Association of Body Composition with Muscle Strength and Endurance among First-Year Medical Students in a South Indian Medical College – A Cross-Sectional Study

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ABSTRACT

This cross-sectional study evaluated the association between body composition, muscle strength, and endurance among first-year medical students at a South Indian medical school using handgrip dynamometry and bioelectrical impedance analysis. In the cohort as a whole, body fat percentage showed a slight but significant link with muscular strength; however, sex-wise analysis showed that muscle mass was highly correlated with endurance in males and BMI and body fat were associated with grip strength in females. These results underline the significance of precise composition measurements over BMI alone in evaluating musculoskeletal fitness in young adults and show sex-specific associations between the body composition and their muscle performance.

Keywords: Body composition; Muscle strength; Muscle endurance; Handgrip dynamometry; Bioelectrical impedance analysis; Medical students; South India; Sex-specific differences.

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BACKGROUND

Due to inactivity, poor eating habits and sedentary lives, obesity has become a major global public health concern, affecting 650 million people worldwide. This leads to metabolic illnesses and around 2.8 million deaths annually.**[1]** With over 135 million people afflicted, the incidence of obesity in India is also quickly increasing due to changes in dietary and lifestyle habits.**[2]**

One important factor influencing metabolic and physical health is body composition, or the proportions of lean and fat mass. Body composition has a big impact on physical performance, influencing things like muscle strength and endurance in addition to fundamental measures like BMI. This is because muscle mass is essential for energy expenditure, metabolic control, and functional ability. **[3]** Achieving optimal muscle strength and endurance is crucial for physical well-being and is associated with improved cardiometabolic risk profile and physical function, among other general health outcomes. **[4]**

First-year medical students often face intensive academic schedules, psychological stress, and prolonged sedentary behaviour. Physical activity patterns, body composition, and musculoskeletal fitness—including muscle strength and endurance—may all be adversely affected by these conditions. **[5]** In addition to being crucial for young adults' everyday functioning capacity, muscle strength and endurance are linked to wider health advantages throughout life, such as a lower chance of chronic illnesses and death when kept at healthy levels. **[6]**

Therefore, assessing the association between body composition and muscle performance, among medical students at the beginning of their rigorous training can help identify early risk factors, raise awareness about physical health, and inform targeted wellness interventions. Such evidence may be critical for promoting fitness and long-term health in future healthcare professionals, ultimately improving both their personal well-being and professional performance.

MATERIALS AND METHODS

Study Design and Participants

After receiving ethics clearance and approval from the Institutional Ethical Committee, 40 first-year MBBS students in a rural medical college in South India, ages 18 to 22, participated in this observational study. Every participant gave their informed consent. The study excluded students who had a history of musculoskeletal conditions, chronic illnesses, recent injuries, or regular participation in competitive sports training.

Evaluation of Body Composition

Anthropometric measurements were taken using the normal procedures. A digital scale with a 0.1 kg calibration

**Author for Correspondence: ravireshma2000@gmail.com* was used to measure body weight. A stadiometer, which was accurate to within 0.1 cm, was used to measure height. [7] BMI was calculated by dividing weight (in kg) by height (in m2). [8]

Lean body mass and body fat percentage were measured using a Tanita BC-601 bioelectrical impedance analyzer (Tanita Corporation, Japan). [9] Participants were instructed to use hand electrodes while standing barefoot in accordance with the manufacturer's instructions. A non-invasive, scientifically proven method for assessing body composition is bioelectrical impedance analysis, or BIA. [10]

Hand muscle strength was measured using the Baseline® Lite Hydraulic Hand Dynamometer. Participants were sitting in comfortable chairs with their feet firmly planted on the floor. Each participant's dominant hand was utilized to evaluate handgrip muscular strength, with the elbow extended at a 90-degree angle and the forearm in a neutral position. During the measurement, the individual was instructed to use their greatest voluntary contraction. Mean of the three values, separated by a 30-second interval between each measurement, was taken as handgrip strength. [11,12,13]

For the measurement of muscle endurance, a sustained isometric handgrip test was performed. Subjects were asked to sustain 50% of the maximum voluntary strength of their handgrip for as long as possible without any variation. This duration of sustaining the force was recorded in seconds. [14,15,16]

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) version 22.0 was used to analyze the data. The mean ± standard deviation was used to display continuous data. Using Pearson correlation, the association between anthropometric measurements and strength and endurance metrics was evaluated. The standard for statistical significance was set at a p-value of less than 0.05.

RESULTS AND DISCUSSION

Forty first-year medical students volunteered to participated in the study. Table 1 displays the baseline anthropometric, body composition, and muscle performance characteristics according to gender. Age differences between men and women were not statistically significant ($p = 0.28$). On the other hand, height and physical structure were considerably higher in males than in females ($p = 0.04$ and $p < 0.001$, respectively). Additionally, men's waist-to-hip ratios were substantially higher ($p < 0.001$). However, BMI, waist circumference, hip circumference, visceral fat, body fat percentage, muscle, and total body water did not significantly differ by gender.

Males had considerably greater mean handgrip muscle strength than females (39.32 ± 8.02 kg vs. 26.32 ± 3.69 kg; $p<0.001$). However, muscle endurance did not significantly differ between the sexes ($p=0.24$) **(Table 1)**.

A statistically significant and somewhat positive correlation was observed between muscle strength and body fat percentage ($r = 0.33$, $p = 0.036$).Both muscle mass and muscular strength and BMI and muscle strength did not show statistically significant associations. Likewise, there were no significant relationships between body fat parameters and muscle endurance ($p > 0.05$ for all) **(Table 2).**

Concerning the sexual differences in correlations, the analysis of correlations by sex produced noteworthy findings (Table 3). Only BMI ($r = 0.48$, $p = 0.027$) and body fat percentage ($r = 0.46$, $p = 0.034$) showed moderate yet significant correlations with muscle strength in females; however, muscle mass did not display any correlation. No significant correlations emerged for muscle endurance either.

Male muscular mass and strength, body fat percentage, and BMI did not significantly correlate. BMI and body fat % do not significantly correlate with muscle endurance, although there is a considerable association ($r = 0.58$, $p = 0.009$) between muscle mass and muscular endurance.

DISCUSSION

This cross-sectional study examined the connections between first-year medical students' muscular function and body composition. In the overall cohort, body fat percentage showed a small but statistically significant positive correlation with muscle strength, whereas BMI and BIA-estimated muscle mass were not significantly associated with either strength or endurance. Sex-stratified analysis indicated differing trends: in females, both BMI ($r = 0.48$, $p = 0.027$) and body fat percentage ($r = 0.46$, $p = 0.034$) exhibited moderate and significant correlations with handgrip strength, whereas muscle mass did not show any correlation with strength. On the other hand, there was no significant correlation between body composition and muscle strength in males, although there was a strong positive relationship between muscle mass and muscle endurance ($r = 0.58$, $p = 0.009$).

These results align with earlier studies that show intricate and frequently contradictory connections between body measurements and muscle performance. BMI, a basic measure of body size, often demonstrates weak or inconsistent correlations with handgrip strength among various age groups and populations, as it fails to differentiate between fat and lean tissue components.[1–3] **[17-19]** As a result, BMI may fail to accurately reflect true muscular capacity. In contrast, body composition measures that directly assess lean mass or fat-free mass tend to show stronger and more consistent associations with muscle strength and functional performance.[4],[6] **[20,21]**

In women, a positive correlation has been observed between grip strength and both BMI and body fat percentage, suggesting that these factors may reflect a larger overall body size and a mass-related mechanical advantage rather than superior muscle quality. Similar observations have been reported in adolescent and adult populations, where absolute strength increases with body size irrespective of proportional muscle mass.[1],[7] .**[17,22]** Sex-based differences on the basis of body composition and muscle function are well-documented; generally, males exhibit greater absolute muscle mass and strength compared to females, largely due to hormonal and physiological influences [9] .**[24]** Male and female differences in muscle mass and functional performance have been well-documented; generally speaking, males tend to have more muscular mass and strength than females for primarily physiological and hormonal reasons.[5] **[10]**

In males, the robust correlation between muscle mass and endurance corresponds with physiological expectations that increased lean tissue aids in improved fatigue resistance during prolonged isometric activities. Endurance performance relies not just on the amount of muscle but also on metabolic efficiency and fiber-type distribution, which may be more accurately represented by total lean mass in younger men.[6] **[21]** The absence of a correlation between body fat percentage and endurance in both genders indicates that adiposity is not a significant factor in influencing fatigue resistance among healthy young adults who do not have functional impairments.[3],[8] **[19,23]**

Overall, the present findings highlight that different components of body composition relate to different aspects of muscle performance in a sex-specific manner. While adiposity-related measures were associated with strength in females, lean mass was the primary determinant of endurance in males, underscoring the importance of considering sex differences when evaluating musculoskeletal fitness in young adults.[4],[9],[10] **[20,24,25]**

Our results are consistent with those of Dhar and Purwar, who found a strong correlation between young adults' muscle performance and body composition indices. In their cross-sectional study, higher body fat percentage and BMI showed meaningful relationships with handgrip strength and endurance, highlighting that both adiposity and overall body size influence muscle function in this age group.[11] **[26]** Their research emphasizes the distinct effects of body composition on muscle performance, which vary by sex and task. This aligns with the current study's conclusion that BMI and body fat percentage are associated with grip strength in females, whereas muscle mass plays a more crucial role in endurance for males.

Evidence from clinical populations further supports the link between body composition and muscle performance. Kowshik et al. studied patients who had head and neck cancer and demonstrated significant associations between handgrip strength, endurance, and body composition parameters.[12] **[27]** Their results highlighted the importance of lean tissue in functional capacity by demonstrating that decreased muscle mass and changed body composition were linked to decreased muscle strength and endurance. Despite the fact that their demography differs from that of healthy medical students, the underlying physiological relationship between muscle mass and performance is consistent with the current study. This is especially true of the substantial correlation between muscle mass and endurance shown in males.

Beyond sports performance, handgrip strength has clinical value and is strongly linked to long-term health consequences. In a very large population-based cohort, Gale et al. found that poor body composition and reduced grip strength were linked to higher mortality.[13] **[28]** This emphasizes how crucial muscle strength is as a comprehensive indicator of health. Although our study involved young, healthy medical students and did not assess long-term outcomes, the observed associations between body composition and muscle function gain significance in light of evidence linking grip strength to survival.

CONCLUSION

In a cohort of first-year medical students, the current study shows sex-specific relationships between body composition and muscle function. Sex-stratified analysis demonstrated robust connections between muscle mass and endurance in males, along with notable correlations between BMI, body fat, and strength in females. Given the cohort's generally modest correlation between muscle strength and body fat percentage, this is especially intriguing. These findings underscore the limitations of using BMI alone to define muscular fitness and emphasize the need for thorough composition analyses to gain a deeper comprehension of muscle function.

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Table 1 - baseline characteristics of the study participants

Parameter	Males (Mean ± SD)	Females (Mean ± SD)	p-value
Age (years)	19.68 ± 0.95	19.38 ± 0.80	0.28

Height (cm)	177.05 ± 7.45	160.76 ± 6.21	**<0.001**
Weight (kg)	73.05 ± 13.71	63.37 ± 14.54	**0.04**
BMI (kg/m²)	23.22 ± 3.60	24.50 ± 5.32	0.37
Waist circumference (cm)	83.26 ± 9.00	78.33 ± 10.15	0.11
Hip circumference (cm)	97.74 ± 9.60	99.33 ± 13.63	0.67
Waist–hip ratio	0.85 ± 0.04	0.79 ± 0.05	**<0.001**
Visceral fat (cm2)	6.52 ± 3.39	4.48 ± 3.47	0.07
Body fat (%)	32.74 ± 12.50	28.43 ± 11.04	0.26
Muscle mass (kg)	44.71 ± 4.13	42.51 ± 6.54	0.21
Total body water (%)	45.77 ± 8.00	46.77 ± 8.51	0.7
Mean hand grip muscle strength (kg)	39.32 ± 8.02	26.32 ± 3.69	**<0.001**
Muscle endurance (s)	82.58 ± 25.79	94.05 ± 34.12	0.24

Table 2. Correlation of body composition parameters with muscle strength and muscle endurance

Body composition parameter	Muscle strength (r)	p value	Muscle endurance (r)	p value
BMI (kg/m²)	0.02	0.9	0.06	0.715
Body fat (%)	**0.33**	**0.036***	–0.07	0.681
Muscle mass (kg)	0.13	0.44	0.07	0.655

Table 3. Sex-wise correlation of body composition parameters with muscle strength and muscle endurance

Sex	Variable	Muscle Strength (r)	p value	Muscle Endurance (r)	p value
Females	BMI	**0.48**	**0.027***	0.03	0.897
	Body fat (%)	**0.46**	**0.034***	0.08	0.738
	Muscle mass (kg)	–0.02	0.966	–0.08	0.73
Males	BMI	0.02	0.937	0.04	0.868
	Body fat (%)	0.24	0.325	–0.18	0.487
	Muscle mass (kg)	–0.05	0.826	**0.58**	**0.009***