Original Article

Changes in training load, running performance, lower body power and biochemical characteristics of back players throughout a professional Rugby Union season

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ABSTRACT

The aim of this study was to observe and quantify changes in training load (TL), running performance, lower body power and biochemical characteristics of professional rugby union back players over an entire season. Eight professional players (age: 25.8 ± 4.6 y) participated in this study. Session-RPE (S-RPE) and microtechnologies (GPS) were used for assessing training load (TL). During the season, running performance was monitored using the YoYo Recovery Test Level-2 (YYRT2) and lower body power performance using the drop jump (DJ) test. Changes in hematological, endocrine and muscle damage parameters were examined through 3 blood samples taken at separate times throughout the season. TL progressively and significantly ($p < 0.001$) decreased throughout the season particularly due to the decrease in the training volume. The last blood sample of the season revealed a significant ($p < 0.001$) increase in hematological parameters and a significant increase ($p < 0.01$) in cortisol blood concentration without change

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in the testosterone/cortisol ratio. No significant change in YYRT2 performance was observed over the season, while DJ test performance was significantly lower during the first 2 blocks of the season compared to other blocks. The training volume showed a significant negative correlation with DJ-test performances (TD: r = -0.49 and S-RPE: r = -0.40, p < 0.001). Although there was a decrease in training volume throughout the season, there was no significant changes in running performance. Furthermore, lower bod y power production showed a significant increase in particular during the last part of the season. **Key words:** LONGITUDINAL STUDY, GPS, S-RPE, TRAINING LOAD, BLOOD SAMPLES

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INTRODUCTION

Rugby union is a dynamic contact sport played between two teams composed of fifteen players (8 forwards and 7 backs) for two 40-min periods. Several studies have analyzed rugby union game demands (Cahill et al., 2013; Coughlan et al., 2011; Lacome et al., 2013; Roberts et al., 2008). They showed players travelled up to 7500 m of which 25% were performed at moderate and high speed running (MHSR). All them showed a significant difference between back and forward players, with backs covering a greater total distance and performing more high intensity running and maximal-speed running than forwards (Coughlan et al., 2011; Duthie et al., 2003). Highlighting, that backs have a more running-based activity than the forwards who perform more static efforts during rucking and wrestling phases. GPS technology allows external training load (ETL) to be monitored during outdoor sessions in team sports (TS) and provides data on the distances and speeds achieved. However, the wrestling and rucking phases remain difficult to evaluate with this technology (Cummins et al., 2013). Therefore, GPS monitoring was carried out with only back players, because an important part of the forwards training was devoted to lineout, scrummaging and rucking which cannot be accurately analyzed with GPS technology.

Furthermore, McLellan et al. (2010 and 2012) largely studied the acute physiological effects resulting from rugby league games. Acute physiological effects induced by impacts, collisions and high speed running resulted in high levels of metabolic and neuromuscular fatigue, biochemical and endocrine perturbations. This acute fatigue may require 2 to 5 days to return to baseline level (McLellan et al., 2010). The accumulation of games and the duration of competitive periods may result in chronic fatigue illustrated by a predominance of catabolic processes and a biochemical disturbance during a TS season (Banfi et al. 2006; Argus et al., 2009; Filaire et al., 2001). Excessive training and/or competitive demands without sufficient recovery time may result in a decrease of physical capacity and an increase in injury risk (Brooks et al., 2008; Coutts et al., 20007; Owen et al., 2015; Gabbet and Jenkins, 2011). In this context, the evaluation and management of training load (TL) during the training week represents an important problem for the professional staff.

Few studies have reported TL during a complete professional TS season (Malone et al., 2015; Gorostiaga et al., 2006; Moreira et al., 2015; Ritchie et al., 2015). Only Gorostiaga et al. (2006) tried to report influence of TL on physical performance during a TS season. Finally, as mentioned above, some studies showed the length of competitive period and the fatigue accumulation generate decreases in power ability and biochemical disturbances. Other studies demonstrated relationships between the TL, running performance and power output during TS season. However, no study analyzed, at the same time, changes in TL, running performance, power ability and biochemical state throughout a professional TS season. Therefore, the aims of this study were to analyze i) changes in TL over the season and ii) observe how the length of the season and the TL influenced power ability, running performance and biochemical characteristics in professional back players.

MATERIALS AND METHODS

Participants

In the beginning, fourteen players volunteered to participate in this study. Finally, 8 professional backline rugby players, all part of the same rugby union team, were retained (The six other players were excluded because they received a long-term injury and/or they had insufficient competition time). Their mean and standard deviation (± SD) for age, body mass, body fat and body mass index were 25.8 ± 4.2 years, 88.4 ± 3.1 kg, 12.7 ± 2.3 % and 27.4 ± 1.1 kg.m², respectively. Six participants were international senior or junior rugby players. All participants gave informed consent to participate in the experiment in accordance with the

Table 1. General organization of the Pro D2 French championship and the measurements carried out

Periods	Pre-season block			TRW	General preparation (block 0)				1st competitive block (block 1)					TRW	2nd competitive block (block 2)					TRW	3th competitive block (block 3)						TRW		4th competitive block (block 4)						PRW	5th competitive block (block 5)				TRW	6th competitive block (including 2 play-off weeks) (block 6)						
Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Games						FG	FG	FG	W	L	D	W	L		W	W	W	W	L		W	L	W	L	W	W			L	D	L		W	W		W	W	L	W		W	W	W	W	W	W	W
GPS						X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X			X	X	X		X	X		X	X	X	X		X	X	X	X	X	X	X
S-RPE						X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Blood sampling															X																	X												X			
Drop jump test						X			X		X	X			X	X	X	X	X		X	X	X	X		X			X				X			X	X	X	X		X		X	X	X	X	X
YYRT2					X										X						X								X												X						

Legend. TRW: Total recovery week (no training and no games); PRW: Partial recovery week (training week without game); FG: Friendly game; W: Win; D: Draw; L: Loss

Table 2. General organization of a typical in-season training week with a duration of 7 days

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	Strength and conditioning session (1h00-1h30)	Strength session (30-45min) Skills (45min-1h15)	Strength or conditioning session (Optional)	Agility/speed session (15-25min) Strategy session (50min-1h15)	Captain session (30-45min)	Rest	Recovery session: Cool-down (Cryotherapy)
PM	Technical session (45min-1h10)	Collective session Match simulation (1h-1h30)	Rest	Strength session: power (20-30min) Technical workout (20-30min)	Rest	Games	Rest

NOTE. Captain session: strategic training at low intensity

Declaration of Helsinki. The study protocols were approved by the Ethics Committee of the local university and were carried out with the agreement of the club's head doctor.

Design

All data were collected during the 2012-2013 season. The Pro D2 championship consists of 16 participating teams with 30 championship matches played over a 37 week period. The organization of the Pro D2 championship is presented in Table 1. During the regular season, players participated in 1 game per week during 6 competitive blocks. These blocks (4-6 weeks) were separated by 1 or 2 recovery weeks. At the end of the regular season, the team ranked no. 1 is promoted to the higher division and play-off games are organized for the teams placed between 2nd and 5th place. The winning team of these play-off games is also promoted to the higher division.

In order to evaluate the participants' training "dose", we used GPS technology and S-RPE methods. These tools allowed us to evaluate respectively the ETL and internal training load (ITL) during each of the competitive weeks (Table 1). A typical in-season week is presented in Table 2. We started recording data in week 6, which includes the first game of the season (a friendly game).

In order to assess participants' "responses" and training adaptations, the YoYo recovery test level 2 (YYRT2), a drop jump test (DJ), and biochemical indicators were used.

Methodology

Training dose assessment

Weekly ETL

10 Hz GPS units (Minimax S4; Catapult Innovation, Melbourne, Australia) were used for assessing weekly ETL during all rugby sessions. After each session, GPS data were downloaded by means of Logan Plus Software (2.5, Team Catapult, Melbourne, Australia) to a computer for analysis of the sessions. 4 to 7 back players were equipped with GPS devices for the same playing positions: fly half, centre, wingers and full back. The individual weekly data were used only if the player was involved in all the training sessions during any given week. The ETL selected parameters are presented in Table 3.

Table 3. External training load parameters used for quantifying external training load during rugby training

TD (m)	Total distance realized by the GPS' users	Training Volume variables
Duration of rugby training (h)	Volume of training for the rugby practice	
MHSR distance (m)	Average distance travelled above 13 km.h^{-1} *	Training Intensity variables
% MHSR	Percentage of total distance covered at a running speed above 13 km.h^{-1}	
AS MHSR (km.h^{-1})	Average of the running speeds above 13 km.h^{-1}	

Legend. TD: Total distance; MHSR distance: Moderate and high speed running distance; AS MHSR: Average speed for moderate and high speed running efforts.

* The threshold of 13 km.h^{-1} was set in accordance with Coughlan *et al.* [2] which constituted as a reference study when the protocol was establish.

Weekly internal training load

After each training session, players were asked to rate the intensity of the sessions on a 10 point scale (CR-10 scale). This intensity was multiplied by the duration of the session in order to obtain a score (S-RPE), (Foster et al. 2001). Weekly ITL corresponds to the sum of S-RPE of the different sessions during the week, expressed in arbitrary units. The "volume" of training represented the total weekly training time (including all types of training), expressed in hours (h). S-RPE method constitutes a valid and practical method to evaluate the ITL in collision based sports (Clarke et al., 2013) strength and conditioning sessions (Egan et al., 2006; Weaving et al., 2014).

Training responses assessment

Blood samples

The collection of samples took place at the same time between 7.00am and 8.00am to avoid circadian variations. Players were fasted. Following collection, the blood samples were placed in heparin tubes, which were then placed in a cooler in order to maintain the temperature of the blood samples at around eight degrees Celsius. Within one hour after the collection, the tubes were centrifuged by an automatic system (Synchron pro CX5 chemistry analyzer, Beckman Coutler Inc., Villepinte, France) in order to analyze the Creatine Kinase (CK) concentration. The other tubes were analyzed by means of a luminescence technique (Pentra 60 C+ - Horiba medical ABX SAS, Kyoto, Japan), which enabled calculation of the number of red blood cells, as well as analysis of the hemoglobin, the leukocytes cells, the reticulocytes and assessment of the level of hematocrit. Lastly, the endocrine status, testosterone (T) and cortisol (C), were studied by means of an automatic system (Vidas, BioMérieux Inc., Craponne, France).

YoYo intermittent recovery test level 2 (YYRT2)

The YYRT2 (Bangsbo et al. 2008) test was conducted in the same conditions, i.e., Monday morning, between 08:00 and 10:00, on grass and after one week of recovery. We used the distance covered (in m), to identify the physical performance. Krustup et al. (2003) showed the validity and the reproducibility of YYRT2 to measure athlete's ability to perform intermittent intensive exercise.

Drop jump test (DJ)

This test was carried out with the Optojump (Optojump Next, Microgate, Bolzano, Italia) (Glatthorn et al., 2011) using a box 0.3m in height. This test was performed during the strength session, which takes place 2 days before matches, after a standardized warm-up. Every subject had three attempts. The first six weeks of the season were used as a learning period for this test. The best performance was used to calculate the DJ power index (DJPI): PI (W.Kg-1) = (g x H)/CT, (with g: gravity acceleration; H: jump height (cm), CT: contact time (s)). For each performance, the percentage of change in DJPI (∆%DJPI) compared to individual mean values were used to monitor week by week changes and to study the correlation with TL parameters.

Statistical analysis

Training dose analysis

A total of 183 rugby trainings, 93 strength and 30 conditioning sessions were analyzed. In compliance with the conditions mentioned in the methodology part, 160 weekly GPS data and 204 weekly ITL were used for this study. A linear regression through scatterplot was used for weekly individual values to represent the changes in weekly TL throughout the season. The coefficients of correlation of linear regression between weekly TL and the number of the training week were presented with 95% confidence interval. In order to study the significant difference between competitive blocks, we performed a one-way analysis of variance (ANOVA) to compare many groups, with a significance level set at $p < 0.05$.

Training responses analysis
We analyzed the DJ test, YYRT2, and blood sample results using a one-way ANOVA with repeated measures. The level of significance was set at $p < 0.05$. When significant differences were found, effect size (ES) was evaluated from the Cohen's d. ES of 0.20-0.60, 0.61-1.19 and ≥ 1.20 were considered small, moderate and large respectively (Hopkins et al., 2009).

Relationship between TL variables and DJ performance and the reliability of DJ test
The correlation between TL variables (GPS, S-RPE) and the individual changes in DJ performances (∆%DJPI) were analyzed using Pearson Correlation (r). Magnitude of effects was qualitatively assessed in accordance with Hopkins (2009) as follows: trivial r > 0.1, small 0.1-0.3, moderate 0.3-0.5, large 0.5-0.7, very large 0.7-0.9, nearly perfect 0.9-0.99, and perfect r = 1. To evaluate the validity and the reliability of the DJ test, the correlations between the first and the second DJ test were carried in addition to the means of % of variation. The same operation was performed for the 2nd last and last DJ test.

RESULTS

Training dose assessment

Weekly TL for back players
Mean ± SD for weekly ITL corresponds to 2076.8 ± 519.5 AU, for a volume of 8.0 ± 1.4 h. 5.9 ± 5.4% of the weekly ITL was devoted to conditioning training, 24.0 ± 7.7% to the strength training and the most important part of the TL corresponds to rugby training with 70.1 ± 8.4%. For ETL parameters, players travelled a total distance of 19316 ± 2923 m including 3996 ± 701 m performed at MHSR.

Changes in TL throughout the season
Figure 1 shows, for each training week, the mean (± SD) changes in a) weekly ITL and training volume; b) weekly total distance travelled and duration of rugby training and c) the AS MHSR efforts and relative part of MHSR. The linear regressions through scatterplot (not presented in figure) showed a progressive and significant decrease ($p < 0.001$) of weekly ITL [r = 0.7 (0.61-0.75)], training volume [r = 0.66 (0.59-0.73)], total distance travelled [r = 0.66 (0.56/0.74)] and duration of rugby training [r = 0.7 (0.61/0.77)] over the season. However, the AS MHSR [r = 0.5 (0.37/0.61)] and %MHSR [r = 0.66 (0.56/0.74)] increased progressively and significantly ($p < 0.001$) throughout the season. No significant change was found through linear regression for absolute MHSR distance. Table 5 shows the changes in weekly TL variables, by comparing each block (mean ± SD of the weeks included in the same block).

Training load during play-off
A decrease of 38% (W46: 1293.7 ± 322.1 AU) and 49% (W47: 1052.4 ± 124.1 AU) were observed in ITL during play-off weeks (the most important phase of the season) compared to the average of the season. The weekly volume for these periods were 6.1 ± 0.5 h for week number 46 and 5.1 ± 0.1 for week number 47 (-24 and - 36% compared to the in-season average).

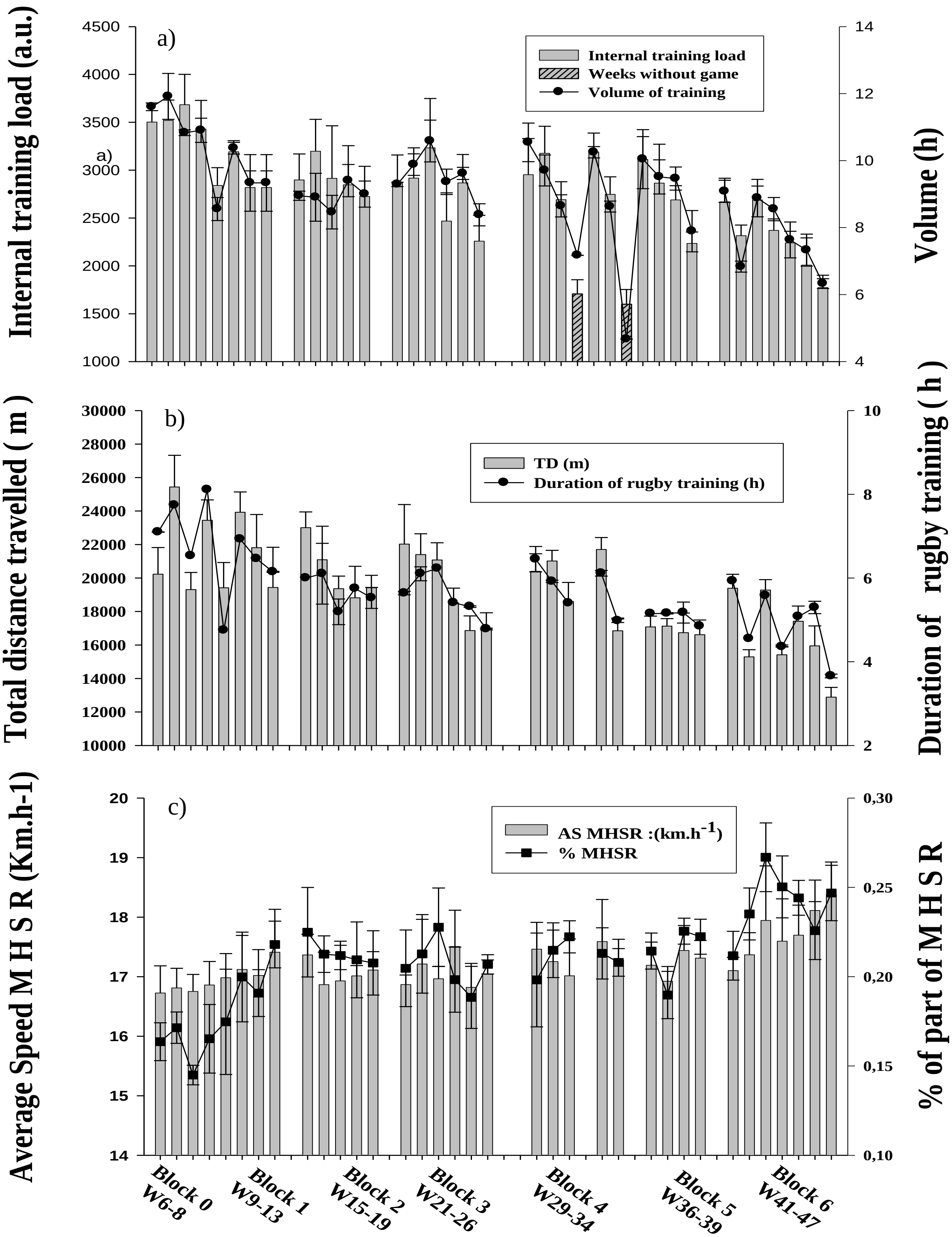

Figure 1. Changes in internal training load, total distance, training volume and speed efforts throughout the season

Note. AS MHSR: Average speed of moderate and high speed running

Evolution throughout the season of: a) Internal training load (S-RPE) and volume of training. b) Total distance travelled and duration of rugby training and c) Average speed of moderate/high speed running (MHSR) efforts and %MHSR relative to total distance travelled.

Training responses assessment

Blood sampling

Blood sampling results reveal a significant increase (p < 0.001) in red blood cell and reticulocyte concentrations during the last part of the season compared to the first two samples. No significant change was observed in T/C ratio over the season despite a significant (p < 0.01) increase in C during the last measure. The other blood sample results over the season are presented in Table 4.

Table 4. Mean (± SD) concentrations for blood parameters at 3 different parts of the season

	Red blood cells	*Hb*	*Hematocrit*	*Leukocytes*	*Ret*	*CK*	*C*	*T/C*	*T*
	Millions .mm3-1	g.100ml-1	%	Thousands .mm3-1	Thousands .mm3-1	UI.l-1	ug.dl-1	ratio	ug.l-1
First part	4.7 ± *0.4*	14.8 ± *0.9*	42.4 ± 2.7	7.0 ± *2.3*	46.11 ± *25.6*	469.9 ± *181.4*	177.9 ± *23.5*	0,033 ± 0.01	5.8 ± *2.3*
Middle of the season	4.6 ± *0.2****	14.5 ± *0.5*	41.2 ± *1.8*	5.5 ± *1.1**	47.8 ± *12.2*	664.1 ± *282.6*	154.5 ± *27.1**	0.033 ± 0.01	5.0 ± *0.9*
Last part	5.0 ± 0.2***$$$	15.0 ± *0.6*	45.8 ± 2.0***$$$	5.9 ± 1.6	76.4 ± *14.4****$$	558.8 ± *420*	215.8 ± *33* **$$$	0.030 ± 0.01	6.3 ± *1.9*
ES Fist part VS middle	*Small 0.4*	-	-	*Moderate 0.8*	-	-	*Small 0.3*	-	-
ES Fist part VS last part	*Moderate 0.9*	-	*Moderate 1.2*	-	*Large 1.2*	-	*Moderate 0.8*	-	-
ES Middle Vs Last part	*Large 1.4*	-	*Large 1.5*	-	*Large 1.5*	-	*Large 1.4*	-	-

Legend. Hb: Hemoglobin; Ret: Reticulocytes; CK: Creatine kinase; C: Cortisol; T: Testosterone; ES: Effect size (Cohen's d) when significant difference was observed
* Significant difference with first part of the season.
$ Significant difference with middle part of the season.
*: p < 0.05, ** : p < 0.01, *** : p < 0.001,
$: p < 0.05, $$: p < 0.01, $$$: p < 0.001.

Running performance and drop jump test

The YYRT2 did not reveal significant change during the season. The DJPI in the block 0 was significantly lower than all other blocks (p < 0.05; d = 0.3, 1.5, 1.8, 1.4, 1.7, 1.5 respectively for block 1, 2, 3, 4, 5 and 6).

CT in blocks 2, 3, 4 and 5 were significantly shorter compared to block 0 ($p < 0.05$; d = 0.9, 1.1, 1 and 1.6 respectively). The only significant difference for H was observed in block 6, which showed better performance for these parameters in comparison with block 0 ($p < 0.05$; d = 1.3).

Reliability of DJ tests and the relationship between TL variables and DJ performance
Correlations between test and re-test in DJ were: r = 0.73, r = 0.74, r = 0.95 respectively for the H, CT and DJPI ($p < 0.001$). The mean for the % of variation was + 2.0 % for the DJPI.

The %ΔDJPI showed significant ($p < 0.001$) and negative correlation with training volume [TD: r = -0.49 (-0.33/-0.62; weekly ITL: r = -0.40 (-0.23;-0.55)]. On the contrary, the intensity variables showed a negative correlation with the %ΔDJPI [AS MHSR: r = 0.27, (0.09/0.45), $p < 0.001$, %MHSR: r = 0.38 (0.21-0.53), $p < 0.01$].

DISCUSSION

The aims of this study were to analyze i) changes in TL over the season and ii) observe how the length of the season and the TL influenced power ability, running performance and biochemical characteristics in professional back players.

Firstly, our results showed a progressive and a significant TL decrease throughout the season, primarily due to a decrease in training volume. Secondly, no significant change in running performance was observed. Moreover, negative significant correlations were found between training volume and lower body power production. Finally, analysis of hematological parameters showed a significant increase in red blood cells and reticulocytes, but no significant change was found in T/C despite a significant increase in cortisol concentration during the last blood sample.

Changes in Training load

The ITL (based on S-RPE method), the TD travelled and the training volume significantly decreased ($p < 0.001$) over the course of the season. The TL decrease was particularly due to the reduction in training volume. Absolute MHSR showed no significant change in spite of the decrease in TD travelled throughout the season. Therefore, the observed decrease in TD travelled seemed to particularly affect the low-speed running efforts. Furthermore, increase ($p < 0.001$) in AS MHSR and relative MHSR highlighted an increase in the intensity of training. The negative association of training volume and training intensity observed in our study was in agreement with other studies (Gorostiaga et al., 2006; Moreira et al., 2015). This observed change in TL exemplifies the traditional theory of periodization (Bompa and Haff, 2009), wherein, the focus is on low-intensity and high volume activity at the beginning of the season while the focus is on high intensity and low volume of training during the last part of the season. The significant increase in training intensity and decrease in training volume from linear regression over the season showed the greatest difference in TL level between block 0 and blocks 5 and 6 (Table 5), especially during the play-off phase. Bosquet et al. (2007) showed in their meta-analysis that the best tapering and peaking strategies involve an exponential decrease of 40-60% for volume training without modification of other training variables (intensity and frequency) during a 2 week period in individual sports. Comparatively, our findings showed a comparable strateg y being used for professional rugby back players during a play-off phase (block 6). In this present study, decrease in training volume was observed while maintaining the intensity variables. This change in TL can be compared to a tapering strategy, which may contribute to the optimization of the physical capacity of back players.

Table 5. Mean (± SD) block by block changes in training load variables throughout an entire season

		Block 0	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	ES
	n	17	21	23	26	24	17	32	
ETL	**Total Distance (m)**	21437.1 ± 3042.4	21504.5 ± 2498.4 [f,g]	20604.7 ± 2074.2 [f,g]	19535.5 ± 2474 [b]	19834 ± 1915.6 [f,g]	16901.9 ± 769.1 [a]	16542.0 ± 2380.4 [a]	**Moderate to large (0.7-1.6)**
ETL	**Duration of rugby training (h)**	7.1 ± 0.5	6.4 ± 1.2 [a,g]	5.8 ± 0.5 [a,b,f,g]	5.6 ± 0.5 [a,b,g]	5.8 ± 0.5 [a,b,f]	5.1 ± 0.2 [a,b]	4.9 ± 0.8 [a]	**Moderate to large (0.7-1.9)**
ETL	**MHSR (m)**	3445.6 ± 758.3	4047.4 ± 648.2	4433.3 ± 720.7 [a,f]	4042.2 ± 757.8	4194.2 ± 542.6 [a]	3598.6 ± 306.8	3964.5 ± 652.2	**Moderate (0.6-1.1)**
ETL	**%MHSR**	0.16 ± 0.01	0.19 ± 0.03 [a,g]	0.21 ± 0.02 [a,b,g]	0.21 ± 0.02 [a,b,g]	0.21 ± 0.02 [a,b,g]	0.21 ± 0.02 [a,b,g]	0.24 ± 0.02 [a]	**Moderate to large (0.7-1.9)**
ETL	**AS MHSR ($Km.h^{-1}$)**	16.8 ± 0.3 [f]	17.1 ± 0.5 [g]	17.1 ± 0.4 [g]	17.1 ± 0.5 [g]	17.3 ± 0.5 [a,g]	17.2 ± 0.4 [g]	17.8 ± 0.7	**Moderate to large (0.7-1.4)**
ETL	**Weekly number of training**	7.1 ± 0.5	6.4 ± 1.2 [g]	5.8 ± 0.5 [g]	5.6 ± 0.5 [g]	5.8 ± 0.5 [g]	5.1 ± 0.2	4.9 ± 0.8	**Moderate (0.7-0.9)**
ITL	**n**	17	22	32	34	31	24	44	
ITL	**S-RPE (AU)**	3000.7 ± 167.5	2375.6 ± 306.6 [a,d,f,g]	2209.2 ± 353.1 [a,f,g]	2016.3 ± 458.4 [a,b,f,g]	2170.6 ± 326.0 [a,f,g]	1889.7 ± 336.1 [a,g]	1566.9 ± 377.3 [a]	**Large (1.6-3.7)**
ITL	**Total Volume (h)**	10.7 ± 0.6	8.6 ± 1.0 [a,g]	7.8 ± 0.5 [a,b,g]	8.3 ± 0.8 [a,g]	8.3 ± 0.9 [a,g]	7.9 ± 0.9 [a,b,g]	6.6 ± 1.1 [a]	**Moderate to large (0.9-1.9)**

Legend. ETL: external training load measuring thanks to GPS technology; ITL: internal training load measuring thanks to S-RPE method; ES: Effect size (*Cohen's d*) (minimum-maximum values)

[a] Significant difference in comparison to block 0; [b] Significant difference in comparison to block 1; [d] Significant difference with block 3

[f] Significant difference in comparison to block 5; [g] Significant difference in comparison to block 6

Level of significance was set at $p < 0.05$

However, more controlled intervention studies are required in order to have a greater understanding of the direct relationship between TL and optimization of certain physical capacities for back players.

Changes in biochemical characteristics

Our findings related to red blood cells and reticulocytes seem to attest an improvement in the transportation of oxygen in the blood resulting from erythropoiesis during the last part of the season when the TL was reduced. In contrast to Banfi et al. (2006) who showed a decrease in red blood cells, hemoglobin, reticulocytes concentrations and hematocrit during the 2nd part of the season in international rugby players. These contradictory results could depend on the TL, because they specified their measures took place after an intensive period of competition. Moreover, the present results revealed an increase in the C concentration in the last part of the season. Concomitantly, the T concentration also increased which resulted in no change in the T/C ratio (Table 4). These results were partially in agreement with Argus et al. (2009) results, which also showed moderate increase in C concentration, but with a small decline in T/C ratio during 13 weeks of a professional RU season in the southern hemisphere. Furthermore, Filaire et al. (2001) found an increase in C and a decrease in T and T/C ratio during a French professional soccer season, especially during the 3rd and 4th periods of the season. They specified that the decrease follows a period of high intensity training. A long competitive period and the competitive stress frequency may generate an increase in the C hormone by the repetition of heavy muscle damages and inflammatory states. No change was observed concerning the CK blood concentration (Table 4) despite the fact that the first sample was taken after a week without a game. High training demand in the first part of the season has been shown to generate increases in CK concentration in the first blood sample (Slaterry et al., 2012). In the present study, the low level of the TL in the last part, may have permitted to obtain a similar CK concentration compared to the other measures despite the frequency of games. However, more blood samples were needed to better understand the effects of game frequency and competitive length on biochemical responses.

Running performance test

Our findings showed no significant change in the YYRT2 performances over the season. These results are in accordance with those of Gabbett et al. (2005) and Gorostiaga et al. (2006) which showed no change in the running test over an entire TS season. However, Akubat et al. (2012) revealed that the weekly TL is positively correlated with an increase in fitness performance especially for aerobic effort. Nevertheless, YYRT2 is a test to evaluate the capacity of an individual to perform repeated intense exercise which requires aerobic and high anaerobic systems contribution (Bangsbo et al., 2008). We assume that maintaining an absolute MHSR (Table 5) distance during the different blocks of the season may have contributed to the maintenance of YYRT2 performances. Indeed, Gorostiaga et al. (2006) found a positive correlation between time devoted to high-intensity effort and individual changes of velocity associated with blood lactate concentration at 3 mmol.l-1. The low-intensity running decrease, in this present study, did not influenced YYRT2 performances because this intensity was insufficient to generate aerobic/anaerobic adaptations.

Drop jump test and relationship with TL

The lowest ($p < 0.05$) performances in DJ test were recorded in blocks 0 and 1 when the ITL and training volume were the highest. Indeed, there are negative and significant ($p < 0.01$) correlations between the ITL, some volume variables of TL and %∆DJPI. A substantial volume of training has been shown to contribute to a decrease in muscular power production by inducing a meaningful inflammatory response and muscle damage, which can reduce the neuromuscular response and physical performance (McLellan and Lovell

2012; Slattery et al., 2012). In the present study, the high level of TL associated with low % values for medium and high speed running may explain the lowest value for drop jump power performance for blocks 0 and 1. Our results seems in agreement with those of Gorostiaga et al. (2006) which revealed the negative influence of the low-intensity efforts on concentric power production during a power squat test. Moreover, Los Arcos et al. (2015) also found a negative correlation between acute TL and neuromuscular performance in a vertical jump test. However, high volumes of training (particularly at low intensity) induces a diminution of lower-body power production and, on the other hand, training with low-volume and higher intensity seems to allow to optimize power production (Gorostiaga et al. 2006, Slattery et al. 2012).

CONCLUSION

The coaches of professional TS are constantly faced with managing the TL to optimize the tactical/technical work without causing too much fatigue. Indeed, the length of the competitive period and the accumulation of competitive stress makes the TL management difficult throughout a season. This study showed that a low level of TL, especially during the last part of the season, may have contributed to the maintenance of running performance. Additionally, the low level of TL during the last part of the season may have contributed in the optimization of lower-body power production. However, further investigations, in the form of more controlled intervention studies, will be required in order to have a greater understanding of the direct relationship between TL and optimization of certain physical capacities for back players.

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