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Anthropometrically estimated lean body mass and neuromuscular performance in young male wrestlers: a cross-sectional study

original paper
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ABSTRACT
Purpose. This study examined the associations between anthropometrically estimated lean body mass and selected neuromuscular performance outcomes in young male wrestlers.
Methods. Fifty-two young male wrestlers completed a cross-sectional body composition and neuromuscular test battery. Estimated lean body mass of 56.53 ± 8.08 kg was derived from anthropometric variables using the Deurenberg equation for percentage body fat, then calculated as body mass minus estimated fat mass. Performance outcomes included squat jump, countermovement jump, 5-m sprint, one-repetition maximum back squat, one-repetition maximum bench press, isometric mid-thigh pull absolute peak force, handgrip strength, and Modified Agility T-test time. Linear regression models adjusted for a competition level examined associations between estimated lean body mass and each outcome.
Results. Estimated lean body mass was positively associated with squat jump, countermovement jump, one-repetition maximum back squat, one-repetition maximum bench press, isometric mid-thigh pull absolute peak force, and handgrip strength, and negatively associated with 5-m sprint time, with all associations being statistically significant ($p < 0.001$). The adjusted association with Modified Agility T-test time approached but did not reach statistical significance ($p = 0.059$).
Conclusions. Anthropometrically estimated lean body mass was consistently associated with force- and power-oriented outcomes in young male wrestlers. Monitoring estimated lean body mass with field-based neuromuscular tests may support athlete profiling, provided that results are interpreted in relation to weight-category demands, training background, competition level, and the indirect nature of the body composition estimate.
Key words: adolescent athletes, body composition, muscle strength, athletic performance, isometric strength, combat sports

Introduction

Wrestling is a combat sport characterised by repeated high-intensity actions requiring maximal strength, muscular power, rapid force development, short-distance acceleration, grip strength, trunk stiffness, and the ability to maintain postural control under unstable and contested conditions [1, 2]. During a bout, athletes must repeatedly push, pull, lift, resist, sprawl, rotate, and reaccelerate while managing opponent contact and weight-category constraints. These actions impose substantial demands on both the upper and lower limbs and require efficient force transmission through the trunk and hips. Consequently, the physical profile of a wrestler cannot be reduced to a single attribute, as the athlete's overall performance depends on the interaction between morphology, maximal force capacity, explosive power, acceleration, grip ability, technical execution, and multidirectional movement efficiency [1, 2].

In youth wrestlers, body composition assessment is of particular importance, given that growth, biological maturation, training exposure, and competitive specialisation occur simultaneously [3–5]. Adolescence is associated with rapid changes in stature, body mass, muscle cross-sectional area, neuromuscular coordi-

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nation, hormonal milieu, and strength development. These changes can enhance performance but may also confound the interpretation of field tests when chronological age alone is considered. For this reason, practical monitoring in young combat-sport athletes should account for both morphological development and functional performance rather than treating anthropometry and physical fitness as independent domains.

Among body composition indicators, lean body mass is of special interest because it approximates the amount of non-fat tissue contributing to force and power production [5, 6]. In wrestling, greater lean tissue may provide a mechanical advantage during forceful contact, clinch control, pulling actions, lifting, braking, and resisting displacement. However, additional mass is advantageous only when it contributes to functional force production without compromising relative power, movement economy, or change-of-direction efficiency. This issue is especially relevant in a weight-category sport, where the practical value of body mass depends on whether the added mass improves performance within the athlete's competitive category [1, 6].

Previous research has demonstrated meaningful relationships between body composition and anaerobic performance in young elite wrestlers [6]. Profiling studies have also indicated that anthropometric characteristics and biomotor abilities differ according to age, training background, and competitive level [3, 4]. In addition, performance-oriented investigations in wrestling have emphasised the importance of maximal strength, lower-body power, and sport-specific fitness for competitive success [1, 2]. Nevertheless, the available literature remains unclear regarding how anthropometrically estimated lean body mass relates simultaneously to a broad neuromuscular test battery in adolescent wrestlers. Addressing this gap has practical significance, because coaches frequently administer multiple field- and laboratory-based tests within the same monitoring period, yet often interpret the results in isolation.

Body composition assessment has a long practical history in wrestling because coaches, physicians, and sport scientists have used anthropometric methods to monitor weight-category management, minimum competitive weight, and the potential risks associated with unsafe weight control. Classical wrestling studies examined skinfold-based procedures and minimum-weight prediction methods in high-school wrestlers, whereas later studies evaluated the cross-validation of prediction equations and near-infrared interactance models for estimating body fat in this population [7–21]. These investigations are relevant to the present study because they demonstrate both the practical value and the measurement sensitivity of field-based body composition estimates in wrestling.

Vertical jump tests, such as the squat jump and countermovement jump, are widely employed to assess lower-limb explosive capacity and the ability to generate vertical impulse [7]. Short sprint tests quantify early acceleration capacity, which is relevant to rapid offensive and defensive actions performed over short distances. Maximal dynamic strength tests, such as the one-repetition maximum back squat and bench press, quantify lower- and upper-body force capacity, whereas the isometric mid-thigh pull provides a standardised measure of whole-body isometric force production when methodological procedures are carefully controlled [8–11]. Handgrip dynamometry is particularly relevant in wrestling because grip ability contributes to opponent control, hold maintenance, and tactical dominance [11]. Finally, the Modified Agility T-test assesses change-of-direction performance, although this quality is influenced not only by strength and power but also by braking strategy, coordination, body control, and movement technique [12].

Clarifying the association between anthropometrically estimated lean body mass and these neuromuscular outcomes may enable coaches to differentiate structural development from functional performance capacity in young wrestlers. Such information may support talent monitoring, individualised strength-and-conditioning prescription, and longitudinal tracking across adolescence. Therefore, the present study examined the associations between anthropometrically estimated lean body mass and selected neuromuscular performance outcomes in young male wrestlers. It was hypothesised that estimated lean body mass would be positively associated with jump performance, maximal dynamic strength, isometric force production, and handgrip strength, and negatively associated with sprint time, whereas its association with change-of-direction performance would be weaker because this quality also depends on braking strategy, coordination, and technical execution.

Material and methods

Study design

This cross-sectional, observational study examined the relationships between anthropometrically estimated lean body mass and neuromuscular performance in young male wrestlers. Body composition was assessed before the physical performance tests. The outcome variables were squat jump (SJ), countermovement jump (CMJ), 5-m sprint time, one-repetition maximum (1RM) back squat, 1RM bench press, isometric mid-thigh pull (IMTP) absolute and net peak force, relative IMTP peak-force indices, handgrip strength, and Modified Agility T-test (MAT) time.

Participants

Fifty-two young male wrestlers participated in the study. The sample characteristics were as follows: age 17.65 ± 0.73 years, height 169.52 ± 7.69 cm, body mass 65.33 ± 9.21 kg, estimated lean body mass 56.53 ± 8.08 kg, body mass index 22.68 ± 2.39 kg · m^{-2}, and competition level (regional, n = 18; national, n = 22; and international, n = 12).

Participants were involved in regular wrestling practice and had training backgrounds compatible with youth competitive participation. Competition level was classified as regional, national, or international and was used as an adjustment factor in the statistical models.

Inclusion criteria were male sex, active participation in wrestling training, and medical clearance to complete maximal and near-maximal physical performance testing. Athletes were excluded if they had sustained a serious musculoskeletal or neuromuscular injury, or had any medical or orthopaedic condition affecting physical performance, during the previous six months. They were instructed to avoid strenuous exercise and caffeine for 24 hours before testing and to maintain their usual hydration and nutritional habits.

Procedures

Testing was conducted indoors at the same training facility under standardised environmental conditions. Anthropometric measurements were performed before physical testing. A standardised warm-up preceded the neuromuscular assessments and included light running or cycling, dynamic mobility exercises, submaximal jumping and pulling drills, and progressive barbell-specific warm-up sets when appropriate. The same testing order was used for all participants, standardised verbal encouragement was provided during maximal-effort tests, and adequate passive recovery was allowed between trials and tests to minimise fatigue.

To reduce learning effects, participants were familiarised with the testing procedures and technical requirements before formal data collection. Maximal strength testing was supervised by experienced strength-and-conditioning practitioners. For safety in this adolescent sample, only technically valid attempts were retained, and testing was stopped when technique deteriorated.

Anthropometric and body composition assessment

Anthropometric measurements were performed in the morning before any physical exercise. Procedures followed standardised recommendations from the International Society for the Advancement of Kinanthropometry. Participants were barefoot and wore light sports clothing. Body mass was measured to the nearest 0.1 kg using a digital scale (Detecto, Webb City, MO, USA), and standing height was measured to the nearest 0.5 cm using a stadiometer (Cescorf, Porto Alegre, RS, Brazil).

Body mass index (BMI) was calculated as body mass divided by height squared (kg · m^{-2}). Percentage body fat (%BF) was estimated using the Deurenberg equation [13]:

$$\%BF = 1.20 \times BMI + 0.23 \times age - 10.8 \times sex - 5.4,$$

where sex = 1 for males.

Fat mass was calculated as body mass × (%BF/100), and lean body mass was operationalised as body mass minus estimated fat mass. Because lean body mass was derived from an anthropometric prediction equation rather than measured using a criterion method, the term estimated lean body mass is used throughout the manuscript, and the findings are interpreted as field-based profiling data rather than diagnostic body composition assessment [13, 14]. The Deurenberg equation was selected because age, sex, height, and body mass were available for the whole sample, allowing a consistent estimate across all participants. Wrestling-specific skinfold or near-infrared interactance equations were considered important for contextual discussion but were not applied because the required input variables were not collected in this dataset. Specifically, the Tipton-Oppliger approach requires multiple skinfold sites, whereas the Oppliger *et al.* near-infrared interactance equations require near-infrared measurement variables; calculating those estimates post hoc would therefore be methodologically invalid [17, 21].

Jumping assessment

Lower-body explosive performance was assessed using the SJ and CMJ. Both tests were performed with the Optojump photoelectric system (Microgate, Bolzano, Italy), which has demonstrated validity and reliability for estimating vertical jump height [7]. For the SJ, participants began from an approximately 90° knee-flexion position, held the position briefly to minimise countermovement, and then jumped vertically as high as possible. For the CMJ, participants began from an upright standing position and performed a rapid downward movement followed immediately by a maximal vertical jump. In both tests, participants kept their hands on their hips to minimise arm-swing contribution. Each participant completed three valid trials, and the best jump height, expressed in centimetres, was retained for analysis. Invalid attempts were repeated when technique did not meet the required criteria.

5-m sprint

Linear acceleration was assessed using a 5-m standing-start sprint performed on an indoor rubberised gym floor. The front foot was positioned 5 cm behind the first timing gate. Photoelectric cells were positioned at 75 cm above the ground to preferentially detect trunk passage rather than limb movement. Participants completed three maximal attempts separated by 2–3 min of passive recovery, and the fastest time was retained for analysis.

Modified Agility T-test

Change-of-direction performance was evaluated using the Modified Agility T-test on the 20-m T-shaped course described by Haj Sassi *et al.* [12]. Participants performed the test as quickly as possible while maintaining the required movement pattern. A trial was considered invalid and repeated if the participant failed to touch the designated cones, failed to maintain a forward-facing trunk position, or crossed the feet during lateral displacement. Participants completed three valid trials separated by adequate passive recovery, and the fastest time was retained for analysis. Shorter completion time indicated better change-of-direction performance.

Maximal dynamic strength

Maximal dynamic strength was assessed using 1RM back squat and 1RM bench press protocols. Testing was conducted under the supervision of experienced conditioning coaches. Following a standardised warm-up, participants completed 5–10 repetitions at approximately 40–60% of the estimated 1RM, followed by 3–5 repetitions at approximately 60–80% of the estimated 1RM. Thereafter, 3–5 single attempts were allowed to determine 1RM, with 3–5 min of recovery between attempts. The load was increased individually according to the athlete's training history, technical execution, and readiness. The heaviest technically valid lift was recorded as the 1RM. The protocol was consistent with commonly reported 1RM procedures and was implemented with qualified supervision in accordance with youth resistance-training safety recommendations [8, 15].

Isometric mid-thigh pull

The IMTP test was used to assess whole-body isometric force-generation capacity [9, 10]. The bar position was individually adjusted to the midpoint between the knee and hip joints. Participants adopted the testing posture, and this individualised body position was reproduced before each attempt. The fixed bar was positioned in contact with the mid-thigh, and participants used their preferred grip. On the command 'Go', they were instructed to pull against the bar as hard and as fast as possible and to sustain maximal effort for 6 seconds. Participants were instructed to avoid pretension before force onset. Vertical ground reaction force was sampled at 1,000 Hz using a force plate (AccuPower, AMTI, Watertown, MA, USA).

Absolute peak force was defined as the highest force recorded during the trial. When the device output was expressed in kilogram-force (kg.f), values were converted to Newtons by multiplying by 9.80665. Net peak force was calculated by subtracting body weight from absolute peak force. Relative absolute and net peak-force values were calculated by dividing the corresponding force value by body mass and were expressed as $N \cdot kg^{-1}$.

Handgrip strength

Maximal handgrip strength was measured using a Harpenden dynamometer (British Indicators Ltd., Burgess Hill, United Kingdom). The dynamometer was adjusted to fit each participant's hand. Participants completed three maximal trials, and the highest value was retained for analysis [11].

Statistical analysis

Data are presented as mean ± standard deviation. Linear regression models adjusted for competition level were used as the primary analyses to examine the associations between estimated lean body mass and neuromuscular performance outcomes. Competition level was entered as a categorical covariate to account for potential performance differences among regional, national, and international wrestlers. IMTP absolute peak force was retained as the primary IMTP regression outcome, whereas net and relative IMTP peak-force values were reported descriptively to improve biomechanical interpretation. For transparency, the results report the unstandardised regression coefficient (*B*), 95% confidence interval (*CI*), standardised beta coefficient (β), coefficient of determination (R^2), and *p*-value for estimated lean body mass in each adjusted model. In addition, exploratory stepwise multiple linear regression was performed as a sensitivity analysis, with estimated lean body mass, age, BMI, and competition level considered as candidate predictors. Entry and removal criteria were set at $p < 0.05$ and $p > 0.10$, respectively. Because stepwise procedures may overfit in small samples, these analyses were interpreted only as supportive and did not replace the primary adjusted association models. Model diagnostics included inspection of residual distribution, linearity, homoscedasticity, and influential observations. The level of statistical significance was set at $p \leq 0.05$. Analyses were conducted using IBM SPSS Statistics, version 24.0 (IBM Corp., Armonk, NY, USA).

Results

Descriptive characteristics of the sample are shown in Table 1, and neuromuscular performance results are presented in Table 2. The mean estimated lean body mass was 56.53 ± 8.08 kg. The sample included regional, national, and international wrestlers, which justified adjustment for competition level in the regression models. Because the present dataset did not include multi-site skinfold or near-infrared interactance variables, no Tipton-Oppliger skinfold-derived or Oppliger near-infrared-derived body fat estimates were calculated.

Table 1. Descriptive characteristics of the participants

Variable	Total sample (*n* = 52) mean ± *SD*
Age (years)	17.65 ± 0.73
Height (cm)	169.52 ± 7.69
Body mass (kg)	65.33 ± 9.21
Estimated lean body mass (kg)	56.53 ± 8.08
Body mass index (kg · m^{-2})	22.68 ± 2.39

Table 2. Neuromuscular performance outcomes

Test	Total sample (*n* = 52) mean ± *SD*
Squat jump (cm)	24.99 ± 3.23
Countermovement jump (cm)	29.81 ± 3.70
5-m sprint (s)	1.139 ± 0.049
1RM back squat (kg)	87.98 ± 20.08
1RM bench press (kg)	51.79 ± 13.64
IMTP absolute peak force (N)	3,011 ± 247
IMTP net peak force (N)	2,370 ± 247
Relative IMTP absolute peak force (N · kg^{-1})	46.1 ± 3.8
Relative IMTP net peak force (N · kg^{-1})	36.3 ± 3.8
Handgrip strength (kg)	42.42 ± 4.34
MAT time (s)	5.70 ± 0.16

1RM – one-repetition maximum
IMTP – isometric mid-thigh pull
MAT – Modified Agility T-test
IMTP values originally recorded in kilogram-force were converted to Newtons by multiplying by 9.80665.
Net peak force was calculated by subtracting body weight from absolute peak force.

Adjusted regression analyses demonstrated that the estimated lean body mass was significantly associated with most neuromuscular outcomes (Table 3). Higher estimated lean body mass was associated with better lower-limb explosive performance, as indicated by posi-

Table 3. Adjusted associations between estimated lean body mass and neuromuscular performance outcomes.

Outcome	*B*	95% *CI*	β	R^2	*p*
Squat jump (cm)	0.236	0.145 to 0.327	0.591	0.420	< 0.001
Countermovement jump (cm)	0.258	0.157 to 0.359	0.564	0.455	< 0.001
5-m sprint (s)	–0.004	–0.005 to –0.003	–0.644	0.579	< 0.001
1RM back squat (kg)	2.138	1.901 to 2.376	0.861	0.898	< 0.001
1RM bench press (kg)	1.472	1.301 to 1.643	0.872	0.886	< 0.001
IMTP absolute peak force (N)	24.00	18.76 to 29.24	0.784	0.673	< 0.001
Handgrip strength (kg)	0.345	0.240 to 0.450	0.643	0.573	< 0.001
MAT time (s)	–0.004	–0.009 to 0.000	–0.217	0.434	0.059

Models adjusted for competition level.
1RM – one-repetition maximum, IMTP – isometric mid-thigh pull, MAT – Modified Agility T-test.
The IMTP coefficient was converted from kilogram-force to Newtons using 9.80665.

tive correlations with SJ (B = 0.236, 95% CI 0.145 to 0.327, $p < 0.001$) and CMJ (B = 0.258, 95% CI 0.157 to 0.359, $p < 0.001$). Estimated lean body mass was also inversely associated with 5-m sprint time (B = –0.004, 95% CI –0.005 to –0.003, $p < 0.001$), indicating that athletes with greater estimated lean tissue tended to accelerate faster over a short distance.

For maximal strength outcomes, the estimated lean body mass showed strong positive correlations with 1RM back squat (B = 2.138, 95% CI 1.901 to 2.376, $p < 0.001$; $R^2 = 0.898$) and 1RM bench press (B = 1.472, 95% CI 1.301 to 1.643, $p < 0.001$; $R^2 = 0.886$). A significant positive correlation was also observed for IMTP absolute peak force after conversion to Newtons (B = 24.00, 95% CI 18.76 to 29.24, $p < 0.001$). Handgrip strength was positively correlated with estimated lean body mass (B = 0.345, 95% CI 0.240 to 0.450, $p < 0.001$). The corrected descriptive IMTP values were 3,011 ± 247 N for absolute peak force and approximately 2,370 ± 247 N for net peak force. Relative absolute and net peak-force values were 46.1 ± 3.8 and 36.3 ± 3.8 $N \cdot kg^{-1}$, respectively.

The correlation between estimated lean body mass and MAT performance followed an expected trend, with greater estimated lean body mass associated with shorter completion times; however, this association did not reach statistical significance after adjustment for competition level (B = -0.004, 95% CI –0.009 to 0.000, $p = 0.059$).

Exploratory stepwise multiple regression models supported the primary interpretation: estimated lean body mass was retained as the principal predictor for SJ, CMJ, 5-m sprint, 1RM back squat, 1RM bench press, IMTP absolute peak force, and handgrip strength. For MAT time, estimated lean body mass was not retained as a final predictor at the conventional threshold, which was consistent with the borderline adjusted association reported above. Overall, the estimated lean body mass emerged as the body composition variable most consistently associated with force- and power-dominant neuromuscular outcomes.

Discussion

The present study investigated the relationship between anthropometrically estimated lean body mass and several neuromuscular performance outcomes in young male wrestlers. The major finding was that the estimated lean body mass was significantly correlated with jump performance, 5-m sprint time, maximal dynamic strength, IMTP peak force, and handgrip strength. The association with MAT time followed an expected trend but did not reach conventional statistical significance after adjustment for competition level. Overall, these findings indicate that the estimated lean body mass is a relevant structural correlate of force- and power-oriented qualities in adolescent wrestlers, while also confirming that multidirectional movement performance cannot be explained by body composition alone.

The positive associations between the estimated lean body mass and SJ and CMJ performance are physiologically coherent. Both tests require rapid force production and effective impulse generation during the propulsive phase of jumping [7, 16]. In adolescent athletes, greater estimated lean mass may reflect greater force-producing tissue and a more favourable neuromuscular profile, both of which can contribute to vertical jump performance. However, because lean body mass in the present study was estimated from anthropometric variables, the findings should be interpreted as practical monitoring evidence rather than as proof that directly measured skeletal muscle mass caused superior jump performance.

The inverse association between the estimated lean body mass and 5-m sprint time suggests that wrestlers with a greater estimated lean tissue tended to accelerate more effectively over a very short distance. This finding has practical relevance, as wrestling actions typically occur over short ranges rather than extended linear distances. Explosive entries, defensive retreats, lateral adjustments, and rapid re-engagement require rapid horizontal force generation. Greater lean mass may contribute to this capacity when it is accompanied by sufficient relative strength and neuromuscular coordination. Nevertheless, sprint performance depends on technical factors such as starting posture, projection angle, stride mechanics, and horizontal force orientation; therefore, estimated lean body mass should be considered one contributor rather than the sole determinant of acceleration ability.

The strongest correlations were observed for maximal dynamic strength outcomes, particularly 1RM back squat and 1RM bench press. This result was expected because maximal strength is closely related to the force-producing tissue mass and the athlete's training history. In wrestling, lower-body strength contributes to stance control, lifting actions, penetration steps, hip extension, and resisting opponent pressure, whereas upper-body strength supports pushing, pulling, framing, and grip-assisted control [1, 2]. The high coefficients of determination computed for these models indicate strong statistical correlations in this sample. However, these values should be interpreted cautiously because body mass, estimated lean mass, and maximal absolute strength are mechanically and biologically interrelated. For applied practice, absolute strength should therefore be complemented by relative strength indices, technical assessment, and weight-category context.

The IMTP peak force reflects the capacity to generate high whole-body isometric force understandardised joint positions and has been recommended when methodological procedures, such as bar position, body posture, sampling frequency, and instruction, are carefully controlled [9, 10]. In the present study, the higher estimated lean body mass was associated with greater IMTP absolute peak force, supporting the interpretation that wrestlers with a higher estimated non-fat tissue mass may exhibit greater whole-body force-generation capacity. Absolute peak force represents the total force recorded during the trial, net peak force represents absolute force minus body weight, and relative indices express force in relation to body mass. Reporting these complementary indices is particularly relevant in a weight-category sport because it clarifies the distinction between absolute force production and force output relative to body size.

Handgrip strength was also positively associated with the estimated lean body mass. This finding is consistent with the specific demands of wrestling, where grip strength contributes to controlling the opponent, maintaining holds, disrupting posture, and initiating offensive or defensive transitions [16]. Although handgrip dynamometry is a relatively simple test and does not reproduce the dynamic complexity of wrestling grips, it remains a useful field measure of upper-body functional capacity. In youth wrestlers, monitoring grip strength alongside body composition estimates may help coaches identify athletes who have favourable general strength development but require additional specific grip endurance, pulling strength, or technical gripping work.

In contrast, the association between estimated lean body mass and MAT performance approached but did not reach statistical significance. This finding is important because it shows that a higher estimated lean tissue mass does not automatically translate into superior change-of-direction performance. The MAT requires braking, lateral displacement, reacceleration, body orientation control, and efficient footwork [12]. These qualities depend on coordination, eccentric strength, technical execution, and movement strategy. In wrestling, agility is further complicated by the need to make movement decisions in response to an opponent. Therefore, body composition may support change-of-direction ability indirectly, but sport-specific agility should be developed through technical drills, reactive tasks, and multidirectional strength-power training rather than through hypertrophy-oriented development alone.

The present findings align with earlier works showing that anthropometric characteristics and body composition are related to anaerobic and neuromuscular performance in wrestlers [3, 4, 6]. They also extend previous research by examining a broader performance battery that included jumping, sprinting, maximal dynamic strength, isometric force, handgrip strength, and change-of-direction ability. This integrated approach is valuable given the multidimensional nature of wrestling performance. A single strength or power test cannot fully describe a wrestler's physical readiness. Instead, coaches should interpret estimated lean body mass together with a set of complementary performance indicators that reflect both absolute force capacity and movement efficiency.

From an applied standpoint, estimated lean body mass may be useful as a monitoring variable when interpreted longitudinally and in relation to weight category. Increases in estimated lean body mass may be desirable when they are accompanied by improvements in relative strength, explosive power, and wrestling-specific movement quality. Conversely, increases in body mass that do not improve force production or that impair speed, agility, or weight-category management may counterproductive. Coaches should therefore avoid interpreting lean body mass as universally advantageous. The key practical question is whether additional mass improves the athlete's capacity to express force rapidly and efficiently within the tactical and regulatory constraints of wrestling.

To recapitulate, the above findings demonstrate that anthropometrically estimated lean body mass was most strongly correlated with force- and power-dominant outcomes, including jumps, short acceleration, maximal dynamic strength, IMTP peak force, and handgrip strength. Its correlationwith change-of-direction performance was weaker, indicating that agility-related qualities require more than structural development. For coaches and sport scientists, these results support the use of estimated lean body mass as one component of wrestler profiling, but not as a standalone marker of performance readiness. The most informative approach is to combine body composition monitoring with a multidimensional neuromuscular test battery and to interpret all outcomes in relation to weight-category demands, training background, technical skill, and competitive level.

Limitations

Several limitations should be acknowledged. First, the cross-sectional design prevents causal interpretation of the observed associations. Second, lean body mass was estimated from anthropometric variables using a prediction equation rather than measured directly by dual-energy X-ray absorptiometry, air-displacement plethysmography, or multi-frequency bioelectrical impedance spectroscopy. Third, the dataset did not include the multi-site skinfold or near-infrared interactance variables required to apply wrestling-specific Tipton-Oppliger or Oppliger equations; therefore, alternative equation-derived bodyfat and leanmass estimates could not be calculated validly. Fourth, maturation status was not directly assessed, although biological maturation can influence body composition and neuromuscular performance in adolescent athletes. Fifth, wrestling-specific technical performance and match outcomes were not included, limiting direct inference to competitive performance. Sixth, the relatively small sample size and adjustment for competition level should be considered when interpreting the magnitude of regression coefficients and R^2 values, especially for exploratory stepwise models. Future longitudinal studies should examine whether changes in estimated lean body mass over time predict changes in neuromuscular qualities and wrestling-specific performance.

Conclusions

Anthropometrically estimated lean body mass was consistently associated with neuromuscular performance in young male wrestlers. Higher estimated lean body mass was correlated with better jump performance, faster short-distance acceleration, greater maximal dynamic strength, higher IMTP absolute peak force, and greater handgrip strength, whereas the adjusted association with MAT performance remained borderline. Descriptive net and relative IMTP indices may add useful context for interpreting force production in relation to body mass. Regular assessment of estimated lean body mass in combination with a field-based neuromuscular test battery may provide practical information for athlete monitoring and individualised training prescription in youth wrestling, provided that results are interpreted in relation to weight-category demands, training background, competition level, and technical performance.

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Ethical approval
The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Local Ethics Committee of the regional education committee (approval No.: RNTA/20, 7 October 2025).

Informed consent
Before participation, wrestlers and their legal guardians were informed about the study purpose, testing procedures, potential risks, and expected benefits. Written informed consent was obtained from legal guardians, and assent was obtained from participants before testing.

Conflict of interest
The authors state no conflict of interest.

Disclosure statement
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