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Association between Skeletal Muscle Mass and Blood Pressure among Healthy Young Adults: A Cross-Sectional Study

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Abstract

Background: Skeletal muscle is the largest metabolically active tissue in the human body and plays an important role in cardiovascular and metabolic regulation. Although obesity is a well-established risk factor for hypertension, the relationship between skeletal muscle mass (SMM) and blood pressure in healthy young adults remains inadequately explored. **Objectives:** The objective of the study was to evaluate the association between SMM and blood pressure among healthy young adults. **Materials and Methods:** A cross-sectional observational study was conducted among 200 healthy medical students aged 18–25 years. SMM was measured using Bioelectrical Impedance Analysis. Blood pressure was recorded using a standardized automated sphygmomanometer following American Heart Association recommendations. Pearson's correlation coefficient was used to assess the association between SMM and blood pressure parameters. Multiple linear regression analysis was performed to identify independent predictors of systolic and diastolic blood pressure (DBP) after adjusting for age, sex, height, and body mass index (BMI). A two-tailed $P < 0.05$ was considered statistically significant. **Results:** The mean SMM was 28.9 ± 5.8 kg. The mean systolic and DBP were 116.8 ± 10.4 mmHg and 74.2 ± 7.8 mmHg, respectively. SMM showed significant positive correlations with systolic blood pressure (SBP) (r = 0.32, $P < 0.001$), DBP (r = 0.28, $P < 0.001$), and mean arterial pressure (r = 0.30, $P < 0.001$), while no significant correlation was observed with pulse pressure (r = 0.09, $P = 0.198$). Multiple linear regression analysis demonstrated that SMM was an independent predictor of SBP ($\beta = 0.23$, $P = 0.009$) and DBP ($\beta = 0.20$, $P = 0.014$) after adjusting for age, sex, height, and BMI. **Conclusion:** SMM is significantly associated with systolic and DBP among healthy young adults. Assessment of SMM may complement conventional anthropometric measures in evaluating cardiovascular health and blood pressure.

Keywords: Bioelectrical impedance analysis, Blood pressure, Body composition, Diastolic blood pressure, Skeletal muscle mass, Systolic blood pressure

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Introduction

Skeletal muscle is the largest metabolically active tissue in the human body, accounting for approximately 35–45% of total body weight in healthy adults. In addition to its primary role in locomotion and posture, skeletal muscle functions as an important endocrine organ by secreting myokines that regulate glucose metabolism, lipid homeostasis, inflammation, and vascular function. Consequently, skeletal muscle mass (SMM) has emerged as an important determinant of cardiometabolic health beyond its traditional mechanical functions.[1,2]

Blood pressure is a vital physiological parameter that reflects the interaction between cardiac output, peripheral vascular resistance, blood volume, autonomic nervous system activity, and vascular compliance. Hypertension is one of the leading modifiable risk factors for cardiovascular morbidity and mortality worldwide. Although obesity and excess adiposity are well-established contributors to hypertension, increasing evidence suggests that body composition, particularly SMM, also plays a significant role in blood pressure regulation.[3,4]

Skeletal muscle contributes substantially to peripheral glucose utilization, accounting for nearly 80% of insulin-mediated glucose uptake. Reduced SMM is associated with insulin resistance, endothelial dysfunction, chronic low-grade inflammation, and increased arterial stiffness, all of which contribute to elevated blood pressure. Conversely, adequate SMM may improve vascular health through enhanced nitric oxide bioavailability, improved metabolic efficiency, and reduced sympathetic nervous system activation.[5,6]

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Assessment of SMM has become increasingly important in clinical and physiological research. It can be estimated using anthropometric measurements, bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry, computed tomography, or magnetic resonance imaging. Among these, BIA offers a simple, non-invasive, cost-effective, and reliable method for estimating SMM in community-based studies and healthy populations.[7,8]

Several epidemiological studies have demonstrated an association between reduced SMM and an increased risk of hypertension, metabolic syndrome, and cardiovascular disease. Individuals with low SMM are more likely to exhibit higher systolic and diastolic blood pressure (DBP), independent of body mass index (BMI). However, some studies have reported conflicting findings, suggesting that the relationship between SMM and blood pressure may be influenced by age, sex, obesity, and physical activity levels. Therefore, further studies are required to clarify this association, particularly among healthy young adults.[9,10]

Young adulthood represents an ideal period for studying the relationship between SMM and blood pressure because age-related sarcopenia and chronic comorbidities are generally absent. Establishing baseline data in healthy individuals may improve understanding of the physiological relationship between body composition and cardiovascular function and may aid in the early identification of individuals at risk of developing hypertension later in life.[11]

The present study was therefore undertaken to evaluate the association between SMM and blood pressure among healthy young adults.

Materials and Methods

Study Design

This cross-sectional observational study was conducted to evaluate the association between SMM and blood pressure among healthy young adults after getting approval from the Institutional Ethics Committee.

Study Setting

The study was carried out jointly in the Departments of Anatomy and Physiology, Viswabharathi Medical College, Kurnool, Andhra Pradesh.

Study Duration

The study was conducted over a period of 6 months.

Study Population

The study included apparently healthy undergraduate medical students aged 18–25 years.

Sample Size

A total of 200 participants were enrolled using convenience sampling after obtaining written informed consent.

Inclusion Criteria

- Healthy male and female medical students aged 18–25 years
- Apparently healthy individuals willing to participate in the study
- Participants who provided written informed consent.

Exclusion Criteria

- Known hypertension or use of antihypertensive medications
- History of diabetes mellitus, cardiovascular disease, renal disease, or endocrine disorders
- Acute illness at the time of examination
- Pregnancy
- Individuals with metallic implants or cardiac pacemakers (contraindication for BIA)
- Professional athletes or individuals undergoing intensive strength training
- Participants with incomplete study data.

Study Variables

Independent variable

- SMM (kg)
- Skeletal muscle index (SMI) (kg/m^2).

Dependent variables

- Systolic blood pressure (SBP) (mmHg)
- DBP (mmHg)
- Mean arterial pressure (MAP) (mmHg)
- Pulse pressure (PP) (mmHg).

Covariates

- Age
- Sex
- Height
- Weight
- BMI.

Instruments Used

- Portable stadiometer
- Calibrated digital weighing scale
- Bioelectrical impedance analyzer (Omron HBF-375/equivalent)
- Automated digital sphygmomanometer (Omron HEM-7120/equivalent).

Data Collection Procedure

After obtaining approval from the Institutional Ethics Committee and written informed consent from all participants, demographic information, including age and sex, was recorded.

Height was measured using a portable stadiometer to the nearest 0.1 cm, while body weight was measured using a calibrated digital weighing scale to the nearest 0.1 kg, with participants wearing light clothing and no footwear. BMI was calculated as weight (kg) divided by the square of height (m^2).

Assessment of SMM

SMM was assessed using BIA with a validated body composition analyzer according to the manufacturer's instructions.
Participants were instructed to:

- Avoid vigorous physical activity for 24 h before assessment
- Avoid alcohol consumption for 24 h
- Fast for at least 2 h before testing
- Empty the urinary bladder before the procedure.

Measurements were obtained with the participant standing barefoot on the analyzer. The device estimated SMM (kg) using impedance-based algorithms.
The SMI was calculated as:

$$\text{SMI (kg/m}^2) = \text{SMM (kg)} \div \text{Height}^2\ (\text{m}^2)$$

Each measurement was recorded once under standardized conditions.

Measurement of Blood Pressure

Blood pressure was measured according to the American Heart Association recommendations.
Participants were instructed to:

- Avoid caffeine, smoking, and strenuous exercise for at least 30 min before measurement
- Rest quietly for 5 min in a seated position
- Sit with the back supported, feet flat on the floor, and the arm supported at heart level.

An appropriately sized cuff was placed on the right upper arm. Three blood pressure readings were obtained at 2-min intervals using an automated digital sphygmomanometer. The average of the last two readings was used for statistical analysis.
The following parameters were recorded:

- SBP
- DBP.

The following indices were calculated:

$$PP=SBP-DBP$$

$$MAP=DBP+1/3\ (SBP-DBP).$$

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM Statistical Package for the Social Sciences Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequency and percentage. The independent samples *t*-test was used to compare continuous variables between males and females. Pearson's correlation coefficient was used to assess the association between SMM and blood pressure parameters. Multiple linear regression analysis was performed to identify independent predictors of systolic and DBP after adjusting for age, sex, height, and BMI. A two-tailed $P < 0.05$ was considered statistically significant.

Results

A total of 200 healthy young adults participated in the study, comprising 108 (54.0%) males and 92 (46.0%) females. The mean age of the participants was 20.9 ± 1.7 years. The mean height, weight, and BMI were 167.8 ± 8.6 cm, 64.5 ± 10.8 kg, and 22.8 ± 3.3 kg/m^2, respectively [Table 1].

The mean SMM was 28.9 ± 5.8 kg, while the mean SMI was 10.2 ± 1.5 kg/m^2. The mean SBP, DBP, MAP, and PP were 116.8 ± 10.4 mmHg, 74.2 ± 7.8 mmHg, 88.4 ± 7.6 mmHg, and 42.6 ± 6.8 mmHg, respectively [Table 2].

Pearson's correlation analysis demonstrated a weak but statistically significant positive correlation between SMM and SBP (r = 0.32, $P < 0.001$), DBP (r = 0.28, $P < 0.001$), and MAP (r = 0.30, $P < 0.001$). No significant correlation was observed between SMM and PP (r = 0.09, $P = 0.198$) [Table 3].

Multiple linear regression analysis was performed to identify independent predictors of SBP after adjusting for age, sex, height, BMI, and SMM. SMM remained an independent predictor of SBP ($\beta = 0.23$, $P = 0.009$). BMI also showed a significant independent association with SBP ($\beta = 0.29$, $P < 0.001$), whereas age, sex, and height were not significant predictors. The overall regression model explained 31.2% of the variability in SBP (Adjusted $R^2 = 0.312$, $P < 0.001$) [Table 4].

Table 1: Baseline characteristics of the study participants (*n*=200)

Variable	*Mean±SD/n (%)*
Age (years)	20.9±1.7
Height (cm)	167.8±8.6
Weight (kg)	64.5±10.8
BMI (kg/m2)	22.8±3.3
Male	108 (54.0)
Female	92 (46.0)

BMI: Body mass index, SD: Standard deviation

Table 2: Skeletal muscle mass and blood pressure parameters

Variable	*Mean±SD*
Skeletal muscle mass (kg)	28.9±5.8
Skeletal muscle index (kg/m2)	10.2±1.5
Systolic blood pressure (mmHg)	116.8±10.4
Diastolic blood pressure (mmHg)	74.2±7.8
Mean arterial pressure (mmHg)	88.4±7.6
Pulse pressure (mmHg)	42.6±6.8

SD: Standard deviation

Table 3: Correlation between skeletal muscle mass and blood pressure parameters

Variable	*Correlation coefficient (r)*	*P-value*
Systolic blood pressure	0.32	<0.001*
Diastolic blood pressure	0.28	<0.001*
Mean arterial pressure	0.30	<0.001*
Pulse pressure	0.09	0.198

*Statistically significant

Table 4: Multiple linear regression analysis for predictors of systolic blood pressure

Predictor	*Standardized β*	*P-value*
Skeletal muscle mass	0.23	0.009*
BMI	0.29	<0.001*
Height	0.10	0.141
Age	0.06	0.401
Sex	0.08	0.223

Adjusted R^2=0.312, *P*<0.001. *Statistically significant. BMI: Body mass index

Table 5: Multiple linear regression analysis for predictors of diastolic blood pressure

Predictor	*Standardized β*	*P-value*
Skeletal muscle mass	0.20	0.014*
BMI	0.27	<0.001*
Height	0.09	0.188
Age	0.05	0.463
Sex	0.07	0.279

Adjusted R^2=0.248, *P*<0.001. *Statistically significant. BMI: Body mass index

A second regression model was constructed using DBP as the dependent variable. SMM remained independently associated with DBP ($\beta = 0.20$, $P = 0.014$), while BMI was the strongest predictor ($\beta = 0.27$, $P < 0.001$). Height, age, and sex did not independently predict DBP. The regression model explained 24.8% of the variability in DBP (Adjusted $R^2 = 0.248$, $P < 0.001$) [Table 5].

Discussion

The present study evaluated the association between SMM and blood pressure among healthy young adults and demonstrated a significant positive association between SMM and SBP, DBP, and mean arterial pressure. Multiple linear regression analysis further identified SMM as an independent predictor of both systolic and DBP after adjusting for age, sex, height, and BMI, suggesting that SMM contributes to blood pressure regulation independent of overall body size.

The mean systolic and DBP observed in the present study were 116.8 ± 10.4 mmHg and 74.2 ± 7.8 mmHg, respectively, which are within the normal reference range for healthy young adults. The weak positive correlation between SMM and blood pressure is physiologically plausible because individuals with greater muscle mass generally have a larger body size, higher metabolic demand, and greater cardiac output, resulting in slightly higher resting blood pressure values while remaining within normal physiological limits.[12]

Skeletal muscle is an important regulator of cardiovascular and metabolic homeostasis. Besides facilitating movement, skeletal muscle acts as an endocrine organ by releasing myokines that influence endothelial function, vascular tone, and insulin sensitivity. Greater SMM has been associated with improved glucose utilization and reduced vascular inflammation, factors that contribute to maintenance of normal blood pressure. Pedersen and Febbraio emphasized the endocrine role of skeletal muscle in regulating metabolic and cardiovascular function through myokine secretion.[5]

The present study demonstrated a significant positive correlation between SMM and SBP. Similar observations have been reported by Srikanthan and Karlamangla, who showed that SMM is closely associated with cardiometabolic health and influences cardiovascular risk independent of adiposity. Although individuals with greater muscle mass may exhibit slightly higher SBP because of increased lean body size and cardiac output, adequate muscle mass remains protective against metabolic disorders associated with hypertension.[9]

A significant positive association was also observed between SMM and DBP. This finding may be explained by the greater to perfuse increased muscle tissue, resulting in modest physiological elevations in resting vascular resistance. Nevertheless, the observed blood pressure values remained within normal limits, indicating physiological adaptation rather than pathological hypertension. Similar findings have been described in studies evaluating body composition and cardiovascular function among healthy adults.[10]

In the present study, SMM remained an independent predictor of both systolic and DBP even after adjustment for age, sex, height, and BMI. This finding suggests that lean body mass contributes independently to blood pressure regulation. Previous investigators have similarly reported that body composition provides better insight into cardiovascular risk than body weight or BMI alone, as BMI does not distinguish lean tissue from adipose tissue.[11]

No significant association was observed between SMM and PP. PP primarily reflects arterial stiffness and vascular compliance rather than body composition. Since the participants in the present study were healthy young adults with normal vascular elasticity, SMM was not expected to exert a significant influence on PP. This observation is consistent with the understanding that arterial stiffness becomes clinically relevant predominantly with aging and cardiovascular disease.[13]

The present findings have important clinical implications. Measurement of SMM using BIA is simple, non-invasive, inexpensive, and suitable for community-based screening. Assessment of SMM may complement conventional anthropometric indices during cardiovascular risk evaluation, particularly in young adults, where BMI alone may not accurately reflect body composition. Such measurements may also be useful in lifestyle intervention programs focusing on physical activity and muscle strengthening for long-term cardiovascular health.[7]

Conclusion

The present study demonstrated a significant positive association between SMM and blood pressure among healthy young adults. SMM was independently associated with systolic and DBP after adjusting for age, sex, height, and BMI. These findings suggest that SMM is an important anatomical determinant of cardiovascular physiology and may complement conventional anthropometric measures in the assessment of blood pressure.

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