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Brief Report

Lower and upper-body power and body composition are associated with shot put performance in collegiate male athletes

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Abstract

International Journal of Exercise Science 19(6): 6012, 2026. 2026. https://doi.org/10.70252/IJES2026612 This study aimed to examine the relationships between shot put performance and upper- and lower-limb power, as well as the influence of body composition, in collegiate athletes under real competitive conditions. Fourteen male collegiate shot putters (24.1 ± 1.7 years; 104.6 ± 10.2 kg; 1.82 ± 0.10 m) underwent body composition assessment using the skinfold thickness method and completed tests of upper-limb power (plyometric push-ups, PPU) and lower-limb power (countermovement jump, CMJ) prior to an official competition. Shot put performance was obtained from the best valid competitive attempt. Pearson's or Spearman's correlation coefficients were applied according to data distribution, and effect sizes and coefficients of determination (r^2) were reported. A strong, positive correlation was observed between PPU performance and shot put distance ($r = 0.74$, $p = 0.003$), while a moderate, positive correlation was found between CMJ and shot put performance ($r = 0.54$, $p = 0.046$), indicating ≈ 29% shared variance. Additionally, body mass index showed a moderate, negative association with PPU performance ($r = -0.556$, $p = 0.041$), and fat mass percentage was moderately and negatively correlated with CMJ performance ($r = -0.541$, $p = 0.045$). These findings indicate that upper- and lower-limb power are associated with shot put performance in collegiate athletes. The PPU and CMJ appear to be practical and ecologically valid tools for performance assessment and athlete monitoring, highlighting the importance of power-oriented training strategies and body composition management in this population.

Keywords: Track and field, power capacity, anthropometric, performance predictor

Introduction

Track and field shot put is a multifactorial event, with success depending both on the technical pattern employed and on the integration of force production throughout the entire body, from the lower to the upper limbs. As an explosive activity, power capacity is essential for performance.[1]

Accordingly, shot put performance is directly related to muscular power involving multiple body segments, which is determined by the amount of muscle mass engaged in the movement.

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This is supported by Kyriazis et al. (2010),[2] who reported a strong correlation (r = 0.76) between lean mass and superior shot put performance, particularly in the linear (non-rotational) technique. While lean mass shows a positive association with power, fat mass exerts the opposite effect. Previous research identified a strong and negative correlation (r = −0.79) between fat mass and hammer throw performance, another track and field event with high muscular power demands, similar to the shot put. This occurs because greater fat mass tends to reduce movement velocity due to the additional body mass that must be displaced, while also increasing energetic cost.[3]

Given that shot put performance is related to power capacity,[2,4] assessing this ability in shot put athletes is necessary for both the upper and lower body. In this context, validated and highly practical tests such as plyometric push-ups (PPU) for the upper limbs and the countermovement jump (CMJ) for the lower limbs can be particularly useful assessment tools.

Considering that body composition appears to influence the ability to generate power,[3] a study involving judo athletes reported a positive relationship between fat-free mass and CMJ performance, whereas fat mass showed a negative correlation (r = −0.742). A similar relationship has been observed for the PPU, in which a higher percentage of body fat negatively affects the height achieved in the test (r = −0.609).[5]

Regarding power, one study investigated variables associated with shot put performance and assessed lower-limb power exclusively using the standing long jump test, which showed a strong correlation with shot put performance (r = 0.888).[6] This finding highlights the relevance of analyzing additional tests aimed at assessing power, such as the CMJ and, particularly for the upper limbs, the PPU. Another study employed the CMJ to examine the relationship between muscular power and rotational shot put performance, demonstrating that the test is a valid indicator of power (r = 0.66) and vertical velocity (r = 0.70), and therefore can be used as a tool for analyzing shot put performance.[7] The use of the PPU to correlate power and performance has been reported in other sports, such as rugby, in which plyometric push-up power is associated with tackling ability during matches. However, despite the motor pattern showing similarities to the shot put, to date there are no investigations examining the use of the PPU in shot put athletes.[8]

From this perspective, it is evident that assessing power through performance tests is of paramount importance for quantifying this capacity in athletic tasks, discriminating athletes' performance status, identifying talented athletes, and monitoring training effects.[9] Since previous studies have primarily focused on maximal strength capacity[10,11] and have given limited attention to muscular power in relation to shot put performance, the CMJ and PPU—simple and effective assessment tools—may allow, respectively, the examination of the relationships between lower- and upper-limb power and shot put performance.

Accordingly, this study aimed to examine the correlations between shot put performance and upper- and lower-limb power, as well as the influence of body composition. We hypothesized that shot put athletes with higher power levels would demonstrate superior throwing performance, whereas body composition would exert an effect such that athletes with greater lean mass would achieve better performance compared with those with higher fat mass. The findings of this study may assist coaches and sports institutions in identifying potential athletes through the application of these initial tests. For example, in Olympic weightlifting, CMJ performance has been shown to reflect neuromuscular capacity and differentiate levels of explosive lower-body power.[12] Additionally, this study may raise awareness of and reinforce the importance of maintaining an appropriate body composition to optimize performance.

Methods

Participants

Fourteen collegiate male shot putters participated in the study, all of whom were undergraduate students enrolled in different academic programs. Their mean characteristics are presented in Table 1. They reported 2 to 3 event-specific training sessions per week, in addition to general physical preparation, and their competitive background in shot put ranged from novice to intermediate levels.

Regarding technique, 64.3% (n = 9) employed the glide/linear style (O'Brien), 35.7% (n = 5) performed the throw from a static position with knee flexion/extension and limited trunk contribution. On the day of testing, all participants were free from musculoskeletal injuries that could impair performance. Written informed consent was obtained from all individuals. This research was conducted in full compliance with the ethical standards established by the *International Journal of Exercise Science*.[13] The protocol was approved by the Institutional Research Ethics Committee (CAAE: 12919719.3.0000.5659).

Table 1. Characteristics of shot putters (n = 14).

Variables	Results (M ± SD)
Age (years)	24.1 ± 1.7
Body mass (kg)	104.6 ± 10.2
Height (m)	1.82 ± 0.1
BMI (kg/m²)	31.5 ± 3.5
FFM (kg)	80.2 ± 5.5
FM (kg)	24.6 ± 6.1
FM (%)	23.0 ± 5.4

Note: kg = kilogram; m = meters; BMI = body mass index FFM = fat free mass; FM = fat mass; FM (%) = percentage of fat mass.

Protocol

Participants were assessed in a single session prior to a collegiate national shot put competition. Testing took place at the same university where the competition was held and prior to the competition to ensure ecological validity, and all participants followed the same assessment sequence on the same day.

Initially, participants were instructed to complete a researcher-developed anamnesis form, which included questions regarding personal characteristics (e.g., age), sport-specific information (training experience and preferred shot put technique), and injury history.

Before testing, participants were instructed to perform a self-selected five-minute timed warm-up. Subsequently, they executed the PPU and CMJ movements at least once to allow an experienced researcher to assess proper technique. After this familiarization, participants completed the official PPU and CMJ attempts in that respective order. A three-minute rest interval was provided between tests, and each participant was evaluated individually.

Finally, participants proceeded to the competition arena, located ≈ 150 meters from the laboratory. A 30-minute interval was observed between the completion of the tests and the start of the competition warm-up. Participants were informed beforehand that the testing procedures were not intended to affect their competitive performance. Figure 1 illustrates the experimental procedures of the study.

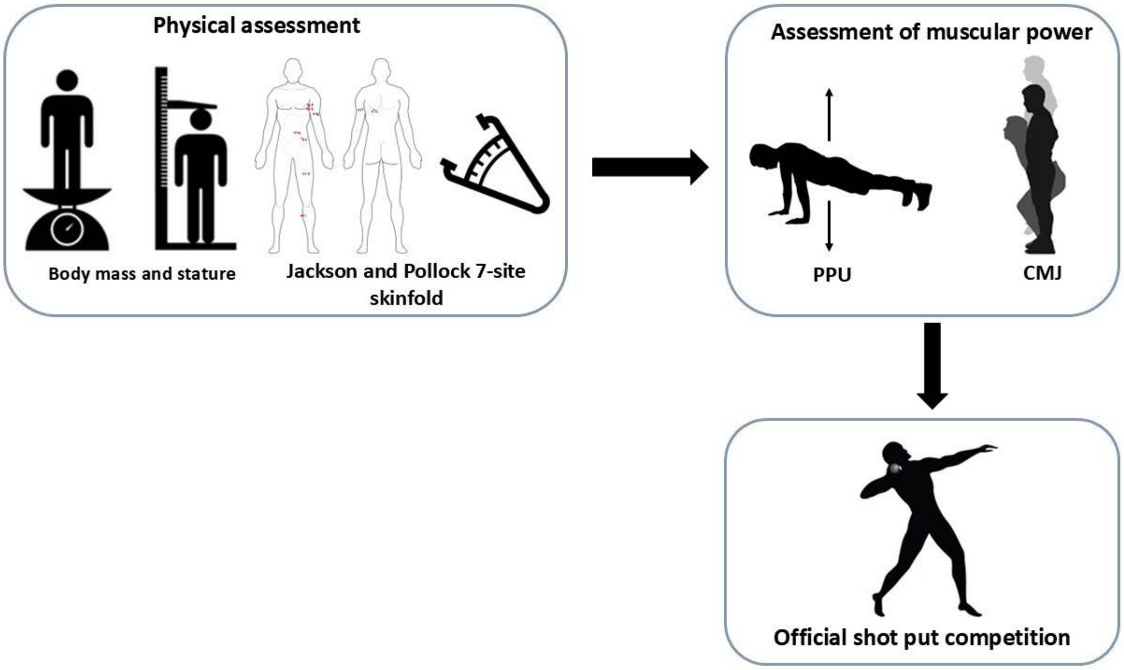

Figure 1. Experimental design of the study.
Note: PPU = Plyometric push up; CMJ = Countermovement jump.

Body composition measurements.
Participants' height and body mass were measured using a fixed stadiometer and scale (Welmy®, standard model, São Paulo, Brazil). The measurements were later used to calculate the participants' BMI, using the following equation: mass (kg)/ height $(m)^2$.

For the calculation of body density, the Jackson and Pollock (1978) seven-site skinfold protocol was used, including the triceps, chest (pectoral), subscapular, midaxillary, suprailiac, abdominal, and thigh sites. Body density was calculated using the equation: 1.112 - 0.00043499 (X1) + 0.00000055 ($X1^2$)- 0.00028826 (X3). X1 = sum of the seven skinfold, X3 = age (years).[14] Skinfold thickness measurements were obtained using a Lange® scientific skinfold caliper (Lange, Cambridge, MA, USA) with a constant spring pressure of 10 g/mm^2, properly calibrated.

Fat mass percentage (FM%) was calculated using the Siri equation: FM% = [(4.95 / Dens) - 4.50] * 100. Fat mass (FM) was calculated using the following equation: FM (kg)= (FM% /100) * BM. Finally, Fat-free mass (FFM) in kg was calculated as the difference between body mass and fat mass, following the two-compartment model of body composition.[15] All skinfold measurements were performed by a unique experienced evaluator following standardized procedures to ensure consistency and reliability.

Power assessment.
For the assessment of PPU, participants were instructed to maintain a straight body position and support most of their body weight with their hands (starting position). After the start signal, the plyometric phase was performed by pushing against the ground with maximal force and velocity, lowering the chest and subsequently fully extending the arms, resulting in loss of hand contact with the ground and reaching the maximum height during the ascending phase of the push-up. Upon landing, participants were instructed to flex the elbows to reestablish contact

with the ground in order to reduce joint stress in the upper limbs.[16] For CMJ, participants were instructed to stand in a bipedal position with their hands placed on the hips. After the start signal, knee flexion to ≈ 90° (monitored by a researcher) was performed, followed immediately by a maximal vertical jump, ensuring that the knees remained fully extended throughout the flight phase.[17] In both tests, participants were assessed individually and performed at least three trials, with a 10-second interval between trials. To control within-session variability, participants performed at least three trials for each test. When trial-to-trial variability exceeded 5%, additional trials were performed until three trials with variability ≤ 5% were obtained. The mean value of the three valid trials was used for analysis. Test performance was assessed using a contact mat (CEFISE®, Nova Odessa, São Paulo, Brazil; Jump System Duo model, 600 × 300 × 8 mm).

Shot put performance.

The shot put competition was conducted outdoors, using a standard circular throwing area with a toe board and a designated landing sector. Ambient temperature ranged between 20°C and 22°C, and all procedures took place in the morning. After a 30-minute warm-up period established by the event organizers—during which participants performed self-selected activities such as light running, ballistic stretching, and simulated throws—each participant completed six attempts using their preferred throwing technique with a 7.260-kg implement. The best valid mark was used to determine the final placing in the competition and was officially recorded. All procedures followed the rules established by the International Association of Athletics Federations (World Athletics).

Statistical Analysis

A priori sample size estimation using G*Power 3.1[18] indicated that, for a statistical power of (1–β) = 0.80, an expected effect size of 0.75, and α = 0.05, a minimum of 12 participants would be required. The expected effect size was defined as a large correlation (r = 0.75), supported by shot put literature reporting strong associations between power- and strength-related measures and throwing performance.[4,6,7]

The normality of the data was assessed using the Shapiro–Wilk test. Only the PPU variable violated the normality assumption; therefore, correlations involving PPU were analyzed using Spearman's rank correlation, while all other variables, which met the assumption of normality, were analyzed using Pearson's product–moment correlation. Correlation coefficients were interpreted according to the following thresholds: < 0.1 (trivial), 0.1 – 0.3 (small), > 0.3 – 0.5 (moderate), > 0.5 – 0.7 (large), > 0.7 – 0.9 (very large) and > 0.9 – 1.0 (nearly perfect).[19] Results are reported as mean ± standard deviation, and coefficients of variation, coefficients of determination (r^2) were reported only for Pearson's correlations, given their interpretability as explained variance, and p-values reported. Statistical significance was set at $p < 0.05$.

Results

Figure 2 illustrates the correlation between upper-limb power (PPU – Panel A) and lower-limb power (CMJ – Panel B) with shot put performance. Both showed significant positive correlations, with Panel A (PPU and throw distance) being strong and Panel B (CMJ and throw distance) being moderate. Mean values were 10.7 ± 3.3 cm for PPU, 35.4 ± 7.4 cm for CMJ, and 8.8 ± 1.7 m for shot put throw distance.

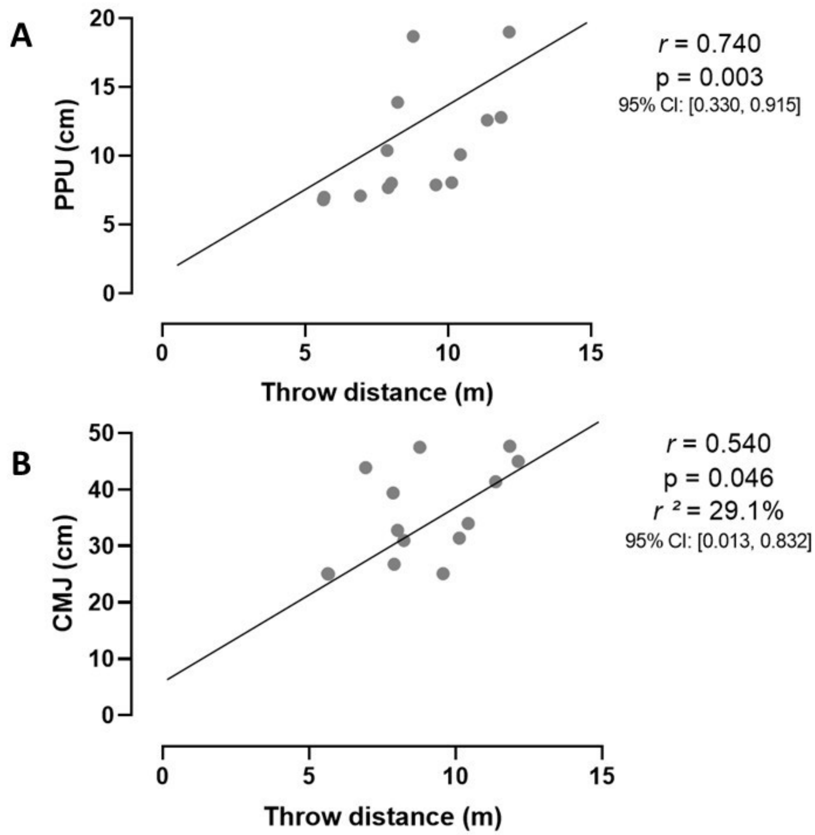

Figure 2. Correlations between PPU and CMJ tests with shot put throw distance.
Note: cm = centimeters; m = meters; Figure A: Effect size = very large, B = large.

Table 2 shows the correlations between anthropometric measures and shot put performance (throw distance), Table 3 shows the correlations between anthropometric/body composition measures and PPU performance, and Table 4 shows the correlations between anthropometric measures and CMJ performance. In all tables, the correlation coefficient (r), p-value, coefficient of determination (r^2), confidence interval, and effect size classification are presented.

Table 2. Correlation, significance, coefficient of determination, CI and Effect size between throw distance (m) and anthropometric/body composition variables.

	r	p-value	r^2	CI 95%	ES
BMI (kg/m²)	0.051	0.861	0.3%	- 0.49 to 0.56	Trivial
FFM (kg)	0.188	0.518	4%	- 0.38 to 0.65	Small
FM (kg)	- 0.230	0.426	5%	- 0.68 to 0.35	Small
FM (%)	- 0.163	0.576	3%	- 0.63 to 0.40	Small

Note: kg = kilogram; m = meters; BMI = body mass index; FFM = fat free mass; FM = fat mass; FM (%) = percentage of fat mass.

Table 3. Correlation, significance, coefficient of determination, CI and Effect size between PPU (cm) and anthropometric/body composition variables.

	r	p-value	CI 95%	ES
BMI (kg/m²)	- 0.556	0.041*	- 0.84 to - 0.01	Large
FFM (kg)	- 0.340	0.223	- 0.74 to 0.24	Moderate
FM (kg)	- 0.516	0.061	- 0.82 to 0.03	Large
FM (%)	- 0.450	0.108	- 0.79 to 0.12	Moderate

*Note: kg = kilogram; m = meters; BMI = body mass index FFM = fat free mass; FM = fat mass; FM (%) = percentage of fat mass. * = $p < 0.05$.*

Table 4. Correlation, significance, coefficient of determination, CI and Effect size between CMJ (cm) and anthropometric/body composition variables.

	r	p-value	*r* ²	CI 95%	ES
BMI (kg/m²)	- 0.434	0.120	19%	- 0.78 to 0.12	Moderate
FFM (kg)	- 0.247	0.393	6%	- 0.68 to 0.32	Small
FM (kg)	- 0.530	0.053	28%	- 0.83 to 0.01	Large
FM (%)	- 0.541	0.045*	29%	- 0.83 to - 0.01	Large

*Note: kg = kilogram; m = meters; BMI = body mass index FFM = fat free mass; FM = fat mass; FM (%) = percentage of fat mass. * = p < 0.05.*

Discussion

This study aimed to examine the correlations between shot put performance and upper- and lower-limb power, as well as to determine whether body composition influences performance. The main findings were as follows: (i) a strong, positive correlation (r = 0.74, p = 0.003) between upper-limb power, assessed by the push-up power test (PPU), and shot put performance, with a very large effect size; (ii) a moderate, positive correlation (r = 0.54, p = 0.046) between shot put performance and lower-limb power (CMJ), indicating ≈ 29% shared variance between the variables and a large effect size; (iii) a moderate, negative correlation between BMI and PPU performance (r = − 0.556, p = 0.041); and (iv) a moderate, negative correlation between percentage of fat mass (FM%) and CMJ performance (r = − 0.541, p = 0.045), also indicating ≈ 29% shared variance.

To the best of our knowledge, this is the first study to examine the correlations between upper- and lower-limb power, body composition, and shot put performance in collegiate athletes under real competitive conditions, thereby highlighting the ecological validity of the present experimental design. Although all participants were undergraduate students, the mean age was slightly higher than typically reported in collegiate samples, which may reflect variability in academic trajectories across university populations.[20]

The strong, positive relationship observed between upper-limb power and shot put performance (r = 0.74, p = 0.003; 95% CI = 0.330–0.915) supports our initial hypothesis, as the test used for assessment (PPU) closely resembles the throwing action from a motor standpoint, particularly in terms of force direction and movement dynamics. The PPU requires rapid horizontal force production through the upper limbs, involving coordinated activation of the pectoralis major, triceps brachii, and anterior deltoid,[21] which are also primary contributors during the final delivery phase of the shot put. In addition, both movements rely on efficient force transfer from the trunk to the upper limbs and require high rates of force development, reinforcing the mechanical similarity between the test and the sport-specific action. Moreover, the muscles primarily involved in the PPU are largely the same as those engaged during the bench press exercise. Previous studies have reported similarly strong, positive correlations (r ≥ 0.75) between bench press strength, assessed by one-repetition maximum (1RM), and shot put performance in populations comparable to the present sample (i.e., school-aged and collegiate athletes).[1,6] However, these studies focused exclusively on maximal strength, without accounting for the contribution of movement velocity and, consequently, power.

In contrast, Terzis et al. (2003)[22] examined the relationship between the bench press, explosive throwing performance (power), and shot put distance, concluding that upper-body power (r > 0.86, p < 0.01) plays a substantial role in shot put performance. Taken together with the findings of the present study and considering the principle of specificity, these results suggest that upper-limb power assessments may be more advantageous than tests of maximal strength alone for evaluating and monitoring shot putters. From a practical standpoint, the use of the PPU may also present logistical advantages compared with traditional assessments such as the bench press. While the latter requires specialized equipment (e.g., barbell, weight plates, and bench) and may impose greater loading, the PPU can be easily implemented in field settings with minimal equipment and time demands. In addition, because it relies on body mass rather than external resistance, it may represent a more accessible and potentially less mechanically stressful alternative for assessing upper-limb power in certain populations. These characteristics further support its applicability as a practical tool for athlete monitoring and talent identification in shot put.

With respect to the lower limbs, the moderate, positive correlation observed ($r = 0.54$, $p = 0.046$) indicates that ≈ 29% of the variance in shot put distance is explained by lower-limb power, as assessed by the countermovement jump (CMJ). Although still relatively underexplored, the contribution of the lower limbs to successful shot put performance represents a relevant aspect that should be considered. Biomechanical analyses have shown that the generation and transfer of energy along the kinetic chain rely heavily on the sequential extension of the legs and hips, highlighting the important role of the lower limbs in the throwing action.[23] From a practical standpoint, these findings suggest that even individuals with limited technical proficiency (e.g., amateur athletes) may achieve satisfactory throwing performance provided they possess substantial lower-limb power.

This finding is consistent with the study by Caughey and Thomas (2022)[6], who reported a strong, positive relationship between lower-limb power, assessed via the horizontal jump, and shot put performance ($r = 0.888$; $r^2 = 78.9\%$). Given that shot put performance critically depends on the ability to generate and transfer force and power vertically from the lower limbs, particularly during the final phase of the movement—characterized by the rapid extension of the ankle, knee, and hip (triple extension)—this relationship is biomechanically plausible. This process occurs predominantly through the action of the stretch–shortening cycle (SSC), in which a rapid eccentric phase immediately precedes concentric contraction, thereby enhancing force and power output via neural and mechanical mechanisms.[24,25] Accordingly, although the horizontal jump assesses the ability to project the center of mass, it is less specific to the predominantly vertical SSC demands of the shot put, suggesting that the CMJ may be a more specific assessment, as it involves less interference from non–task-specific technical skills, thereby favoring greater sensitivity and reproducibility.[26]

In our study, two technical styles were adopted for shot put execution (64.3% = O'Brien/linear; 35.7% = static). From a biomechanical perspective, these different styles may require distinct segmental contributions. For example, during the linear shot put, the thigh muscles—particularly the rectus femoris and biceps femoris—are crucial for performance, as they exhibit high levels of activation throughout a large portion of the movement cycle, thereby contributing substantially to impulse generation and athlete displacement. This contribution is naturally reduced in the static throw,[27] in which a greater proportion of power is derived from the upper limbs, especially during the final phase of the throw (delivery).[28] In this context, it is plausible that these technical differences influenced the magnitude and variability of the observed correlations, as the determinants of performance may not be uniform across participants. Consequently, the presence of different motor strategies within the sample may have attenuated or masked potentially stronger associations among the variables analyzed.

With regard to anthropometry and body composition, a moderate, negative correlation was observed between BMI and PPU performance ($r = -0.556$, $p = 0.041$). However, the confidence interval was wide and approached the null value (95% CI = − 0.84 to − 0.01), indicating substantial uncertainty regarding both the magnitude and direction of this association. Therefore, this finding should be interpreted with caution and does not allow for definitive inferences about the influence of BMI on upper-limb power.

Although BMI is widely assessed and commonly associated with obesity, it does not distinguish between fat mass and lean mass and may underestimate or overestimate true adiposity, particularly in physically active or athletic populations, such as the participants in the present study. For this reason, BMI should be interpreted with caution and, ideally, complemented by direct measures of body composition (e.g., skinfold thickness) when the goal is to accurately characterize body fat status and its relationship with performance or health. A recent systematic review has highlighted these limitations and recommends prudence in the isolated use of BMI in both clinical and sport settings.[29]

When examining the moderate, negative correlation between fat mass percentage (FM%) and CMJ performance ($r = -0.541$, $p = 0.045$; 95% CI = −0.83 to −0.01), with a coefficient of determination of ≈ 29%, it can be inferred that higher FM% is associated with lower jump height (i.e., reduced power output), indicating that FM% negatively influences lower-limb power. This relationship may be explained by the fact that adipose tissue is functionally non-contributory to movement, particularly in tasks requiring high levels of force and power, such as the CMJ and shot put. Excess adiposity may also exert deleterious effects on muscle activation. From a practical standpoint, fat mass negatively affects performance by increasing the system's inert mass—additional mass that does not contribute to force production—thereby impairing power generation and transfer,[30] which can result in lower movement velocity and, consequently, reduced performance. This interpretation is consistent with the literature, which indicates that performance in throwing events fundamentally depends on the ability to rapidly convert force into power within very short time windows, particularly during the final phase of the movement.[3]

Finally, the remaining body composition variables analyzed did not appear to be associated with shot put performance or with upper- and lower-limb power. Previous studies have shown that total body mass and body mass index are not significantly associated with throwing distance, reinforcing the notion that global indicators of body composition have limited explanatory power for shot put performance, particularly given the complex and multifactorial nature of the event.[3,31] This further suggests that anthropometric advantages (e.g., greater stature) do not necessarily translate into technical superiority or longer throwing distances, underscoring the importance of assessing functional capacities, such as power and coordination, when evaluating shot put performance.[31]

It is essential to acknowledge several limitations of this study. These include the lack of standardization of the throwing technique used by the athletes and the relatively small sample size ($n = 14$), despite the use of an a priori sample size estimation. The small sample size may limit the stability and generalizability of the observed correlations, particularly in light of the wide confidence intervals identified for some variables. Therefore, these findings should be interpreted with caution, and future studies with larger samples are warranted to confirm the present results. Additionally, the inclusion of male athletes only limits the generalizability of the findings to female populations. In addition, body composition was assessed using skinfold thickness measurements, a doubly indirect method. Nevertheless, although laboratory-based techniques are considered the reference standard, evidence indicates that when skinfold assessments are performed by experienced evaluators and using population-appropriate equations, they demonstrate high reliability and provide acceptable estimates for variables such as fat-free mass in athletic populations. Furthermore, Jagim et al. (2023)[32] emphasize that in applied and sport settings, feasibility, cost, and reproducibility should be considered alongside validity when selecting assessment methods, which supports the appropriateness of the protocol adopted in the present study.

As future directions, evaluating a larger sample of shot putters across different training levels would be valuable to determine whether these relationships differ according to competitive status. In addition, the inclusion of female athletes is warranted to improve the generalizability of the findings. Finally, future studies should investigate whether these associations are consistent across different shot put techniques, allowing a more comprehensive understanding of the influence of power and body composition on performance.

We conclude that there are significant relationships between upper- and lower-limb power and shot put performance, as well as a negative correlation between BMI and upper-limb power and between fat mass percentage and lower-limb power. Based on the associations observed between PPU and CMJ performance and the competitive outcomes in the shot put event, these tests may be considered potential performance predictors for shot put in collegiate athletes and could be incorporated into assessment batteries aimed at athlete identification and selection.

From a practical standpoint, coaches may use the results of the PPU and CMJ tests to identify athletes' strengths and weaknesses in power production, thereby informing the development of targeted training strategies aimed at maintenance and/or improvement. For instance, lower-limb deficits may be addressed through plyometric exercises and Olympic weightlifting derivatives, whereas upper-limb limitations may benefit from the inclusion of ballistic movements. In addition, periodic monitoring of these tests may assist in tracking neuromuscular adaptations over time and in adjusting training loads, as well as in selecting appropriate and targeted exercises. Coaches are also advised to monitor body composition in collaboration with the nutrition team and to aim to maintain low levels of fat mass, as this may be beneficial for optimizing performance.

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