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The Squat One Repetition Maximum May Not Be the Best Indicator for Speed-Related Sports Performance Improvement in Elite Male Rugby Athletes

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Abstract: In the strength and conditioning field, a variety of training exercises are being applied to improve speed-related performance, but there is a lack of traditional strength training guides that can be used for training effectiveness. The aim of this study was to assess the impact of a six-week traditional strength training program on elite rugby players and explore the relationships between the one repetition maximum (1RM) of traditional strength exercises and athletic performance. Twenty elite rugby players (age = 30.5 ± 1.5 years, mass = 96.7 ± 16.6 kg, height = 179.3 ± 6.0 cm) completed the strength training program, and 1RM values for bench press, squat, deadlift, and power clean, along with athletic performance metrics (20 m and 40 m sprints, vertical jump, broad jump, Bronco test, L-run), were measured before and after the training period. Medium effect sizes were observed in the deadlift ($p = 0.04$, d = 0.49) and bench press ($p = 0.019$, d = 0.57) 1RM, while the squat exhibited a very large effect size ($p < 0.001$, d = 2.08). Both before and after training, greater power clean 1RM demonstrated a strong correlation with each athletic performance test. However, bench press 1RM, both pre-and post-training, did not significantly associate with functional performances ($p > 0.05$). Notably, power clean 1RM showed the strongest correlation with athletic performance; despite being the most significant improvement in squat 1RM after the six-week training period, it was not associated with athletic performance outcomes in rugby players. This study underscores the varied impact of specific strength exercises on athletic performance, emphasizing the distinct role of power clean 1RM in predicting speed-related performance in male rugby players.

Keywords: bench press; power clean; rugby conditioning; strengthening; athletic training; strength assessment

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1. Introduction

Rugby is a physically demanding sport that requires a combination of physical attributes such as proficiency in body contact, sprinting capability, and agility. These attributes are essential for high-intensity sports activities [1] and contribute significantly to optimal performance against competitors. In the past two decades, conventional strength training methods such as deep squat, deadlift, clean, and bench press have faced skepticism as outdated techniques. On the one hand, training methodologies increasingly incorporate exercises aimed at injury prevention, such as movement screening or rubber resistance exercises [2,3]. In recent years, with the development of sports technology, there has been a growing reliance on machine-measured data [4]. While these technological advances have their benefits, they tend to make conventional strength training less important. However, research argues that high-intensity traditional strength training, widely viewed as antiquated, can still produce favorable outcomes in readying athletes for unpredictable sports scenarios [5]. Specifically, it enhances neural activity, increases the rate of force development, and effectively produces power [6,7]. In addition, these trainings elevate muscle firing rates and motor unit activities through calcium regulation in the sarcoplasmic reticulum [8]. Previous research suggests that traditional strength training has a positive impact on rugby performance [9,10].

Several studies have examined training methods for improving sports performance. Hartmann et al. [11] discovered that strength training, based on a periodization model, generated a potentiation effect on strength and speed-strength, which lasted for 48–148 h. Participants who showed higher squat [12] and bench press [13] capacities achieved quicker sprint times, indicating a favorable association between conventional strength training and speed performance. Swinton (2014) discovered that athletes with exceptional deadlift records had better performance in the 505 agility test, which is critical in tactical sports such as rugby [14]. Variations in performance outcomes have been observed based on instructional differences or training execution, despite numerous studies emphasizing the beneficial effects of traditional strength training [15].

Identifying the most effective strength training tool for maximizing performance becomes crucial in achieving the specific goals of strength training for athletes, potentially outweighing the adoption of various training methods. Therefore, prioritizing the identification of the optimal strength training tool is imperative for athletes seeking to enhance their performance. However, there is a lack of information regarding which traditional strength training methods coaches should select for their strengthening programs, as there is no consensus on the optimal strength assessment based on previous investigations [11–14]. Therefore, this investigation aimed to evaluate the effect of six weeks of traditional strength training and to identify the relationships between the improvement of speed related performance and each strengthening exercise. To accomplish this aim, we hypothesized that six weeks of traditional strength training would improve speed-related performance in male rugby players and that improvements in squat and power clean would correlate with improved speed-related performance. The study outcomes can be a significant indicator for evaluating the impact of strength testing on enhancing sports performance. Furthermore, a close connection between specific strength training exercises and performance enhancement can offer valuable insights for strength conditioning coaches seeking to design effective strength programs.

2. Materials and Methods

2.1. Participants

Twenty elite-level rugby players participated in the current study, voluntarily. The participants had an average age of 30.5 ± 1.5 years, a body mass of 96.7 ± 16.6 kg, and a height of 179.3 ± 6.0 cm. An a priori power analysis using G*power was conducted to determine the minimum number of participants required. Effect size calculations were based on a comprehensive review of various studies demonstrating improvements in athletic performance after strength training, indicating medium to large effect sizes [16]. Nineteen participants, at minimum, were deemed necessary to observe a medium-large effect size (Cohen's d = 0.8) at an alpha level of 0.05, with a power (1 − β) of 0.8. Participants were elite rugby players currently playing for the professional team, and all data were collected from players who agreed to participate in the study. Players were eligible to participate in the study if they were a member of the team but were excluded if they were unable to participate in the strength testing and training due to an injury within the last three months. In addition, those who used drugs, medications, or dietary supplements for performance-enhancement purposes were omitted as part of the exclusion criteria. The Institutional Review Board of the University approved the study protocol, and all participants provided written informed consent.

2.2. Procedure

This study utilized a cross-sectional design, as depicted in Figure 1. Participants underwent diverse tests during pre-testing sessions that spanned three days. Uniformly scheduled testing sessions were implemented to minimize the potential impact of circadian rhythms, with all participants receiving standardized meals on the day of testing. Pre- and post-testing procedures were administered consistently throughout the study.

Figure 1. Study procedure: RM, repetition maximum.

2.3. 1RM Test

The 1RM testing procedures adhered to guidelines set by the National Strength and Conditioning Association (NSCA) [17] and were overseen by a strength & conditioning (S&C) coach accredited by the World Rugby S&C. On the day of the 1RM test, participants completed the bench press, squat, deadlift, and power clean in a random order following explicit instructions outlined in the testing protocol. Prior to the 1RM testing, a standardized 15-min dynamic warm-up was conducted. Subsequently, participants performed a submaximal warm-up lifting session for all exercises, which consisted of five sets (repetitions: 8, 3, 1, 1, and 1; intensity: 50, 70, 80, 90, and 100% of estimated 1RM), as referenced in [18]. Between trials, a rest period of 3 mins was granted, with a 5-min break given between exercises following the 1RM test [19]. All 1RM information collected was normalized based on body weight to conduct subsequent analysis [20].

2.3.1. Bench Press

Participants conducted the bench press on a strong bench located within the power rack (Respect Athlete, Mokpo, Republic of Korea). They were permitted to choose their own grip and width, before lifting the barbell and lowering it to approximately 3 cm above the xiphoid process. After lightly touching the barbell to their chest, they fully extended their elbows and pushed the barbell upward. Participants were directed to coordinate their hip movement with the extension of their elbow, and any attempt where the barbell bounced off the chest was excluded.

2.3.2. Squat

Participants performed squats using an Olympic barbell (XPodium, Cheonan, Republic of Korea) in a high-bar position within a power rack. The squat descent ended when the thigh was parallel to the ground, with subsequent return to the starting position. A strength and conditioning coach monitored squat depth laterally to the power rack, while safety bars were positioned 5–10 cm below the lowest point of the movement to prevent injury.

2.3.3. Deadlift

Participants utilized the customary technique for performing the deadlift exercise, using a grip they personally chose (excluding the reverse grip). Once the grip was chosen, it remained constant throughout the post-testing session. Starting from a position where the feet were separated by approximately shoulder-width and the hips were between the shoulder and knee height, the participants were directed to extend their knee and hip, raising the barbell off the ground until it was in an upright position [21].

2.3.4. Power Clean

During the power clean evaluation, participants assumed a self-selected grip and situated themselves in front of the Olympic barbell. In the initial pull, the hips and knees were forcefully extended to raise the barbell from the floor. After that, the subjects propelled their hips forward in preparation for the second pull. By employing a dynamic extension of their hips, knees, and ankles, participants seamlessly moved into the catching phase with a partial squat position. This detailed process aims to enhance the production of explosive power necessary for the effective implementation of the power clean.

2.4. Performance Test

2.4.1. 20 m/40 m Sprint Test

Performance tests were conducted 48 h after the 1RM tests, preceded by a 10-min standardized warm-up. In the 20 m and 40 m sprint tests, subjects assumed a 2-point starting position without the use of starting blocks. Positioned on the starting line, subjects initiated the sprint explosively upon the strength and conditioning (S&C) coach's whistle. Each participant underwent two sprint trials, and the best recorded time was selected for analysis. An automatic timing gate (Daewoo Sports Industry, Seoul, Republic of Korea) was employed to record the times, with a 90 s resting interval between trials. The 20 m sprint and 40 m sprint were completed as separate components of the testing protocol (Figure 2).

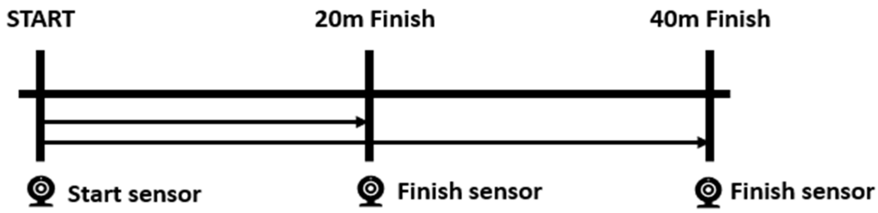

Figure 2. Illustration of 20 m/40 m sprint test.

2.4.2. Vertical Jump

The vertical jump test utilized the Vertec. The starting point for each jump was determined by extending the hands to the highest reachable distance. Subsequently, participants were instructed to execute a maximal jump, and the highest point achieved was recorded [22]. Two trials of the vertical jump were conducted with a 30 s interval between attempts, and the best score was utilized for analysis.

2.4.3. Broad Jump

The broad jump was conducted on the floor using a tape measure. Participants positioned themselves on the starting line with both feet and initiated a forward jump with bent knees, utilizing arm swing for support [23]. Two trials of the broad jump were completed, separated by a 30 s interval. The best score obtained was selected for analysis.

2.4.4. L-Run

The L-run involved placing three cones in an L-shaped configuration, each 5 m apart. Participants commenced the run explosively upon the starting whistle, progressing forward and executing a left turn at the second cone. At the third cone, a right-sided turn was performed before returning to the second cone and finally back to the starting line. Participants were directed to complete the course as swiftly as possible [24]. Running times were recorded using an automatic timing gate (Figure 3). Two L-run trials were completed with a 2 min interval between attempts, and the best score was chosen for analysis.

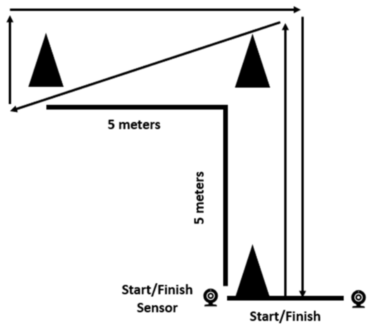

Figure 3. Illustration of L-run test.

2.4.5. Bronco Test

For the Bronco test, cones were placed at 20 m, 40 m, and 60 m. Participants were instructed to run from the starting lint to the 20 m point and back, then run from the starting line to the 40 m point and back, and finally run from the starting line to the 60 m point and back [25]. When they completed the 20 m, 40 m, and 60 m shuttle run (total of 240 m), it was counted as completion of one repetition. Participants were required to complete five repetitions, to run for total of 1200 m, as quickly as possible(Figure 4). A hand-held stopwatch was used to record running time (Casio HS-80TW-1D).

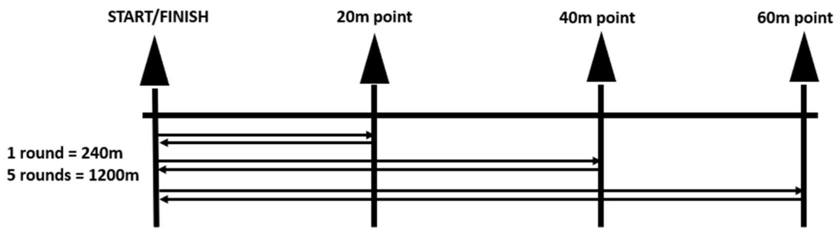

Figure 4. Illustration of Bronco test.

2.5. Strength Training Protocol

All subjects completed a strength training program 4 times a week for 6 weeks. Each session lasted 90 min, including a pre-activation program. The strength training program was designed based on the results of 1RM pre-testing. The goal intensity of strength training was the level of 90% of 1RM pre-testing. The intensity of the 1st week training was an average of 65% of 1RM, then the intensity was gradually increased up to 90% of 1RM at the 6th training week. The volume of the training was manipulated through the repetitions and sets. The work: rest ratio was set as a 1:3. The brief training protocol is described in Table 1. Since this exercise intervention was part of pre-season training, all participants completed standardized pre-activation programs and body-building protocols in addition to the strength training.

2.6. Statistical Analysis

The Shapiro–Wilk test was conducted to assess the data normality, and it was confirmed that the data were normally distributed ($p > 0.05$). Due to the normal distribution, data are described in terms of the mean and standard deviation (SD). A paired-T test was utilized to determine differences between pre-training and post-training effects. Pearson correlations were performed to determine the significance of the association between each traditional strength test and functional performance. Effect sizes were reported by Cohen's d, which was classified as 0.2 = small, 0.5 = medium, 0.8 = large, and 1.3 = very large. Statistical analyses were performed using RStudio version 4.2.3 (RStudio, Inc., Boston, MA, USA) with statistical significance set a priori at $\alpha \leq 0.05$.

Table 1. Six-week strength training protocol.

Exercise	Week 1 Sets/Reps	Week 1 %1RM	Week 2 Sets/Reps	Week 2 %1RM	Week 3 Sets/Reps	Week 3 %1RM	Week 4 Sets/Reps	Week 4 %1RM	Week 5 Sets/Reps	Week 5 %1RM	Week 6 Sets/Reps	Week 6 %1RM
BP	5/6–10	60–72	5/5	75–77	5/3–5	80–83	5/5	85–87	5/2–4	88–90	4/3–5	90
SQ	5/8	63–66	5/6–8	68–72	5/5–8	75–78	5/5	82–85	3–4/2–4	88–90	3/2–4	90
CL	7/3	60–70	7/3–5	73–75	7/3–5	77–80	7/2–5	83–87	6/2–4	90	6/1–5	90
DL	5/8	65–68	5/6–7	72–75	5/5	78–83	3/5	85–88	3/3–4	90	3/1–3	90

RM, repetition maximum; SQ, squat; DL, deadlift; CL, power clean.

3. Results

3.1. 1RM Test

The 1RM test results for all strength assessments demonstrated a notable increase following six weeks of strength training, as presented in Table 2. Moderate effect sizes were observed in deadlift (d = 0.49) and bench press (d = 0.57), signifying a meaningful improvement. Remarkably, the squat exhibited a very large effect size (d = 2.08), indicating the most substantial enhancement in 1RM after the strength training period. Furthermore, improvements were observed in the 20 m sprint, 40 m sprint, vertical jump, and broad jump after strength training. However, the Bronco test and L-run test did not exhibit any noticeable improvement, as outlined in Table 2.

Table 2. Pre- and post-performance and 1RM test.

	Pre	Post	t-Statistics	p	95% CI Lower	95% CI Upper	ES
20 m (s)	3.01 ± 0.15	2.93 ± 0.16	4.70	<0.001	0.049	0.127	1.08
40 m (s)	5.47 ± 0.37	5.35 ± 0.31	3.61	0.002	0.051	0.194	0.83
VJ (cm)	57.42 ± 6.71	60.87 ± 5.75	−4.65	<0.001	−4.995	−1.895	−1.04
BJ (cm)	249.00 ± 17.05	260.11 ± 17.32	−4.33	<0.001	−16.529	−5.693	−1.02
Bronco (s)	359.90 ± 43.60	362.45 ± 43.88	−0.53	0.605	−12.700	7.600	−0.12
L-run (s)	8.13 ± 0.42	8.12 ± 0.38	0.28	0.781	−0.105	0.138	0.06
BP (kg/body mass)	1.41 ± 0.21	1.44 ± 0.23	−2.56	0.019	−0.058	−0.059	−0.57
SQ (kg/body mass)	1.79 ± 0.24	1.93 ± 0.26	−9.31	<0.001	−0.165	−0.104	−2.08
DL (kg/body mass)	1.92 ± 0.35	2.01 ± 0.35	−2.21	0.04	−0.179	−0.005	−0.49
CL (kg/body mass)	1.12 ± 0.19	1.21 ± 0.19	−4.98	<0.001	−0.121	−0.049	−1.11

BP, bench press; SQ, squat; DL, deadlift; CL, power clean; VJ, vertical jump; BJ, broad jump; L, L-run; ES, Cohen's d effect size: 0.2 = small, 0.5 = medium, 0.8 = large, and 1.3 = very large.

3.2. Relationships between Pre-Strength Training and Functional Performance

A greater bench press 1RM was correlated with superior performance in the 40 m sprint, while a greater deadlift 1RM was associated with enhanced results in the 20 m sprint, 40 m sprint, Bronco test, and L-run tests. Notably, a higher power clean 1RM exhibited positive associations with all performance tests. However, squat 1RM did not show significant relationships with any of the functional performances, as depicted in Figure 5.

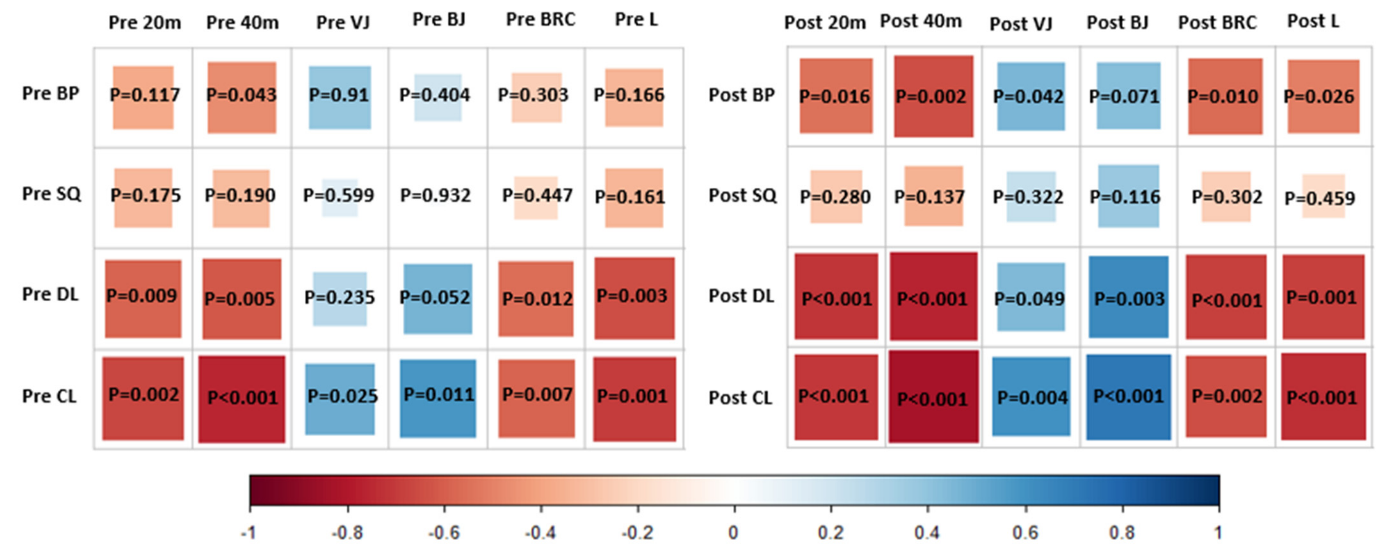

Figure 5. Correlation matrix between pre- and post-traditional strength test 1RM and functional performance test. Larger squares and darker blues indicate strong positive relationships. Larger squares and darker reds indicate stronger negative relationships: BP, bench press; SQ, squat; DL, deadlift; CL, power clean; VJ, vertical jump; BJ, broad jump; BRC, bronco test; L, L-run.

3.3. Relationships between Post-Strength Training and Functional Performance

Following six weeks of strength training, improvements in bench press, deadlift, and power clean 1RM were linked to improvements in all performance tests. However, it is noteworthy that bench press 1RM did not exhibit significant associations with all functional performances, as illustrated in Figure 5.

4. Discussion

Following six weeks of traditional strength training, significant enhancements were observed in 1RM records across all exercises. Notably, the squat exhibited the most substantial improvement in 1RM, with a notably large effect size (d = 2.08). Despite this improvement, the squat surprisingly showed no correlation with power output. Conversely, post-training bench press 1RM demonstrated associations with most performance records, excluding the long jump. Furthermore, post-training deadlift and clean 1RM exhibited high correlations with several performance tests (deadlift: 20 m and 40 m; clean: 20 m, 40 m, broad jump, L-run).

The finding that the greatest improvement in squat performance did not correlate with performance test results is intriguing. Overcoming a sticking point, indicative of a slow or weak phase in the movement, is crucial for increasing squat weights [26]. Athletes are traditionally instructed to push hard with their heels to overcome such sticking points. However, this approach may hinder the kinetic connection between the feet and the hip, potentially resulting in a posterior tilt of the pelvis [27]. Considering the importance of optimal frontal plane foot mechanics in sports movements like changes of direction and sprinting [28], traditional squat exercises for weight gain may not be conducive to athletic performance development. A previous study reported that while the net joint moment of the knee joint was greater than the hip joint when performing a back squat, the net joint moment of the hip was greater when performing a deadlift [18]. In this regard, given that studies have shown that increased gluteus maximus activity is associated with increased maximal running speeds [29], it is likely that the increased knee extensor capacity during squats had less of an impact on the speed-related performance measured in this study. Despite the lack of correlation between squat 1RM improvement and sport performance in this study, squats remain integral for overall strength and fitness in athletes [30]. In addition, there is a study that showed increasing the squat 1RM was effective in improving vastus lateralis and gluteus maximus muscle thickness [31]. Therefore, tailoring squat training based on the specific characteristics of each sport and applying squats in proper periods based on training periodization may enhance their efficacy, allowing strength and conditioning coaches to maximize athletes' performance.

An additional intriguing discovery in this study was the relationship between bench press 1RM and performance outcomes. Unlike the conventional bench press, which focuses on isolated upper limb strength, subjects in this study employed the modified hip drive bench press method. This method emphasizes kinetic connectivity from a distal body part to the proximal center, requiring a strong pushing toe, lifting heel, and hip muscle contraction during the bench press. This approach likely promotes the connectivity and elasticity of the posterior chain [32]. Previous research has highlighted the posterior chain's role in generating horizontal force, a key factor in sprinting [33,34]. Additionally, heavy bench presses with hip drive may indirectly teach athletes how to transfer energy from ground reaction force to specific tasks.

From a biomechanical perspective, hip joint angular velocity, a crucial factor for speed and power development in athletes, results from energy transfer from the ground. Improving hip angular velocity requires a perfect hip hinge position. The deadlift and power clean, which involve a second pull movement representing a hip hinge position, may benefit hip joint angular velocity enhancement [35]. However, caution is warranted as athletes attempting to improve hip angular velocity through deadlifts and power cleans may exhibit lower back hyperextension, disrupting forefoot mechanics and forcing the heel to press the ground. To address this, the study implemented specific instructions for deadlifts, emphasizing pressing the ground with the whole foot in the starting position and pressing the big toe during the second pull. The power clean followed a similar approach, with athletes pressing the big toe strongly, lifting the knee high, and executing a power clean instead of a full squat during the receiving phase. The dynamic posture adopted aimed to maximize motor unit mobilization in the intrinsic muscles of the hips and feet. The study speculates that this approach influenced performance improvement over the six-week training period.

The results indicate that 1RM improvement in bench press, deadlift, and power clean is highly associated with athletes' field performance. These findings suggest that 1RM improvements in these exercises can serve as valuable metrics for assessing athletes' performance in a weight training room setting. While the study presents interesting insights into the relationships between 1RM strength and field performance, a potential limitation lies in the use of simple bivariate correlation instead of multiple linear regression. Despite this statistical limitation, the results offer valuable insights for strength-conditioning coaches exploring the connections between 1RM strength and field performance. It is important to note that the study focused exclusively on male elite rugby athletes, limiting direct applicability to general populations.

5. Conclusions

After six weeks of training, power clean 1RM demonstrated the strongest association with athletic performance in rugby players. Although squat 1RM experienced the most significant improvement, it showed no correlation with athletic performance in rugby players. In conclusion, the application of power clean 1RM to evaluate speed-related performance improvements in male rugby players in a strength-conditioning environment is likely to be effective.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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