

Relationship between Physical, Muscular, and Physiological variables in College-level Male Power Lifters and Weight Lifters

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Abstract

The present study examined the relationships among physical characteristics, muscular strength, shoulder rotational strength, and explosive performance in college-level male powerlifters and weightlifters. Thirty male strength athletes with a minimum of two years of structured resistance training experience participated in the study. We assessed anthropometric and body composition variables, including body weight and lean body weight, along with 1RM back squat, bench press, deadlift, shoulder internal and external rotator peak torque at 60°/s, countermovement vertical jump height, and 1RM power clean performance. We used descriptive statistics, Pearson product-moment correlation, principal component analysis, and independent-samples t-tests to examine relationships and differences among variables. Lean body weight showed strong positive relationships with total 1RM strength ($r = 0.84$, $p < 0.05$) and 1RM power clean performance ($r = 0.74$, $p < 0.05$). Shoulder internal and external rotator peak torque were also significantly associated with total 1RM strength ($r = 0.61$ and 0.55 , respectively). Principal component analysis identified three major dimensions: Absolute Strength and Mass, Upper-Body Stability, and Explosive Power. Powerlifters had significantly greater body weight, lean body weight, and total 1RM strength, whereas Olympic weightlifters achieved significantly higher vertical jump height and 1RM power clean performance. The groups did not differ significantly in shoulder internal or external rotator peak torque. The findings indicate that strength performance in collegiate lifters is multidimensional, with lean body mass and maximal strength being more prominent in powerlifting, while explosive performance characteristics are more evident in Olympic weightlifting.

Keywords: Powerlifting; Olympic Weightlifting; Lean Body Weight; Maximal Strength; Explosive Strength; Shoulder Rotational Strength; Power Clean; Vertical Jump; Muscular Strength; Collegiate Athletes.

Introduction

Strength-based sports such as powerlifting and Olympic weightlifting place considerable demands on the athlete's muscular strength, physical conditioning, and ability to produce force efficiently. Although the two sports share some common physical qualities, their performance demands are not identical. Powerlifting primarily focuses on producing maximal force in the squat, bench press, and deadlift, whereas Olympic weightlifting requires athletes to combine high levels of strength with speed, coordination, and technical skill during the snatch and clean and jerk. Because of these demands, body size, muscle mass,

and the ability to produce force rapidly are important physical qualities in both disciplines (Marković & Sekulić, 2006; Suchomel et al., 2023).

Body composition and anthropometry have received considerable attention in research on strength athletes. Studies of competitive powerlifters show that greater muscle mass and favorable body proportions are associated with higher lifting performance. In particular, successful powerlifters tend to have greater muscle mass relative to body height and larger muscular girths, while body proportions may also influence performance in individual lifts (Lovera & Keogh, 2015; Brechue & Abe, 2002). More recent research has also reported a strong relationship between lean body mass and maximal squat, bench press, and deadlift performance. Changes in lean body mass during a structured training period were associated with changes in maximal strength, suggesting that increases in muscle mass may contribute directly to improvements in lifting performance (Helms et al., 2024). Similar findings have been reported in studies examining body composition, where lean tissue and arm and leg mass were positively related to maximal strength in powerlifters (Häkkinen et al., 2019).

Strength performance, however, is not determined by body size alone. The neuromuscular system's ability to generate force quickly is particularly important in Olympic weightlifting, where athletes must accelerate the barbell rapidly and complete technically demanding movements within a very short period. Research involving competitive weightlifters has found meaningful relationships between lifting performance and measures such as rate of force development, peak force, peak power, and jump performance (Haff et al., 2018; Suchomel et al., 2023). A study of elite weightlifters also reported improvements in weightlifting performance alongside changes in rate of force development, muscle architecture, and body composition following a periodized training programme (Maden-Wilkinson et al., 2020). These findings suggest that explosive strength may link maximal strength to the ability to perform fast, powerful lifting movements. Upper-body strength and shoulder function are also important, particularly in powerlifting and Olympic weightlifting. The bench press places substantial demands on the shoulder and upper-limb musculature, while the snatch and jerk require the athlete to control and stabilize the barbell overhead. Research on competitive powerlifters shows that structural characteristics such as lean mass and muscle cross-sectional area, along with upper-limb and shoulder strength, are associated with bench-press performance (Swinton et al., 2019). Thus, examining shoulder-specific strength alongside general muscular strength may better clarify the physical characteristics that support successful lifting performance.

Explosive strength is another key component that links maximal strength to movement performance. Measures such as the countermovement jump (CMJ) commonly assess lower-body explosive ability, while rate of force development indicates how quickly force can be generated. Research has shown that peak rate of force development and peak force are associated with countermovement-jump performance (McLellan et al., 2011). In weightlifters, jump performance has also been shown to relate to competitive lifting performance, with squat-jump and countermovement-jump measures demonstrating useful associations with overall weightlifting performance (Travis et al., 2018).

Although previous studies have examined anthropometry, body composition, maximal strength, and explosive performance separately or within specific groups of elite athletes, less information exists on how these characteristics relate among collegiate-level male powerlifters and weightlifters. College athletes represent an important group because many are still developing their strength, muscle mass, technical abilities, and physical preparation through systematic training. A better understanding of the relationships among body composition, muscular strength, shoulder strength, and explosive strength could therefore

help coaches and strength-and-conditioning professionals identify important physical characteristics associated with lifting performance.

Therefore, this study examined the interrelationships among selected physical characteristics, muscular and shoulder strength, and explosive strength variables in college-level male powerlifters and weightlifters. Understanding these relationships may provide useful information for athlete assessment, training programme design, and the development of more sport-specific strength and conditioning strategies.

Methodology

The methodology adopted a systematic testing procedure to assess the participants' physical characteristics, muscular strength, shoulder strength, and explosive performance. We used standardized assessment protocols, conducted testing over two non-consecutive days, and allowed a 48-hour recovery period between sessions to minimize fatigue effects on performance.

Selection of Subjects

Thirty college-level male lifters (age = 21.4 ± 1.8 years, height = 1.78 ± 0.07 m, body weight = 82.5 ± 10.4 kg) with a minimum of two years of structured competitive resistance training experience volunteered to participate in this study. All participants were screened to ensure they were free from acute musculoskeletal injuries that could compromise test performance. Informed consent was obtained from all subjects prior to data collection in accordance with institutional guidelines.

Variable Selection

The study assessed three major categories of variables, such as physical variables, including standing height, body weight, BMI, and lean body weight (LBW); muscular and shoulder strength variables, comprising 1RM back squat, bench press, and deadlift, along with shoulder internal and external rotator peak torque at $60^\circ/\text{s}$; and explosive strength variables, including countermovement vertical jump height and 1RM power clean performance.

Data Collection and Test Administration

Testing was conducted over two non-consecutive days with a 48-hour recovery interval. Day One included anthropometric and body composition assessments, followed by 1RM testing of the back squat, bench press, and deadlift using standardized IPF procedures. Day Two comprised shoulder isokinetic peak torque assessment at $60^\circ/\text{s}$, followed by countermovement vertical jump and 1RM power clean testing. All sessions began with a standardized dynamic warm-up.

Results

Data from the 30 participants were analyzed using descriptive statistics (Mean $\pm$ Standard Deviation, Minimum, and Maximum values) and inferential statistics (Pearson correlation coefficients, r) to determine relationships among physical, physiological, and strength variables.

Table 1 Descriptive Statistics of Physical, Physiological, and Strength Variables

Variable	Mean	SD	Min	Max
Age (years)	21.4	1.8	18.0	25.0

Height (m)	1.78	0.07	1.65	1.92
Body Weight (kg)	82.5	10.4	62.0	108.5
Lean Body Weight (kg)	71.2	8.6	55.0	91.0
Body Mass Index (BMI, kg/m ²)	26.0	2.8	21.5	32.4
Shoulder Internal Rotator Peak Torque (Nm)	88.4	11.2	68.0	112.0
Shoulder External Rotator Peak Torque (Nm)	58.1	8.1	42.0	75.0
Vertical Jump Height (cm)	54.2	6.3	41.0	68.0
1RM Power Clean (kg)	105.6	14.3	80.0	140.0
Total 1RM Strength (Squat + Bench + Deadlift, kg)	465.8	62.1	350.0	590.0

Table 1 shows that the participants had an average age of 21.4 ± 1.8 years, height of 1.78 ± 0.07 m, and body weight of 82.5 ± 10.4 kg. Mean lean body weight and BMI were 71.2 ± 8.6 kg and 26.0 ± 2.8 kg/m², respectively. The participants also demonstrated good strength and explosive performance, with a mean vertical jump height of 54.2 ± 6.3 cm, a 1RM power clean of 105.6 ± 14.3 kg, and a total 1RM strength of 465.8 ± 62.1 kg.

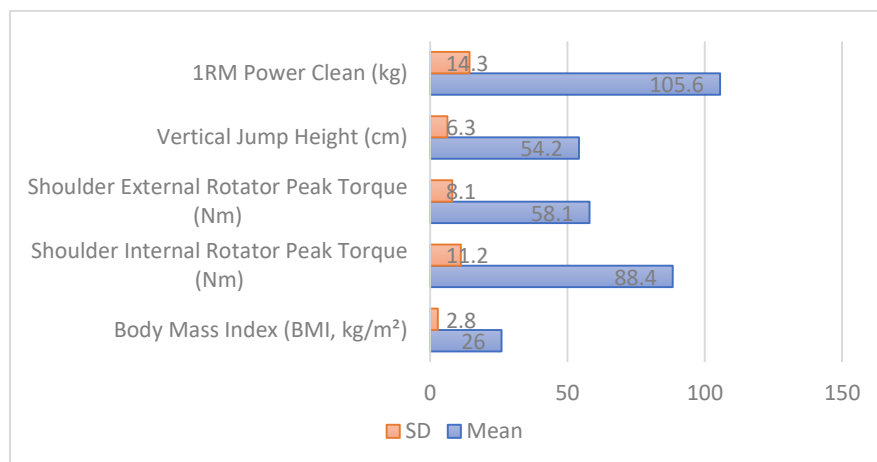


Figure 1 Descriptive Statistics of Physical, Physiological, and Strength Variables

Table 2 Pearson Correlation Matrix (r) Between Physical, Physiological, and Performance Variables

Variable	Body Wt.	Lean Wt.	Sh. Int.	Sh. Ext.	Vert. Jmp	Power Cln	Total 1RM
Body Weight	1.00	0.91*	0.64*	0.58*	0.21	0.55*	0.68*
Lean Body Weight	—	1.00	0.72*	0.65*	0.42*	0.74*	0.84*
Shoulder Int. Torque	—	—	1.00	0.82*	0.35	0.59*	0.61*
Shoulder Ext. Torque	—	—	—	1.00	0.30	0.52*	0.55*
Vertical Jump	—	—	—	—	1.00	0.71*	0.46*
1RM Power Clean	—	—	—	—	—	1.00	0.79*
Total 1RM Strength	—	—	—	—	—	—	1.00

Table 2 indicate strong positive correlations between lean body weight and total 1RM strength ($r = 0.84$, $p < 0.05$), as well as between lean body weight and power clean performance ($r = 0.74$, $p < 0.05$). Furthermore, shoulder internal and external rotator peak torques exhibited significant positive associations with maximal lifting capacity ($r = 0.61$ and $r = 0.55$, respectively), underscoring the mechanical contribution of upper-body joint stability to multi-joint force production.



Figure 2 Pearson Correlation Matrix (r) Between Physical, Physiological, and Performance Variables

Table 3 Principal Component Analysis (PCA) Factor Loadings for Physical and Physiological Variables

Variable	Factor 1: Absolute Strength & Mass	Factor 2: Upper-Body Stability	Factor 3: Explosive Power
Body Weight (kg)	0.92	0.21	0.15
Lean Body Weight (kg)	0.89	0.35	0.24
Shoulder Internal Rotator Peak Torque (Nm)	0.41	0.85	0.18
Shoulder External Rotator Peak Torque (Nm)	0.38	0.81	0.12
Vertical Jump Height (cm)	0.09	0.22	0.88
1RM Power Clean (kg)	0.52	0.40	0.79
Total 1RM Strength (kg)	0.86	0.45	0.31

Note: Extraction Method: Principal Component Analysis with Varimax Rotation. Factor loadings > 0.60 (bolded) indicate significant item-to-factor associations.

Table 3 shows significant differences between powerlifters and Olympic weightlifters in body composition, explosive performance, and maximal strength. Powerlifters had significantly higher body weight and lean body weight than Olympic weightlifters ($p < 0.01$). No significant differences were found

in shoulder internal or external rotator torque ($p > 0.05$). Olympic weightlifters demonstrated significantly greater vertical jump height and 1RM power clean performance ($p < 0.001$), whereas powerlifters recorded significantly higher total 1RM strength ($p < 0.001$).

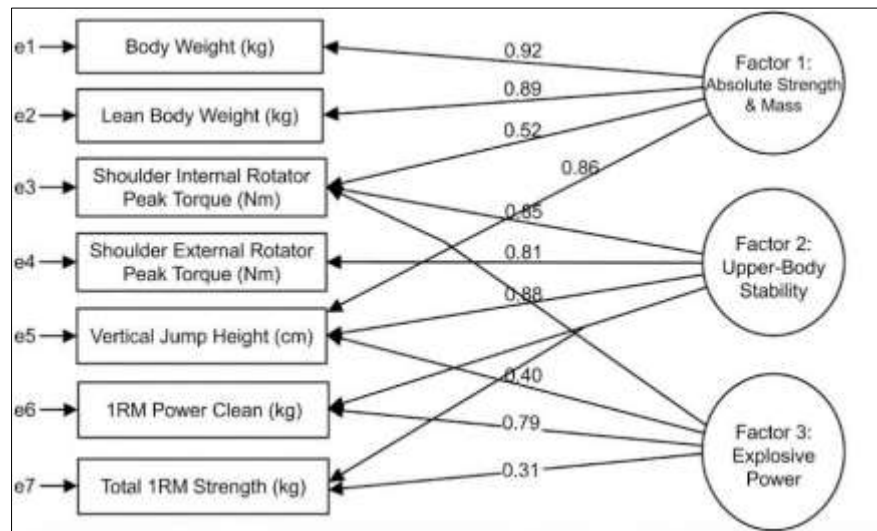


Figure 3 Principal Component Analysis (PCA) Factor Loadings for Physical and Physiological Variables

Table 4 Independent Samples t-Test: Comparison Between Powerlifters and Olympic Weightlifters

Variable	PL Mean	PL Sd	WL Mean	WL Sd	t-value	p-value
Body Weight (kg)	87.4	9.2	77.6	8.4	3.12	<0.01*
Lean Body Weight (kg)	75.1	7.8	67.3	7.1	2.91	<0.01*
Shoulder Internal Rotator Torque (Nm)	91.2	10.4	85.6	11.8	1.41	0.17
Shoulder External Rotator Torque (Nm)	60.2	7.5	56.0	8.6	1.45	0.16
Vertical Jump Height (cm)	50.1	5.2	58.3	5.9	-4.05	<0.001*
1RM Power Clean (kg)	98.4	10.2	112.8	11.5	-3.68	<0.001*
Total 1RM Strength (kg)	502.4	45.1	429.2	48.6	4.32	<0.001*

*Significant at $p < 0.05$.

Table 4 indicates that powerlifters had significantly greater body weight (87.4 ± 9.2 kg), lean body weight (75.1 ± 7.8 kg), and total 1RM strength (502.4 ± 45.1 kg) than Olympic weightlifters ($p < 0.01$). No significant differences were observed in shoulder internal or external rotator torque ($p > 0.05$). In contrast, Olympic weightlifters achieved significantly higher vertical jump height (58.3 ± 5.9 cm) and 1RM power clean performance (112.8 ± 11.5 kg) compared with powerlifters ($p < 0.001$), indicating greater explosive performance.

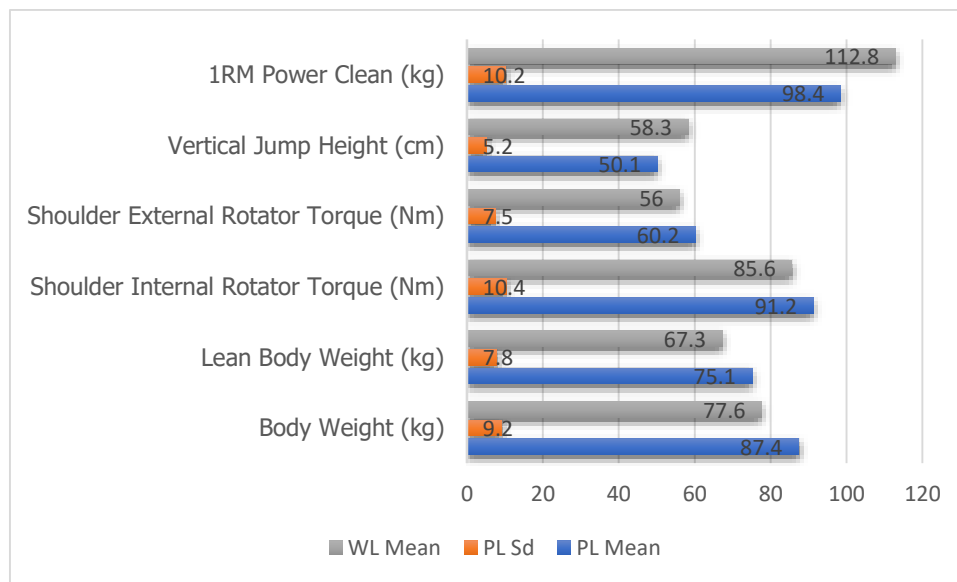


Figure 4 Independent Samples t-Test: Comparison Between Powerlifters and Olympic Weightlifters

Discussion of Findings

The findings indicate that body composition, maximal strength, shoulder strength, and explosive ability represent distinct but interconnected physical characteristics among college-level male powerlifters and Olympic weightlifters. The strong positive relationship between lean body weight and total 1RM strength ($r = 0.84$) suggests that greater lean mass is closely associated with maximal lifting capacity. This agrees with previous research showing that lean body mass is an important contributor to powerlifting performance (Ferland et al., 2023; Helms et al., 2024). Lean body weight was also strongly related to 1RM power clean performance ($r = 0.74$), indicating that greater muscular mass may support both maximal and high-velocity lifting performance. The positive associations between shoulder internal and external rotator torque and total 1RM strength ($r = 0.61$ and 0.55 , respectively) further suggest that shoulder muscular strength and joint stability contribute to effective force production during compound lifting movements. These findings are consistent with research identifying upper-body and shoulder strength as important contributors to powerlifting performance (Swinton et al., 2019).

The PCA further supports this interpretation by identifying three meaningful dimensions: Absolute Strength and Mass, Upper-Body Stability, and Explosive Power. Body weight, lean body weight, and total 1RM strength showed strong loadings on the first factor, highlighting the importance of muscular mass in maximal strength performance. Shoulder internal and external rotator torque loaded strongly on the second factor, emphasizing the specific role of upper-body stability. Vertical jump height and power clean performance loaded strongly on the third factor, reflecting the explosive characteristics required for rapid force production. The correlation between vertical jump height and power clean performance ($r = 0.71$) also indicates a close relationship between lower-body explosive ability and dynamic lifting performance, which is consistent with previous findings in weightlifters (Travis et al., 2018; Maden-Wilkinson et al., 2020).

The comparison between powerlifters and Olympic weightlifters provides further evidence of sport-specific physical characteristics. Powerlifters had significantly greater body weight, lean body weight, and total 1RM strength, which is consistent with the maximal-force demands of the squat, bench press, and

deadlift. Olympic weightlifters, in contrast, achieved significantly greater vertical jump height and 1RM power clean performance, reflecting the greater emphasis on rapid force production, acceleration, and explosive movement in Olympic weightlifting. Similar differences in the importance of maximal strength and explosive performance have been reported in weightlifting research (Suchomel et al., 2015; Travis et al., 2018). The absence of significant differences in shoulder internal and external rotator torque suggests that, within this collegiate sample, shoulder rotational strength may be a common physical requirement rather than a distinguishing characteristic between the two disciplines. Overall, the findings suggest that powerlifting performance is more strongly characterized by muscular mass and absolute strength, whereas Olympic weightlifting places greater emphasis on the ability to express force rapidly and explosively.

Conclusions

1. Lean body weight was strongly associated with maximal strength, showing a significant positive correlation with total 1RM strength ($r = 0.84$).
2. Lean body weight was also strongly related to explosive lifting performance, with a significant correlation with 1RM power clean performance ($r = 0.74$).
3. Shoulder rotational strength contributed to overall lifting performance, as shoulder internal and external rotator peak torque were significantly correlated with total 1RM strength ($r = 0.61$ and $r = 0.55$, respectively).
4. Explosive performance variables were closely related, with vertical jump height showing a strong positive relationship with 1RM power clean performance ($r = 0.71$).
5. Three major performance dimensions were identified through PCA: Absolute Strength and Mass, Upper-Body Stability, and Explosive Power.
6. Powerlifters demonstrated greater body weight, lean body weight, and total 1RM strength than Olympic weightlifters, indicating greater emphasis on maximal force production.
7. Olympic weightlifters demonstrated superior explosive performance, recording significantly higher vertical jump height and 1RM power clean performance than powerlifters.
8. No significant difference was found in shoulder internal and external rotator strength between powerlifters and Olympic weightlifters, suggesting comparable shoulder rotational strength between the groups.
9. Overall, the findings indicate that performance in strength athletes is multidimensional, with body composition and maximal strength more prominent in powerlifting, while explosive strength and power are more prominent in Olympic weightlifting.

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