Index was greater on the MD−2 than on the MD−4 for U18 players, indicating that the respiratory/muscular TL relationship was also considered by the coaching staff to minimize pre-match fatigue in the oldest players; iv) on-field rugby union sessions did not lead to significant intra-session respiratory and muscular RPE-TL differences; and v) *large*-to-*very large* and positive correlations were found between accumulated differential TL and changes in Bronco test performance in U18 players, suggesting the relative impact of TL on physical preparedness to compete.

Table 1. Typical weekly training schedule for U16 and U18 male rugby union players.

Monday	Tuesday		Wednesday	Thursday		Friday	Saturday		Sunday
Day off	Conditioning	20′	*Day off*	Small-sided games	30′	*Day off*	Competition		*Day off*
	Technical skills	40′		Position-specific training	30′		U16	60′	
	Position-specific training	30′		Tactical training	30′		U18	70′	

Table 2. Physical fitness performance test results and comparisons from test 1 (T1) to test 2 (T2) in U16 and U18 male rugby union players.

	T1	T2	Δ (%) [95%, CI]	*p*	Cohen's *d* effect size
U16					
CMJ (cm)	29.0 ± 7.61	30.1 ± 6.95	4.9 [0.5; 9.5]	0.06	−0.55, *moderate*
S5 (s)	1.15 ± 0.09	1.16 ± 0.09	1.0 [−1.4; 3.4]	0.51	−0.18, *trivial*
S10 (s)	1.98 ± 0.15	2.00 ± 0.15	0.7 [−0.8; 2.2]	0.42	−0.23, *small*
Bronco test (s)	386 ± 57.3	376 ± 40.8	−2.1 [−5.3; 1.3]	0.24	0.33, *small*
U18					
CMJ (cm)	37.5 ± 5.41	37.2 ± 4.56	−0.6 [−3.5; 2.5]	0.65	0.12, *trivial*
S5 (s)	1.09 ± 0.09	1.08 ± 0.08	−1.1 [−2.8; 0.7]	0.29	0.29, *small*
S10 (s)	1.87 ± 0.12	1.85 ± 0.12	−0.7 [−1.8; 0.5]	0.32	0.28, *small*
Bronco test (s)	343 ± 34.5	346 ± 34.0	0.9 [−1.0; 2.8]	0.43	−0.22, *small*

Δ, change from T1 to T2; CI, confidence intervals; CMJ, countermovement jump; S5, sprint time at 5-m; S10, sprint time at 10-m

Table 3. Descriptive data (coefficient of variation [CV]) of accumulated and weekly respiratory (RPEres-TL) and muscular (RPEmus-TL) perceived effort-based training loads of U16 and U18 male rugby union players.

	Accumulated	Weekly
U16		
RPEres-TL (AUs)	8379 ± 3876 (46%)	1412 ± 380 (27%)
RPEmus-TL (AUs)	8429 ± 3669 (44%)	1418 ± 283 (20%)
dRM-Index	0.99 ± 0.14 (14%)	0.99 ± 0.17 (17%)
U18		
RPEres-TL (AUs)	9009 ± 2630 (29%)	1583 ± 212 (13%)
RPEmus-TL (AUs)	9007 ± 2987 (33%)	1593 ± 222 (14%)
dRM-Index	0.99 ± 0.17 (17%)	1.00 ± 0.11 (11%)

AUs, arbitrary units; dRM-Index, RPEres-TL / RPEmus-TL ratio

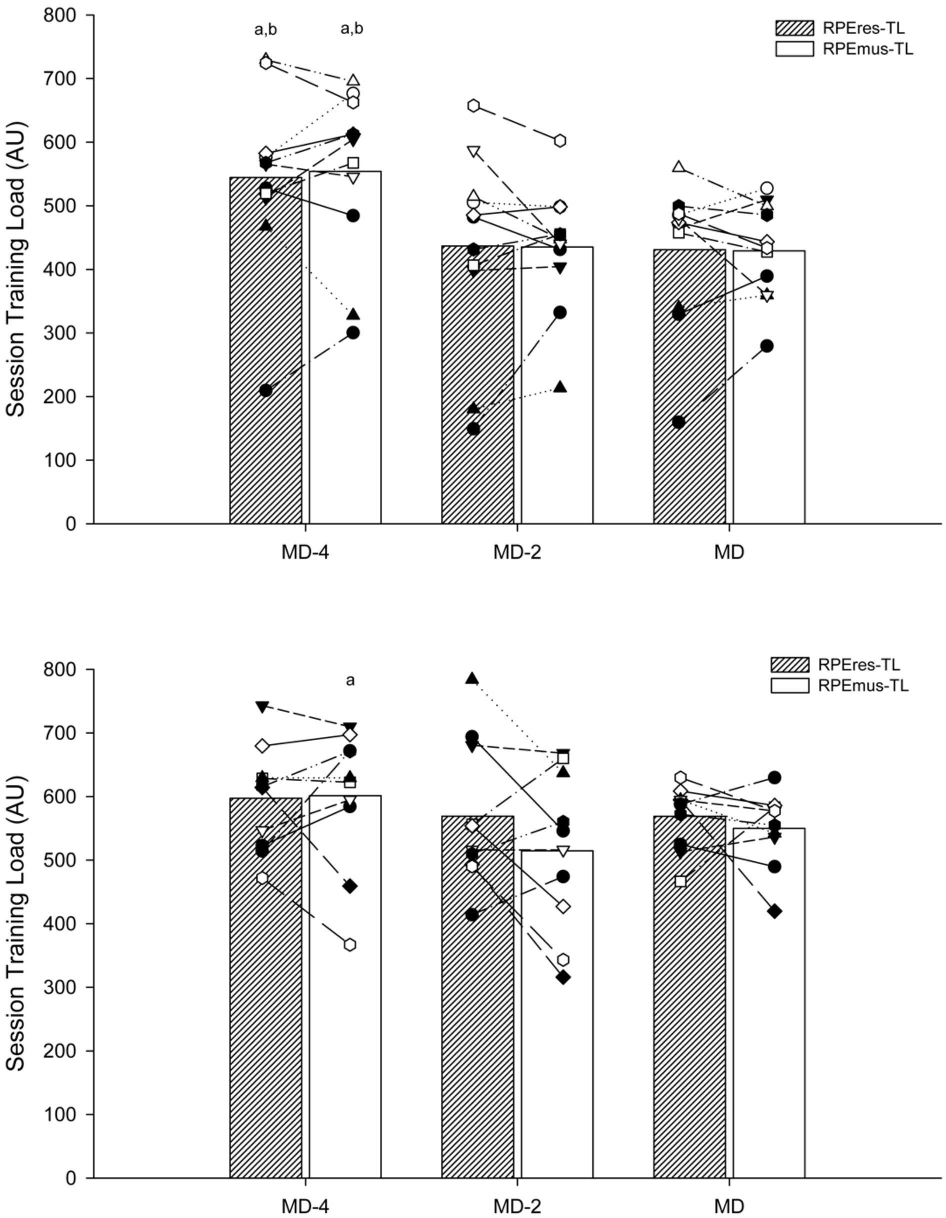

Figure 1. Distribution of perceived respiratory (RPEres-TL) and muscular (RPEmus-TL) training loads along the week during the 10-week competitive period for U16 (*n* = 14; upper panel) and U18 (*n* = 14; lower panel) players.

Columns indicate the mean of the team for both RPEres-TL and RPEmus-TL for each training and match session. Symbols, linked with black solid lines, indicate the individual means of each of the players for both RPEres-TL and RPEmus-TL for each training and match session. MD–4 and MD–2 are the training sessions performed on four and two days before the match-day (MD), respectively. Note: a, significantly higher compared to the MD–2 session at the p < 0.05 level; b, significantly higher compared to the MD session at the p < 0.05 level

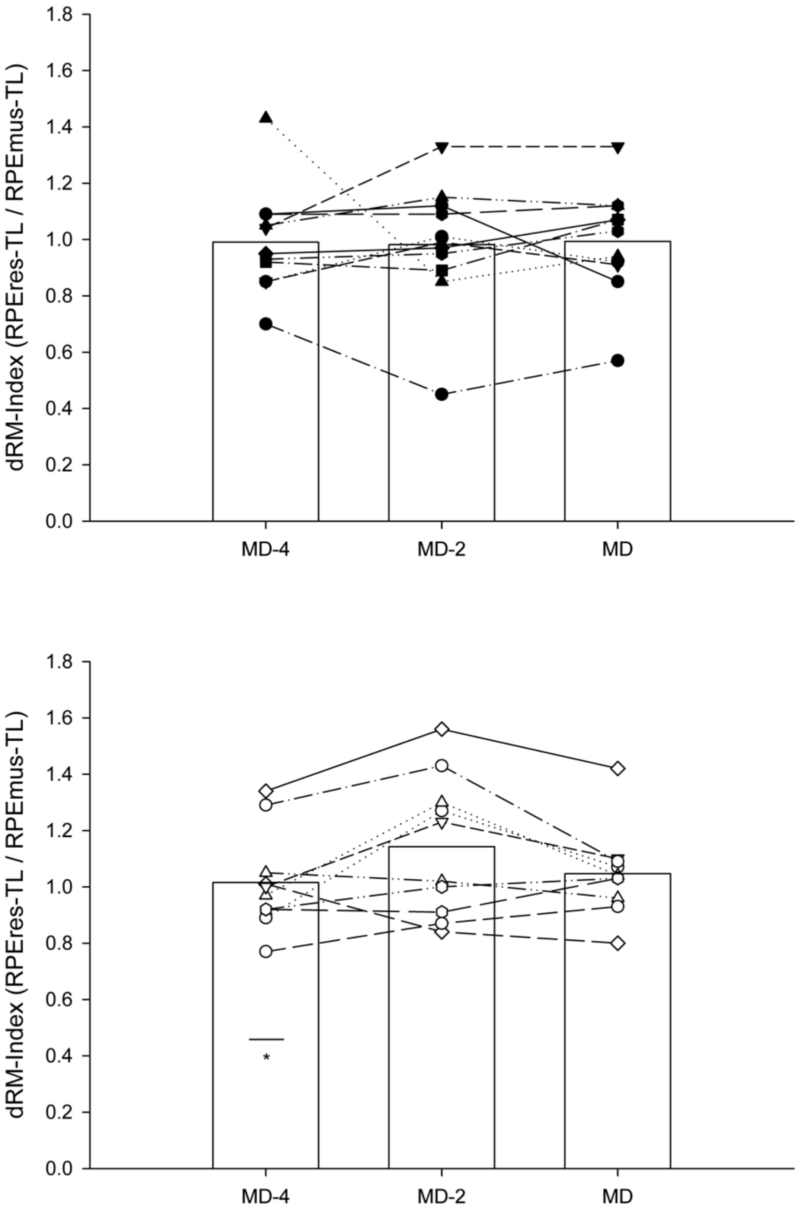

Figure 2. Perceived respiratory (RPEres-TL) and muscular (RPEmus-TL) training load ratio (dRM-Index) along the week during the 10-week competitive period for U16 (*n* = 14; upper panel) and U18 (*n* = 14; lower panel) players.

*Columns indicate the mean of the team for the dRM-Index for each training and match session. Symbols, linked with black solid lines, indicate the individual means of each of the players for the dRM-Index for each training and match session. MD−4 and MD−2 are the training sessions performed on four and two days before the match-day (MD), respectively. Note: *, significantly lower compared to the MD−2 session at the p < 0.05 level*

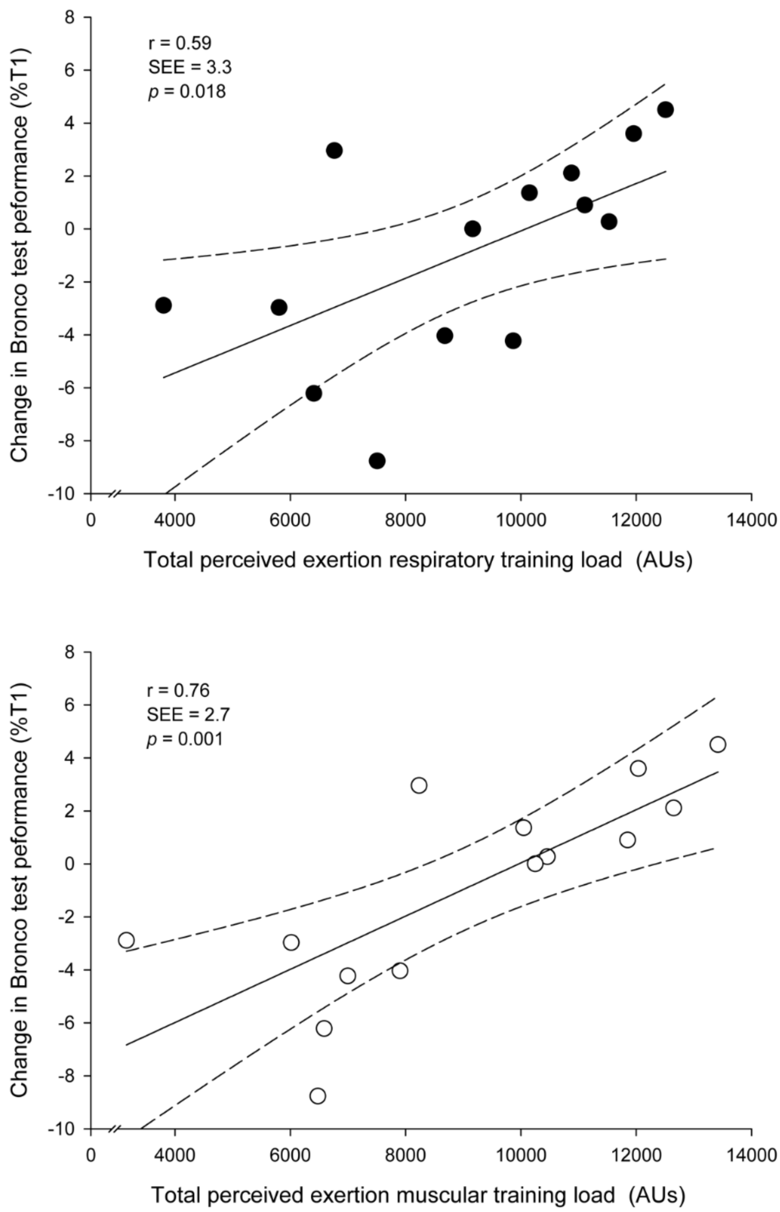

Figure 3. Individual data points and linear relationships between accumulated perceived respiratory (RPEres-TL; upper panel) and muscular (RPEmus-TL; lower panel) training loads during the 10-week competitive period with changes in Bronco test performance for U18 male rugby union players.

Note: solid lines, linear regressions; dashed lines, 95% confidence intervals

U16 and U18 rugby union players' weekly RPEres-TL and RPEmus-TL (Table 3) were similar to the global RPE-TL reported in coetaneous elite English players (1217 ± 364 AUs excluding the match TL, and 1425 ± 545 AUs) (Phibbs et al., 2018a, 2018b). These weekly TLs showed, in our study, considerable variability (Atkinson and Nevill, 1998) between players (CV: 13.4 to 26.9%). In agreement to our results, Till et al. (2020) summarized that weekly global RPE-TL variability was considerable in youth male English rugby union players. However, this study found that TL was not constant along the week and varied according to the players' category and type of the differential RPE-TL (Figure 1). For U16 players, the MD−4 session resulted in the highest RPE-TL, both respiratory and muscular. This MD−4 session was more than 72 hours before the match, enabling fatigue markers to return to baseline values (Till et al., 2020). Regarding U18 players, while non-significant variations were observed in the RPEres-TL along the week, the RPEmus-TL in the MD−4 was higher than in the MD−2 session. It seems, therefore, that the RPEmus-TL trend along the week does not endure consistent in both rugby union categories. Consequently, this is translated to a differed dRM-Index pattern across categories, being the dRM-Index in the MD−2 session greater than in the MD−4 session in U18 players (Figure 2). The training day closest to the next match was more respiratory (dRM > 1; i.e., central) compared to MD−4 in the oldest players. Since the trend of both RPEres-TL and RPEmus-TL was similar throughout the training week, the dRM-Index did not vary between sessions in U16 players. The different weekly load pattern between teams could be due to the design and implementation of distinct tasks by each coach to achieve the same training goals (Zanin et al., 2021). Another factor could be the differentiated physical profile between the two teams: U16 players exhibited 30% less CMJ performance than U18 players, but in the Bronco test, they demonstrated an average of 12% higher performance compared to U18 players (Table 2). It is well-known that depending on a player's physical profile, training and matches impose different metabolic loads on the player (Arregui-Martin et al., 2020). Collectively, these results indicated a thoughtful effort in the preparation of the upcoming match in both U16 and U18 teams attempting to ensure optimal recovery enhancing players' readiness to compete. Furthermore, in addition to absolute RPE-TL values, the dRM-Index can enable a more profound description of the quantification of the RPE-TL. The dRM allows to detect different "speed-muscular" (dRM < 1), "endurance-respiratory" (dRM > 1) or "hybrid" (dRM ≈ 1) trends in the teams' and individuals' responses to the training.

Like previous studies in junior elite and non-elite association football players (Gil-Rey et al., 2015), in this study significant differences were not found between weekly RPEres-TL and RPEmus-TL during the competitive period in both age groups (Table 3). In contrast, *large* differences were found between weekly RPEres-TL and RPEmus-TL (18413 ± 2632 vs. 20560 ± 1778 AUs) in professional rugby union players over an eight-week pre-season training period (McLaren et al., 2018b). The reason for these contrasting results is uncertain. However, this may be partially explained by the different categories, loads' magnitude, specific aims of the training sessions, and the different competitive periods (McLaren et al., 2018b). In the young footballers (Gil-Rey et al., 2015) and in these rugby players, TL was quantified during the in-season period (i.e., 2–4 training sessions per week) when specific physical conditioning training sessions were not performed. On the other hand, professional rugby players were adults, and completed 28 ± 2 training days and 67 ± 5 training sessions over the eight-week pre-season period including specific physical conditioning training sessions (McLaren et al., 2018b). Moreover, we did not find significant intra-session differences ($p > 0.05$; *trivial*-to-*small*) between RPEres-TL and RPEmus-TL for training sessions or matches (Figure 1). Similarly, McLaren et al. (2017) found *trivial* differences between RPEres-TL and RPEmus-TL during skill-based conditioning sessions in professional male rugby union players. These results show that the mean respiratory and muscular responses are similar during team sport training sessions, suggesting that both dimensions (central and peripheral) are similarly demanded. However, Figure 2 highlights individual different responses for particular RPE-TLs. For instance, 21% of U16 and U18 players showed dRM > 1 in every session during the week, indicating a general higher individual respiratory response to every session. In contrast, one U16 and two U18 players showed dRM < 1 in every session, indicating a generally higher individual muscular response to every session. The dRM-Index individual responses, therefore, seem to be helpful for team coaches and conditioning staff to further individualize monitoring of the training process in a cost-effective simple manner in rugby union.

In this study, non-significant *trivial*-to-*small* correlations were found between both RPEres-TL and RPEmus-TL and changes in neuromuscular performance (i.e., CMJ, S5 and S10) for U16 and U18 players. These results are in line with previous studies with junior footballers (Gil-Rey et al., 2015). In contrast, *trivial*-to-*very* *large* positive correlations were found between the global RPE-TL and changes in CMJ and sprint performances in U18 and U19 rugby players (Dobbin et al., 2018; Weakley et al., 2019). These results suggest that the deconstruction of the RPE does not provide additional information into the TL dose-response relationship with neuromuscular fitness in young team sport players. On the other hand, *large*-to-*very large* and positive correlations (Figure 3) were found between TL and changes in the Bronco test performance for U18 rugby union players. In this line, Gil-Rey et al. (2015) also found *large*-to-*very large* positive correlations between TL and changes in endurance performance in footballers of similar age. These consistent relationships indicate that those youth players accumulating more differential RPE-TL during the competitive period, often associated with lower baseline aerobic conditioning (Arregui-Martin et al., 2020; Gil-Rey et al., 2015), are prone to maintain their endurance performance, while those accumulating less differential RPE-TL tend to decrease their endurance performance. In agreement with these results in youth players, in professional senior rugby players it was observed that players accumulating more RPEres-TL were those who improved their performance in the Yo-Yo Intermittent Recovery Test Level 1 (McLaren et al., 2018b). Hence, the deconstruction of the RPE seems to increase the capacity to associate TL with changes in endurance performance in rugby union players.

To the best of our knowledge, this is the first study describing the differential RPE-TL and the dRM-Index during competitive training weeks and assessing RPEres-TL/RPEmus-TL associations with changes in physical fitness performance in a rugby union academy. The TL pattern across the week suggests a deliberate effort in distancing the higher load (especially muscular load) from matches. Together with absolute RPE-TL values, the dRM-Index provides additional information about the general, but also individual, nature of training stimuli of the sessions. The respiratory RPE-TL did not exceed the muscular RPE-TL during on-field training sessions, suggesting that this type of training yields a similar average central and peripheral effort. The differential RPE-TL, especially the muscular load, was robustly associated with changes in endurance performance. Despite these promising findings, caution is warranted due to the limitations of the study. On the one hand, the data were collected from a single club, thus club particularities prevent us from extrapolating our findings to other rugby union academies. On the other hand, an assessment of the players' sprinting capacity over longer distances or their ability to change direction would have enriched the study, but as it is often the case in modest settings, the club's facilities did not allow for these tests. In any case, basic neuromuscular performance of players was assessed. Aside from the inherent limitations of youth sports academies, this is a real-world, well-established study with participants who represent most of the athletic population (McKay et al., 2022), making the research more relevant to sports practice (Haugen, 2024).

Conclusions

The results of the study indicate the potential utility of the differential RPE-TL to assess load in rugby union academies. The RPEres-TL, RPEmus-TL, and the dRM-Index provide detailed information concerning the teams' mean and players' individual training responses. It is worth mentioning that this TL monitoring procedure is time-efficient and no-cost. Differential RPE-TL and its index allow identifying different trends in the weekly load distribution of each competitive category in youth rugby union. Moreover, the differential RPE-TL, especially the muscular load, might be useful to partially predict endurance performance changes in a dose-response manner. These findings are of particular interest to the supporting staff of rugby union academy teams to optimize their training process.

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