A Study of Body Composition as a Predictor of Muscle Quality and Endurance- A Cross-Sectional Study

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KEYWORDS
BMI; body fat percentage; bioelectrical impedance analysis; endurance; handgrip strength.

ABSTRACT

Background: The alarming rise in sarcopenic obesity is compromising the quality of life for millions, underscoring the urgent need to unravel the factors contributing to muscle decline. Sarcopenic obesity, characterized by the concurrent loss of muscle mass and accumulation of excess fat, is a growing public health concern. This condition, often exacerbated by aging and poor lifestyle, negatively impacts muscle quality and contributes to a multitude of comorbidities. Previous research has demonstrated a significant association between obesity and reduced muscle strength compared to non-obese individuals, hindering activities of daily living such as stair climbing and walking. This study aims to investigate the predictive role of body composition on muscle quality and endurance.

Methods: This cross-sectional study was carried out on 385 healthy male and female subjects aged between 18-67 years. The staff and students of JMMC and RI were selected for the study based on the inclusion and exclusion criteria, after obtaining the Institutional Ethical Clearance. Handgrip strength (HGS) and endurance (HE) was measured using handgrip dynamometer while body composition was assessed using Omron body fat analyser. Comparisons were done between age and gender. Statistical analysis was done using Independent T test, One-Way ANOVA and Mann Whitney test on SPSS version 20.

Results: As age advances, there is statistically significant increase in BMI and BFP (body fat percentage) in both the genders. Increase in BMI and BFP is more pronounced in females with significant decrease in muscle mass percentage and HGS. Females had significant decline in endurance in all age groups ($p<0.001$).

Conclusion: As the BMI and BFP increase with age, the muscle quality deteriorates. Females have more adiposity, poor muscle strength and endurance even though BMI remains same in both genders. To identify the early onset of decrease in muscle quality and endurance, a combination of parameters like BMI, BFP, HGS and HE should form a part of routine clinical screening.

1. Introduction

The frenetic pace of modern life, with its constant demands, has led to a rise in lifestyle-related diseases. According to the India Ageing report 2023, India's aging population is growing rapidly, while the number of children is decreasing (1,2). This has resulted in a surge of age-related diseases like osteoarthritis, stroke, heart attacks, and osteoporosis. Importantly, these conditions can often appear early, reflecting the broader trend of lifestyle-related health issues.

Skeletal muscles are vital for a high-quality life, but they require regular maintenance due to their constant wear and tear. A healthy weight and regular exercise are essential for staying young and fit (3,4). A sedentary lifestyle coupled with poor nutrition can exacerbate existing health issues or precipitate new ones. Handgrip dynamometers are affordable, easy-to-use tools that assess overall and upper body muscular strength. They're well-suited for evaluating grip strength and endurance in medical environments (5). These devices are also useful for predicting nutritional index and mortality, especially among the elderly (5,6). Handgrip strength is the greatest amount of force your fingers can produce. It's influenced by age, gender, and body size. Endurance is the ability to sustain muscular force during an activity (7,8). Loss of muscle quality can lead to reduced working capacity, increased mortality, and morbidity (9).

As the world's second-most populous country, India is facing a growing obesity epidemic (10). Obesity is a preventable health issue often overlooked in medical settings (11). Research shows that lower levels of physical activity are linked to significantly reduced endurance, especially in overweight and obese individuals (12). Poor BMI is associated with stress, hypertension and lowered quality of life (13,14,15). Both body mass index (BMI) and body fat percentage (BFP) are commonly employed metrics to gauge an individual's overall body fat content, but which tool can provide a more complete picture is of uncertain. Knowing the right tool will help us to monitor the progression towards weight management goals.

Sarcopenia, a condition marked by muscle loss and weakness, can impair muscle function and physical performance (16,17,18). It can affect both underweight and overweight individuals (19). When excessive muscle loss combines with increased body fat, it results in sarcopenic obesity (20). People with sarcopenic obesity are more prone to functional decline, disability, and frequent hospitalizations (9,17). According to a 2021 National Statistical Office (NSO) report, India's elderly population is growing rapidly, with the proportion of seniors increasing from 10.9% in 1961 to 14.2% in 2011 and projected to reach 15.7% in 2021 (21). Given the serious health consequences of sarcopenia, including disability, morbidity, and mortality, early assessment, diagnosis, and intervention can help older adults maintain a comfortable and independent lifestyle.

There is a limited number of inconclusive studies on the relationship between body composition and muscle performance in South Indian populations. Additionally, many previous studies have focused on subjects with medical backgrounds, potentially introducing bias. Existing research on body composition and muscle function lacks a comprehensive analysis that includes diverse age groups and genders. Prioritizing health in youth is crucial for a better quality of life in old age (21). Keeping this in mind, we aim to investigate the connection between body composition and muscle performance and to raise awareness about exercise, nutrition, and the impact of mismatched body composition on muscle health.

2. Materials and Methods

The present cross-sectional study was conducted among 385 healthy staff and students (aged 18-67 years) at the department of Physiology, Jubilee Mission Medical College and Research Institute, Thrissur. Randomly chosen participants from five age groups (18-27, 28-37, 38-47, 48-57 and 58-67 years) were included in the study after providing informed consent and receiving institutional ethical approval.

The following parameters were assessed: height, weight, hand length (HL), hand span (HS), handgrip strength (HGS), handgrip endurance (HE) and body fat composition. Data were collected using a stadiometer, measuring tape, digital and manual dynamometer and an Omron Body Composition Monitor (HBF-375).

Inclusion criteria

a) All consenting male and female subjects

b) Age group – 18 – 67 years

Exclusion criteria

1. History of

a. Metabolic disease

b. Recent surgeries or hospitalization (6 months)

c. Acute illness or chronic illness

d. Pregnancy or nursing mothers or menstruating females

e. Fracture / deformity/ neurological deficit/ musculoskeletal disorders

2. Lack of interest in participation

Method of data collection

1. Height – height was measured in centimeters using a stadiometer with subjects barefoot, back straight with relaxed abdomen and heels together.

2. HL– hand length was determined by measuring the distance from the tip of the middle finger to the distal wrist crease using a measuring tape.

3. HS- Handspan was assessed using a tape measure. It was measured by placing the hand as wide as possible and measuring from the tip of the thumb to the tip of the small finger

4. HGS – digital handgrip dynamometer was used to analyse the HGS. The device's strain gauge sensor known for its precision, provides readings of gripping power up to 198 pounds or 90 kilograms. This device has memory storage feature where it stores 19 users along with their basal data (gender and age). Based on age and gender, each test result was categorized as 'weak', 'normal', or 'strong'. Before the test, participants received clear instructions and a demonstration. They were asked to place their dominant hand on a table, keep their elbow at a 90-degree angle and press the dynamometer handle with maximum force. The highest sustained force over 3 seconds was recorded as the HGS in kilograms. Three readings were taken for analysis with one minute rest between each reading to control the effects of fatigue. The maximum value out of the three readings was taken as the HGS. The subjects were motivated verbally during each trial (8).

5. HE- Manual handgrip dynamometer is used to assess the HE. The instrument measures the strength of an isometric grip with a reading range of 0 to 130 kg. Participants were required to maintain a continuous contraction of their dominant hand at one-third of their maximum HGS and the time was recorded in seconds by using the stop watch. The subjects were motivated verbally during the procedure (8).

6. Body composition – Body composition was assessed using body fat analyser. The device uses bioelectric impedance mechanism uses electric current (800 μA) with frequency of 50kHz that flows between electrodes at different rates through the body depending upon its composition. This is a validated objective measure of body composition (fat mass, fat free mass and water) and is one of the popular methods for the estimation of BMI, BFP, subcutaneous fat percentage and muscle mass percentage. Under controlled environment, subjects were made to stand on the scale that contains electrodes with bare foot. Once the basic details were entered, they were made to hold a hand electrode with their elbow extended. Their knees and back were maintained in extended position (22).

Based in Asian standards, BMI was categorized as follows: < 18.5kg/m2 (underweight), 18.5-22.9 kg/m2 (normal), 23.0 – 24.9 kg/m2 (overweight), >/=25 kg/m2 (obese) (20). Body fat levels were categorised based on gender (male (M) / female (F)) provided by the device; ≥ 25% (M) /≥35% (F) – very high; 20-25% (M)/30-35% (F) – high; 10-20% (M)/20-30% (F)-normal; <10%(M)/< 20% (F) – low.

Statistical Analysis

Descriptive statistics were reported as mean and standard deviation (SD). The statistical analysis was done by employing One-way ANOVA, Independent T test and Mann-Whitney U test. Pearson's correlation coefficient (r) was used for testing the correlation of muscle mass percentage and subcutaneous fat percentage with hand parameters among age and gender. The data collected were analysed using SPSS software version 20. A p-value of <0.05 was considered significant and <0.01 was considered highly significant.

3. Results

The present study was done to assess the effect of body composition on muscle quality and endurance. Based on inclusion and exclusion criteria, 385 subjects were included in the study, out of these 152 (39.5%) males and 233 (60.5%) were females. The table 1 presents the mean and standard deviation of BMI, BFP, HS, HL, HGS and HE.

Table 1 – Descriptive statistics of various anthropometric parameters of the study group

Anthropometric parameters	N	Minimum	Maximum	Mean±SD
AGE	385	18.00	71.00	33.03±12.96
HEIGHT (cm)		1.61	187.00	161.4±12.21
WEIGHT (kg)		36.30	107.00	63.86±12.43
BMI (kg/m^2)		14.50	90.10	24.52±5.26
BFP (%)		7.20	45.70	28.78±7.09
HS (cm)		2.00	91.50	20.01±4.15
HL (cm)		1.70	24.00	18.63±1.49
HGS (kg)		12.30	65.40	29.96±9.41
HE (sec)		2.00	181.00	46.11±31.87

Fig 1 depicts the distribution of study participants according to the age in which 162 subjects belonged to the 18-27 years group, 94 subjects belonged to the 28-37 years group, 63 subjects belonged to the 38-47 years group, 45 subjects belonged to the 48-57 years group and 11 subjects belonged to the 58-67 years.

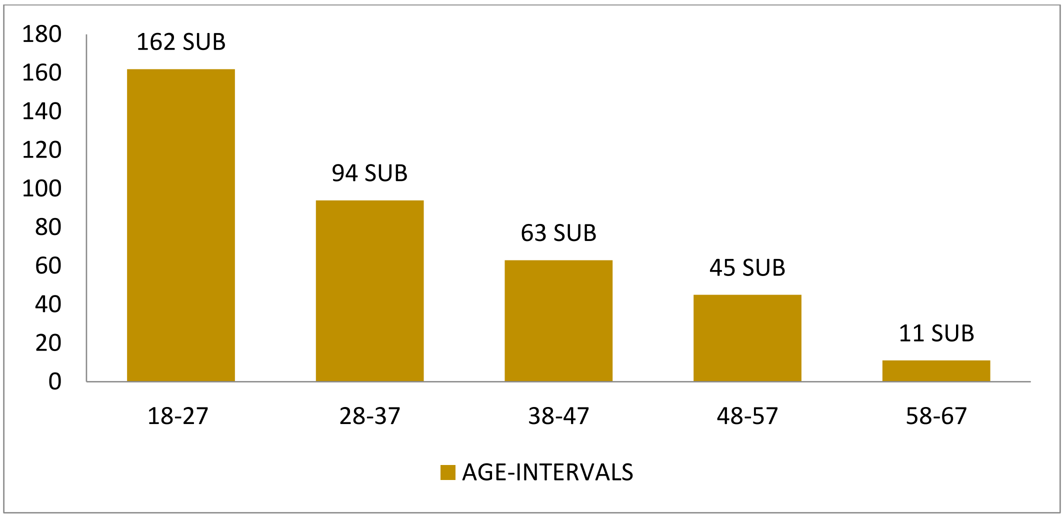

Fig 1 – Distribution of study participants according to age

Fig 2 and fig 3 illustrate the distribution of BMI and BFP among males and females, respectively. Both genders exhibited higher prevalence for overweight and obese category of BMI as well as BFP but females are pronounced when compared to males but overall, the population in the study has a higher prevalence of overweight and obesity, which aligns with the global trends.

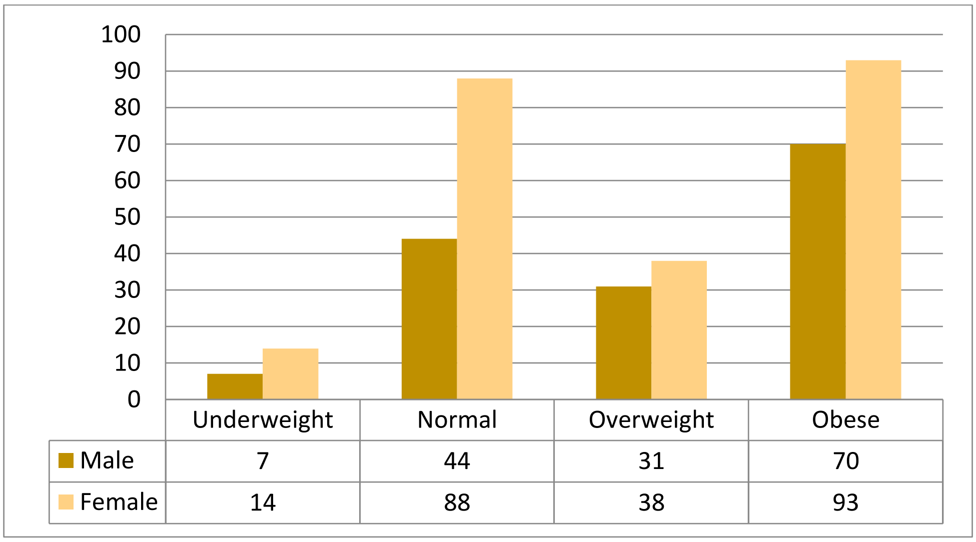

Fig 2 - Distribution of study population based on BMI

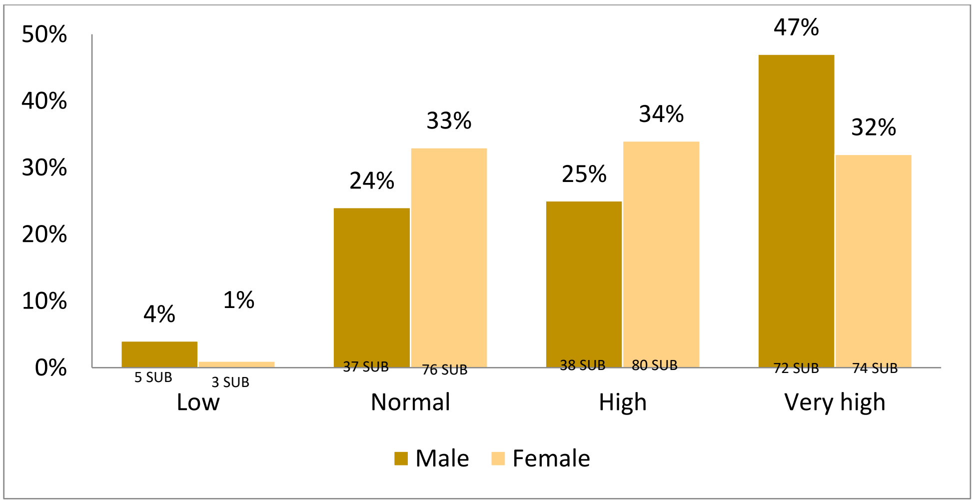

Fig 3- Distribution of study population based on body fat percentage

Table 2 describes that females have statistically significant lesser HS, HL, HGS and HE when compared to males.

Table 2- Gender based analysis of hand parameters

Gender	HS (cm)	HL (cm)	HGS (Kg)	HE (sec)
Male (n = 152)	21.59±5.94	19.58±1.09	38.43±8.73	66.55±34.76
Female (n=233)	18.97±1.68	18.01±1.38	24.44±4.41	32.78±21.05
p value	0.001**	0.001**	0.001**	0.001**

Values are mean±SD; HS – handspan; HL – hand length, HGS- handgrip strength, HE- hand endurance. Comparison is made between hand parameters with gender (male and female) using Independent T test.

* p value < 0.05 – significant ;** p value < 0.01 – highly significant

Using Pearson correlation, a moderate positive significant correlation of height (r=0.485, p <0.001) and weight (r=0.418, p <0.001) with HGS was observed. A low positive significant correlation of height (r=0.350, p <0.001) and weight (r=0.288, p <0.001) with HE was observed. A moderate negative significant correlation of BFP (r= -0.542, p <0.001) with HGS and a low negative significant correlation of BFP (r= -0.365, p <0.001) was also observed. No significant correlation of BMI with HGS or HE was found. These findings of correlation are depicted in table 3.

Table 3: Correlation between anthropometric parameters with handgrip strength and hand endurance

Variables correlated	Correlation coeff.(r)	p-value
Height vs HGS	0.485	0.001**
Height vs HE	0.350	0.001**
Weight vs HGS	0.418	0.001**
Weight vs HE	0.288	0.001**
BMI vs HGS	0.071	0.163
BMI vs HE	0.058	0.253
BFP vs HGS	-0.542	0.001**
BFP vs HE	-0.365	0.001**

Values are mean±SD; BMI– body mass index; BFP- body fat percentage; HL – hand length, HGS- handgrip strength, HE- hand endurance. Correlation between anthropometric parameters with HGS and HE using Pearson correlation.

* p value < 0.05 – significant ;** p value < 0.01 – highly significant

Comparison of HGS between genders shows reduction in strength as the age advances as well as females had decrease in HGS which is statistically significant as shown by table 4.

Table 4 -Age and gender related comparison of HGS

Age Intervals (years)	males (n=152)	HGS (males) Mean±SD	females (n=233)	HGS (females) Mean±SD	p value
18 – 27	60	43.9±8.0	102	25.5±4.4	<0.001**
28-37	35	38.2±8.0	59	24.3±4.0	<0.001**
38-47	21	34.4±6.0	42	23.7±4.4	<0.001**
48-57	23	33.6±5.1	22	22.6±3.6	<0.001**
58-67	13	29.1±6.4	8	20.4±6.0	0.006**
p value		<0.001**		0.001**	

Values are mean±SD; BMI– body mass index; Arm ScF% – arm subcutaneous percentage, Arm MM%- arm muscle mass percentage, HGS- handgrip strength, HE- hand endurance. Comparison is made between body composition, muscle strength and endurance among different age groups using One- Way Anova.

* p value < 0.05 – significant ;** p value < 0.01 – highly significant

Table 5 shows the endurance levels of both the genders decrease with age while endurance in female drastically decreases and within the age, comparison of endurance between both genders reveals a much lesser endurance level in females.

Table 5- Age and gender related comparison of muscle endurance

Age Intervals (years)	Males	Endurance (males)	Females	Endurance (females)	p value
	(n=152)	Mean±SD	(n=233)	Mean±SD	
18 – 27	60	73.4±32.4	102	28.7±17.8	<0.001**
28-37	35	64.9±33.2	59	40.0±25.4	0.001**
38-47	21	65.3±27.0	42	34.9±21.3	<0.001**
48-57	23	61.9±41.7	22	33.2±19.0	0.013**
58-67	13	49.5±43.6	8	19.4±11.5	0.011**
p value		0.034**		0.034**	

Values are mean±SD; To find out the statistically significant mean variation of hand endurance between the genders among various age groups, Mann-Whitney test is used.

* p value < 0.05 – significant ; ** p value < 0.01 – highly significant

Table 6 shows that females have statistically significant higher arm subcutaneous fat percentage while muscle mass percentage, HGS and HE are lower when compared with males.

Table 6-Analysis of BMI, arm subcutaneous fat percentage, arm muscle mass percentage, handgrip strength and endurance in male and female subjects

Gender	BMI	Arm Sc F%	Arm MM%	HGS (Kg)	HE (Sec)
Male (n=152)	24.82±4.08	23.28±6.00	37.38±3.30	38.43±8.73	66.55±34.76
Female (n=233)	24.32±5.90	44.61±5.99	26.57±4.40	24.44±4.41	32.78±21.05
p value	0.361	<0.001**	<0.001**	<0.001**	<0.001**

Values are mean±SD; BMI– body mass index; Arm ScF% – arm subcutaneous percentage, Arm MM%- arm muscle mass percentage, HGS- handgrip strength, HE- hand endurance. Comparison is made between body composition, muscle strength and endurance with gender (male and female) using Independent T test.

* p value < 0.05 – significant ;** p value < 0.01 – highly significant

Table 7 shows that as the age advances, an increase is seen in BMI and arm subcutaneous fat percentage while arm muscle mass percentage, HGS and HE decreases, which is statistically significant.

Table 7-Analysis of BMI, arm subcutaneous fat percentage, arm muscle mass percentage, hand grip strength and endurance in different age groups

Age interval	BMI	Arm Sc F%	Arm MM%	HGS (Kg)	HE (Sec)
18-27 yrs (n=162)	22.35±3.62	33.52±11.19	33.18±5.91	32.32±10.69	45.25±32.46
28-37 yrs (n=94)	25.58±3.45	38.29±11.63	29.60±6.73	29.49±8.87	49.26±30.85
38-47 yrs (n=63)	26.60±9.00	39.41±12.08	28.39±6.48	27.26±7.06	45.05±27.24
48-57 yrs (n=45)	26.59±4.18	37.82±13.29	28.95±6.82	28.22±7.09	47.89±35.37
58 –67yrs (n=21)	25.75±3.47	34.20±13.45	29.67±6.37	25.76±7.46	38.05±37.60
p value	<0.001**	0.002*	<0.001**	<0.001**	0.63

Values are mean±SD; BMI– body mass index; Arm ScF% – arm subcutaneous percentage, Arm MM%- arm muscle mass percentage, HGS- handgrip strength, HE- hand endurance. Comparison is made between body composition, muscle strength and endurance among different age groups using One- Way Anova.

* p value < 0.05 – significant ;** p value < 0.01 – highly significant

4. Discussion

The silent battle against sarcopenic obesity rages on, as our bodies grapple with the dual threats of dwindling muscle and burgeoning fat. Our increasingly sedentary lifestyles, fueled by unhealthy diets and constant stress, are paving the way for a surge in this condition. While modern medicine has extended our lifespans, it has also introduced new challenges, such as the growing prevalence of sarcopenic obesity. As a result, sarcopenic obesity and its associated metabolic syndromes will be the problems to be delt with in the foreseeable future. The insidious nature of sarcopenic obesity lies in its dual attack: while fat accumulates, muscle atrophies, leaving our bodies vulnerable to a host of health problems. Our modern, sedentary lifestyles are slowly eroding our muscle strength and endurance, setting the stage for a silent epidemic of NCD. The once normal physiological phenomenon of sarcopenia has now become pathological by being early in its onset. Hence, this study aims to explore the relationship between body composition, muscle strength and endurance as well as to investigate whether the progression of muscle aging in individuals deviates from the expected pattern.

Asians are disproportionately affected by abdominal and truncal obesity, which can lead to a higher risk of metabolic abnormalities at any given BMI (23,24). Fig 2 and 3 illustrate the distribution of subjects across various BMI and BFP categories respectively. The data presented in these figures demonstrate that a significant proportion of our study participants exhibit higher body fat levels, regardless of age or gender.

Our study participants had a mean HGS of 29.96±9.41 kg and a mean HE of 46.11±31.87 sec. Previous studies have reported variability in HGS and HE (25,26) which may attributed to differences in muscle fibre type and racial variations in muscle fibre phenotype, influencing the force and fatigability of muscles. Testosterone generally contributes to a higher percentage of type 2 muscle fibres in males compared to females, who typically have a higher proportion of type 1 fibres. These differences in muscle fibre composition typically lead to increased muscle strength in males and increased muscle endurance in (25,27). In our study, however, both HGS and HE were higher in males than females (table 2), consistent with findings from several previous studies (25,26,29) except for one study that reported higher muscle endurance in females (28). The variability in HE observed in our study and others could be attributed to differences in the calculation of the endurance time, reduced oxygen delivery to active muscles or may be due to decreased motivation (26).

As shown in Table 3, height and weight demonstrated significant positive correlations with HGS and HE consistent with findings from previous studies (29,30). Additionally, we observed that males in our study had larger handspans and hand lengths compared to females (table 2). Taller individuals have longer arms, fingers and a larger hand surface area, which can contribute to greater HGS and HE. Finger span, particularly the length of the middle finger, has been shown to be significantly linked to HGS (29,31). While body weight includes both lean mass and fat mass, both of which can influence HGS and HE, excess body fat can create additional resistance during movement, forcing individuals to produce greater muscle strength for a particular amount of work. Overall, excessive body fat can limit the endurance and movement capacity (32).

A comparison of HGS and HE between genders revealed a statistically significant decline in both strength and endurance with advancing age (table 4 and table 5 respectively). When comparing males and females within each age group, females consistently demonstrated significantly lower HGS and HE compared to males, aligning with numerous previous studies (26,30). Among males, the 18-27 age group exhibited significantly higher HGS and HE compared to older age groups. However, in females, while HGS was also higher in the 18-27 age group compared to older age groups, the observed strength levels were notably lower than expected. This prompts the inquiry of whether the current generation is physically weaker compared to prior generations. These results emphasize the stealthy and progressive decline of muscle strength. The observed changes in muscle function may be attributed to evolving lifestyles, including changes in financial status, economic conditions, physical activity levels and nutritional habits (30).

An analysis of BMI, arm subcutaneous fat percentage, muscle mass percentage, HGS and HE between genders is presented in table 6. Although BMI was similar for both males and females, women exhibited a higher subcutaneous fat percentage compared to men. The study population falls within the overweight category (males-24.82±4.08; females-24.32±5.90). While muscle mass primarily contributes to BMI in men, fat mass is the primarily contributor in women. In our study, men exhibited significantly higher levels of arm muscle mass percentage, HGS and HE than women. Based on these observations, it is reasonable to infer that individuals with a higher muscle mass will likely exhibit greater HGS and HE. No correlation was found between BMI and HGS and HE while moderately negative significant correlation was found between BFP and HGS and HE. This supports the notion that both BMI and BFP should be considered when monitoring health status. The correlation between body composition and muscle parameters has varied across studies, with some studies reporting positive correlations between BMI and HGS, while others found negative correlations. Regarding HE, some studies observed negative correlations with BMI, whereas others found no significant correlation. Additionally, most studies have reported negative correlations between BFP and both HGS and HE (25,26,28,28,30). Collectively, these findings suggest that increasing body fat can limit optimal muscle strength and endurance, rather than simply increasing body weight.

Table 7 provides a comprehensive comparison of fat distribution, muscle distribution, HGS and HE across different age groups, including BMI. With advancing age, BMI generally increases, although this trend is not statistically significant in the oldest group (58-67 years). A steady increase in subcutaneous arm fat is seen with age. However, after middle age (over 57 years), the fat percentage comes down, providing an explanation for the decrease in BMI. The muscle mass percentage also shows a decline with age and at every age group the percentage of muscle mass is found to be less than the arm subcutaneous fat percentage irrespective of the gender bringing into an alarming trend in health decline as manifested by more fat and less muscle. Notably, the reduction in endurance with age does not correspond to the same extent of decline in HGS. The loss of strength is more pronounced than the loss of endurance.

The observed changes in muscle level could be attributed to age related sarcopenia. According to the 2010 European group on sarcopenia, three stages of sarcopenia are defined: pre sarcopenia (loss of muscle mass only), sarcopenia (loss of muscle mass and strength) and severe sarcopenia (loss of muscle mass, strength and endurance) (33). Our study findings indicate a decrease in muscle strength but not a statistically significant decline in endurance, suggesting the presence of sarcopenia in our participants. This condition may be partially attributed to increased BFP.

Adult population forms the backbone of the nation. Compared to the elderly, adults have greater potential to increase muscle mass and strength. Ultimately, sarcopenia leads to a cascade of negative consequences, including poor immunity, prolonged and repeated hospitalization, delayed recovery, increased morbidity, reduced quality of life coupled with increased dependency for daily basic activities, development of lifestyle associated diseases and poor working capacity (34). Therefore, maintenance of muscle is of prime importance for a healthy and independent old age. Sarcopenia can be delayed through targeted interventions. It has been noted that exercise play a role in improving and maintaining muscle strength and endurance. Both resistance and endurance training have been shown to stimulate muscle growth by inducing oxidative, metabolic and heat stress on skeletal muscle through cellular signalling pathways. This process is known as "exercise preconditioning" which helps to counteract muscle wasting caused by inactivity (35).

We were unable to establish a definitive cause and effect relationship due to its design which was the main limitation in our study. One study has highlighted the difference in the strength of the upper limb and lower limb (36). Our study was done using the upper limb for assessment of strength and endurance. Hence, including both the limbs in our analysis would have enhanced the comprehensiveness of our research. The body fat analyser utilizes the BIA mechanism to assess BFP. While it is a relatively inexpensive and easy to use tool, the sensitivity of its results can vary when compared to those obtained from MRI. Additional factors like regional fat distribution and biochemical markers of adiposity can take another notch in the area of research.

5. Conclusion

The findings of the present study highlight the early onset of sarcopenia and also that in comparison to males, the female population is at higher risk in all age groups. While BMI remains same in males and females, arm subcutaneous fat percentage is higher while arm muscle mass percentage, HGS and HE are significantly lower in females. Endurance declines significantly across age in both the genders but when the endurance is compared between the genders, it is lower in females across any age groups. The HGS is also significantly lower with age in both the genders while HGS in males is significantly higher than their females counterparts at any age. A tailored exercise regimen can be effective in improving overall muscle health.

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DISCLOSURES

No conflict of interest, financial or otherwise, are declared by the authors.

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