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Physiological variables associated with performance in a European professional male rugby team: Analysis of a training intervention

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Abstract The main objective of this study was to identify the impact on conditional variables through a training intervention. A retrospective observational study was conducted in a professional rugby team, where an intervention was conducted for 4 weeks. Data were collected for a total of 18 weeks: 14 weeks pre-intervention, including 7 matches; and 4 weeks post-intervention, including 4 matches. The variables selected and analysed were distance (m), sprint distance (m), distance per minute (m/min), maximum speed (km/h), high intensity actions (n) and accelerations and decelerations $>3\,m/s^2$ (n). In training, a significant difference was found before and after the intervention in Dist. Sprint ($t = 4.303$), in Vel. Max ($t = 4.141$), and in Acc +Dec$>3\,m/s^2$ ($t = 2.939$). In the match data, changes were observed in the mean of the variables before and after the intervention, highlighting the Dist. Sprint (t = -2.295) and Max Speed (t = -0.805). In this specific context, coaches and professionals should be aware of the conditional variables that have the greatest impact on the game, with the aim of optimising the training methodology and focusing on the specific needs of each team to improve performance.

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Introduction

Rugby is characterised by intermittently presenting match scenarios involving high-intensity efforts and physical contacts interspersed with low-intensity situations.[1,2]

Physical demands in rugby players have been studied for many years, and it has been shown that these demands vary depending on players' positions in the team, with significant differences found between the forwards and backs groups.[3–5] Physiological demands also vary depending on total ball-in-play time and elapsed match time, as this affects the number of high-intensity actions required of the players.[2,6] Furthermore, monitoring workloads in team sports is essential to optimise performance, modelling the training load, intensity and duration, and reduce the risk of injury.[7–9] This load control can be carried out either through internal load, external load or both, as there are some studies that show that they are related to each other. [10,11]

Global positioning systems (GPS), which provide a greater understanding of the physical demands of rugby, are currently used to evaluate the movement patterns of players during training and competition and can facilitate the planning and implementation of training programs to develop adaptations specific to the demands of the match(2,12). The demands revealed by research into male rugby matches indicate that the distance travelled by each player is between 4500 and 7000 m in total, while the volume is between 55 and 70 m/min.[1,3,12,13] Most of this distance covered by players would be considered low-intensity activity, with an average of approximately 2500 to 4000 m travelled at $<13 \pm 2$ km/h.[2,4] Concerning high-intensity activity, the following variables are found to be the most significant: distance travelled at high speed (HSR), finding that players travel between 800 and 1500 m at $>15 \pm 2$ km/h[2,13,14] the players' maximum speed, found to be 27 ± 3 km/h in professional rugby players;[3,12] the number of repeated high-intensity effort (RHIE) scenarios, with 10 ± 5 RHIE per match per player;[12,14] and the total number of accelerations/decelerations of over 3 m/s^2, being a variable that could be associated with collisions during matchplay.[15,16] Although most of the actions are low intensity, it is those of high intensity which are most related to the situations and scenarios that have the highest impact on matchplay and results, and this suggests that an increased ability to repeat high-speed sprints (RSA) could be related to the specific key performance indicators (KPI) of each position.[17] Differences can also be observed in the values of physiological variables such as HSR, accelerations and decelerations of over 3 m/s^2, and high-intensity impacts, which relate to the "Win/Lose" result of the matches.[18]

Some studies have found that the actions that have the highest impact on the match, and therefore the most significant influence on the outcome, are contest situations such as tackling and rucks, alongside runs with the ball, metres gained in possession of the ball, and line breaks.[19–21] The investigations indicated that the probability of victory or defeat cannot be determined using any single variable but that a group of variables, comprising Gainline Success, Effective Ruck, Dominant Tackle and Tackle Assist, related to the previously mentioned indicators, would have a positive impact on the results and could explain 63.5% of the variance of the matches won throughout the season.[22] These match scenarios are related since in all of them there is a contest for possession and invasion of territory by both teams,[22–24] generating situations where players engage in contest situations and runs with the ball, involving high-intensity accelerations/decelerations, high-speed runs and an accumulation of groups of RHIE.[12,14,16]

Despite the existence of studies that analyse the possible relationship between the demands of competition and training in rugby through the use of GPS systems and find an association in some physiological variables such as distance, distance per minute and high-speed meters.[25,26] To the authors' knowledge, in the current literature, despite the existence of interventions with sprinting tasks prior to resistance training,[27] there have been no studies on the possible impact of an intervention protocol in a training programme for the physiological demands of professional men's rugby during training and matches.

Considering the most relevant high-intensity physiological variables and their possible relationship with the actions that most impact matchplay,[14,17,18] the objective of this study was to analyse the impact that an intervention protocol in the training program could have on the most relevant physiological demands in training and matches.

Method

Study design

A retrospective observational study of a season of a male professional rugby team (UE Santboiana) was undertaken, in which a conditioning intervention was carried out in the training program. The data was collected between September 2021 and January 2022, during the first half of the 2021/22 *División de Honor* league. Data was obtained from 11 regular league matches within 18 training weeks, divided into 14 pre-intervention weeks, which included seven matches, and four intervention weeks, which included four more matches. The performance variables analysed were obtained through 10 Hz Playertek GPS units, integrated with a 400 Hz triaxial accelerometer and a 10 Hz triaxial magnetometer (PlayerTek Pod; 10-Hz; Catapult Group; Melbourne; Australia; Firmware: J3.18). Previous research has documented the validity and reliability of 10 Hz GPS devices in studying distance and speed in team sports.[28,29] The units (dimensions: 85 mm × 40 mm × 20 mm) were placed in a protective bag in the upper thoracic region between each participant's shoulder blades.

Each player was assigned a GPS device throughout the data collection period. The information collected was stored in the company's application, to be analysed later with the Catapult playertek® software (https://go.playertek.com; Leeds, United Kingdom). The database collected specific information from each selected player's training sessions and matches. After obtaining the data, six of the physiological performance variables provided by the devices were selected for analysis (see Table 1), and their values were compared before and after the intervention. The chosen variables and analysed were: Distance in metres, Sprint Distance in metres (Sprint D), Distance per Minute in metres per minute (D/min),[1,12,30] Maximum Speed in kilometres per hour (Max S),[3] the number of High Intensity Actions (Power

Table 1 Description of the performance variables analysed.

Performance variables (https://go.playertek.com/#/)

Variable	Label	Description	Unit
Sprint Distance	Sprint D	Sprint Distance is the total distance recorded in speed zones 4 and 5. Sprints are defined as runs at speeds of over 21.6 km/h.	Metres (m)
Maximum Speed	Max S	The maximum speed maintained for at least 0.5 of a second.	Kilometres per hour (Km/h)
High Intensity Actions	Power Play	A power play is defined as a significant action (such as an acceleration or high-speed running event) in which power output is above 20 W per kilogram of body weight. Counting power plays gives an indication of the number of intense actions each player was involved in, which are more physically demanding.	Total number (n)
Distance per Minute	D/min	The average distance per minute covered by each player.	Metres per minute (m/min)
Accelerations and Decelerations >3 m/s^2	Acc+Dec>3 m/s^2	Number of times a player makes an acceleration or a deceleration of over than 3 m/s^2.	Total number (n)

Plays), and the number of Accelerations and Decelerations of over 3 metres per second (Acc+Dec>3 m/s^2).[12,14] These variables were selected as they were considered to be the most relevant for the description of the physiological demands of rugby matchplay and rugby training. [2,4,15,16]

Participants

A total of 30 professional rugby players from the UE Santboiana rugby club's first team were included in the study. According to the availability of the devices, the data of 15 players from each training session and match was analysed. Players playing in all positions were included: eight forwards with heights of 183 cm ±11 cm and weights of 104 kg ±14 kg, and seven backs with heights of 175 cm ±10 cm and weights of 81 kg ±11 kg. This division was intended to cover the differing demands of the match depending on the player's position.[3,13,18] The criteria for inclusion in the study were to be of legal age, a member of the first team squad, and to have been selected for at least one of the matches.

All players were evaluated as part of their training schedule to minimise the possibility of any player being injured due to participation in the study. Both players and club were informed of the risks and benefits of the study and agreed to participate. Players could refuse permission for their data to be used at any time. The use of the data complied with the standards of the Declaration of Helsinki, revised in Fortaleza (World Medical Association, 2013), and received institutional approval from the *Comitè d'Ètica d'Investigacions Clíniques de l'Administració Esportiva de Catalunya* (Number 012/CEICGC/2022).

Performance variables

It was determined that of the variables analysed, Sprint D and Max S were reliable, showing the following intraclass correlation coefficients (ICC) 95% CI = 0.14 - 0.08; interval values of coefficient of variation (CV) at 95% CI = 0.22 - 0.02), and effect size (S) = Cohen's d 1.23 - 0.16.

Periodisation

Data recording was carried out over 18 consecutive weeks during the competition period of the first half of the regular league season (September-January). These 18 weeks were divided into four mesocycles for 5 ± 1 weeks. The first seven league matches were played in the first three mesocycles before the intervention, and the intervention was implemented in the fourth mesocycle, in which the following four matches took place (see Fig. 1).

The periodisation of the mesocycle followed the block periodisation model (Issurin, 2008), and the delivery of the content was structured in four orientations (general, directed, specific and competitive).[31]

Within this period, players received five hours per week of technical-tactical team training, 18 weeks of training were analysed, 14 weeks of observation and data collection, and four weeks of intervention were implemented.

The usual structure of each of the microcycles in each mesocycle was as follows: Monday rest and active recovery; Tuesday double session with individual strength and technique work in the morning and a group training session in the afternoon focused on recovery and tactical aspects of matchplay; Wednesday double session with individual strength and technique work in the morning, and a group training session in the afternoon focused on the highest intensity actions and matchplay scenarios; Thursday rest; Friday double session with individual strength and technique work in the morning and a pre-match group training session in the afternoon; Saturday: travel, rest or match in the afternoon; Sunday: match at noon.[22]

During the intervention, the Tuesday and Friday sessions were unchanged. Still, the Wednesday sessions were modified to allow the development and implementation of the

Planning of intervention period
U.E. Santboiana DHA - 2021/22 Season

MONTH	Sep.		Oct.				Nov.				Dec.					Jan.			
MESOCYCLE	M2 - 5w - Special					M3 - 6w - Competition						M4 - 4w - Competition				M5 - 5w - Competition			
MICROCYCLE FOCUS	S	C	C	C	R-D	S	C	C	R-S	C	R-D	S	C	R-D	S	C	C	C	C
MICROCYCLE Nº	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OPPONENT		Gernika	Cisneros	La Vila			Abelles	Barça		Salvador			VRAC			ARU	Cisneros	Ciencias	La Vila
RW / IW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	IW	IW	IW	IW

Fig. 1 Planning for the period of the season in which the intervention was carried out, mesocycles and focus of mesocycles. Adapted from Guerrero et al., 2023. Note. M2: Mesocycle 2; M3: Mesocycle 3; M4: Mesocycle 4; M5: Mesocycle 5; S: Specific; C: Competitive; R-D: Recovery-Directed; R-S: Recovery-Specific; RW: Recording data week; IW: Intervention week.

drills proposed for the intervention. All sessions began with a standard 10′ activation activity, including work on joint mobility, core stability and muscle activation. The Wednesday sessions before the intervention were organised as follows: activation (10′), a group matchplay drill with defence focus (10′) (see Fig. 2), and a technical-tactical drill with an emphasis on the tackle (1 vs 1) and the decision making of the ball carrier and tackler's close support, the attackers' priority being the conservation of the ball and continuation of the attack, and the defenders' priority the recovery of possession (10′). After a hydration break (3′), unit work was carried out with the team separated into groups of forwards and backs (30′). The forwards worked on winning possession of the ball at the scrum while the backs worked on kicking and strategic launch plays in attack (with live defence) from different field areas. The objective of the final drill (30′) was whole team matchplay to train the organisation on the attack from different restart situations and from different locations of the field, incorporating transition phases from attack to defence to generate highly demanding scenarios [32].

Once the intervention was implemented, this organisation was modified. The sessions began with a group activation drill (10′), followed by a technical-tactical drill in situations of 3 vs 3 and 6 vs 6 in reduced space focussed on tackling and recovering the ball in defence and the principle of advancing and supporting the attack (10′). The next element was dedicated to the intervention, with a duration of 12′ (see Fig. 3). After a hydration break (3′), unit work was carried out with the team separated into groups of forwards and backs. The forwards worked on scrummaging, while the backs worked on kicking strategy and strategic launch plays in attack and defence from different areas of the field (30′). Finally, the last drill of the session was dedicated to team matchplay on the full pitch to train organisation and reorganisation in attack and defence using different restarts and different areas of the field (25′).[32]

Through the drills carried out in the intervention, we attempted to influence the physiological variables of Sprint Distance, Maximum Speed, High-Intensity Actions, and Accelerations and Decelerations of over 3 m/s^2. Following the study period, data from training and matches was extracted from the period before the intervention and from the period of the intervention itself.

Results

Eleven rugby matches from a regular Spanish rugby *División de Honor* league season were analysed. During the study period, the first seven matches took place before the intervention and the last four during the intervention.

Before the intervention, the descriptive analyses recorded a total team average Sprint D of 106.296 (± 131.437), Max S of 24.895 (± 72.883), Power Play of 20.859 (± 10.237), D/min of 43.359 (± 8.668) and average Acc+Dec>3 m/s^2 of 81.771 (± 33.763). After the intervention, the average Sprint D was 62.324 (± 79.947), Max S 23.859 (± 2.993), Power Play 20.347 (± 11.250), D/min 43.369 (±8.554) and Acc+Dec>3 m/s^2 73.616 (± 28.415). The variables Sprint D, Max S, and Power Play have significantly low p values (all $<$ 0.001); D/min (0.457) and Acc+Dec>3 m/s^2 (0.023) (see Table 2).

In the training sessions, a significant difference was found in Sprint D before and after the intervention, $t = 4.303$ ($p < 0.001$). The effect size, calculated as Cohen's d, was approximately 0.369, indicating a moderate effect (SE Cohen's $d = 0.087$).

A significant difference was also observed in Max S before and after the intervention with $t = 4.141$, ($p < 0.001$) Cohen's d (0.369) (SE Cohen's $d = 0.087$).

Significant differences were also described in Acc+Dec>3 m/s^2 before and after the intervention; $t = 2.939$, ($p = 0.003$) Cohen's $d = 0.252$ (SE Cohen's $d = 0.086$).

It is important to note that in the cases of Sprint D and Acc+Dec>3 m/s^2, a Brown-Forsythe test was performed to evaluate the equality of variances. It was found that this equality was not achieved ($p < 0.05$), which means that the

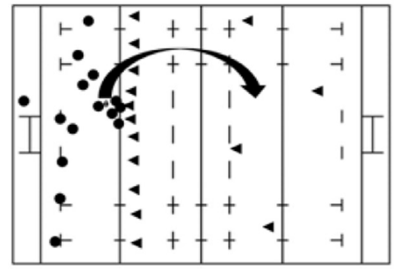
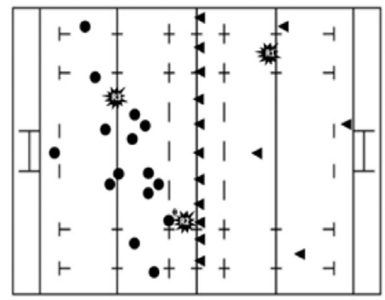
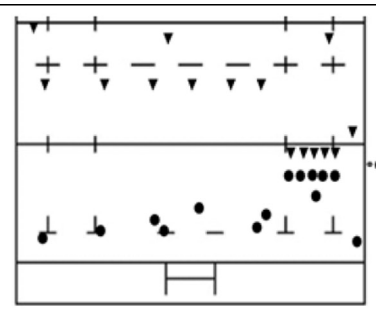
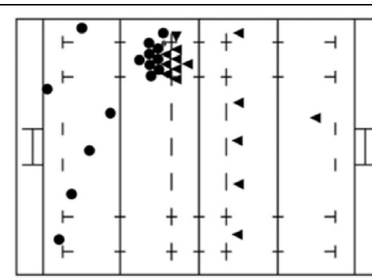
Activity and organisation	Description	Diagram
Defensive reorganisation after kick Restart after three phases Organisation 15 vs 15	Team defends three phases from three rucks (indicated by coloured cones) in different places on field. Teams swop roles to restart.	
Defensive organisation around ruck Restart after three phases Organisation 15 vs 15	Team defends three phases from three rucks (indicated by coloured cones) in different places on field. Teams swop roles to restart.	
Defensive organisation from lineout Restart after three phases Organisation 15 vs 15	Defending team organises defensive line and pressures attacking team for three phases from a lineout.	
Defensive organisation from scrum Restart after three phases Organisation 15 vs 15	Defending team organises defensive line and pressures attacking team for three phases from a scrum.	

Fig. 2 Characteristics of exercises carried out before intervention (defence focus).

results should be interpreted taking into account this possible difference in the variances between the groups before and after the intervention (see Table 3).

Concerning the characteristics of the matches, before the intervention, the average values of the variables analysed were: Sprint D 2487.279 (± 554.547), Max S 27.199 (± 0.794), Power Play 442.714 (± 28.099) and Acc+Dec>3 m/s^2 1334.571 (± 108.065).

After the intervention, the mean values were: Sprint D 3323.925 (± 632.215), Max S 27.543 (± 0.364), Power Play 454.500 (± 75.235) and Acc+Dec>3 m/s^2 1285.000 (± 22.605) (see Table 4).

Changes were observed in the mean of the variables before and after the intervention, with increases observed after the intervention, notably the Sprint D with a t value = −2.295, Cohen's d, = −1.439 (SE Cohens 0.735). The distance covered in a sprint increased significantly after the intervention, suggesting an increase in the players' ability to perform sprints. Max S also showed a noticeable increase after the intervention with t = −0.805, indicating an improvement in the players' speed. Power Play, t = −0.383, did not significantly change after the intervention.

The effect sizes between the pre- and post-intervention physiological variables ranged from small to moderate. The

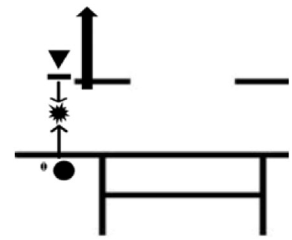
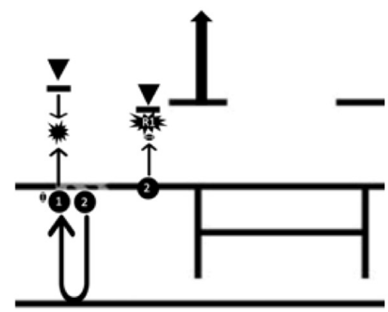
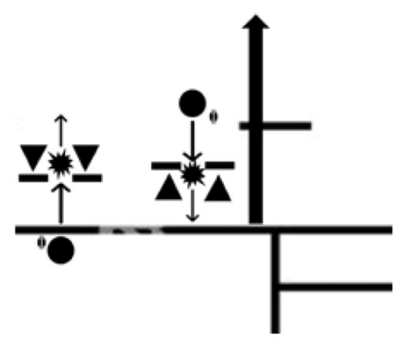
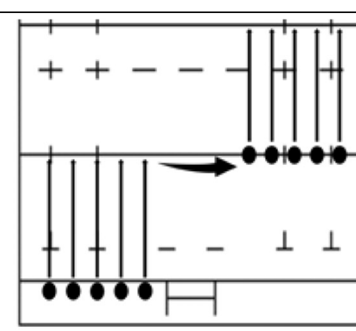
Activity and organisation	Description	Diagram
Ball carrier drives out and back + 50m sprint Repeat every 60” Groups of two players	**Part 1:** Player with ball starts on try line and player with shield on 5m line. On contact attacking player drives to 5m line. Reset and repeat. **Part 2:** Both players sprint 50m.	
Ball carrier drive + ruck cleanout + 50m sprint Repeat every 60” Groups of three players	**Part 1:** Attackers start from try line and player with shield from 5m line. On contact, attacker hits and drives to 5m line, and attacker without ball runs to dead ball line and back. **Part 2:** Ball carrier goes to ground to set up ruck and second attacker cleans out ruck. **Part 3:** All players sprint 50m.	
Ball carrier drives between defenders out and back + 50m sprint Repeat every 60” Groups of three players	**Part 1:** Player with ball starts from try line and players with shields set up in front of attacker. On contact, the attacker hits and drives between the two shields to 5m line. **Part 2:** The attacker repeats the action in the opposite direction towards the try line. **Part 3:** All players sprint 50m.	
Defensive line pressure (22m sprint) + Reset + Defensive line pressure (28m sprint) Repeat every 20” Groups of five players	**Part 1:** Five players form a defensive line on the try line and pressure at a sprint to the 22m line. **Part 2:** They reset as a defensive line on the 22m line. **Part 3:** They pressure at a sprint to the halfway line.	

Fig. 3 Characteristics of exercises carried out during the intervention.

results suggest a significant difference in Sprint D in matches ($p = 0.047$), showing a greater average distance after the intervention. However, although the Max S and Power Play values increased in matches after the intervention, no significant differences were found ($p = 0.442$) and ($p = 0.711$), respectively.

Discussion

The present study analysed the results of a training intervention on the physiological data of a male professional rugby team during the first half of the regular league season. The main findings of this study are the significant changes in the

Table 2 Descriptive values before and after the intervention in the training sessions.

	Sprint D		Max S		Power play		D/min		Acc.+Des. >3 m/s2	
	1	2	1	2	1	2	1	2	1	2
Valid	475	190	475	190	475	190	475	190	475	190
Missing	0	0	0	0	0	0	0	0	0	0
Mean	106.296	62.324	24.895	23.859	20.859	20.347	43.359	43.369	81.771	73.616
Std. Deviation	131.437	79.947	2.883	2.993	10.237	11.250	8.668	8.554	33.763	28.415
Minimum	0	0	18.200	17.390	2.000	1.000	23.090	14.950	6.000	13.000
Maximum	711.500	370.300	32.060	33.640	54.000	54.000	74.700	61.950	178.000	159.000

Table 3 Differences between training sessions before and after the intervention.

Independent Samples T-Test

	t	df	p	Cohen's d	SE Cohen's d
Sprint D	4.303	663	< .001	0.369	0.087
Max V	4.141	663	< .001	0.355	0.087
Power Play	0.566	663	0.572	0.049	0.086
D/min	−0.013	663	0.990	−0.001	0.086
Acc+Dec>3 m/s2	2.939	663	0.003	0.252	0.086

Note. Student's *t*-test.
Brown-Forsythe test is significant ($p < 0.05$), suggesting a violation of the equal variance assumption.

Table 4 Descriptive values before and after the intervention in games.

	Sprint D		Max S		Power Play		Acc+Dec>3 m/s2	
	1	2	1	2	1	2	1	2
Valid	7	4	7	4	7	4	7	3
Missing	0	0	0	0	0	0	0	1
Mean	2487.279	3323.925	27.199	27.543	442.714	454.500	1334.571	1285
Std. Deviation	554.547	632.215	0.794	0.364	28.099	75.235	108.065	22.605
Minimum	1376.555	2473.200	26.240	27.000	391.000	350.000	1130.000	1259.000
Maximum	3055.100	3996.200	28.165	27.764	469.000	529.000	1416.000	1300.000

variables Sprint D and Max S in-match data after the application of the intervention in the training program.

Although rugby is a highly variable and high-intensity sport,[1,2] it can be observed that after an intervention in training involving specific conditioning drills and analysis, there was an increase in Max S and Sprint D during matches, with higher peak speeds being achieved for longer. The increase in these variables could have a relationship to the physiological and technical-tactical demands of the sport itself, and the higher values in these variables could be associated with an increase in the intensity of the matches.[12,14,18]

Some studies consider Max S and Sprint D physiological capabilities that appear in high-intensity actions.[12,17] These high-intensity actions significantly affect team performance, with a higher number of groups of high-intensity efforts or Repeated High-Intensity Efforts (RHIE) being able to improve performance,[14] and also the existance of technical-tactical groups of actions that significantly affect a team's performance, such as defensive line breaks and runs with the ball.[22]

The results of the current intervention and the observations mentioned above suggest a possible relationship between Max S, Sprint D, and RHIE, as these physiological variables may be part of these RHIE scenarios.[14] Furthermore, relevant technical-tactical actions in the match, such as defensive line breaks and runs with the ball, would require the ability to execute them at high speed,[12,22] and it may be considered that an improvement in these physiological capabilities, through an intervention in the training sessions, could produce an advance in the performance of a team.

The incorporation of new technologies in the field of sports analysis, as well as the possible relationship between different internal and external load management tools such as RPE and GPS systems, could provide benefits to future studies and provide detailed information on the association between the physical demands and performance,[26,28,33,34] allowing the development of training plans that meet the specific physiological demands that rugby requires for the different positions on the field through the adaptation and periodisation of training.[35,36]

This study has certain limitations since the data extracted corresponds to the first part of the regular league season, so the sample may vary depending on the opponent, the competition calendar, and the players analysed. Although technology was used, not all athletes could record their data in training sessions and matches. Although this data must be interpreted in the competitive and sporting context of the team, the research can show notable changes in certain match variables, suggesting that if more resources were available to obtain a larger sample, more significant results could be extracted.

The present study concludes that significant changes have been observed in the Max S and Sprint D match data after an intervention protocol in four-week training sessions through specific drills focused on the physical variables associated with intensity and speed.

By understanding which physiological variables have the highest impact on rugby, each coaching staff can optimise their training methodology and load control, with the aim of reducing the incidence of injury and attending to the specific needs of each team to improve its performance.

Conflicts of interest

The authors declare that they have no conflicts of interest to report.

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IRB Approval

The use of personal data followed the standards of the Helsinki Declaration (World Medical Association, 2013) and received the institutional approval of the Comitè d'Ètica d'investigacions Clíniques de l'Administració Esportiva de Catalunya (Number 012/CEICGC/2022).

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