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Does Olympic Weightlifting Enhance Strength, Power, and Speed in Adolescent Rugby Union Players?

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ABSTRACT

This interventional controlled study investigated the effects of Olympic weightlifting (OWL) on strength, power, and speed in adolescent rugby union players. Under-17 rugby union players were divided into two groups (WLG and CON) [n: 46, age: 15.4 (0.5) years, stature: 175 (6.1) cm, body mass: 73.7 (15.6) kg]. The WLG participated in an 8-week OWL program. Pre- and post-intervention assessments measured countermovement jump height, 10m and 30m sprint times, and a 5RM back squat.

Results showed no substantial differences between groups at pre- and post-intervention for strength, power, and speed. Strength significantly improved for both groups from pre-to-post. In addition, the WLG demonstrated a greater rate of strength development in comparison to the CON group (MLE = 7.30, SE = 1.83, 95%CI = [3.65, 10.94], t = 3.99, $p < 0.001$). Power did not present substantial changes between pre and post for both groups. Speed performance decreased from pre to post for both WLG and CON ($p < 0.001$). Nonetheless, smaller decreases were observed in the WLG for 10m (+0.05 vs +0.09 sec) and 30m (+0.12 vs +0.20 sec) sprints. Furthermore, anthropometrics (i.e., stature and body mass) proved to be important factors contributing to strength, power, and speed development.

The study found no clear evidence to support the benefit of OWL in developing strength, power, and speed in adolescent athletes without prior experience with these exercises. However, OWL may enhance absolute strength gains and mitigate speed performance declines in youth rugby players. Stature and body mass significantly affected these performance metrics, highlighting the need to consider individual differences and developmental changes. Continuous assessment and careful adjustment of training programs are crucial during adolescence to account for variations in stature and body mass.

Keywords: strength, power, speed, Olympic weightlifting, rugby, long-term athletic development.

INTRODUCTION

Rugby union is a collision-based invasion sport involving high-intensity activities like scrummaging, tackling, and running, interspersed with variable rest (28, 38, 61). Success in rugby union requires a wide range of physical, technical, and tactical skills, particularly strength, power, and speed, which differentiate players by competitive level (3, 28, 32, 41). Players need absolute strength for tackling, rucking, mauling, and scrummaging (51, 68); explosive power for rapid acceleration and direction changes (24, 25, 71, 75); and speed for line breaks and chasing opponents (29, 55, 71). To optimize strength, power, and speed adaptations and minimize injury risk, a progressive long-term training pathway from youth to senior level is recommended (27, 52, 62, 63).

Throughout an athlete's development, various factors influence physical growth and performance capabilities, particularly during adolescence when rapid increases in strength and power often occur (31, 46, 53, 84). However, these periods of rapid growth can sometimes lead to temporary declines in coordination and balance, as well as increased injury risk due to the strain placed on the musculoskeletal system by new biomechanical demands (12, 78, 87, 88, 94). The interaction of growth spurts, changes in body composition, and varying rates of neuromuscular adaptation are key considerations during athletic development (54, 78, 83). Furthermore, significant hormonal changes during adolescence may alter energy availability and recovery times, influencing the training response and adaptation processes (59, 92).

Comfort et al. (20) recently advocated for the integration of Olympic weightlifting (OWL) exercises and their derivatives outlining that the high power-outputs and rate of force development (RFD) reported during OWL movements indicate their potential to enhance maximum strength, vertical jump height, linear sprints, and changing direction performances and should be included into strength and conditioning programs to enhance overall athletic performances (18, 19, 40, 81). The authors also noted that despite safety concerns, substantial evidence supports OWL as safe and beneficial resistance training for children and adolescents (30, 52, 53, 54). Meta-analyses further demonstrate OWL training's effectiveness in improving strength, power, and speed across various athletic populations (6, 34, 64). Nonetheless, contrasting findings are still available in the literature. For instance, some studies found no significant differences in vertical power outputs, 10m, and 30m sprint performance between OWL and types of training (15, 37, 70, 85). These findings are also supported by a recent systematic review with meta-analysis which demonstrated that OWL did not enhance sprint performance (23). Therefore, there is still contrasting evidence on the impact of OWL on strength, power, and speed in adolescent athletes.

This study aims to investigate the effects of an 8-week OWL training program on absolute strength, vertical jump height, and sprint time in Italian elite under-17 (U17) rugby union players. Due to the contrasting findings from previous literature, a specific hypothesis on the effect of OWL on these physical components could not be formulated. However, due to the changes in body mass and stature that occur during adolescence, these components are expected to contribute to the physical performance of young athletes.

METHODS

Subjects

At the beginning of the study 46 young rugby union players (Table 1) were recruited from an Italian semi-professional club and assigned to a control (CON) and intervention (WLG) group. This sample was due to the resource constraints at the club. The two groups were exposed to the same training over the past year, and the WLG was composed by players that enrolled into an extra-curricular program of the club at the start of the sport season. Hence, no additional players could be included in the WLG group due to a lack of additional resources. Resource constraints have been identified by Lakens (49) as a valid justification for sample size. At the time of the study, participants trained three times per week, including three rugby-based and two gym-based sessions, and regularly took part in the elite U17 national championship. However, as is common in longitudinal studies, some dropouts occurred (66, 90). Six participants from the WLG and 10 from the CON dropped out of the study because of injuries, illnesses or lack of compliance (if $< 80\%$ of training sessions) throughout the entire intervention period. Thus, leading to a post intervention sample size of 17 players for WLG and 13 players for CON (Table 1). It was assumed that dropouts were completely random (90). All players were informed about the experimental design and testing procedures. Participants' parents provided informed consent prior to testing. Ethical approval for this study was granted by the Setanta College Research Ethics Committee. All measurements were in accordance with the guidelines of Good Clinical Practice and were in line with the Declaration of Helsinki.

Procedures

Experimental Design

The entire intervention took place at the beginning of the Italian elite U17 rugby union season, from September to December, for a total duration of 10 weeks, including 8 weeks of intervention training. Both groups were assessed pre- and post-intervention on anthropometrics (e.g., stature and body mass), countermovement jump (CMJ) height, 10m and 30m sprint times, and five-repetition maximum back squat (5RM BS). Pre- and post-intervention tests were conducted on two different subsequent days, in the same order and at the same time of day. Sleep hygiene was assessed with

Table 1. Descriptive statistics for anthropometrics of the WLG and CON groups at the start of the intervention.

	CON		WLG	
Characteristics	**Pre**	**Post**	**Pre**	**Post**
Sample size	23	13	23	17
Stature (cm)	175.26 [5.38]	177.69 [5.96]	174.78 [6.79]	175.88 [5.32]
Body mass (kg)	72.05 [8.74]	70.34 [7.93]	75.26 [20.39]	73.74 [10.11]
Age (years)	15.61 [0.50]	15.54 [0.52]	15.26 [0.45]	15.18 [0.39]

Mean [standard deviation].

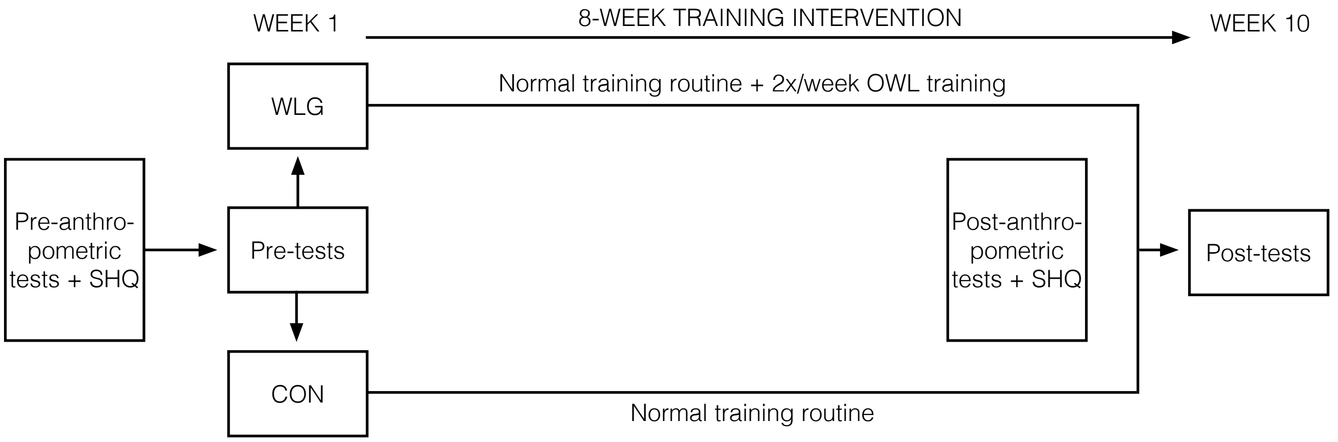

Figure 1. Flow chart of the entire experimental design. Anthrop. tests = stature and body mass measures; 2x/week = 2 training sessions per week.

Table 2. Typical training week of the entire team (WLG+CON) across the 8-week intervention.

Time	Monday		Tuesday		Thursday	
	Forwards	**Backs**	**Forwards**	**Backs**	**Forwards**	**Backs**
7-7.30pm	Unit (pitch-based)	Lower-body workout (gym-based)	Unit (pitch-based)	Upper-body workout (gym-based)	Unit (pitch-based)	Speed and acceleration drills (pitch-based)
7.30-8pm	Lower-body workout (gym-based)	Unit (pitch-based)	Upper-body workout (gym-based)	Unit (pitch-based)	Speed and acceleration drills (pitch-based)	Unit (pitch-based)
8-9pm	Rugby (all team together)		Rugby (all team together)		Rugby (all team together)	

a self-rated questionnaire (SHQ) that was delivered one week before pre- and post-intervention assessments (91). The SHQ contained 20 questions about sleep hygiene, quality, duration, and habits, and it was completed by players and managed using Google Forms (Google LLC, Mountain View, California, United States). Participants were advised to maintain their usual liquid and food intake throughout the entire intervention period. The experimental design is presented in Figure 1.

Over the course of the 8-week intervention, the weekly training regimen comprised three rugby-based practice sessions held in the evenings of Monday, Tuesday, and Thursday. The typical training regimen of the team is presented in Table 2.

Throughout the 8-week period, the WLG engaged in two additional 60-minute OWL training sessions. Tuesday's session focused on clean and jerk techniques and their derivatives, while Thursday's session on snatch techniques and their variations. At the beginning of each session, after a general warmup, a specific OWL routine with an empty bar was performed to reacquaint participants with proper exercise mechanics. Given that the participants were novices in OWL and adhering to the long-term developmental models for OWL skills in youth-based cohorts proposed by Pichardo et al. (70) and Morris et al. (64), the progression of volume, intensity, load management, and difficulty was systematically adjusted over the weeks based on individual capacities and requirements (20,

Table 3. WLG training protocol across the 8-week intervention.

					DAY 1					
Exercise	**Variables**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Exercise**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Hang clean pull + Hang power clean	sets & reps	3 x 5+5	3 x 5+5	3 x 5+5	3 x 5+5	Clean pull + Hang power clean	3 x 3+3	3 x 3+3	3 x 3+2	3 x 3+2
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Hang power clean + Front squat	sets & reps	3 x 3+2	3 x 3+2	3 x 3+2	3 x 3+2	Hang squat clean + Front squat	3 x 2+2	3 x 2+2	3 x 2+1	3 x 2+1
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Power clean + Hang power clean	sets & reps	4 x 2+1	4 x 2+1	4 x 2+1	4 x 2+1	Squat clean + Hang power clean	4 x 2+1	4 x 2+1	4 x 2+1	4 x 2+1
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Push press	sets & reps	4 x 6	4 x 6	4 x 6	4 x 6	Push jerk	4 x 4	4 x 4	4 x 3	4 x 3
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
RPE (0-10)		4	4	5	5		6	6	7	7
					DAY 2					
Exercise	**Variables**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Exercise**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Hang snatch pull	sets & reps	3 x 5	3 x 5	3 x 5	3 x 5	Snatch pull	3 x 4	3 x 4	3 x 3	3 x 3
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Snatch deadlift + Hang power snatch	sets & reps	3 x 2+2	3 x 2+2	3 x 2+2	3 x 2+2	Power snatch + Overhead squat	3 x 2+2	3 x 2+2	3 x 2+2	3 x 2+2
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Power snatch	sets & reps	4 x 3	4 x 3	4 x 3	4 x 3	Squat snatch	4 x 2	4 x 2	4 x 2	4 x 2
	rest	2'-3'	2'-3'	2'-3'	2'-3'		2'-4'	2'-4'	2'-4'	2'-4'
Snatch balance	sets & reps	4 x 5	4 x 5	4 x 5	4 x 5	Snatch balance + Overhead squat	4 x 3+2	4 x 3+2	4 x 2+2	4 x 2+2
		2'-3'	2'-3'	2'-3'	2'-3'			2'-4'	2'-4'	2'-4'
RPE (0-10)		4	4	5	5		6	6	7	7

Since the participants were absolute beginners in using OWL exercises, the load selection for each exercise and session was individually determined by the expert coach. This decision was based on the athlete's technique proficiency, lift timing, and physical condition. RPE = rate of perceived exertion. The Borg CR10 scale was used for RPE values.

64, 70). The Borg CR10 scale for rating perceived exertion (RPE) was employed as a general guideline for managing loading progression by the expert coach (8). It is important to mention that, given the additional stress of rugby and other factors in the participants' lives, the expert coach occasionally suspended progressive loading for some players throughout the 8-week period, providing them with additional recovery time to address injuries, fatigue, or other personal circumstances. Table 3 outlines the acute training variables and progressions of WLG's training intervention across the 8-week duration.

Anthropometrics

Anthropometric data of body mass and stature were collected twice during the entire intervention, three days before commencing the pre- and post- intervention tests, respectively. Stature was measured to the nearest 0.5 cm using a wall-mounted measuring tape (ADE Germany GmbH, Hamburg, Germany). During each measurement, participants were required to maintain an upright stance, arms relaxed beside the body, head neutral, and heels together while wearing only their underwear and competition shorts. Body mass was measured using an electronic scale (Imetec s.p.a., Azzano San Paolo, Bergamo, Italy).

CMJ

The first day of testing vertical power and sprint time were investigated. To assess vertical power, CMJ height was evaluated (factorial validity: r = 0.87; test-retest reliability: ICC = 0.88) (60, 80). Prior to the test, participants conducted a 10-minute specific warm up comprising dynamic stretching, plyometric exercises, and three submaximal repetitions of CMJ, in order to enhance the post-activation performance enhancement (PAPE) (7). To determine CMJ height a portable contact platform was utilized (Chronojump Contact Platform DinA2, Boscosystem, Barcelona, Spain). The device has been shown to have acceptable validity and reliability (validity: r = 0.99; reliability: ICC = 0.99) (72). All jumps were executed with hands on the hips, with legs fully extended during flight times, and with ankles in plantar flexion at landing to ensure standardization of tests (89). Participants performed a downward movement followed by an explosive leg extension. To avoid alterations in the coordination pattern, the depth of the downward movement was self-selected. Each participant performed three attempts, each interspersed by a 3-minute rest period. The average of the three trials was used for data analysis (1).

10m and 30m sprints

To assess speed, 10m and 30m sprint times were assessed. This method has been previously reported as having acceptable reliability (ICCs = 0.96 to 0.98) (16). Ten minutes following the CMJ test, participants completed a 15-minute warm-up protocol consisting of dynamic joint mobility exercises, various skipping drills, and progressive 10-to-30m sprinting (86). Subsequently, players performed three 30m sprints on the rugby pitch (synthetic grass), with 3-minute rest in between. Sprint times were recorded using three double-beam time gates positioned at 0m, 10m, and 30m using the WICHRO Wireless Race Kit (Chronojump, Boscosystem, Barcelona, Spain). Subjects sprinted from a two-point start position with their front foot 0.3m behind the starting line (2). The average of the three attempts for both the distances (10m and 30m) was used for data analysis (1).

5RM BS

On the second day of testing, the 5RM BS was employed to assess absolute strength, which has been reported as one of the most frequently used tests for evaluating this physical characteristic in male adolescent rugby players (67). However, in the literature, there is a lack of test-retest reliability assessments of 5RM BS in adolescent athletes. Participants performed a modified form of a 5RM BS protocol as used by Harries, Lubans, and Callister (35) on sub-elite adolescent rugby union players. The measurement initiated after a specific warm-up protocol, which comprised mobility and muscular activation exercises as well as submaximal sets (43). The test was completed using a 20-kg Olympic barbell, bumper plates, and a squat rack with safety bars (Kingsbox, Tng Oprema d.o.o., Sezana, Slovenia). The range of motion was standardized, with each repetition completed from an upright posture, when the player then descending to a position with the anterior superior iliac spines below the knee-cap horizontal level, then instantly reversing motion and ascending back to the upright position (11, 77). The depth of the squat was visually verified by the lead test administrator, positioned at an angle of 30°-40° in front of the subjects, to ensure that the required depth was achieved for each repetition (74). Participants performed 5-repetition sets gradually increasing the load until failure. The heaviest 5-repetition set completed was recorded for analysis.

Statistical Analyses

Data and statistical analyses were conducted using R v4.3.1 (73) in RStudio (RStudio Team, 2018, v1.2.1335). Differences in dropouts between groups were identified using Fisher exact test. Before any formal statistical analysis, data were investigated to detect potential outliers, which were defined as "an observation (or subset of observations) which appear to be inconsistent with the remainder of that set of data" (4). Potential outliers were identified using univariate (i.e., box plots, 3 x standard deviation, modified z-scores) and multivariate (i.e., leverage, changes in Akaike Information Criteria, DFFITS, Cook's distance) approaches. This study used a frequentist approach for statistical analysis and inference (79). The effects of time (i.e., pre versus post intervention), group (i.e., WLG versus CON), and their interaction were investigated initially using a simple linear model (i.e., analysis of variance) and then using general linear mixed-effects models with the package's stats and lme4 (5, 39). Time, group, and their interaction were initially included as fixed effects whilst the intercept was included as a random effect that could vary based on the subjects. Successively, stature and body mass of the participants were included in the models as covariates and maintained only if there was evidence that they would improve model fit. Model selection was based on the initial hypotheses, simplicity of the model, Akaike Information Criteria, likelihood ratio test (79). After fitting the models, estimated marginal means were computed for the main factors using the emmeans package (50). Post-hoc comparisons between factor levels were adjusted to control the false discovery rate using Bonferroni (50). Model assumptions were investigated using the performance package (57). Linearity, normality of residuals, and normality of random effects were visually inspected. Multicollinearity was identified by a variance inflation factor greater than five (J42). Homogeneity of variance was detected using the

Breusch-Pagan test (10). When heteroscedasticity was violated, model parameters were re-estimated using cluster-robust covariance estimation using the parameters package (56).

Statistical inference was conducted using the maximum likelihood estimates for the parameters of the models, and their respective standard errors (79). Wald statistics (i.e., z and t values) were calculated to test the null hypotheses that model coefficients were equal to zero (79). A Wald statistic close to zero suggests that the data is consistent with the null hypothesis, whereas more extreme values suggest evidence against the null hypothesis (22). The probability values (i.e., *p* values) produced from the Wald statistics were interpreted following Cox's recommendation: $p \geq 0.1$ "accord with the null hypothesis is as good as could reasonably be expected", $p \leq 0.01$ "there is, for most purposes, overwhelming evidence against the null hypothesis", intermediate values "there is some evidence against the null hypothesis" (22). In addition, 95% Wald confidence intervals were computed to identify a range of parameter values compatible with the data under the specified model (79). An effect was identified based on its Wald statistic, *p* value, and confidence interval not including zero. Ultimately, Cohen's d effect sizes, with respective standard errors and 95% confidence intervals, were determined using the effect size function from emmeans package (50) and using the residual standard deviation of the general linear mixed-effects model and its degrees of freedom.

RESULTS

There was no evidence to support the existence of differences in the dropout patterns for both groups (Fisher exact test: $p = 0.3534$). After dropouts, only 70% of the participants completed both the pre- and post-intervention SHQ questionnaires. In the pre-intervention SHQ, 33.3% of those participants who replied to both claimed they slept an average of 8 or more hours each night, compared to 23.8% in the post-intervention questionnaire. In addition, during the pre-intervention SHQ, 38.1% reported a deep sleep routine, compared to 28.6% in the post-intervention questionnaire.

The process of outlier detection led to the identification of player IDs 0 and 22 as potential outliers for 10m and 30m sprints. These players presented the greatest body mass of the sample (i.e., > 103 kg) which was not consistent with the rest of the participants (i.e., median: body mass = 72.05). Due to the player's extreme anthropometrics, it was decided to remove players 0 and 22, belonging to the WLG group, from the analysis of 10m and 30m sprints. All available observations were maintained for the analysis of CMJ and 5RM BS. Descriptive statistics are presented in Table 4.

The process of model selection led to the final models used for inference being linear mixed-effects models whose fixed effects are presented in Table 4. Estimated marginal means and effect sizes are included in Table 5. No difference between groups and pre-post intervention was identified for CMJ. However, taller players demonstrated a greater CMJ height, and heavier players exhibited a lower CMJ. Sprint performance over 10 and 30 meters presented similar findings, with a decrease from pre- to post-intervention for both groups by 0.09 seconds in the CON group and by 0.05 seconds in the WLG group (Table 6). Furthermore, taller players showed better sprint performance, and heavier players inferior performance (Table 5). Strength improved for both groups from pre to post intervention, but estimated marginal means post-hoc analysis did not identify differences between groups at the two time points (Table 6). However, the rate of increase in the OWL group was substantially higher than in the CON group (time x group: MLE [SE] = 7.30 [1.83], 95%CI = [3.65, 10.94], $t = 3.99$, $p < 0.001$) (Table 5). In addition, heavier players were stronger with a greater 5RM BS. The estimated values from the final models with respective 95% Wald confidence intervals are presented in Figure 2.

Table 4. Descriptive statistics without outliers for WLG and CON in CMJ, 10m sprint, 30m sprint, and 5RM back squat pre- and post- intervention tests. Mean [standard deviation].

	CON		WLG	
Characteristics	**Pre**	**Post**	**Pre**	**Post**
CMJ Height (cm)	33.19 [6.41]	35.62 [7.55]	30.77 [6.02]	32.96 [6.16]
10 m sprint (s)	1.96 [0.12]	2.01 [0.15]	1.94 [0.08]	1.99 [0.13]
30 m sprint (s)	4.70 [0.34]	4.78 [0.42]	4.63 [0.23]	4.73 [0.31]
5RM BS (kg)	68.69 [13.67]	79.15 [16.57]	69.52 [12.61]	89.71 [13.31]

Notes: CMJ = countermovement jump, BS = back squat, WLG = weightlifting group, CON = control group.

DISCUSSION

This study examined the effects of OWL training on strength, power, and speed in adolescent rugby union players. In line with previous studies (23, 37), there is no clear evidence to support the benefit of OWL in developing strength, power, and speed in adolescent athletes without previous experience with these exercises, as an addition to other training methods (i.e., traditional resistance training, plyometric training). Specifically, there was no difference between groups both at pre- and post-intervention for strength, power and speed (Table 5).

Strength improved on average by 10 kg from pre- to post-intervention for both groups (Table 5). Furthermore, the rate of strength development was substantially greater in the WLG compared to the CON (Table 5), thus demonstrating that OWL may allow adolescent male athletes to increase their strength more rapidly over time. Consequently, practitioners may consider OWL as a more efficient tool for developing strength than traditional resistance training in adolescent male athletes. These findings align with those of other studies, indicating that OWL may enhance maximal strength performance more effectively than other training methods (36, 44). The contribution of OWL to vertical power outputs remains unclear, as no statistical differences were detected between WLG and CON after the 8-week training intervention period (Table 5). Similarly, the study by Channell and Barfield (15) found no significant difference in improving vertical power between OWL and traditional resistance training.

Speed performance decreased over time, likely due to growth, increased fatigue, and testing conditions. Most participants (86.7%) grew by at least 1 cm, with a higher proportion in the WLG group (94.1%) compared to the CON group (76.9%). These anthropometric changes may have influenced physical adaptations during the training intervention (52, 76, 84, 92). This growth appears to have significantly impacted speed-related performance in both groups (9, 17, 94). Zabaloy et al. (94) reported reduced sprint durations in adolescent rugby players, attributing this to anthropometric changes. Similarly, Casserly et al. (12) identified

Table 5. Fixed effects for the models used for inference.

DV	Fixed effect	MLE	SE	95%CI	*t*	*p*
CMJ	Intercept	33.15	1.13	[30.88, 35.41]	29.22	<0.001
	Time	-0.19	0.75	[-1.68, 1.30]	-0.26	0.799
	Group	-1.45	1.61	[-4.68, 1.78]	-0.89	0.374
	Stature	0.49	0.15	[0.19, 0.78]	3.32	0.001
	Body mass	-0.23	0.06	[-0.35, -0.11]	-3.95	<0.001
	Time x group	0.24	0.97	[-1.69, 2.17]	0.25	0.80
10m	Intercept	1.97	0.02	[1.93, 2.00]	107.92	< 0.001
	Time	0.09	0.02	[0.04, 0.13]	3.60	< 0.001
	Group	-0.03	0.03	[-0.08, 0.02]	-1.02	0.309
	Stature	-0.0097	0.0023	[-0.01, -0.01]	-4.19	< 0.001
	Body mass	0.0059	0.0017	[0.00, 0.01]	3.59	< 0.001
	Time x group	-0.04	0.03	[-0.10, 0.02]	-1.33	0.188
30m	Intercept	4.70	0.06	[4.59, 4.82]	82.94	< 0.001
	Time	0.20	0.03	[0.13, 0.27]	5.73	< 0.001
	Group	-0.09	0.08	[-0.25, 0.06]	-1.20	0.234
	Stature	-0.03	0.0069	[-0.04, -0.01]	-3.76	< 0.001
	Body mass	0.01	0.004	[0.00, 0.02]	2.67	0.010
	Time x group	-0.08	0.04	[-0.16, 0.01]	-1.81	0.076
5RM	Intercept	69.01	2.67	[63.69, 74.33]	25.86	< 0.001
	Time	10.76	1.11	[8.54, 12.98]	9.65	< 0.001
	Group	-0.13	3.54	[-7.19, 6.94]	-0.04	0.972
	Body mass	0.30	0.10	[0.09, 0.50]	2.86	0.006
	Time x group	7.30	1.83	[3.65, 10.94]	3.99	< 0.001

Table 6. Post-hoc comparisons for time and group and effect sizes.

DV	Group	Contrast	Estimate	SE	95%CI	*t*	*p*	ES [95%CI]
CMJ	CON	Pre – Post	0.19	0.79	[-1.33, 1.72]	0.26	0.80	0.10 [-0.71, 0.91]
	WLG	Pre – Post	-0.05	0.66	[-1.41, 1.30]	-0.08	0.94	-0.03 [-0.75, 0.69]
	Pre	CON – WLG	1.45	1.62	[-1.81, 4.71]	0.89	0.37	0.77 [-0.97, 2.51]
	Post	CON – WLG	1.20	1.71	[-2.23, 4.64]	0.70	0.48	0.64 [-1.19, 2.48]
10m	CON	Pre – Post	-0.09	0.02	[-0.13, -0.04]	-4.07	0.0003	-1.58 [-2.42, -0.74]
	WLG	Pre – Post	-0.05	0.02	[-0.09, -0.01]	-2.46	0.02	-0.87 [-1.62, -0.13]
	Pre	CON – WLG	0.03	0.03	[-0.03, 0.08]	0.88	0.38	0.48 [-0.62, 1.58]
	Post	CON – WLG	0.06	0.03	[-0.002, 0.13]	1.93	0.06	1.19 [-0.06, 2.44]
30m	CON	Pre – Post	-0.20	0.03	[-0.27, -0.13]	-6.13	< 0.0001	-2.50 [-3.44, -1.56]
	WLG	Pre – Post	-0.12	0.03	[-0.18, -0.06]	-4.07	0.0003	-1.53 [-2.34, -0.72]
	Pre	CON – WLG	0.09	0.08	[-0.08, 0.26]	1.10	0.28	1.17 [-0.98, 3.33]
	Post	CON – WLG	0.17	0.09	[-0.01, 0.35]	1.94	0.06	2.15 [-0.10, 4.40]
5RM BS	CON	Pre – Post	-10.80	1.46	[-13.7, -7.77]	-7.36	< 0.0001	-2.88 [-3.82, -1.94]
	WLG	Pre – Post	-18.10	1.28	[-20.7, -15.44]	-14.13	< 0.0001	-4.83 [-5.93, -3.74]
	Pre	CON – WLG	0.12	3.81	[-7.56, 7.81]	0.03	0.97	0.03 [-2.02, 2.09]
	Post	CON – WLG	-7.17	3.98	[-15.15, 0.81]	-1.80	0.08	-1.92 [-4.08, 0.24]

Notes: DV = dependent variables, CMJ = counter movement jump, CON = control group, WLG = weightlifting group, SE = standard error, 95%CI = 95% confidence interval, t = Wald statistic, p = probability value, – = subtraction operator, ES = effect size. The estimate is determined as the difference between Pre and Post, and between CON and WLG, and its unit of measurement is cm for CMJ, seconds for 10m and 30m sprint, and kg for 5RM BS.

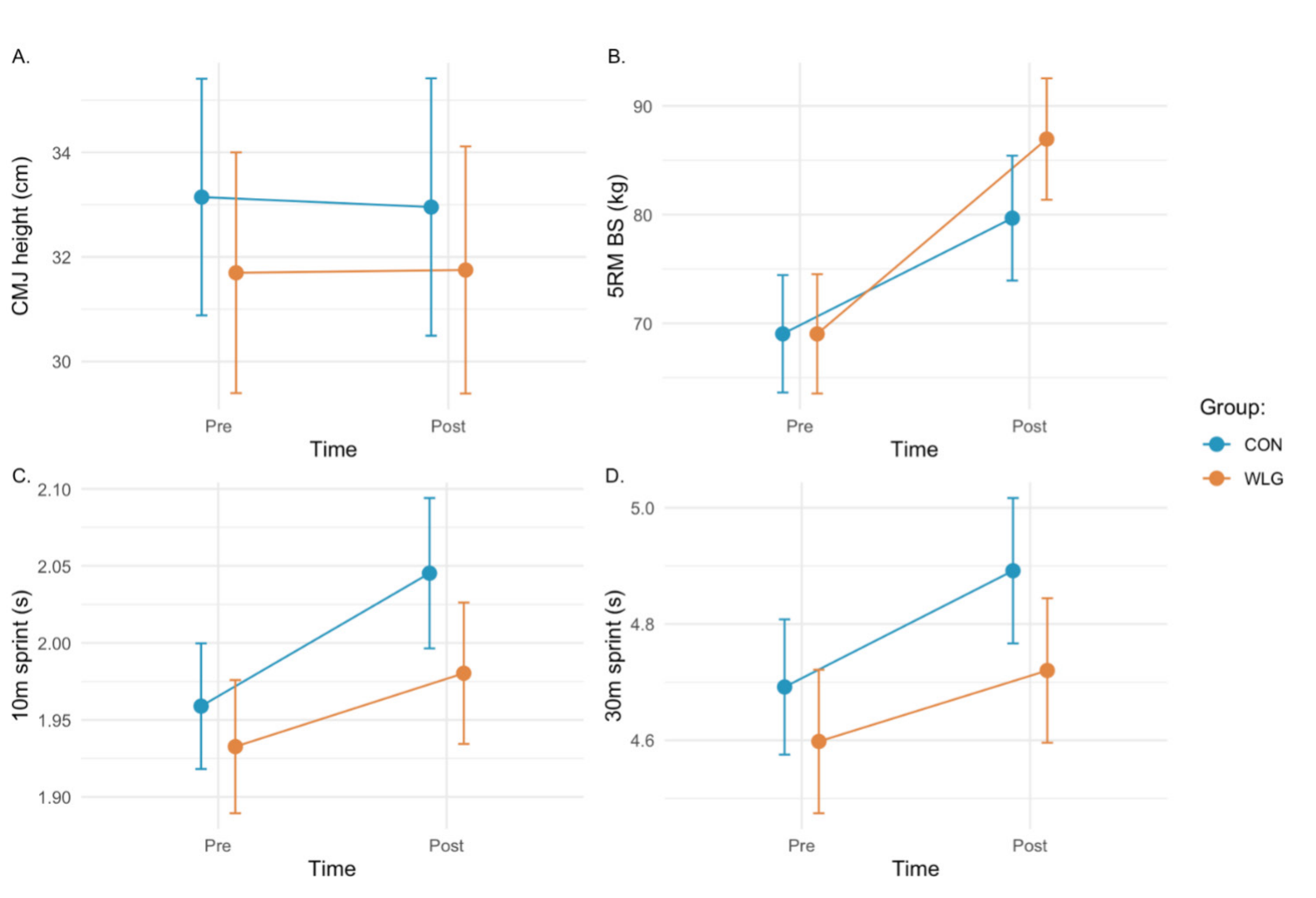

Figure 2. Model estimated values and 95% Wald confidence intervals for CMJ, 5RM BS, 10m and 30m sprint for both CON and WLG groups.

these changes as a likely mediator of speed performance. The current study's findings align with Tricoli et al. (85), who observed no improvements in 30m sprint performance in college students, and Pichardo et al. (70), who found no differences in 10m sprint times between OWL and a combination of plyometrics training and traditional resistance training.

Another possible influencing factor may be the difference in ambient temperature between pre-intervention and post-intervention testing. The current investigation was conducted in northern Italy in 2022, where the external temperature varied significantly between September (average *t* = 22° to 16° C) and December (average *t* = 5° to -1° C). Colder conditions may have led to performance impairments during the post-interventional testing (13, 33). More specifically, the participants' maximal muscular contractile potential and the rate of force production may have been decreased by the cold temperature, implying that power and speed abilities may have been partly affected (26, 33, 69). It is worth outlining that WLG had a reduced impairment in 10m (+0.05 vs +0.09 sec) and 30m (+0.12 vs +0.20 sec) sprint performance compared to CON (Table 5). Therefore, these outcomes may indicate that OWL partly assisted the players in mitigating impairments in sprint ability. Based on this evidence, practitioners should monitor the growth of their athletes and be aware that growth and environmental constraints (e.g., temperature) may affect sprint performance. In addition, practitioners may consider the use of OWL to avoid excessive decreases in sprint ability of adolescent male athletes.

The vast majority of participants (86.7%) demonstrated an increase in stature by at least 1 cm, with those in the WLG exhibiting a higher proportion (94.1%) compared to those in CON (76.9%). These anthropometric variations may be regarded as factors that may possibly have influenced physical adaptations during the entire training intervention (52, 76, 84, 92). This is supported by the evidence from the current study which demonstrated that stature and body mass have a substantial effect on strength, power and speed performance. This phenomenon might be seen as a consequence of the challenges related to the growing youth player, where high-quality coordination, balance, muscle activation patterns and motor unit recruitment may be negatively affected, potentially resulting in a temporary decrease in performance (12, 56, 78, 87, 94). 265the importance of growth monitoring in adolescent male athletes.

Participants' complete lack of OWL background is another important aspect to consider. In order to perform these complex movements (i.e., snatch and clean & jerk) under heavy loads a systematic long-term approach is recommended (20, 64, 82). In the early phases of this process, the emphasis should be on building the athlete's technical literacy rather than optimizing their strength and power development, to avoid technical deficiencies that may become more difficult to correct later in the athlete's development (58, 82). In fact, the quality of lifting technique can influence an athlete's ability to produce force (14, 48, 65). As a result, given that the participants were beginners in OWL, and the intervention had a technical coaching focus primarily, they may have been unable to express their maximal force production during the OWL-based sessions, possibly leading to reduced gains in strength, power, and speed related metrics. Additionally, as reported in the results section, the lower percentage of participants sleeping 8 or more hours per night and reporting a deep sleep routine between pre- and post-intervention assessments may have contributed to decrements in overall performance, most likely due to fatigue caused by school-related stress and ongoing championship demands (21, 45, 93).

Limitations of the present study include that the participants were all from the same rugby club and the non-randomized selection, due to personal choices made before the beginning of this interventional controlled trial, limiting the generalizability of the study findings. Although the mixed-effects models used can appropriately handle the data structure of the study, the dropout in both groups may have contributed to increasing the variability in the data, and definite conclusions should be made with caution. Another limitation of the present study was the assessment of stature and body weight only, without using any Peak Height Velocity (PHV) assessment tools, such as the Khamis and Roche's method (47) to carefully monitor maturational status, which may have been beneficial to further personalize training progressions. Moreover, while stature was assessed, limb length anthropometrics were not, and variations in limb growth may have some impact on players' movement efficiency and capacity. This, however, is not an area that has been adequately addressed within the wider research literature. Conclusively, the length of the SHQ (20 questions) may have impacted on the compliance of the subjects in filling out both pre- and post-intervention forms.

CONCLUSION

Based on the present findings, there is no clear evidence to support the benefit of OWL in developing strength, power, and speed in adolescent athletes without previous experience with these exercises, as an addition to other training methods (i.e., traditional resistance training, plyometric training). However, practitioners may decide to use OWL, as incorporating OWL movements into training programs for youth rugby union athletes may result in more rapid increases in absolute strength, and it may mitigate the decrease in speed performance in adolescent athletes. In addition, it was identified that both stature and height substantially affect the strength, power, and speed performances of adolescent athletes. This supports the importance for practitioners of accounting for individual differences in response to this training method and outlines the importance of constantly assessing and cautiously considering the potential alterations in stature and body weight that occur during this period of life to better understand their impact on physical performance.

FUTURE RECOMMENDATIONS

Integrating an OWL-based learning period before intervention trials, especially for athletes new to this training method may lead to different results. Therefore, future research should employ randomized participant selection and assess the long-term effects of OWL on athletic performance and injury risk in young rugby players following an introductory period to these exercises. Exploring the benefits of combining OWL exercises with other training methods (i.e., traditional resistance training, plyometric training) and utilizing PHV assessment tools like Khamis and Roche's (47) method and conducting Peak Weight Velocity (PWV) studies could enhance understanding.

CONFLICTS OF INTEREST

The authors do not have conflicts of interest.

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ETHICAL APPROVAL

Ethical approval for this study was granted by the Setanta College Research Ethics Committee. All measurements were in accordance with the guidelines of Good Clinical Practice and were in line with the Declaration of Helsinki.

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