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Integrated Training Program for Rugby Sevens: A Multivariate Approach of Motor, Functional, and Metabolic Components

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Abstract

Purpose: This study assessed the adaptations resulting from implementing an experimental, integrated training program tailored to sex-specific traits. The aim was to enhance motor abilities, aerobic capacity, and metabolic variables in female and male rugby sevens athletes. Methods: Employing a combined observational and experimental design, initial and post-intervention assessments were conducted over three months (March–June 2023) with 24 elite professional players, divided equally by sex (12 females, 12 males). The protocol consisted of 12 micro-cycles, each lasting 7 days and comprising 12 training sessions. The evaluations included sprint and jumping tests, as well as functional assessments such as resting metabolic rate and cardiopulmonary exercise testing. Results: Using one-way repeated measures ANOVA, significant improvements were noted across all performance parameters ($p < 0.001$), with effect sizes ranging from small to very large. Sex-specific differences were evident, with females demonstrating consistent improvements in aerobic capacity and jumping ability, while males excelled in explosive power and longer sprints. Despite initial performance disparities, both sexes improved in short-distance sprints (10 m and 40 m). Cardiovascular efficiency improved as indicated by reduced maximum heart rates and lower respiratory quotients. Conclusions: Males showed superior progress in strength and explosive power tests, reflecting distinct physiological traits. These findings underscore the need for individualized and sex-specific training programs to optimize performance in high-intensity sports, such as rugby sevens.

Keywords: rugby sevens; integrated training; sex differences; metabolic adaptations; motor performance

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1. Introduction

Modern sevens rugby involves a high level of physical, technical, tactical and psychological demands, requiring athletes to undergo multidimensional preparation to meet the requirements of high-level competition. Modern sevens rugby imposes complex physiological demands characterized by intermittent high-intensity efforts, repeated physical contacts and multiplanar neuromuscular demands [1,2]. In rugby, motor actions involve the simultaneous activation of neuromuscular, cardiovascular, and metabolic systems in a functional synergy that cannot be replicated through segmented training [3,4]. This specificity requires reconsidering traditional training paradigms that treat performance components in isolation. Contemporary research predominantly addresses the development of motor

capacities through segmented methodologies; however, this methodological fragmentation overlooks the principle of functional interdependence in biological systems and fails to generate optimal adaptations for the specific requirements of rugby according to sex [4–7].

In this context, integrated training strategies are gaining increasing relevance, as they enable the synergistic development of multiple motor and physiological qualities necessary for optimal performance. An integrated approach involves the intelligent combination of physical training within a periodized planning framework, adapted to the specificity of rugby [2,8,9]. Recent studies show that training programs that simultaneously address multiple aspects of physical performance—such as speed, strength, endurance, and agility—yield significant gains in players' physical efficiency compared with training focused on a single parameter [8–11]. Moreover, these multivariate approaches enable training to be personalized for each athlete, taking into account their unique characteristics, strengths, and areas needing development. Thus, by adapting the program to each athlete's specific needs, the body's physiological adaptations are optimized, and superior sports performance is achieved [10–16]. Unlike most studies that analyze either motor or physiological parameters in isolation, our study proposes an integrated approach, simultaneously evaluating motor and functional parameters in a rugby-specific context. Additionally, our study is distinguished by its analysis of sex differences in training response, offering a comparative perspective between female and male athletes, an aspect frequently neglected in high-performance sports research [11,17–19].

Studies indicate that faster rugby players are more successful at breaking through defenses, evading tackles, and scoring tries than slower teammates. Their speed allows them to engage the defensive line more quickly, prompting opponents to make inefficient defensive choices and creating opportunities for missed tackles. From a defensive angle, faster players also demonstrate higher tackle efficiency [20,21]. Rugby players require physical actions like high-intensity running and directional changes during games, making physical fitness crucial for performance [22]. The significance of developing motor qualities has been emphasized, especially among coaches of adolescent players [23]. In contact sports such as rugby, optimizing physical fitness is essential for actions such as tackles and scrums [24,25]. Throughout the competitive season, training for strength, speed, and explosive power is vital, although elite athletes often see limited improvement in these areas [26]. This has spurred ongoing efforts to find innovative training methods [27–29].

Recent advancements in rugby research have illuminated substantial deficiencies, particularly in examining isolated performance components, while largely overlooking the intricate interactions among motor skills, functional capabilities, and metabolic processes. Most studies tend to adopt a univariate perspective, which inadequately captures the multifaceted nature of athletic performance. This limitation is further exacerbated by the current methods for quantifying training load, which predominantly rely on a narrow range of physiological markers, often constrained by field-based measurement limitations. As a result, there remains a significant gap in understanding the synergistic mechanisms underpinning integrated physiological adaptations and their practical implications for rugby training methodologies. Currently, the literature lacks a holistic perspective that accounts for the interplay among various performance determinants. This fragmentation underscores an urgent need for a comprehensive multivariate framework to effectively integrate these diverse physiological elements. Such an approach would not only enhance the relevance of academic research to the sport's physiological demands but also improve training practices by aligning them more closely with the complex realities of rugby performance.

Our study presents a personalized and integrated training program, assessed through multivariate analyses that include standardized tests, and advanced evaluations, such as

indirect calorimetry and cardio-pulmonary exercise testing (CPET). This integrated model aims to enhance sports training theory and optimize rugby performance.

This study aims to evaluate adaptations following the implementation of an experimental integrated training program tailored to sex-specific characteristics, targeting improvements in motor components, aerobic capacity, and metabolic variables in female and male rugby athletes. We hypothesized that the implementation of a 12-week integrated training program would result in significant improvements in the physical fitness of rugby players and that the magnitude of these adaptations would differ by sex, particularly in motor abilities, aerobic capacity, and metabolic variables.

2. Materials and Methods

2.1. Participants

The study included 24 elite professional senior rugby sevens players, comprising 12 females (50%) and 12 males (50%). Female players had a mean height of 162.8 cm and a mean body mass of 59.4 kg at baseline, while male players had a mean height of 182.0 cm and a mean body mass of 87.1 kg. The study sample consisted of 24 elite professional senior rugby sevens (7 s) players, including 12 females (50%) and 12 males (50%). All participants were active members of the national high-performance rugby sevens program and competed regularly at national and international levels throughout the competitive season. The athletes had a minimum of five years of competitive rugby experience and were accustomed to the high training volumes and intensities specific to this discipline.

At the time of the study, all athletes were clinically fit, free from injury, and medically cleared for high-intensity exercise. They followed a centralized training program conducted under the supervision of coaches and strength and conditioning specialists. Both female and male groups were integrated within the same training framework, with sex-specific adaptations applied when necessary.

Inclusion criteria: active athletes, absence of injury in the last 6 months (including during the study), minimum age 18 years, minimum 4 years of experience as active players, minimum two national team selections, participation in the entire experimental program, and complete completion of evaluations from both initial (It) and final (Ft) sessions. G*Power 3.1.9.4., analysis for the study with 12 subjects per group (n = 24 total) and a statistical power ($1 - \beta$) of 0.95 indicates adequate statistical power (82.5%). Athletes were excluded from the study if they had experienced musculoskeletal injuries within the previous six months, undergone surgical interventions, or presented medical conditions (cardiovascular, respiratory, metabolic, or neurological) incompatible with high-intensity exercise; if they used substances or medications that could influence physiological responses; failed to fully participate in the training program or in the initial and final assessments; were involved in other concurrent training interventions; experienced acute illness episodes during the testing period; or did not provide informed consent. This G*Power analysis indicated that a minimum of 11 participants in the study group was necessary to achieve the desired level of statistical power.

2.2. Research Design

The study used observational and experimental methodologies, including initial baseline and post-intervention evaluations, and was conducted over a 3-month period from March to June 2023, during which 12 training micro-cycles were performed, each micro-cycle having 7 days, with 12 training sessions per micro-cycle. The study included an initial evaluation (It), implementation of the 12-week experimental program, and final evaluation (Ft).

The training periodization was carried out according to the three specific periods in sports preparation: preparatory, pre-competitive, and competitive. The experimental program included integrated training in the context of rugby, as well as training for strength optimization, conducted both in the strength room (indoor) and on the rugby field (outdoor). The program was individualized for each player, with a muscle activation program adapted to the sport's particularities and their fitness level. Integrated exercises were implemented in the first part of the 12 training sessions, each lasting 30 min. During the preparatory period, the micro-cycle intervention consisted of 6 integrated training sessions, structured as follows: 2 anatomical adaptation sessions with integrated field exercises; 2 sessions targeting aerobic capacity in game contexts; and 2 sessions to educate movement speed, performed with the ball. During the pre-competitive period, the training sessions—the 6 training sessions—were structured as follows: 2 sessions for developing speed and agility; 2 sessions for improving specific aerobic explosive power through workshop work with the ball and through aerobic power exercises 3 vs. 2 players; 2 sessions focused on developing explosive strength with integrated means (on the rugby field outdoor).

The integrated training program was organized at the level of each training session into three distinct sections: warm-up, main training phase, and cool-down. The structure of each session aimed to progressively prepare the athletes for the mechanical, metabolic, and neuromuscular demands specific to rugby, while also facilitating recovery and injury prevention.

The warm-up lasted approximately 15–20 min and included general aerobic activation (light running), joint mobility exercises, and dynamic stretching targeting the ankle, knee, hip, and spinal joints. This was followed by neuromuscular activation and coordination drills (skipping, low-intensity jumps), as well as progressive accelerations and changes of direction. During this phase, exercises such as single-leg balance followed by a lateral sprint and drop jump combined with a sprint and change of direction were integrated to prepare the athletes for explosive actions and rugby-specific demands.

The main training phase, lasting approximately 60–75 min, combined strength, speed, aerobic capacity, and rugby-specific exercises in an integrated manner (Table 1). Examples of exercises included barbell squats followed by lateral movement and controlled contact, horizontal sled pushes followed by a sprint, Nordic hamstring exercises followed by a rapid stand-up and a 1 vs. 1 duel, zig-zag sprints with passing and a final sprint. In addition, small-sided games (3 vs. 3) with intensity-based rules were incorporated, integrating intermittent aerobic and anaerobic efforts, decision making, and physical contact. Through this structure, mechanical, metabolic, and neuromuscular demands reflected the real requirements of competition, promoting effective functional adaptations and direct transfer to game performance.

The cool-down, lasting approximately 10–15 min, consisted of active recovery exercises (light running or cycling), mobility and flexibility exercises, as well as breathing and relaxation techniques. During this phase, low-intensity running combined with joint mobility and controlled breathing was used to reduce residual fatigue, optimize recovery, and maintain long-term training availability.

The training program was structured throughout the competitive season, respecting the alternation between preparatory, competitive, and recovery phases, with particular emphasis on training load control and the progressive adaptation of the athletes. The program combined strength training, rugby-specific exercises, and aerobic capacity development, and was tailored to positional demands and the players' training level.

Table 1. Training load was periodized and recovery strategies were integrated; however, nutrition and objective recovery markers were not systematically controlled.

Integrated Exercise	Integrated Components	Brief Description	Main Objective
Squat + lateral movement + controlled contact	Strength + stability + rugby-specific	3–5 barbell squats followed by a 5–7 m lateral movement and controlled contact using a pad or partner	Increase contact tolerance and knee/hip joint stability
Drop jump + sprint + change of direction	Explosive power + speed + decision making	Plyometric jump followed by a 10–20 m sprint and a change of direction in response to a visual or auditory cue	Improve acceleration and reactive ability in game situations
Nordic hamstring + rapid stand-up + 1 vs. 1 duel	Eccentric strength + injury prevention + game-specific	2–4 Nordic hamstring repetitions followed by an explosive stand-up and a short 1 vs. 1 duel	Reduce the risk of posterior thigh muscle injuries
Small-sided game (3 vs. 3) with intensity rules	Aerobic capacity + tactics + contact	30–60 s bouts with short recovery periods, including mandatory tackling/ruck involvement	Enhance intermittent high-intensity performance specific to rugby
Single-leg balance + lateral sprint	Proprioception + agility + neuromuscular control	5–10 s single-leg balance followed by a 5–10 m lateral sprint and controlled deceleration	Prevent ankle sprains and improve movement control
Horizontal push (sled) + sprint	Rugby-specific strength + speed + anaerobic capacity	10–15 s horizontal pushing followed by a 10 m sprint	Improve scrum-related explosive power production and transition speed
Zig-zag sprint + passing + final sprint	Speed + coordination + metabolic stress	Rapid changes of direction with passing while running, followed by a final sprint	Maintain technical accuracy under fatigue
Low-intensity running + mobility + breathing	Recovery + injury prevention + autonomic regulation	Active recovery combined with joint mobility exercises and controlled breathing	Optimize recovery and reduce accumulated fatigue

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the National University of Physical Education and Sport in Bucharest, with no. 103/2023.09.26.

The integration of training modalities was designed so that the mechanical, metabolic, and neuromuscular demands reflected the real requirements of the game, thereby reducing training fragmentation and promoting effective functional adaptations. Emphasis was placed on the development of foundational strength, neuromuscular stability, movement control, and the progressive management of external load, which are considered essential for performance enhancement.

External variables were partially controlled in accordance with the specific demands of rugby. Training load was structured through periodized micro-cycles and competitive phases, respecting the principles of progression, work–recovery alternation, and sport specificity. Exercise volume and intensity were adjusted to the athletes' training level, and recovery strategies were systematically integrated into the training process.

Nutritional intake and objective recovery markers (e.g., sleep quality or biological indicators of fatigue) were not standardized or individually monitored throughout the intervention, which should be considered when interpreting the study findings.

2.3. Evaluation Tools

The study included motor and functional tests selected to relate to the objective. The motor tests were structured into two categories: running tests and jumping tests, as well as specific physical performances related to speed and explosive strength, which were evaluated.

- Running tests: 10 m, 40 m, 100 m speed test performed with the Smart Speed Timing Gate system [30]. Motor evaluation was carried out with a free start from the standing position, in a straight line, measuring times for each running distance.
- Vertical jump test with prior flexion, performed on the Optojump platform (Microgate, 39100 Bolzano, Italy, 2020) [31]. A minimum of 3 jumps were performed to calculate the average for Counter Movement Jump (CMJ).
- Squat Jump test (SJ) without preloading phase, used to evaluate pure jumping capacity and explosive power specific for Squat jump (SJ).
- Lower-limb explosive performance was assessed using the Optojump Next system (Microgate, 39100 Bolzano, Italy, 2020). For the countermovement jump (CMJ), participants started from an upright position with hands on hips, performed a rapid countermovement, and immediately executed a maximal vertical jump. For the Squat Jump (SJ), participants began from a static semi-squat position (~90° knee flexion), held for 2–3 s to eliminate the stretch–shortening cycle. Then they performed a maximal vertical jump without prior countermovement.
- Three trials were performed for each test, with 30–60 s of rest between attempts. The highest jump height (cm), calculated from flight time by the Optojump software 2020, was retained for analysis.

The functional tests were standardized and performed under the same conditions for all subjects. Functional tests evaluated aerobic capacity, resting metabolic rate, and physiological reactions to effort:

- Resting metabolic rate (RMR): evaluated through indirect calorimetry using the COSMED system, considered the gold standard for measuring energy consumption at rest [32,33].
- Cardio-pulmonary exercise test (CPET): for evaluating exercise capacity, performed with the Quark CPET system using the Bruce protocol on a treadmill. This graded test enabled the estimation of VO_2max and the monitoring of cardiovascular and respiratory responses during progressive effort.

The evaluation was carried out after the first accommodation micro-cycle. Each evaluation was performed on different days, in the first part of the day, before the first training session. The order of test performance was as follows: running tests, jumping tests, and functional tests, RMR and CPET.

2.4. Statistical Analysis

A detailed statistical analysis was performed to evaluate training adaptations and sex differences in performance. Descriptive statistics included means, standard deviations (SD), and variances. Normality was verified using Shapiro–Wilk tests ($p > 0.05$). Repeated Measures ANOVA examined within-subject changes, providing F-statistics and p-values while adjusting for individual baselines. Confidence intervals (95%) indicated plausible population values, with intervals excluding zero suggesting significant effects. We calcu-

lated the Partial Eta Squared (ηp^2), with effect sizes classified as * $\geq$ 0.01 (small effect), ** $\geq$ 0.06 (moderate effect), and *** $\geq$ 0.14 (large effect). Post hoc pairwise comparisons with the Bonferroni correction were used to calculate mean differences and confidence intervals. Independent samples *t*-tests were used to compare sex differences between groups at both time points (initial and final tests), reporting mean differences, standard errors (SE), and *p*-values. Results were considered statistically significant at $p < 0.01$ **; $p < 0.05$ *.

3. Results

In Table 2, we present the primary descriptive statistics for the study sample. Table 3 presents the results of a one-way repeated-measures ANOVA, accompanied by pairwise comparisons, to evaluate performance changes between the initial and final assessments for both female and male groups, thereby highlighting their respective progress. In Table 4, we report the mean differences computed using an independent Student's *t*-test, enabling a comparative analysis between the female and male groups within the study.

In Table 2, the motor components assessment data demonstrate consistent improvements across all measured parameters following the intervention period. The aerobic capacity and metabolic data reveal substantial changes following intervention. The speed assessment data show consistent improvements in sprint performance for both sexes across all distances, with normal distributions maintained for parametric analysis (Shapiro–Wilk $p > 0.17$). Notable improvements were observed in short-distance sprints, with females reducing 10 m times by 5.7% (from 2.01 $\pm$ 0.07 to 1.90 $\pm$ 0.09 s) and males by 6.6% (from 1.70 $\pm$ 0.09 to 1.59 $\pm$ 0.13 s). For the 40 m sprint, females improved by 4.9% (from 6.01 $\pm$ 0.34 to 5.71 $\pm$ 0.32 s) and males by 6.8% (from 5.27 $\pm$ 0.25 to 4.91 $\pm$ 0.21 s). The 100 m sprint saw smaller gains, with females improving by 2.8% (from 15.50 $\pm$ 0.88 to 15.07 $\pm$ 0.73 s) and males by 3.5% (from 12.36 $\pm$ 0.43 to 11.92 $\pm$ 0.35 s). Improvements diminished with increased sprint distance, indicating adaptations were greater in acceleration and short bursts than in speed endurance. Males showed greater absolute improvements across all distances.

The explosive power variables showed normal distributions (Shapiro–Wilk tests: $p > 0.05$), validating parametric statistical methods. In the Countermovement Jump (CMJ), females improved from 28.86 $\pm$ 2.36 cm to 32.10 $\pm$ 2.66 cm (11.2% increase), while males increased from 41.72 $\pm$ 7.13 cm to 44.63 $\pm$ 6.41 cm (6.9% increase). For Squat Jump Height (SJ), females improved 12.6% (28.93 $\pm$ 2.42 cm to 32.56 $\pm$ 2.75 cm), and males improved 9.3% (38.55 $\pm$ 7.41 cm to 42.13 $\pm$ 6.38 cm). Both groups maintained normal distributions ($p > 0.07$).

In aerobic capacity, both groups exhibited significant improvements, with females' Maximal Oxygen Uptake (VO_2max) increasing by 80.1% and males by 136.4%. Absolute Oxygen Consumption (VO_2/L) increased by 23.3% in females and by 6.1% in males, with stable distribution characteristics. Both groups significantly reduced their Heart Rate Maximum (HRmax), indicating improved cardiovascular regulation, with normal distributions maintained.

The metabolic assessment indicated modest improvements in energy expenditure, with females increasing daily energy expenditure by 2.6% and males by 4.4%. Significant shifts in the Respiratory Quotient (RQ) toward greater fat oxidation were observed, indicating enhanced fat utilization and improved metabolic flexibility, with both sexes converging toward similar final RQ values. These results suggest enhanced metabolic efficiency, characterized by increased energy output and a shift toward fat-based fuel utilization patterns.

Table 2. Descriptive statistics for the parameters of the study components.

Components	Motor Test	Group	Time	Mean	SD	Variance	Shapiro–Wilk *p*
Speed	10 m	Female	It	2.008	0.066	0.004	0.287
			Ft	1.895	0.089	0.008	0.353
		Male	It	1.703	0.087	0.008	0.176
			Ft	1.591	0.130	0.017	0.170
	40 m	Female	It	6.010	0.340	0.116	0.218
			Ft	5.713	0.317	0.101	0.453
		Male	It	5.265	0.245	0.060	0.060
			Ft	4.910	0.213	0.045	0.342
	100 m	Female	It	15.500	0.879	0.773	0.433
			Ft	15.065	0.728	0.531	0.805
		Male	It	12.356	0.428	0.184	0.864
			Ft	11.919	0.352	0.124	0.982
Explosive power	CMJ (cm)	Female	It	28.862	2.359	5.565	0.326
			Ft	32.100	2.657	7.061	0.997
		Male	It	41.724	7.127	50.801	0.124
			Ft	44.626	6.408	41.068	0.201
	SJ (cm)	Female	It	28.925	2.415	5.837	0.142
			Ft	32.562	2.747	7.548	0.618
		Male	It	38.545	7.405	54.836	0.257
			Ft	42.125	6.382	40.733	0.170
Aerobic capacity	VO_2max	Female	It	34.256	4.907	24.081	0.404
			Ft	39.531	3.580	12.822	0.285
		Male	It	40.125	4.558	20.782	0.797
			Ft	45.587	5.520	30.479	0.393
	VO_2/L	Female	It	2.093	0.323	0.105	0.809
			Ft	2.581	0.398	0.159	0.152
		Male	It	3.562	0.495	0.245	0.468
			Ft	3.781	0.545	0.298	0.176
	HRmax	Female	It	186.312	9.890	97.829	0.612
			Ft	176.187	5.647	31.896	0.164
		Male	It	192.500	8.302	68.933	0.959
			Ft	182.625	8.578	73.583	0.709
Metabolic changes	Kcal/day	Female	It	1860.125	316.897	1004.117	0.905
			Ft	1908.250	326.482	1065.000	0.112
		Male	It	2530.625	398.028	1584.917	0.585
			Ft	2641.437	300.138	900.196	0.990
	RQ	Female	It	0.826	0.039	0.002	0.213
			Ft	0.732	0.036	0.001	0.313
		Male	It	0.822	0.086	0.007	0.281
			Ft	0.733	0.038	0.002	0.257

SD—Standard deviation, Shapiro–Wilk *p*—level of significance of normality test.

Table 3. ANOVA—one-way repeated measures and Pairwise Comparisons between initial and final test of female and male groups.

Component	Motor Test	Group	Within-Subjects Effects			Pairwise Comparisons			
			F	*p*	ηp^2	ΔX(Ft − It)	*p* [a]	95% CI	
								Lower	Upper
Speed	10 m	Female	42.207	<0.001	0.738	−0.114 *	<0.001 **	−0.151	−0.076
		Male	29.405	<0.001	0.662	−0.112 *	<0.001 **	−0.157	−0.068
	40 m	Female	60.307	<0.001	0.801	−0.297 *	<0.001 **	−0.378	−0.215
		Male	46.447	<0.001	0.756	−0.355 *	<0.001 **	−0.466	−0.244
	100 m	Female	36.198	<0.001	0.707	−0.436 *	<0.001 **	−0.590	−0.281
		Male	110.188	<0.001	0.880	−0.437 *	<0.001 **	−0.526	−0.349
Explosive power	CMJ (cm)	Female	155.496	<0.001	0.912	3.237 *	<0.001 **	2.684	3.791
		Male	115.338	<0.001	0.885	2.902 *	<0.001 **	2.326	3.478
	SJ (cm)	Female	81.179	<0.001	0.844	3.637 *	<0.001 **	2.777	4.498
		Male	43.943	<0.001	0.746	3.581 *	<0.001 **	2.429	4.732
Aerobic capacity	VO_2max	Female	36.159	<0.001	0.707	5.275 *	<0.001 **	3.405	7.145
		Male	152.640	<0.001	0.990	5.463 *	<0.001 **	2.785	8.140
	VO_2/L	Female	53.634	<0.001	0.658	0.488 *	<0.001 **	0.294	0.681
		Male	23.003	<0.001	0.167	0.219	<0.001 **	−0.050	0.488
	HRmax	Female	25.906	<0.001	0.633	−10.125 *	<0.001 **	−14.365	−5.885
		Male	26.069	<0.001	0.635	−9.875 *	<0.001 **	−13.997	−5.753
Metabolic changes	Kcal/day	Female	1432.479	<0.001	0.990	48.125	<0.001 **	−221.177	317.427
		Male	1090.189	<0.001	0.986	110.813	<0.001 **	−61.381	283.006
	RQ	Female	9921.368	<0.001	0.998	−0.094 *	<0.001 **	−0.117	−0.071
		Male	2604.500	<0.001	0.994	−0.089 *	<0.001 **	−0.119	−0.059

It—initial test; Ft—final test, ΔX—difference of means, CI—confidence interval; *p*—statistical significance; ηp^2—Partial Eta Squared. The mean difference is significant at the 0.05 level. a—Adjustment for multiple comparisons: Bonferroni; $p < 0.01$ **; $p < 0.05$ *.

The one-way repeated measures ANOVA revealed statistically significant improvements across all measured parameters ($p < 0.001$), with Partial Eta Swuared ranging from small to very large, indicating substantial training-induced adaptations. Notably, there were sex-specific differences in adaptation patterns and the magnitudes of the effects (Table 3).

Speed performance across all distances showed significant improvements, with effect sizes ranging from large to very large. The 10 m sprint improved similarly for both sexes (females: −0.114 s, males: −0.112 s; ηp^2 = 0.738–0.662), while the 40 m sprint highlighted the largest sex differences (females: −0.297 s, males: −0.355 s; ηp^2 = 0.801–0.756). The 100 m sprint's improvements were nearly identical (females: −0.436 s, males: −0.437 s), with males showing the largest effect size (ηp^2 = 0.880) (Table 3, Figure 1).

Explosive power metrics also improved significantly (ηp^2 = 0.707–0.924), with CMJ performance increasing in both groups (females: +3.237 cm, males: +2.902 cm; ηp^2 = 0.912–0.885) (Figure 1).

Table 4. Mean differences of the Independent Student *t*-test for the male and female groups of the study.

Component	Motor Test	Initial Test (It)			Final Test (Ft)		
		Mean Difference	SDE	*p*	Mean Difference	SD	*p*
Speed	10 m	−0.305	0.027	<0.001 **	−0.303	0.039	<0.001 **
	40 m	−0.744	0.104	<0.001 **	−0.802	0.095	<0.001 **
	100 m	−3.143	0.244	<0.001 **	−3.145	0.202	<0.001 **
Explosive power	CMJ (cm)	12.8	1.876	<0.001 **	12.526	1.734	<0.001 **
	SJ (cm)	9.620	1.947	<0.001 **	9.563	1.737	<0.001 **
Aerobic capacity	VO_2max	5.868	1.674	0.001 *	6.056	1.645	0.001 *
	VO_2/L	−1.468	0.147	<0.001 **	−1.200	0.168	<0.001 **
	HRmax	−6.187	3.228	0.061	−6.437	2.567	0.017 *
Metabolic changes	Kcal/day	670.500	127.193	<0.001 **	733.187	110.8	<0.001 **
	QR	−0.003	0.023	0.003 *	0.001	0.0137	0.926

It—initial test; Ft—final test, CI—confidence interval; *p*—statistical significance; $p < 0.01$ **; $p < 0.05$ *.

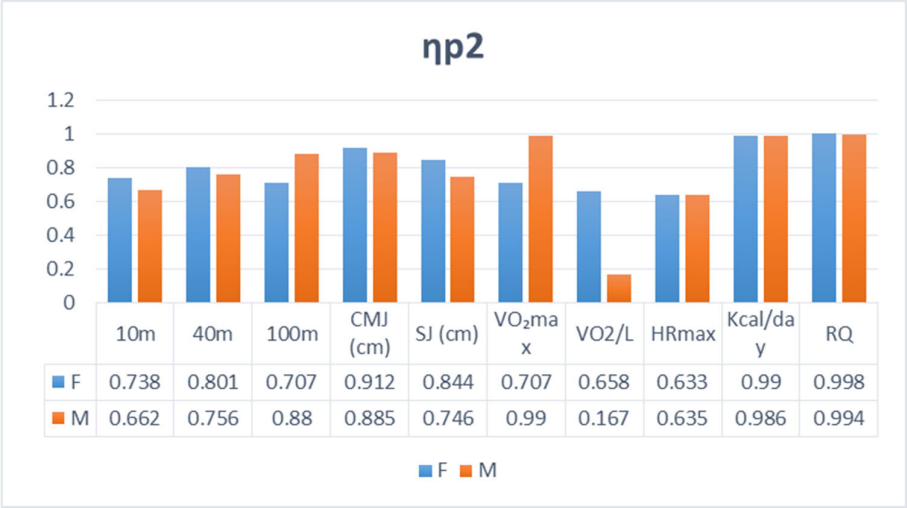

Figure 1. Partial Eta Squared (ηp^2) values.

In aerobic capacity, VO_2max showed significant differences (females: F = 36.159, males: F = 152.640; ηp^2 = 0.707–0.990), with females improving in absolute VO_2 (+0.488 L/min, ηp^2 = 0.658) while males showed non-significant changes (Graph 1). Maximum heart rate (HRmax) reductions were significant in both groups (females: −10.125 bpm, males: −9.875 bpm; ηp^2 = 0.633–0.635).

Metabolic adaptations showed significant changes in caloric expenditure but questionable practical significance, while respiratory quotient improvements were highly significant (ηp^2 = 0.998–0.994). The findings indicate meaningful training adaptations that support practical effectiveness in enhancing athletic performance. Females excelled in aerobic and jumping parameters, while males showed advantages in explosive power and sprinting, suggesting that sex-specific training strategies could improve outcomes.

Independent samples *t*-tests conducted between groups on the initial and final study tests revealed significant baseline performance differences by sex across most parameters, with different adaptation patterns observed after the intervention period.

Baseline sex differences in speed progress were highly significant across all sprint distances ($p < 0.001$). Males showed better initial performance advantages of 0.305 s (10 m), 0.744 s (40 m), and 3.144 s (100 m). After the intervention, these sex gaps remained almost the same (0.304 s, 0.803 s, and 3.146 s, respectively), indicating similar improvement patterns with males maintaining their performance advantage (Table 4).

Independent samples *t*-tests revealed significant baseline performance differences between sexes in initial and final tests, particularly in speed and explosive power. Males outperformed females in sprint distances (10 m: 0.305 s, 40 m: 0.744 s, 100 m: 3.144 s) with minimal change post-intervention. Males consistently held advantages in explosive power measures, such as CMJ (12.86 cm) and SJ (9.62 cm), ($p < 0.001$), highlighting superior training adaptation in males.

In aerobic capacity, initial VO_2 Max showed a male advantage of 5.86 mL/kg/min ($p = 0.001$), which persisted post-intervention (6.05 mL/kg/min, $p = 0.004$). Absolute VO_2 slightly decreased from 1.47 to 1.20 L/min, indicating stable oxygen consumption improvements. Cardiovascular adaptations varied, with non-significant baseline differences evolving into significant post-intervention gaps ($p = 0.017$). Males also exhibited substantial metabolic advantages both initially (670.5 kcal) and post-intervention (733.2 kcal), with a 9.4% increase in the sex gap.

The results indicated that males retain performance advantages in speed and explosive power while also displaying better aerobic adaptation. Females showed similar relative improvements across most parameters, indicating that they respond to training similarly, despite having lower absolute performance levels.

4. Discussions

4.1. Specific Discussion of the Study

The study aimed to investigate the impact of an integrated training program, conducted over 12 weeks, on the development of speed, strength, explosive power, aerobic capacity, and metabolic adaptations in senior rugby players, with a focus on sex. The obtained results highlight statistically significant improvements in both groups (female and male) for all evaluated parameters, but with notable differences in magnitude and specificity between sexes. The results of the study demonstrate that the integrated approach produces superior adaptations compared to unidimensional training methods. The simultaneous improvements in aerobic and anaerobic capacity, explosive strength, and agility suggest that synergistic interactions between different physiological systems can be optimized through careful programming. This finding is consistent with previous studies emphasizing the importance of competitive training in team sports, in which players must simultaneously demonstrate multiple physical qualities [34–37].

The superior progress recorded by the male group, compared to the female group, in strength and explosive power tests (CMJ—countermovement jump, SJ—squat jump, and SJ_Explosive power—power developed in jumping) is attributed to physiological differences such as higher testosterone levels, greater muscle mass, and more developed fast-twitch muscle fibers, as well as a more intense adaptive response of the body to strength training, giving males a consistent and reproducible advantage in developing explosive capacities. At the same time, the data reveals that both groups recorded consistent progress in speed over short distances (10 m and 40 m), but with maintenance of the initial performance difference, males maintaining an absolute advantage. Recent studies reveal that most of the time, through any applied methods, males have greater progress [38–42].

Regarding aerobic capacity, both females and males showed significant increases in VO_2max, but the adaptive response was more pronounced in males, who maintained a higher absolute performance level. The decrease in HRmax in both groups confirms

improved cardiovascular efficiency, as a more efficient cardiovascular system requires fewer beats per minute to sustain the same physical effort, reflecting a positive adaptation of the heart to training. However, sex differences became significant post-intervention, indicating a different physiological response to effort: males typically exhibit a greater capacity to reduce heart rate due to a larger stroke volume (the heart pumps more blood per beat), superior cardiac mass, and improved cardiorespiratory efficiency, while females tend to maintain slightly higher heart rates for the same level of effort, reflecting differences in heart size, blood volume pumped, and hormonal response to intense exercise [43–45].

At the metabolic level, both groups exhibited moderate increases in daily energy consumption and a significant reduction in RQ (Respiratory Quotient), indicating a shift toward more efficient use of lipids as an energy source. In this regard, metabolic adaptations manifested similarly between groups, indicating a convergence of physiological mechanisms for energy efficiency [46–48].

The results of this study contribute to a deeper understanding of how a structured, complex integrated training program differentially influences motor and physiological parameters by sex. The results align with previous studies that have shown that males tend to exhibit a consistent advantage in strength and speed parameters, while females demonstrate greater consistency in aerobic adaptations and cardiovascular regulation. Additionally, our data complements the specialized literature regarding how metabolic adaptations (increased energy consumption and efficiency of fat oxidation) occur regardless of sex, emphasizing the relevance of complex interventions in sports preparation [46–51].

Our study emphasizes that implementing a diverse training program that combines the development of speed, strength, explosive power, and aerobic capacity significantly enhances overall physical performance in rugby sevens. Prior research supports this integrated approach, demonstrating that rugby sevens simultaneously requires multiple energy systems and various physical qualities [52–55]. Additionally, sex differences in training adaptation highlight the need for personalized programs that leverage each group's potential and address specific characteristics of sports development and performance. Studies have documented notable sex differences in responses to strength and explosive power training, as well as in energy metabolism [56,57]. Hunter [58] also demonstrates that women have greater resistance to muscle fatigue but develop lower absolute strength than men, which requires differentiated training strategies. A number of studies have argued for sex-specific training programs in team sports, emphasizing that applying the same protocols to both sexes may be suboptimal [59,60]. Implementing such a program requires multidisciplinary skills and a deep understanding of the interactions among physiological systems, underscoring the importance of collaboration among sports science specialists. Bompa and Buzzichelli [61], advocate a holistic approach to training periodization that integrates knowledge from physiology, biomechanics, and sports nutrition. A number of studies have demonstrated that training programs that account for the complex interactions among physiological systems elicit superior adaptations compared to isolated approaches [62–65].

4.2. The Limits of Study, Practical Implications and the Future Direction of the Study

The research has several limitations, including a small sample size of 24 athletes, which affects the generalizability of the results to all rugby players. The 12-week intervention highlights short-term adaptations but does not address long-term sustainability. The study exclusively involved professional athletes, limiting its relevance to amateurs or those in training. Additionally, it did not monitor factors such as nutrition, sleep quality, or psychological stress, which could affect performance. Lastly, while sex differences were analyzed, the study did not fully consider the physiological adaptations of rugby players.

The practical implications of this study significantly enhance the sports training process in rugby sevens by establishing a comprehensive research model that integrates multiple performance dimensions and facilitates effective theory-practice transfer. Results demonstrate that integrated training programs produce substantial improvements across key performance indicators: speed, strength, explosive power, aerobic capacity, and metabolic efficiency. Sex-specific analysis reveals that personalized training approaches optimize physiological adaptations, with male athletes demonstrating superior gains in strength and explosive power due to hormonal and neuromuscular advantages, while female athletes exhibit greater consistency in aerobic adaptations, reflecting different cardiovascular response patterns. The implementation of advanced evaluation technologies—including cardiopulmonary exercise testing and indirect calorimetry—provides coaches with precise, objective data to individualize training loads, monitor real-time progress, and prevent overtraining, effectively combating performance plateaus and supporting sustainable long-term athletic development.

Future research should expand along several critical directions: longitudinal multiseason studies examining career longevity and injury prevention; integration of wearable technology, GPS tracking, and AI-powered algorithms for real-time monitoring and predictive modeling; biomechanical analysis using 3D motion capture to assess technical efficiency and injury risk patterns; nutritional interventions and recovery protocols to enhance training adaptations; psychological and cognitive performance assessment under fatigue conditions. These future directions would substantially expand the scientific foundation for evidence-based training in rugby sevens and contribute to advancing high-performance sport science methodologies.

5. Conclusions

The study confirms the effectiveness of an integrated training program in enhancing the performance of rugby sevens players, with significant improvements in motor, functional, and metabolic parameters. Both male and female athletes made progress; however, their adaptations varied. Male showed greater improvements in strength, explosive power, and speed, while women displayed more consistent enhancements in aerobic and cardiovascular fitness. The reduction in maximum heart rate in both groups indicates increased cardiovascular efficiency, and the decrease in respiratory quotient suggests a better ability to utilize lipids for energy, which is essential for endurance in intermittent games. These findings underscore the importance of training programs that account for individual and sex-specific traits to optimize performance. The study also highlights the benefits of advanced evaluation methods, such as indirect calorimetry and cardiopulmonary exercise testing (CPET), for objectively tracking physiological changes in athletes. Overall, it supports integrated training as an effective strategy for enhancing the performance of elite rugby players and preventing stagnation. Future research should investigate the application of integrated training across various age groups and levels in rugby, as well as other factors that impact training and performance.

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