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Research article

Effects of preseason training on body composition, running performance, biochemical markers and workload variation in professional rugby union players

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A R T I C L E I N F O

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A B S T R A C T

Few studies have examined the impact of a preseason training intervention through systematic measures in Pro D2 rugby union (RU). Therefore, this study aimed to describe the effects of 12 weeks of preseason training (three blocks) on body composition, running performance, biochemical markers, and workload (WL) variation in professional RU players. Physiological (physical and biochemical) responses to preseason WL were analyzed by examining changes in anthropometric characteristics, Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) test, blood samples (BS), Hooper index (1–7), the 10-Hz global positioning system (GPS), and session rating of perceived exertion (s-RPE) in nineteen elite male players. Changes throughout the preseason were analyzed using the one-way and mixed-model analysis of variance. Significant ($p < 0.01$) improvements occurred in anthropometry and Yo-Yo IR1 running performance in forwards and backs. Total distance ($p < 0.01$) and impact ($p < 0.05$) during the second block were meaningfully higher than the other two blocks, with backs showing higher values than forwards. As expected, WL decreased significantly ($p < 0.01$) during the last training block. The WL variations were correlated with changes in biochemical markers over the preseason period. The collected data can be used for i) profiling French Pro D2 rugby championships players, ii) establishing effective training strategies, and iii) setting preseason WL expectations.

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1. Introduction

Rugby union (RU) is a high-intensity, heavy-contact field game played between two teams of 15 players for 80 min and differs in physical performances required depending on the position [1–3]. Previous time-motion analysis studies have reported that RU players typically cover between 5000 and 7000 m during a match, with backs (numbers 9–15) covering greater absolute distance than forwards (numbers 1–8) [4,5]. Due to the intermittent nature of the sport, players require highly developed anthropometric and physical characteristics, along with tailored training strategies, to compete at the elite level [5,6]. Generally, a French professional RU club's championship is composed of a long calendar season (8–10 months) preceded by a short preseason training phase (6–13 weeks). The latter represents a period of intensified training during several consecutive weeks. It is also seen as a crucial period for optimizing adaptations to meet the physical demands of competition [7–9].

To date, most studies concerning elite RU players have investigated either anthropometric characteristics [10,11], physical qualities [12,13], biochemical markers [2,14] or workload (WL) [15] during the championship. Anthropometric characteristics, such as body mass (BM), body fat (BF) and BF percentage, are essential for superior performance in rugby [6], with forwards typically having higher values for these anthropometric parameters than backs [11,16]. These anthropometric characteristics are also related to the aerobic capacity of professional RU players [16,17], which is critical in intermittent sports, significantly impacting competition outcomes [6]. The Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) test is a well-established and standardized test that evaluates an individual's capacity to perform high aerobic intermittent exercise repeatedly, making it essential to assess players' running performance [12]. Along with changes in anthropometric and physical performance variables, biomarkers can provide further insight into the physiological changes that players experience during the training season [2,18]. It has been stated that intermittent exercise and the number of body contact in rugby play positively correlate with the increase in muscle damage and inflammation markers, such as creatine kinase (CK) [19,20]. In addition to biochemical markers, the rating of perceived exertion (RPE) and session-RPE (s-RPE) have been considered to be valid, reliable, and handy tools for indicating players' internal workload (IWL) [21–24]. Moreover, the use of global positioning system (GPS) technology in team sports has opened up a range of possibilities to monitor the external workload (EWL) performed by players [3,21,25]. To optimize physiological adaptations and minimize the risk of overtraining and injuries, a comprehensive approach incorporating both EWL and IWL monitoring is crucial in elite RU players [26].

One of the main goals of the preseason training period in RU is to develop fitness in preparation for the upcoming competition season [8]. Bourdon et al. [26] stressed that monitoring should be implemented at the start of every preseason. Nevertheless, contrarily to in-season, systematic tracking methods of RU players during the preseason period have rarely been studied [9]. Therefore, the purpose of this study was to focus on the changes in body composition, running performance, biochemical markers, and WL variation in a French Pro D2 RU club during the preseason training period. We hypothesized that body composition and running performance profiles would improve following the 12-week training phase. Besides, significant differences in biochemical and WL characteristics would exist between forwards and backs because of their specific physical demands.

2. Materials and methods

2.1. Experimental design

Subjects completed the preseason phase which consisted of three specific training blocks (Table 1). The first block, with a duration of 3-weeks, focused mainly on strength endurance to rebuild physical attributes after the off-season. The second block (4-weeks in total) of high-intensity training and small-sided games aimed to improve aerobic and anaerobic fitness. The third block, which included 3-weeks of typical conditioning sessions (i.e., strength, endurance, speed, and recovery), players completed low-intensity conditioning efforts with relatively short rest intervals to fit RU work to rest ratio.

The scheduling and organization of testing are presented in Table 1. All testing sessions were held in the club to ensure minimal disruption to the players' daily schedule. Players were familiar with each testing protocol. Pre-tests, including anthropometry and aerobic measurements, were performed during week 1 [16,27]. Post-tests were retaken before the end of preseason (week 10). On-field training and Yo-Yo IR1 tests were performed on outdoor natural grass fields (100 × 70 m^2) [28]. Blood samples were collected before

Table 1
Organization testing and monitoring procedures in the preseason.

	Preseason											
Months	June				July				August			
Weeks	1	2	3	4	5	6	7	8	9	10	11	12
Periods		Block 1		RW1		Block 2			RW2		Block 3	
Anthropometric tests	×									×		
Yo-Yo IR1	×									×		
BS			×		×			×		×		
HI & s-RPE	Every training day											
GPS	Every on-field training session											

RW: recovery week; × : test time; Yo-Yo IR1: Yo-Yo intermittent recovery level 1 test; BS: blood samples; HI: Hooper index; s-RPE: session rating of perceived exertion; GPS: global positioning system (10Hz).

and after the recovery weeks (RW) [20,29]. The RW was implemented between two training blocks during this preseason phase. Running activity was monitored every on-field training session using GPS technology [25,27]. Hooper index (HI) and the s-RPE were used to quantify the well-being and IWL separately [24,25,30].

2.2. Subjects

Nineteen professional male (age: 27.1 ± 3.1 years; height: 186.8 ± 8.3 cm; weight: 100.6 ± 14.2 kg) RU players (10 forwards and 9 backs) from the same team (French second division rugby championship, Pro D2) volunteered to take part in this study. All subjects participated in preseason training and testing (Table 2). None of the subjects reported any current or ongoing neuromuscular diseases or musculoskeletal injuries during the time of the experiment. Before starting the protocol, subjects attended a presentation and received information outlining the experimental procedures. All subjects gave informed consent to participate in the experiment in accordance with the Declaration of Helsinki, and all of them were free to withdraw from the study at any time without penalty. The study protocol was conducted with the support of the medical and technical staff of the professional team. Finally, the study respected the ethical guidelines of Rennes University and the research laboratory associated with this study.

2.3. Procedures

2.3.1. Anthropometric characteristics

The subjects refrained from consuming any medications or pharmacological agents that could affect the assessments for 24 h before testing. Before breakfast, the BM was measured with the subjects wearing only light indoor clothing using a stadiometer and electronic scales (H251-001, Abilanx, France). Skinfold thickness was measured via 3 sites (triceps, midaxillary, and supraspinal) with Harpenden calipers (Harpenden, British Indicators, England) to estimate BF and BF percentage [10]. All right-side skinfold measurements were conducted by the same investigator to collect the average. Fat-free mass (FFM) was then estimated as the difference between BM and BF.

2.3.2. Running performance

The Yo-Yo IR1 test was realized in the same conditions (Table 1). Before testing, subjects carried out a standardized initial warm-up. The Yo-Yo IR1 protocol consisted of repeated 2 × 20-m runs, with each shuttle separated by a 10-s active recovery period. The running speed increased progressively and was controlled by audio bleeps [12,28]. The test involved 4 shuttles (0–160 m) with increasing speed from 10 to 13 km h^{-1}, followed by 7 shuttles (160–440 m) ranging from 13.5 to 14.0 km h^{-1}. Subsequently, the speed increased 0.5 km h^{-1} every 8 shuttles (i.e., after 760, 1080, 1400, 1720 m, etc.) until the subjects reached their voluntary exhaustion or missed 2 consecutive audio signals [13,28]. The distance covered (in meters) was recorded and represented the test result.

Table 2
Examples of weekly training schedule for each block.

		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Block 1	A.M.	Strength session (Upper body-45min) [400AU]	Strength session (Lower body-45min) [400AU]	Strength session (Regeneration-1h) [200AU]	Strength session (Upper body-1h) [350AU]	Strength session (Lower body-1h)+ Rugby training (45min) [600AU]	OFF	OFF
	P.M.	Cardio session (1h) [200AU]	Cardio session (1h) [350AU]	OFF	Cardio session (1h) [400AU]	Cardio session (45min) [200AU]	OFF	OFF
Block 2	A.M.	Strength session (Whole body-1h) [500AU]	Strength session (Upper body-1h) + Rugby training (45min-1h) [600AU]	Cardio session (45min) [300AU]	Strength session (Whole body-1h) [500AU]	Strength session (Lower body-45min) + Rugby training (45min) [500AU]	Optional strength training (30–45min) [350AU]	Passive recovery (contrast water therapy and physiotherapy)
	P.M.	Skills session (45min) [300AU]	OFF	OFF	Small sided games (45min) [300AU]	OFF	Small sided games (45min) [300AU]	OFF
Block 3	A.M.	Strength session (Lower body-1h) [300AU]	Cardio session (speed-1h) [400AU]	OFF	Speed + Gymnastics (1h) [400AU]	Strength session (Whole body-1h) [250AU]	OFF	Passive recovery (massage and physiotherapy)
	P.M.	Skills session (45min) [350AU]	Small sided games (30min) [200AU]	Physical Therapy	Small sided games (45min) [300AU]	Rugby session (1h) [350AU]	OFF	OFF

A.M.: ante meridiem before noon; P.M.: post meridiem after noon; min: minute; h: hour; AU: arbitrary unit.

2.3.3. Biochemical markers

The collection of blood samples (BS) took place between 7:00–9:00 a.m. to account for circadian variations. Players were in a fasted condition on each occasion. These BS were taken four times during the preseason period (Table 1). After collection, the BS were placed in heparin tubes, which were then placed in a cooler to maintain the temperature at −80 °C. Within 1 h of collection, the tubes were sent to an independent laboratory where they were centrifuged using an automatic system (Synchron Pro CX5 Chemistry Analyzer; Beckman Coutler, Inc., Villepinte, France) to analyze the blood enzymology. These included markers of muscle damage, i.e., CK [20]. Moreover, endocrine status, i.e., testosterone (T), cortisol (C), and insulin-like growth factor-1 (IGF-1) were also analyzed through an automatic system (Vidas; BioMerieux, Inc., Craponne, France). Consequently, T/C and IGF-1/C ratios were calculated and used for analysis [31].

2.3.4. Psychological Adaptations

Perceived sleep quality and quantities of stress, fatigue, and muscle soreness were evaluated using the HI questionnaire according to a 7-point Likert scale (range score 1 [very, very good] to 7 [very, very poor]) [30,32]. Subjects provided their HI scores by touching the respective score on a tablet approximately 30 min before each training session. The results were automatically saved to the player's profile by Genetrainer (a mobile application). Overall psychological adaptations were determined by summing the four scores.

2.3.5. External workload

The on-field training EWL was collected via 10 Hz GPS and Global Navigation Satellite System (GLONASS) enabled units with an embedded 100 Hz tri-axial piezoelectric accelerometer technology (Sport tracker V4, McLlyod, France). The micro-technology (44 × 77 × 20 mm, weighing 43 g) was activated 30 min before each training session to ensure a clear satellite reception. Units were placed on the upper thoracic spine, between the scapulae, in a customized vest. Each subject was assigned the same unit throughout the preseason period. The strength of a GNSS signal (over 60%) received during data acquisition and the horizontal dilution of precision (HDOP) (less than 3) was satisfactory [33]. The GPS information was transmitted and processed using the associated Sports tracking software (McLlyod, France). Metrics included total distance (TD), high-speed running distance (HSR) (>14 km h^{-1}), percentage of distance at high-speed running (%HSR), sprint distance (SD) (>21 km h^{-1}), the number of accelerations performed (ACC$_{num}$; >2 m s^{-2} for a duration lasting at least 0.5 s) and the number of impacts over 4 G [15,33].

2.3.6. Internal workload

Approximately 30 min after each training session, IWL was measured with Borg's category ratio (CR-10) scale to collect players' individual RPE [22,23]. The players were prompted to respond to the question, "How was your session?" They were encouraged to provide a global rating of the entire session using any intensity cues they deemed relevant, with a rating of 0 representing rest and a rating of 10 representing the hardest exercise exertion [24]. The RPE score was then multiplied by the training session's total duration (in minutes) to obtain the s-RPE (arbitrary units, AU) [23,25].

2.4. Statistical analysis

Statistical analyses were completed using SigmaStat 4.0 program (Jandel Scientific, San Rafael, CA, USA). Data are presented as mean ± *SD*. Prior to analysis, assumptions of normality in the data were made using the Shapiro-Wilk test and visualization of normality plots. The changes (from pre to post) in body composition and Yo-Yo IR1 results were examined using paired *t*-test. Differences in blood parameters during the preseason were evaluated with one-way ANOVA on repeated measurements. Changes in GPS, HI, training volume, and s-RPE parameters for each positional group were analyzed using mixed-model ANOVA, with the timing phase as the within-subject factor and playing position as the between-subject factor. Differences between forwards and backs were compared using an independent *t*-test. Significance was set as $p < 0.05$. Confidence intervals (95% CI) were calculated for all measures analyzing positional differences. When significant differences were observed, data was subsequently analyzed using the effect size (ES)

Table 3
Changes (mean ± *SD*) in anthropometric characteristics between pre- and post-tests.

		Pre-test	Post-test	ES (*d*) pre *vs.* post
Team $n = 19$	BM (kg)	100.6 ± 14.2	101.1 ± 14.4	Unclear
	BF (kg)	20.9 ± 7.1	17.3 ± 5.8[a]	0.8 (Moderate)
	BF (%)	20.3 ± 4.8	16.7 ± 3.6[a]	0.6 (Small)
	FFM (kg)	79.7 ± 8.3	83.8 ± 9.1[a]	−0.5 (Small)
Forwards $n = 10$	BM (kg)	111.6 ± 7.7	111.7 ± 7.8	Unclear
	BF (kg)	25.9 ± 4.5	21.2 ± 4.0[a]	0.8 (Moderate)
	BF (%)	23.2 ± 3.2	18.9 ± 2.5[a]	0.5 (Small)
	FFM (kg)	85.7 ± 5.4	90.5 ± 4.7[a]	−0.6 (Small)
Backs $n = 9$	BM (kg)	88.4 ± 8.0	89.4 ± 10.1	Unclear
	BF (kg)	15.4 ± 5.0	12.9 ± 4.0[a]	1.5 (Large)
	BF (%)	17.2 ± 4.4	14.2 ± 3.0[a]	1.1 (Moderate)
	FFM (kg)	73.0 ± 5.2	76.5 ± 6.7[a]	−0.9 (Moderate)

ES: effect size; BM: body mass; BF: body fat; FFM: fat-free mass.
[a] Significant difference when compared with pre-test values ($p < 0.01$).

calculation. Threshold values for ES were: ≤0.2, trivial; 0.21–0.60, small; 0.61–1.20, moderate; 1.21–2.0, large; ≥2.0, very large [34]. The G-Power statistical software (version 3.1.9.7; University of Düsseldorf, Düsseldorf, Germany) was utilized to determine that the minimum sample size of $n = 15$ was required for a statistical power $(1 - \beta) \geq 0.80$ at an alpha level of $p \leq 0.05$ [35].

3. Results

3.1. Anthropometric characteristics

Table 3 shows the changes in anthropometric characteristics of professional RU players categorized by position during the experimental period. No significant change was observed for BM ($p = 0.05$). In both absolute (kg) and relative (%) values, BF decreased between pre- and post-test in all subjects and for both positions. However, FFM increased between pre- and post-test for the team and position groups.

3.2. Running performance

The Yo-Yo IR1 results are depicted in Table 4. There was an improvement in running performance in all subjects. Backs achieved a greater total distance than forwards.

3.3. Biochemical parameters

Table 5 presents the impact of RW on all biochemical and hormonal variables. Compared to BS1 (end of block 1), CK levels decreased in BS3 and BS4 (i.e., after block 2) for the team, with the CK level of BS3 being significantly lower than that of BS2. However, for forwards, significantly lower CK values were observed only in BS3 compared to BS1. In backs, the CK level of BS3 was lower than that of BS1 and BS2, with a similar trend observed in BS4. Moreover, forwards had greater CK values than backs during BS1 ($p < 0.05$; ES = 2.5), BS3 ($p < 0.01$; ES = 4.5), and BS4 ($p < 0.01$; ES = 4.8).

The biomarker T showed more stability than CK during the testing period. A higher T value was only observed in BS3 when compared to BS1 for the team and backs. The C concentration was higher in BS3 than BS1 and BS2 for the team and both position groups, whereas in BS4, it was lower than BS3 for the team and backs but higher for forwards than BS2. Consequently, the T/C ratio of BS3 was lower than BS1 and BS2 for the team and forwards. At BS4, the T/C ratio presented slightly higher values than at BS3 for all players. No differences in T/C ratio were found in backs during all testing protocols ($p > 0.05$).

Concerning protein synthesis, the team showed a higher level of IGF-1 at BS2 compared to BS1, while the forwards had higher levels of IGF-1 at both BS1 and BS2 compared to BS3 and BS4. No significant differences were observed in IGF-1 between test times for backs ($p > 0.05$). As a result, the IGF-1/C ratio in BS2 was higher than BS1, while BS3 was lower than BS1, BS2, and BS4 for the team. For forwards, the IGF-1/C ratio in BS3 was lower than BS1 and BS2, while BS4 was lower than BS2. For backs, the IGF-1/C ratio in BS3 was lower than in BS2 and BS4.

3.4. Workload monitoring

Table 6 presents the EWL and IWL measures during the three blocks. The greatest TD and impact occurred in block 2. It was observed that, in terms of % HSR, the percentage was higher during block 1 than during the other blocks. Results confirm that HSR, volume, and s-RPE had lower values during block 3 compared to the two others. No significant differences were detected in ACC_{num} across three blocks of the preseason. Moreover, a large correlation existed between s-RPE and HI ($p < 0.01$; $r^2 = 0.609$).

Table 6 also presents the different WL variables during the three blocks according to playing position. It highlights that backs realized greater HSR and SD than forwards during all training blocks. The same features also occurred in block 2 where backs were exposed to greater TD, HSR, SD, ACC_{num}, and impacts than forwards. However, regarding playing position, our results show no significant differences concerning the % HSR, HI, training volume, and s-RPE across the preseason phase ($p \geq 0.05$).

4. Discussion

The preseason period is a crucial time point when professional RU players aim to improve their physical capacities. The impact of a

Table 4
Changes (mean ± *SD*) in Yo-Yo IR1 between pre- and post-tests.

	Pre Yo-Yo IR1 (m)	Post Yo-Yo IR1 (m)	ES (*d*) pre *vs.* post
Team $n = 19$	1821.2 ± 465.9	2322.1 ± 456.2[a]	−1.1 (Moderate)
Forwards $n = 10$	1622.1 ± 434.8[b]	2072.0 ± 346.1[a b]	−1.2 (Large)
Backs $n = 9$	2042.4 ± 430.8	2600.0 ± 346.05[a]	−1.3 (Large)

Yo-Yo IR1: Yo-Yo intermittent recovery level 1 test; ES: effect size.
[a] Significant difference when compared with pre-test values ($p < 0.01$).
[b] Significant difference between forwards and backs ($p < 0.01$).

Table 5
Changes (mean ± *SD*) throughout the preseason in biochemical parameters for all subjects and depending on the players' position.

	Blood parameters (units)	BS1	BS2	BS3	BS4	ES (*d*) between tests
Team $n = 19$	CK (U•L^{-1})	466.7 (196.5)	386.8 (186.4)	283.5 (103.7)[a, b]	302.6 (114.0)[a]	0.2–1.2 (Tr to M)
	T (ng•ml^{-1})	5.4 (1.9)	5.5 (1.7)	5.8 (1.9)[a]	5.7 (1.9)	0.1–0.2 (Tr to S)
	C (μg•dl^{-1})	12.5 (2.3)	11.8 (2.5)	15.0 (1.8)[a, b]	13.2 (3.1)[c]	0.3–1.7 (S to L)
	T/C (AU)	0.5 (0.2)	0.5 (0.2)	0.4 (0.2)[a, b]	0.5 (0.2)[c]	0.0–0.5 (Tr to S)
	IGF-1 (ng•ml^{-1})	183.0 (60.8)	190.8 (62.9)[a]	184.3 (48.5)	182.3 (46.3)	0.0–0.2 (Tr)
	IGF-1/C (AU)	15.4 (6.9)	17.4 (8.2)[a]	12.4 (3.6)[a, b]	15.1 (6.4)[c]	0.0–0.8 (Tr to M)
Forwards $n = 10$	CK (U•L^{-1})	536.8 (65.8)[d]	414.5 (77.4)	341.9 (29.3)[a, d]	368.3 (34.3)[d]	0.5–4.8 (Tr to V.L.)
	T (ng•ml^{-1})	5.6 (0.8)	5.8 (0.7)	6.0 (0.8)	5.8 (0.7)	0.0–0.5 (Tr to S)
	C (μg•dl^{-1})	12.2 (1.0)	11.7 (1.0)	15.1 (0.8)[a, b]	13.9 (1.1)[b]	0.5–3.8 (S to V.L.)
	T/C (AU)	0.5 (0.1)	0.5 (0.1)	0.4 (0.1)[a, b]	0.5 (0.1)	0.0–1.0 (Tr to M)
	IGF-1 (ng•ml^{-1})	205.7 (21.9)	212.8 (22.4)	196.5 (16.6)[a, b]	193.3 (15.0)[a, b]	0.2–1.0 (Tr to M)
	IGF-1/C (AU)	18.1 (2.6)	19.8 (2.8)	13.2 (1.3)[a, b]	16.2 (2.3)[b]	0.6–3.0 (S to V.L.)
Backs $n = 9$	CK (U•L^{-1})	388.9 (52.9)	356.1 (31.2)	218.7 (24.8)[a, b]	229.7 (22.6)[a, b]	0.5–4.9 (S to V.L.)
	T (ng•ml^{-1})	5.0 (0.4)	5.2 (0.1)	5.6 (0.4)[a]	5.6 (0.5)	0.0–1.5 (Tr to L)
	C (μg•dl^{-1})	12.9 (0.4)	12.0 (0.7)	14.9 (0.3)[a, b]	12.4 (0.9)[c]	0.5–5.7 (S to V.L.)
	T/C (AU)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	Unclear
	IGF-1 (ng•ml^{-1})	157.7 (13.0)	166.3 (14.9)	170.1 (14.1)	170.1 (14.9)	0.0–0.9 (Tr to M)
	IGF-1/C (AU)	12.5 (1.2)	14.7 (2.3)	11.4 (0.9)[b]	14.0 (1.8)[c]	0.3–1.9 (S to L)

BS: blood sampling; ES: effect size; Tr: trivial; M: moderate; S: small; L: large; V.L.: very large; CK: creatine kinase; T: testosterone; C: cortisol; IGF-1: insulin-like growth factor-1; AU: arbitrary unity.
[a] Significant difference when compared with BS1 (p value at 0.05 or 0.01).
[b] Significant difference when compared with BS2 (*p* value at 0.05 or 0.01).
[c] Significant difference when compared with BS3 (*p* value at 0.05 or 0.01).
[d] Significant difference between forwards and backs at the same test time (*p* value at 0.05 or 0.01).

Table 6
Changes (mean ± *SD*) throughout the preseason in weekly workload and Hooper score for all subjects and depending on the players' position.

	Workload parameters	Block 1	Block 2	Block 3	ES (*d*) 1st *vs.* 2nd	ES (*d*) 1st *vs.* 3rd	ES (*d*) 2nd *vs.* 3rd
Team $n = 19$	TD (m)	10254.1 (2735.7)	13784.0 (5560.5)[a]	9137.8 (4571.1)[b]	−0.81 (M)	0.30 (S)	0.91 (M)
	HSR (m)	2109.4 (940.9)	2263.0 (1173.9)	1242.3 (929.4)[a, b]	−0.14 (Tr)	0.93 (M)	0.96 (M)
	% HSR (%)	20.6 (6.9)	15.7 (9.0)[a]	14.1 (7.1)[a]	0.61 (M)	0.93 (M)	0.20 (Tr)
	SD (m)	403.3 (345.1)	430.8 (394.4)	272.0 (312.1)[b]	−0.07 (Tr)	0.40 (S)	0.45 (S)
	$ACC_{num} > 2$ m s^{-2} (n)	115.8 (49.9)	123.8 (115.3)	131.9 (84.0)	−0.09 (Tr)	−0.21 (S)	−0.08 (Tr)
	Impacts (n)	37.0 (19.4)	47.0 (29.8)[a]	29.1 (20.9)[b]	−0.40 (S)	0.40 (S)	0.70 (M)
	HI (AU)	35.7 (8.4)	37.8 (14.6)	32.2 (0.6)[b]	−0.18 (Tr)	0.37 (S)	0.43 (S)
	Volume (h)	9.8 (0.7)	10.1 (2.6)	8.0 (0.8)[a, b]	−0.16 (Tr)	2.39 (V.L.)	1.09 (M)
	s-RPE (AU)	3935.8 (539.5)	3732.2 (1038.0)	2500.1 (814.5)[a, b]	0.25 (S)	2.08 (V.L.)	1.32 (L)
Forwards $n = 10$	TD (m)	9097.0 (1985.5)	11092.5 (3674.8)[a, c]	8433.9 (3149.3)[b]	−0.68 (M)	0.25 (S)	−0.78 (M)
	HSR (m)	1704.8 (779.4)[c]	1598.6 (774.1)[c]	952.9 (548.6)[a, b, c]	0.14 (Tr)	1.12 (M)	0.96 (M)
	% HSR (%)	19.0 (6.6)	14.1 (9.7)	13.6 (6.6)	0.59 (S)	0.82 (M)	0.06 (Tr)
	SD (m)	276.3 (350.4)[c]	176.7 (216.8)[c]	187.6 (229.3)[c]	0.34 (S)	0.30 (S)	0.05 (Tr)
	$ACC_{num} > 2$ ms^{2} (n)	113.4 (48.5)	100.2 (108.3)[c]	120.0 (56.4)[c]	0.16 (Tr)	−0.12 (Tr)	−0.23 (S)
	Impacts (n)	27.3 (13.3)[c]	35.0 (25.2)[c]	23.8 (13.7)[b]	−0.38 (S)	0.26 (S)	0.55 (S)
	HI (AU)	34.2 (7.2)	38.3 (14.1)	32.1 (9.9)[b]	−0.37 (S)	0.24 (S)	0.51 (S)
	Volume (h)	9.7 (0.6)	9.9 (2.5)	8.0 (0.8)[a, b]	−0.11 (Tr)	2.4 (V.L.)	1.02 (M)
	s-RPE (AU)	4011.3 (527.8)	3806.0 (974.0)	2671.9 (875.8)[a, b]	0.26 (S)	1.85 (L)	1.22 (L)
Backs $n = 9$	TD (m)	11479.4 (2934.9)	17083.3 (5679.6)[a]	9867.8 (5657.7)[b]	−1.24 (L)	0.36 (S)	−1.27 (L)
	HSR (m)	2537.7 (925.7)	3077.5 (1067.7)	1542.5 (967.6)[a, b]	−0.54 (S)	1.05 (M)	1.51 (L)
	% HSR (%)	22.4 (6.8)	17.6 (7.6)	16.6 (5.7)	0.67 (M)	0.92 (M)	0.15 (Tr)
	SD (m)	537.7 (291.9)	742.1 (335.6)	359.4 (363.5)[b]	−0.65 (M)	0.54 (S)	1.09 (M)
	$ACC_{num} > 2$ m s^{-2} (n)	118.1 (52.6)	152.8 (119.0)	144.3 (105.1)	−0.37 (S)	−0.32 (S)	0.08 (Tr)
	Impacts (n)	47.3 (19.9)	61.8 (28.6)	34.6 (25.5)	−0.59 (S)	0.56 (S)	1.00 (L)
	HI (AU)	33.5 (14.3)	35.1 (17.6)	30.4 (13.2)[b]	−0.10 (Tr)	−0.23 (S)	0.30 (S)
	Volume (h)	9.8 (0.7)	10.0 (2.5)	8.0 (0.8)[a, b]	−0.11 (Tr)	2.39 (V.L.)	1.08 (M)
	s-RPE (AU)	3851.9 (511.4)	3650.3 (1113.0)	2309.1 (708.2)[a, b]	0.23 (S)	2.50 (V.L.)	1.44 (L)

ES: effect size; Tr: trivial; M: moderate; S: small; L: large; V.L.: very large; TD: total distance; HSR: high-speed running (>14 km h^{-1}); %HSR: the percentage of distance at high-speed running; SD: sprint distance (>21 km h^{-1}); ACC_{num}: number of accelerations (>2 m s^{-2}); Impacts: number of impacts (>4 G); HI: Hooper index; s-RPE: session rating of perceived exertion; m: meter; n: number; h: hour; AU: arbitrary unit.
[a] Significant difference with values of block 1 (*p* value at 0.05 or 0.01).
[b] Significant difference compared with values of block 2 (*p* value at 0.05 or 0.01).
[c] Significant difference between forwards and backs at the same block (*p* value at 0.05 or 0.01).

condensed preseason period on body composition, running performance, biochemical markers, and WL profiles in professional RU players remains relatively unknown [7,8,36,37]. The current study implemented repeated measures and an observational design to examine the effects of a 12-week preseason training period on anthropometric characteristics, aerobic capacities, biochemical adaptations, and WL variation. Our results describe the significant improvement of anthropometric characteristics and aerobic capacity as well as the biochemical adaptations in elite RU players during a preseason period. A 1-week rest period appears to be an effective recovery strategy between two training blocks. Furthermore, positional differences in EWL parameters were noticeable during position-oriented training sessions.

The present study found no significant changes in BM after preseason training. These results are similar to those observed in professional soccer players [38]. We believe that this finding could be explained by the professional players' fitness and dietary regimen during the off-season. Indeed, the off-season training program ensured the maintenance of basic fitness levels and, thus, affected the lack of change in BM after the 12-week preseason training period. Furthermore, in the current study, backs had lower BM than forwards which could be attributed to the demands of playing position during competition. Such findings corroborate those of a previous study in the European Rugby Championship [16]. Moreover, our results found significant differences in BF (%) and FFM during the preseason. Previous research also demonstrated that strength and high-intensity training improved FFM and influenced BF (%) positively [1,7]. However, it should be noted that the subjects' BF (%) was much higher than in Argus's study [7] (20.3% *vs.* 13.7%). The reason for this may reside in the subjects' differences in playing standards, team selection, and playing environment (greater in Argus's study).

Differences between backs and forwards were found in the Yo-Yo IR1 level at pre- and post-test ($p < 0.01$). Similarly, other studies have shown that backs have a better aerobic capacity than forwards [4,28]. In addition, although EWL of forwards and backs were different during the preseason, the changes in Yo-Yo IR1 for the two positions were similar at the end of preseason (27.3% *vs.* 27.7%). These results highlight the efficiency of a 12-week preseason training period program.

Periodic biomarker assessments in elite sports offer an accurate and objective method for evaluating training-related stress, recovery needs, and overall health conditions [16,29]. Moreover, changes in markers of muscle damage showed how the organism coped with neuromuscular and hormonal stress imposed by preseason WL [15]. In our study, greater CK values were found during the first two testing time points and decreased as the preseason progressed. Several studies showed that intensified training could increase inflammation and muscle damage markers [15,20,39]. The first training block after the off-season may induce microtrauma to the structural and contractile components within muscle fibres [40], which was particularly noticeable in forwards due to their higher involvement in contact drills compared to backs. Additionally, the differences in weekly training schedules during the three blocks may have contributed to the significant variation in muscle damage markers. It is possible that coaches implemented tapering strategies to reduce WL and stress and maximize performance, as suggested by previous studies [41,42]. Furthermore, the reduction in CK values from BS1 to BS3 could be attributed to the use of contrast water therapy, as shown in Table 2 [43–45].

In contrast to CK, the preseason T concentration remained relatively stable, with the only significant ($p < 0.05$) difference observed between BS1 and BS3 for the team and backs. Because of the length of block 2 (4-weeks), a higher training volume was observed during this block, which probably led to an elevated T concentration in all subjects. Such increases in anabolic hormones may suggest a physiological predisposition to an aggressive state and, therefore, superior performance during practice [46]. The anabolic and catabolic state of skeletal muscle is a dynamic process. Hence, to assess neuromuscular adaptations during the preseason [31], C and T/C ratios were considered in the current study. Elevated C concentrations have been shown to indicate poor adaptation to training, which can lead to performance decrements and fatigue accumulation [29,31]. Our results showed a significant difference in C concentration at BS3 ($p < 0.01$) compared to the other three test times, resulting in a significantly ($p < 0.01$) lower T/C ratio compared to the other test time points. This observation appears to correspond to the intense training schedule that the players were exposed to in the middle of the preseason period (block 2: weeks 5 to 8) [14,43,44].

Generally, a RU preseason includes a few weeks of recovery. However, limited studies have analyzed the impact of a preseason RW on relevant bio-signals of fatigue or readiness [19,47]. Therefore, BS were collected before and after each RW (weeks 4 and 9) to verify the effects of physical rest on selected biomarkers. Our results indicate that C concentration decreased after RW1 (week 4) and was significantly ($p < 0.01$, BS4 *vs.* BS3) lower after RW2 (week 9). These results confirm that C concentration is closely related to the recovery process [18] and suggest that rest periods may be required to obtain adequate recovery from accumulated tissue damage [29]. Although T concentration was relatively stable, the T/C ratio was significantly ($p < 0.05$, BS4 *vs.* BS3) higher for the team after RW2. In contrast, the IGF-1 level has been shown to increase after RW1 ($p < 0.05$, BS2 *vs.* BS1). These changes lead to an increased IGF-1/C ratio, with values significantly ($p < 0.05$, BS2 *vs.* BS1; $p < 0.01$, BS4 *vs.* BS3) higher after the RW. Such findings corroborate those of previous studies in male RU players which inspected players' anabolic state [18]. Nassib [48] found that a decrease in C and an increase of IGF-1 levels were associated with an improved Yo-Yo IR1 performance in young boxers. Additionally, several investigations have found significant positive correlations between fitness and circulating IGF-1 levels [48]. Therefore, we can assume that the rebound of the IGF-1/C ratio, observed after both RW, could represent a homeostasis state and be associated with player recovery. Thus, performance practitioners and coaches should implement, when possible to do so, biochemical testing between each block to monitor individual adaptation and to avoid overtraining, notably by using the CK, T, C, IGF-1, T/C, and IGF-1/C ratio [48].

Many studies have investigated WL in RU players across short and long durations [1,15]. However, little information exists of the preseason WL imposed on elite players. The current study represents a unique body of data, given that it examines detailed biochemical and WL responses at a professional level. According to the results, IWL (quantified using s-RPE) was relatively stable during the first two blocks (3935.8 and 3732.2 AU, respectively) but decreased significantly ($p < 0.01$) to 2500.1 AU during block 3 (Table 6). Decreases in IWL were realized through reductions in volume and intensity (as shown in Tables 2 and 6). In the current study, a reduction in training volume of 18.4% (*vs.* block 1) and 20.8% (*vs.* block 2) occurred in block 3 without compromising the improvements of physical fitness. Indeed, our results were related to other studies that highlight the importance of preseason WL reduction for the preparation and development of elite-level players [36,41,49]. The rationale behind this tapering design is to induce optimal performance before competitions [19,41,42,47]. Recently, Fernandes et al. [27] reported that the frequency of accelerations differed significantly across the early and mid-competitive phases. However, our study found no significant differences in acceleration numbers among the three training blocks (Table 6). These discrepancies may be associated with variations in the study subjects, experiment duration, and speed selection for acceleration. Furthermore, the current study help bridge the gap between IWL and fatigue. Indeed, as the s-RPE decreased from block 2 to 3, the HI also decreased significantly ($p < 0.01$). The relationship between IWL (s-RPE) and daily fatigue (HI) may be beneficial for monitoring the impact of WL variation on players' overall well-being [32]. Hence, the correlation ($p < 0.01$; $r^2 = 0.609$) observed here also values the use of the Hooper questionnaire (sleep, stress, fatigue, and soreness level) as a practical tool to monitor the IWL [32].

Table 6 outlines the s-RPE changes, by position, during preseason. Forwards demonstrated higher s-RPE than backs during the three blocks. These findings are consistent with the work of Bradley [8], who reported higher weekly s-RPE in forwards (3398 ± 335 AU) during the preseason period. Interestingly, we found that backs' EWL was higher than forwards for all measured parameters. The GPS variables in our study showed that backs had greater TD ($p < 0.01$, in block 2), HSR ($p < 0.01$, all blocks), SD ($p < 0.01$, all blocks), ACC_{num} ($p < 0.01$, in blocks 2 and 3), and impacts ($p < 0.01$, in blocks 1 and 2) than forwards. This is in line with research from Cahill [4] which indicates that backs cover greater distance than forwards, during both training and matches. The differences between backs and forwards may be due to the specific training drills performed by each position [3,8]. In fact, forwards, compared to backs, tend to complete heavier physical tasks due to their involvement in mauls, rucks, and scrums [17]. Therefore, this category of high-intensity efforts, which are not represented in the GPS report, should be evaluated through the use of s-RPE [15].

Although data were collected on a routine basis within the professional team, this study had some limitations. One was related to the speed threshold selection, as we used pre-set absolute speed thresholds according to the playing level and previous research on the analysis of RU performance [50,51]. The use of absolute speed thresholds facilitates player monitoring, whereas unable to acknowledge the relative intensity of activity. A possible solution to this limitation is to individualize speed thresholds based on players' physiological assessment [27,51]. Another limitation was that the players were only split into two distinct positional groups. Future research with a larger sample size and specific categorization of individual positions (such as prop, hooker, lock, flanker, and no. 8 for forwards; scrum-half, fly-half, center, wing, and full-back for backs) would be of interest to determine the preseason training effects on each specific positional group [8]. Furthermore, it should be noted that the findings of the current study only reflect the practices within the single club analyzed. These potential limitations should be considered when interpreting the changes in anthropometric and physiological characteristics, as well as WL variation during the preseason and applying the results of this study to other RU players.

5. Conclusions

The current findings provide evidence that the monitoring of body composition, running performance, biochemical markers, and WL can give valuable information necessary for optimizing the planning of a training schedule and for implementing RW during a RU preseason period. Moreover, the results hold practical implications for performance practitioners and coaches in their quest to develop optimal body composition and physical attributes in elite RU players.

6. Practical applications

We suggest that coaches i) provide WL variation to enhance physiological adaptations and ii) program biochemical marker monitoring between blocks of preseason training. These findings support previous research and highlight positional differences, thus supporting the need to design specific training programs for each position. Finally, the data obtained from this study provide valuable information concerning the physical development of elite athletes.

Production notes

Author contribution statement

Xiaopan Hu; Noe Thierry Baba; Kilian Philippe; Danyang Jiang; Simon Boisbluche; Olivier Maurelli; Jacques Prioux: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e16250.

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