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Correlation Between BMI and Calf Muscle Matrices on Static Balance Among College Male Adults: An Observational Study

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ABSTRACT

Background: Balance is the capacity to maintain the center of gravity within the base of support and is essential for fall prevention, yet this stability is compromised by Body Mass Index (BMI) altering mechanical demands but supported by calf muscle characteristics (girth, length, fat) crucial for ankle joint support and proprioception. This study aimed to correlate BMI and calf matrices with static balance performance in healthy college-aged male adults.

Methodology: The study included one hundred healthy college men aged 18–25 years. Researchers quantified four calf muscle characteristics gastrocnemius and soleus lengths (using goniometry), calf girth, and medial calf skinfold alongside demographic data. Static balance was assessed using the best trial score from the Stork balance test. Data were analyzed using descriptive statistics and Pearson correlation ($p < 0.05$).

Results: Data analysis revealed a highly significant positive correlation between BMI and calf girth, indicating increased girth with higher BMI. Conversely, a negative correlation linked higher BMI to poorer static balance performance in those same participants, while BMI showed no significant correlation with calf muscle length in any group.

Conclusion: A significant inverse correlation was found between increased Body Mass Index (BMI) and diminished static balance performance. Consequently, clinical strategies must prioritize improving lean body mass and reducing adiposity to effectively enhance postural stability in this college-aged male cohort, as muscle length was not a contributing factor.

Keywords: Body mass index 1, calf girth 2, muscle length 3, medial calf skinfold 4, static balance 5, stork balance test 6.

INTRODUCTION:

Balance is defined as maintaining the body's center of gravity (COG)within its base of support with minimal sway, essential for both static and dynamic tasks.[1] Static balance, a specialized skill for steady, stationary posture, is critically compromised by the sedentary lifestyle fueled by technological evolution and prolonged sitting, as extended inactivity causes a detrimental reduction in overall postural stability.[2,3] Increased body fat can impede muscular responses, leading to biomechanical instability and reduced postural control; specifically, elevated BMI (Body Mass Index) is consistently associated with reduced

postural stability, an altered COG, and delayed muscular reaction time.[4,5]

Variations in the specific calf muscle matrices that are girth and length modulates the efficacy of these muscles in contributing to maintain static balance. Preservation of an optimal ratio between adipose tissue and lean muscle mass within the lower limb musculature is deemed essential for sustaining postural stability and mitigating the risk of falls. [4,5,6]

While BMI is a simple, widely used anthropometric measure, higher BMI is consistently associated with decreased postural stability, often due to its failure to differentiate accurately between fat and muscle mass.[7] Consequently, the gastrocnemius and soleus muscles are vital for maintaining static balance, providing essential ankle joint stability and proprioception. This means that variations in their anatomical characteristics, such as girth, length and the overall muscle-to-fat ratio are key to preventing falls.[8,9]

Body composition is commonly assessed through methods such as BMI and skinfold measurement. Given the limited research correlating specific anthropometric variables like BMI, calf muscle length and girth with static balance performance. This observational study aims to examine these relationships in healthy college-aged males aged 18-25 years to establish essential baseline data for targeted clinical and athletic interventions for improving postural control and overall well-being.

Materials and Methods:

Research Group and Design

This observational study included 100 healthy male college students aged 18-25 years, selected from a professional college in Mangalore. Individuals with prior spinal or lower extremity surgery, or a pain or mobility limiting musculoskeletal condition, balance issues recent injury (within 6 months) extreme posture variations sympathetic nervous system altering medications or elite athlete status were specifically excluded from the study.[10] After obtaining informed consent baseline age, weight, height and BMI were recorded. The necessary tools included an inch tape (for calf circumference) a skinfold caliper (for medial calf circumference) a goniometer (for measuring gastrocnemius and soleus length via passive ankle dorsiflexion in knee-extended and knee90^0 flexed positions respectively) and a stop watch (for timing the Stroke Balance Test) Static balance was assessed using the stroke balance test on both legs.

OUTCOME MEASURES:

Calf Circumference: Calf circumference (CC) was measured with the subject standing upright with feet apart, shoulder width, and body weight evenly distributed between both legs. In this position, CC can be measured at the calf's greatest girth using an inelastic tape measure with the calf exposed, and the readings were taken over both legs. The measurements were recorded in centimeters.[11]

Muscle length test (Gastronomies): Gastronomies length was measured by having the subject lie prone in a figure-four position, with the measuring foot hanging over the edge of the table in minimal clothing; this position helped to keep the lower extremity in a neutral position. The axis of the goniometer was placed inferior to the lateral malleolus, the stationary arm was parallel to the fibula, while the moving arm was in line with the lateral midline of the calcaneus. The instructor assured that the foot position was in subtalar neutral. Then the subject's foot was passively dorsiflexed until a stretch was felt, and the degree of dorsiflexion at the ankle was measured using a goniometer. The measurements were recorded in degrees.[12]

Muscle length test (Soleus): Soleus length was measured by having the subject lie prone with 90-degree knee flexion in minimal clothing so that the gastronomies activation would be absent. The subject was in

minimal clothing, and the instructor assured that the foot was maintained in subtalar neutral. The axis of the goniometer was placed inferior to the lateral malleolus, the stationary arm was parallel to the fibula, while the moving arm was in line with the lateral midline of the calcaneus. Then the subject's foot was passively dorsiflexed until a stretch was felt, and the degree of dorsiflexion at the ankle was measured using a goniometer**.** The measurements were recorded in degrees.[13]

Skin fold measurement (Medial calf): The skin fold measurement of the calf was obtained at a point where the medial surface of the calf, at the level of the largest circumference. A tape measure should be used to determine this point. The subject should place their foot on a chair so that the knee is at approximately 90 degrees. A vertical pinch parallel to the long axis of the leg is taken. The measurements were recorded in millimeters. [14,15]

Stork Balance Test: Stork balance test was performed by the subject standing on one foot, and the opposite foot was on the inside of the knee of the other leg for support, and the head was kept at eye level. Then, the subject is advised to keep their hands over the ASIS, and the subject is asked to raise the heel. The time is noted for how long the subject can withstand without losing balance by keeping their hands over the ASIS and without hopping, jumping, or excessive postural sway with the help of a stopwatch. The timings were noted in seconds, with 3 trials; among the three, the best timing was taken for each leg. [16]

Statistical Analysis:

The normality of the data distribution was assessed using the Kolmogorov- Smirnov test. As the data demonstrated a normal distribution, descriptive results were reported using the Mean ± Standard Deviation (SD). Subsequently, the Pearson Correlation Coefficient (r) was the primary inferential test employed to determine the linear relationships between the measured variables. The level of statistical significance for all analyses was predetermined at $p < 0.05$ with 95% confidence Interval.

Results:

Table 1 represents the demographic characteristics of the study participants with the mean age of the subjects reflecting a homogenous age group. The average height and weight were found to be within the normal range according to WHO classification. These baseline measurements provided essential context for understanding the physiological variability within the sample and form reference point for subgroup correlations with calf muscle matrices and static balance performance.

Demographics	Mean±SD
AGE	20.81±1.80
WEIGHT	65.18±13.83
HEIGHT	171.18±6.45
BMI	22.194±4.28

Table 1: Demographic Data

Table 2 presents the correlation between BMI and muscle length of the gastronomies and soleus muscles as well as calf girth. Among individuals with normal BMI, a statically significant positive correlation was noted with calf girth on both the right ($r = 0.694$) and left ($r = 0.660$) sides ($p < 0.05$) indicating that

individuals with higher BMI within the normal range tended to have greater calf circumference. In overweight participants a similar trend was evident with positive significant correlations between BMI and both right ($r = 0.65$) and left ($r = 0.587$) calf girth values ($p < 0.05$). Conversely, underweight individuals showed a weak to moderate negative correlation in muscle length (MLSL: $r = -0.387$) and a significant inverse relationship with left calf girth (MLGL: $r = -0.472$; $p < 0.05$). These findings suggest that individuals with low BMI may demonstrate diminished muscle bulk and extensibility, while those with higher BMI, particularly in the normal to overweight range, tend to show increased muscle girth, possibly due to greater lean mass accumulation in the lower extremities.

BMI	MLSR	MLSL	CGR	CGL	MLGR	MLGL
UNDERWEIGHT (n=23)	-0.219	-0.387	0.289	0.283	-0.472*	-0.234
NORMAL (n=53)	0.098	-0.096	0.694*	0.66*	0.067	0.02
OVERWEIGHT (n=20)	-0.206	-0.254	0.65 *	0.587*	-0.106	-0.134

* p value <0.05 statistically significant

Table 2: Correlation between BMI & Muscle length & girth

Table 3 highlights the relationship between BMI and static balance performance as assessed through the Stork Balance Test for both lower limbs. In individuals with a normal BMI range, there was a statistically significant negative correlation between BMI and balance time on both the right ($r = -0.32$) and left ($r = -0.289$) legs ($p < 0.05$), suggesting that even within a normal BMI range, increased body mass may have a slight detrimental effect on balance control. Among the overweight group, this inverse relationship was more prominent on the left leg ($r = -0.476$; $p < 0.05$), potentially indicating asymmetrical postural adjustments or side-dominance influencing stability. Interestingly, the underweight category demonstrated an inconsistent pattern, showing a weak positive correlation on the right side ($r = 0.27$) and a strong negative correlation on the left side ($r = -0.71$), though neither was statistically significant. These outcomes reflect that increased body mass, particularly beyond the optimal range, may compromise neuromuscular control and static postural performance, supporting prior evidence on the impact of body composition on balance efficiency.

BMI	SBR	SBL
UNDERWEIGHT (n=23)	0.27	-0.71
NORMAL (n=25)	-0.32*	-0.289*
OVERWEIGHT (n=20)	-0.334	-0.476*
OBESE (n=2)	NA	NA

*- p value <0.05 statistically significant

Table 3: Correlation between BMI and Balance

Discussion:

The primary objective of this observational study was to determine the correlation between BMI, specific calf muscle matrices, and static balance performance among college-aged male adults. In this study,

statistical analysis revealed three critical findings. Initially, a highly significant positive correlation between BMI and calf girth was observed in both normal and overweight subjects, indicating that overall mass correlates with lower limb volume which was in align with the study done by Akil et al and Kim et al. [17, 11] Furthermore, a significant inverse correlation linked higher BMI to diminished static balance performance in these same cohorts. Finally, BMI demonstrated no significant correlation with calf muscle length in any group, nor did it correlate with balance in underweight subjects.

Relationship between BMI & calf metrices

The findings of the present study revealed a strong positive correlation between BMI and both calf muscle girth and length in individuals classified as normal weight and overweight. This initial result by Hawes & Martin confirms that body composition, particularly overall mass, plays a crucial role in influencing lower limb muscle morphology.[15] However, this finding by Stewart et al, immediately leads to a functional dilemma: while some literature suggests greater muscle volume could be inherently protective.[18] Whereas our studies, overall results indicate that this larger girth does not translate to superior balance, challenging the notion that size alone is beneficial. This dichotomy is resolved by examining the quality of the mass. To illustrate this point, Bataweel et al. and Ryan et al. collectively demonstrate that a normal BMI typically correlates with a higher proportion of beneficial lean muscle mass for increased extensibility and functional flexibility.[19,8] whereas advancing BMI toward overweight and obesity results in a higher proportion of detrimental subcutaneous and intramuscular fat mass.[20] This functional dichotomy was further supported by Tsiros et al.who stated that this excess adipose tissue mechanically impedes muscle stretch, restricts joint range of motion, and limits muscle elongation, thereby hindering muscle extensibility and biomechanical efficiency .[21] Ultimately, this biomechanical hindrance indicates that while calf girth is a valid anthropometric marker, its utility is limited because it fails to assess the functional, contractile quality necessary for stability, an assessment which was in correlation with the study done by Bonnefoy et al, Kim et al and Malisoux et al,.[22,11,23] Therefore, the observed relationship between BMI and calf muscle characteristics in our study underscores that maintaining an optimal body composition, one that favors lean muscle mass(LBM), is essential to preserve the muscular flexibility and lower limb function, which directly underpins static balance performance.

Relationship between fat mass and balance

The statistical analysis in this study established a crucial link between localized adiposity and balance impairment demonstrating a weak negative correlation between calf fat mass and static balance in the normal BMI group, which escalated to a moderate negative correlation in the overweight category. This negative effect was particularly pronounced on the left side, suggesting that factors like asymmetrical fat distribution or lateral dominance may influence balance control by affecting postural stability more significantly on one side of the body which align with the study done by Moeın and Movaseghı.[24]

Biologically, carrying extra body mass raises the body's center of gravity (COG), increasing the body's inertia and necessitating larger more frequent postural corrections to maintain stability which was in significance with the study done by Greve et al, Ledin ,Odkvist and Shumway-Cook et al.[25,5,1] This study established a crucial link between localized adiposity and balance impairment demonstrating a weak negative correlation between calf fat mass and static balance even within the normal BMI group. This finding is strongly supported by the study done by Bataweel et al. on the biomechanical mechanism, namely the accumulation of adipose tissue which actively exacerbates stress because the higher proportion

of fat mass disrupts proprioceptive feedback and sensorimotor integration, thereby limiting the body's ability to respond effectively to postural perturbations.[19,25] Conversely, the resultant biomechanical stress overloads ankle stabilizers during unilateral stance, accelerating fatigue and sway, which aligns perfectly with the strong negative correlations found between higher BMI/adiposity and shorter balance times in this study which significantly aligns with the study done by Kejonen et al.[4]

A study on the muscle quality by Castillo-Rodríguez et al. reported that strength and balance are closely linked to Lean Body Mass, contributing positively to neuromuscular control. This positive LBM mechanism stands in direct contrast to our finding of a weak negative correlation between calf fat mass and static balance, even in the normal BMI group. The overall functional impairment caused by excess fat mass supports general observations of noticeable postural impairments in high-BMI cohorts. This trend aligns with our specific finding that asymmetrical fat distribution or lateral dominance may significantly influence balance control on one side of the body.[19] While A. D. Stewart suggested that larger calf muscles could offer a protective advantage against falls, [18] our results indicate that when this mass is composed primarily of detrimental adiposity, the functional disadvantage inherent in the fat-to-lean ratio decisively outweighs the structural size.

Influence of Body Composition on Static Balance Performance The observed differences in calf muscle measurements across BMI groups reflect crucial underlying changes in muscle composition. As demonstrated by Akil et al. men with normal and overweight BMI exhibit larger calf circumferences, reflecting a greater accumulation of mass that includes both lean muscle
and fat tissue, while underweight individuals have proportionally smaller dimensions.[17] This distinction is critical because, as highlighted by Tsiros et al. excess adipose tissue both subcutaneous and intramuscular mechanically impedes muscle stretch and joint movement.[21] This physiological impact of excess body mass on posture control is significant and supports our findings. The soft-tissue stiffness caused by adipose tissue restricts the dorsiflexion range, severely limiting the essential "ankle strategy" for balance correction.[19] Mechanically, carrying extra weight raises the COG and increases inertia demanding larger, more frequent postural corrections. [25] This escalated demand leads to accelerated ankle stabilizer fatigue and sway, validating the strong negative correlation observed in our overweight group. Conversely, static balance findings align with Castillo-Rodríguez and Akil et al, confirming that a higher proportion of LBM correlates with stronger, more responsive muscles, directly improving stability. Therefore, this evidence collectively confirms that a higher fat-to-lean ratio significantly impairs proprioceptive feedback and leads to the poorer balance documented in overweight individuals.[26] To summarize, our findings support the clinical imperative that stability is driven by the functional quality of muscle mass. Crucially, the absence of a correlation between BMI and calf muscle length reinforces that simple dimensions are not the primary determinant of stability.[12] Instead, LBM and its associated muscle strength and responsiveness are key.[27,28] Clinical interventions must therefore prioritize training strategies aimed at improving the fat-to-lean mass ratio to enhance postural stability, rather than focusing solely on increasing muscle size or flexibility.

The study's constraints include a small and unequally distributed sample which limited statistical power and generalizability. A key limitation was the reliance on rudimentary anthropometrics (BMI and single-site skinfold measurement) which proved inadequate for accurately distinguishing functional lean body mass from inert fat tissue. Furthermore, using only the Stork static balance test failed to capture the dynamic stability required for everyday movement.

Future research must address these issues by using a larger more diverse participant sample. Methodologically, adopting advanced body composition analysis (BIA or DEXA scans) is necessary for the precise quantification of LBM and fat. To gain functional relevance, studies should integrate dynamic balance assessments (e.g., Y-Balance Test or TUG) and objective measures of calf muscle strength. Ultimately, using multivariate statistics in longitudinal intervention studies will be essential to establish a clear cause-and-effect relationship between targeted body composition changes and enhanced postural stability.

Conclusion:

In alignment with supporting literature, our findings establish that the lean-mass-to-fat ratio is the primary physiological determinant of static balance in college-aged males. Consequently, we conclude that training strategies must focus on enhancing lean body mass specifically within the normal to overweight categories, as this approach is essential for reducing the risk of falls and mitigating the impact of musculoskeletal injuries in the lower extremities.

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