

bigger challenge in the future. The worldwide prevalence of sarcopenia has been observed to be between 10% and 27% above 60 years of age using different diagnostic criteria.^[1] As per the World Health Organisation (WHO), 1 out of 6 people will be over the age of 60 years by the year 2030, with the number of people over 80 years tripling between 2020 and 2050.^[3] Early detection and diagnosis of sarcopenia are pivotal for effective management to improve the quality of life and independence of the elderly.

However, based on current literature, there are no universally accepted diagnostic criteria for the diagnosis of sarcopenia. Different working groups on sarcopenia, such as the International Working Group on Sarcopenia (IWGS), European Working Group on Sarcopenia (EWGSOP) or Asian Working Group on Sarcopenia (AWGS), have defined generalised cut-offs for diagnosis in populations. AWGS has provided diagnostic criteria that are specific to the Asian population. According to AWGS 2019, sarcopenia is diagnosed when low muscle mass is accompanied by either low muscle strength or low physical performance. The criteria recommend a stepwise screening approach, starting with assessment of muscle strength and/or physical performance to screen for low muscle strength and performance, the presence of which is termed probable sarcopenia. This is followed by measurement of muscle mass to screen for low muscle mass, the coexistence of which is then termed sarcopenia.^[4]

The cut-offs provided by these organisations, such as the AWGS, might not be completely accurate if individual populations are taken into account. This might be due to the difference in genetic, environmental and lifestyle factors unique to each population, which endows them with distinctive body compositions and functionality. Therefore, there is a necessity for having population-specific cut-offs or standards for more accurate categorisation of sarcopenia in a given population.

This study aims to initiate bridging of this gap by comparing the percentage of sarcopenia identified among elderly Indians adults (60 years and above) using a population-specific cut-off derived from a young healthy group of Indians (18–40 years of age)^[5] and the pre-established cut-off provided by the AWGS. The cut-off values of the population-based reference data had been derived in our previous study by Sucharita S *et al.*, by measuring the body cell mass index (BCMI) and muscle strength of 18–40 year old healthy young adults.^[5] Existing evidence has recommended the population-specific cut-off for low muscle mass or strength to be considered as the value <2 standard deviation (SD) of the sex-specific mean of a young healthy adult population for characterising sarcopenia,^[6] which has been followed here as well.

MATERIALS AND METHODS

Subjects

Thirty-three eligible Indian community-dwelling adults aged 60 years and above (14 females and 19 males) were recruited after obtaining written informed consent. Participants were excluded based on any known history of conditions that can affect muscle mass and/or strength, such as uncontrolled diabetes and hypertension, cardiovascular, renal or liver disorders, anaemia, known Vitamin D or B₁₂ deficiency, peripheral neuropathy, muscular dystrophy, any form of joint injury or osteoarthritis. Accurate measures of body composition (whole-body potassium counter [WBKC]) and muscle strength (isokinetic dynamometer) were evaluated for all the study participants. The study protocol was approved by the Institutional Ethics Committee (reference number: 122/2019) of St John's Medical College and Hospital and was in accordance with the Declaration of Helsinki, 1975.

Body composition

Anthropometry

Anthropometric measurements were carried out for all participants using standard protocols.^[7] The measurement included height (in cm), weight (in kg), waist and hip circumferences (in cm). The waist–hip ratio (W:H) was calculated.

Bio-electrical impedance analysis (BIA)

A non-invasive BIA using the Tanita SC-240 body composition analyser (Tanita Cooperation, Tokyo, Japan) was conducted on all participants. Any participant who had any existing pacemaker metal rod, plate or equivalent present in their body was excluded from the measurement as per BIA measurement guidelines. The participants were instructed to stand on the machine barefoot with their feet touching all four metal plates.

WBKC

The WBKC used in this study is one of the classic and accurate standard non-invasive techniques to assess body composition (whole-body fat mass [FM] and fat-free mass [FFM]). Measurement of total body potassium (TBK) is used as a marker for the body cell mass (BCM) and as an index of the FFM, on the assumption that the FFM has a constant proportion of potassium. The measurement lasted 30 min during which the participants had to lie still in a supine position. The TBK content was measured by the WBKC, from which the BCM was calculated using the formula mentioned in our previous paper by Sucharita *et al.*^[5] The total body water content required for the calculation of the

FFM from BCM was obtained from the BIA measurement of the participants. The BCMI, which is an indicator of muscle mass and nutritional status, was derived by dividing the BCM (in kg) by height (in m) squared (kg/m^2).

Muscle strength

Lower limb

The muscle strength of the knee extensor muscle for the subjects was measured using the isokinetic dynamometer (Kin Com AP1, Chattanooga Group, Tennessee, USA). The isokinetic dynamometer is a gold standard instrument to assess non-invasive muscle function. The participants were instructed to warm up for 5 minutes before the actual measurement. Post which, they were made to sit upright on the seat and were strapped in using the stabilisation straps laid out across the hips and trunk to avoid body force exertion during the experiment. The assessment was conducted on the right leg unless contraindicated by the presence of any prior injury or pain in the leg. The maximal isometric peak torque and the peak isokinetic strength at two angular velocities, 60 and 120°/s, were measured using the same protocol as previously mentioned in our paper by Sambashivaiah *et al.*^[8] Three readings were noted for each type of motion and angular velocity, out of which the highest recording was included for analysis.

Upper limb

Muscle function of the upper limb was evaluated by a load cell (Model TR 12, IPA, Bangalore, India). The best of 3 trials of maximal voluntary contraction (MVC) was used in the analysis. The trials were recorded with constant encouragement and adequate intervals between them. The rate of decline of the sustained MVC was also recorded to understand the static endurance. This was recorded up to when 50% of the maximal value was reached, and this rate (kg/s) was taken as the index of static endurance.

Physical performance

The physical performance of the participants was assessed using the short physical performance battery (SPPB) test. This included measures of balance, gait speed and chair rise. For the balance test, participants were shown 3 standing positions (side by side, semi-tandem and tandem positions), each to be maintained for 10 s. In case they were unable to maintain any of the positions for 10 s, the time till which they were able to hold the position was recorded. For the gait speed test, they were asked to walk a distance of 3 m at their normal pace, and the time taken to cover the distance was recorded. Finally, they were asked to perform 5 sit-stand-sit cycles at a self-selected speed (start and end in a sitting

position) for the chair rise test. Each participant was scored between 0 and 12 based on their performance for the SPPB, and a cut-off of ≤ 9 for impaired physical function or limited physical function and > 9 for normal physical function was fixed as per the SPPB guidelines available.^[9]

Frailty status

The frailty status was assessed using the FRAIL scale. The FRAIL scale consists of 5 elements, namely, fatigue (F), resistance (R), ambulation (A), illness (I) and loss of weight (L), which were assessed by a combination of interview, objective measurements and medical history. The scoring ranges from 0 to 5, with 0 being the best score and 5 being the worst. The cut-off for the FRAIL scale score has been categorised as: 0 = Non-frail; 1–2 = Pre-frail and ≥ 3 = Frail.^[10]

Physical activity level (PAL) and nutritional intake

The physical activity of the participants was determined using an interviewer-based physical activity questionnaire^[11] which records the total time spent in various physical activities recorded under different domains. The nutritional intake of the participants was assessed by the 24-h dietary recall, where the participants were asked a series of questions to recall in detail the meals consumed on the day before the interview. They were given a set of standardised measurements for reference.

Assessment of low muscle mass and strength from population-specific cut-off

The assessment of low muscle mass and strength has been done from population-specific cut-offs that we have derived as part of our previous paper on healthy young adults using the same parameters. As per the literature, the cut-off for determining sarcopenia has been set at < 2 SD of the sex-specific mean of the young healthy adult population. In our study, we have found the BCMI (surrogate marker for muscle mass) cut-off for sarcopenia to be $6.5 \text{ kg}/\text{m}^2$ and $4.58 \text{ kg}/\text{m}^2$ for males and females, respectively. Similarly, the isometric peak torque cut-off has been observed to be 50.2 Nm and 33.2 Nm for males and females, respectively.^[5]

Statistical analysis

A sample size of $n = 33$ was studied in this paper. Given the exploratory nature of the study and being a preliminary analysis, this number was considered for the study.^[12] All data are presented as mean and SD. An independent *t*-test was used to compare the variables between the sexes. The difference between the diagnostic systems (AWGS vs. Indian) has been assessed by the McNemar Chi-square test. The level of significance was set at 0.05. The statistical analyses were

performed using Statistical Package for the Social Sciences (SPSS) version 25 (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp.).

RESULTS

Among the 33 participants, 19 were male (57.6%) and 14 were female (42.4%). The age, anthropometric measurements, biochemical measurements, diet and PAL of all the participants are presented in Table 1. The age was comparable between the two sexes, as was the BMI. The males had a significantly higher waist circumference compared to the females ($P < 0.01$). Males also demonstrated significantly higher FFM (52.1 ± 6.78 vs. 38.4 ± 5.4 , $P < 0.001$) and lower fat percentage (27.0 ± 4.95 vs. 38.5 ± 4.32 , $P < 0.001$) compared to females as measured by the BIA.

The detailed description of the body composition (using the WBKC) and muscle strength (using the isokinetic dynamometer and hand dynamometer) among the participants is demonstrated in Table 2. The males showed a significantly higher BCM ($P < 0.01$), BCM percentage ($P = 0.03$) and FFM ($P < 0.001$) and lower FM ($P < 0.001$) compared to the

female participants measured by the WBKC, similar to the BIA findings. With regards to the muscle strength parameters, males demonstrated a higher isometric peak torque and MVC compared to the females ($P < 0.001$); however, the endurance was found to be comparable between the 2 sexes.

Physical performance, being the 3rd diagnostic variable for sarcopenia, was also assessed among our population. More than half of the male participants (57.9%) and 35.7% of the females in our study demonstrated low physical performance. The assessment of frailty demonstrated 10.5% of the males to be frail and 31.6 % to be pre-frail, whereas 85.7% of the females were pre-frail, with no overt frailty observed among the females.

An attempt was made to associate BCMI, isometric peak torque and SPPB score with sarcopenia classification. Significantly lower mean BCMI and SPPB total score ($P < 0.05$ for both) were noted among the sarcopenic individuals, followed by the probable sarcopenia and normal group of individuals. Although statistically not significant, isometric peak torque showed a similar trend.

Comparison of individual muscle mass and function parameters with the reference young population showed

Table 1: Comparison of age, anthropometric measurements, biochemical measurements, PAL and dietary intake between males and females.

Parameter	Overall (n=33) Mean±SD	Male (n=19)			Female (n=14)			P-value
		Mean±SD	95% Confidence interval		Mean±SD	95% Confidence interval		
			Lower bound	Upper bound		Lower bound	Upper bound	
Age (year)	69.8±5.91	69.7±6.21	67.1	72.5	70.0±5.71	66.9	73.1	0.90
Anthropometry								
Height (cm)	160.5±7.91	165.1±5.05	162.8	167.4	154.2±6.77	150.6	157.8	<0.001
Weight (kg)	68.2±12.6	72.0±12.1	66.4	77.6	63.0±11.8	86.7	99.3	0.04
BMI (kg/m ²)	26.3±3.79	26.4±4.00	24.6	28.2	26.3±3.63	24.4	28.2	0.98
WC (cm)	85.8±9.76	90.4±8.93	86.3	94.5	73.8±22.3	61.9	85.7	<0.01
HC (cm)	98.5±8.30	96.9±7.60	93.4	100.4	93.5±28.3	78.1	109.5	0.62
Biochemistry								
Glucose (mg/dL)	102.7±24.8	99.8±17.2	91.9	107.7	106.6±32.7	89.1	124.1	0.44
Cholesterol (mg/dL)	201.2±47.7	186.1±40.7	167.4	204.8	221.7±50.2	194.9	248.5	0.03
Urea (mg/dL)	25.3±6.58	24.3±5.24	21.9	26.7	26.7±8.18	22.3	31.1	0.32
Creatinine (mg/dL)	0.88±0.16	0.95±0.16	0.88	1.02	0.79±0.10	0.74	0.84	<0.01
Lifestyle (physical activity and diet)								
PAL	1.39±0.12	1.38±0.13	1.33	1.45	1.42±0.10	1.37	1.47	0.38
Energy intake (kcal)	1699.6±604.6	1858.5±679.6	1422.2	1977.0	1483.9±416.6	1261.2	1706.6	0.07
Protein intake (%)	12.3±2.12	12.0±1.08	11.3	13.3	12.8±3.03	11.2	14.4	0.32
CHO intake (%)	60.0±7.14	62.3±5.59	56.7	63.3	56.8±7.96	52.5	61.1	0.02
Fat intake (%)	27.7±6.74	25.7±5.94	24.6	30.8	30.4±6.99	26.7	34.1	0.04

BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, PAL: Physical activity level, CHO: Carbohydrate, SD: Standard deviation. The CHO, protein and fat intake has been demonstrated as a percentage of total calories. Significance at $P < 0.05$; derived by an independent *t*-test. *P*-values highlighted in bold denotes significant difference between males and females ($P < 0.05$).

Table 2: Comparison of body composition and muscle strength between the two sexes among older Indian adults.

Parameter	Overall (n=33) Mean±SD	Male (n=19)			Female (n=14)			P-value
		Mean±SD	95% Confidence interval		Mean±SD	95% Confidence interval		
			Lower bound	Upper bound		Lower bound	Upper bound	
Body composition								
TBK (g)	83.3±24.7	93.8±23.4	83.1	104.5	69.5±19.4	59.1	79.9	<0.01
BCM (kg)	19.6±5.80	22.0±5.51	19.5	24.5	16.3±4.58	13.9	18.7	<0.01
BCM (%)	28.5±6.39	30.6±5.92	27.9	33.3	25.7±6.08	22.5	28.9	0.03
BCMI (kg/m ²)	7.50±1.99	8.04±2.03	7.11	8.97	6.80±1.77	5.85	7.75	0.09
FFM (kg)	44.8±8.63	49.7±7.30	46.4	53.0	38.4±5.47	35.5	41.3	<0.001
FM (%)	34.4±5.73	30.6±3.61	28.9	32.3	39.3±3.92	37.2	41.4	<0.001
Muscle strength								
Isometric peak torque (Nm)	42.7±11.8	49.1±9.69	44.7	53.5	33.9±8.23	29.5	38.3	<0.001
Isokinetic at 60° (Nm)	28.3±10.1	31.0±10.8	26.0	36.0	24.6±7.95	20.4	28.8	0.07
Isokinetic at 120° (Nm)	26.0±8.84	28.4±9.18	24.2	32.6	22.5±7.32	18.6	26.4	0.66
MVC (kg)	17.6±4.86	20.0±4.07	18.1	21.9	14.29±3.81	12.3	16.3	<0.001
Isometric MVC (kg)	16.7±5.43	18.4±5.85	15.7	21.1	14.2±3.77	12.2	16.2	0.02
Time to 50% MVC	3.80±6.77	4.71±8.12	0.98	8.44	2.56±4.34	0.24	4.88	0.37
Static endurance	7.35±4.69	7.37±4.85	5.14	9.60	7.33±4.64	4.85	9.81	0.98

TBK: Total body potassium, BCM: Body cell mass, BCMI: Body cell mass index, FFM: Fat free mass, FM: Fat mass, MVC: Maximum voluntary contraction, SD: Standard deviation. Significance at $P < 0.05$ derived by an independent t-test. P-values highlighted in bold denotes significant difference between males and females ($P < 0.05$).

a higher prevalence of low muscle strength and physical performance compared to muscle mass in both males and females, as represented in Figure 1. Combining all 3 variables of sarcopenia diagnosis and comparing the cut-off for the diagnosis of sarcopenia in our population as derived from our reference population data and the existing cut-off provided by AWGS demonstrated a much higher diagnosis of probable sarcopenia (previously known as pre-sarcopenia) (91%) and no diagnosis of sarcopenia or severe sarcopenia among the population when using AWGS cut-off. However, using the population-specific reference data, we have demonstrated that 57% of the population have probable sarcopenia and 7% each have sarcopenia and severe sarcopenia, as represented in Figure 2. It was observed that 67% of the normal individuals, as per the AWGS criteria, had an agreement with our criteria, whereas among the individuals with probable sarcopenia, 59% had an agreement with our criteria. There was a significant difference in the proportion of individuals with sarcopenia as assessed by the McNemar Chi-square test ($P < 0.001$). We have demonstrated the distribution of the muscle mass (represented by BCMI) and strength between the young adult and older population studied, as shown in Figure 3.

DISCUSSION

This study has explored the diagnosis of sarcopenia among the Indian elderly population using established

cut-offs provided by the AWGS^[4] and compared it with a population-specific reference data that has been derived from healthy young Indians 18–40 years of age without any comorbidities.^[5] The comparison of sarcopenia diagnosis using the AWGS cut-off values and population-specific reference data raises important considerations for clinicians and researchers. The AWGS has developed diagnostic criteria based on specific cut-off values for muscle mass, muscle strength and physical performance. However, the application of population-specific reference data for sarcopenia diagnosis remains an important consideration. Studies comparing different sarcopenia diagnostic criteria among the Chinese population have shown a wide range in prevalence between 11.8% and 57.1% depending on the criteria used.^[13] A Polish study also demonstrated that the prevalence of sarcopenia ranges between 0% and 6.43% depending on the algorithm used.^[14] Numerous studies in different populations have also shown such variability in sarcopenia prevalence based on the algorithms used; this highlights the importance of deriving population-specific diagnostic cut-offs for the same to ensure accurate diagnosis and timely intervention. Using sex-specific population-based reference data for deriving the cut-off values to diagnose sarcopenia, this study addresses the limitation of applying uniform reference standards across diverse populations. This is especially important in the Indian context, considering the unique body type demonstrated by them. The use of population-specific thresholds improves

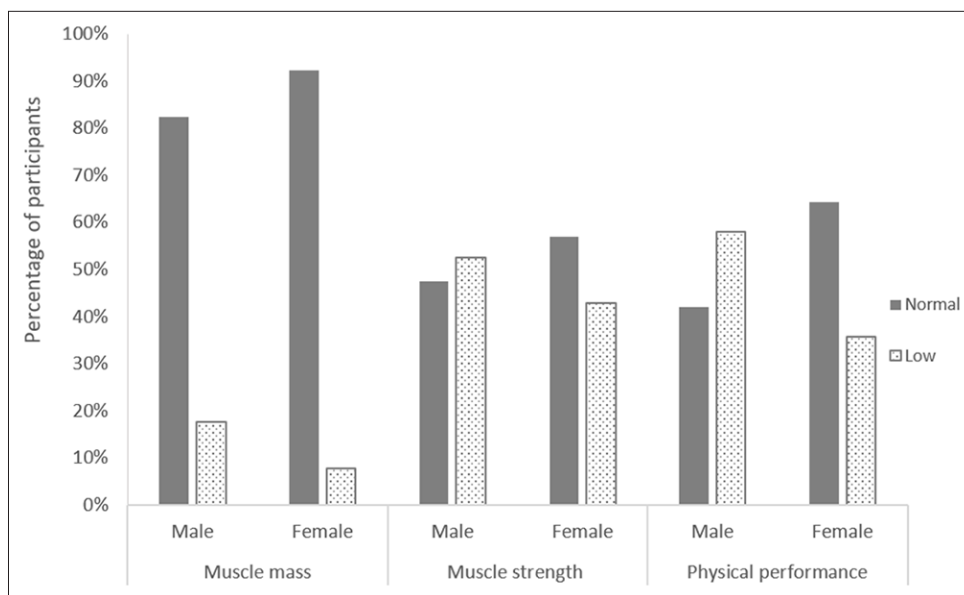


Figure 1: Percentage of elderly participants below 2 standard deviation of sex-specific young adult reference (low) for parameters of muscle mass, strength and physical performance.

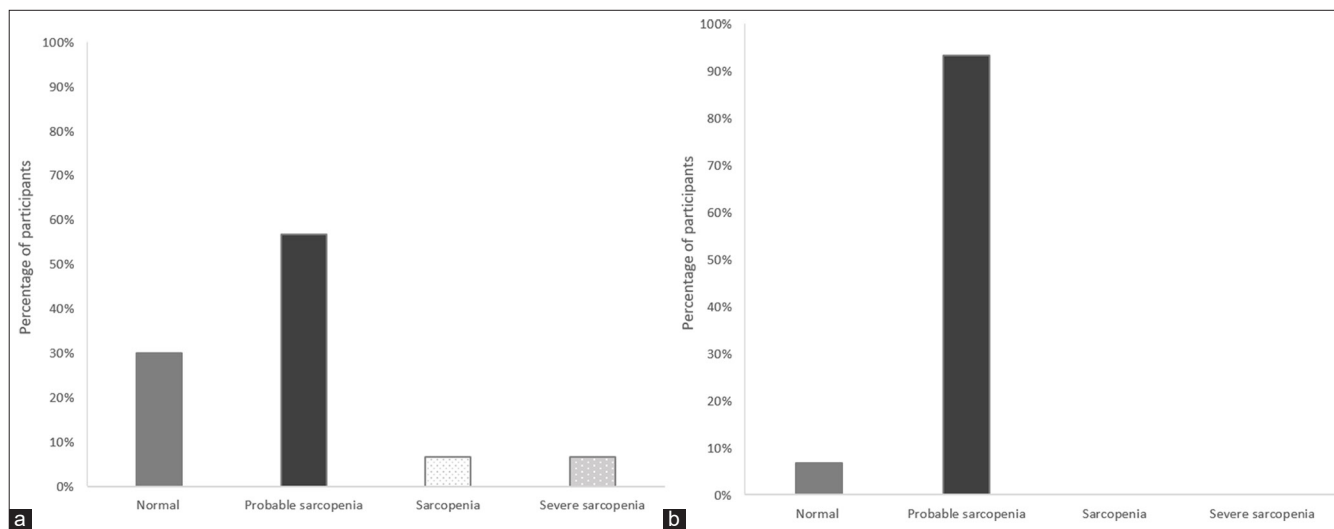


Figure 2: (a) Derived from sex-specific reference data of muscle mass and muscle strength of the young healthy participants. (b) Derived from pre-defined cut-off provided by the AWGS for muscle mass, muscle strength and physical performance.

the diagnostic precision of sarcopenia, making it more relevant for the population in question. Muscle mass, muscle strength and SPPB are the three diagnostic criteria that are used for sarcopenia classification clinically as per literature evidence. Sex-specific low muscle mass and strength cut-offs were defined in our previous paper by Sucharita *et al.*,^[5] for BCMI (a marker for muscle mass) and isometric peak torque (a marker for muscle strength) in the younger healthy adult population, as mentioned above. These sex-specific cut-offs to categorise males and females separately as having normal or low muscle mass or strength have been used in the analysis.^[5] Our findings revealed differences between the

AWGS cut-off values and population-specific reference data for sarcopenia diagnosis. The AWGS criteria demonstrated an overestimation of probable sarcopenia (previously known as pre-sarcopenia) and no diagnosis of sarcopenia. This shows that while the AWGS criteria have been valuable in providing standardised diagnostic guidelines, their universal applicability to diverse populations might result in the misclassification of individuals and delayed intervention.

The discrepancies observed between the AWGS cut-offs and population-specific reference data emphasise the importance of considering ethnic, racial and regional variations in muscle mass, strength and physical performance. It is well-known

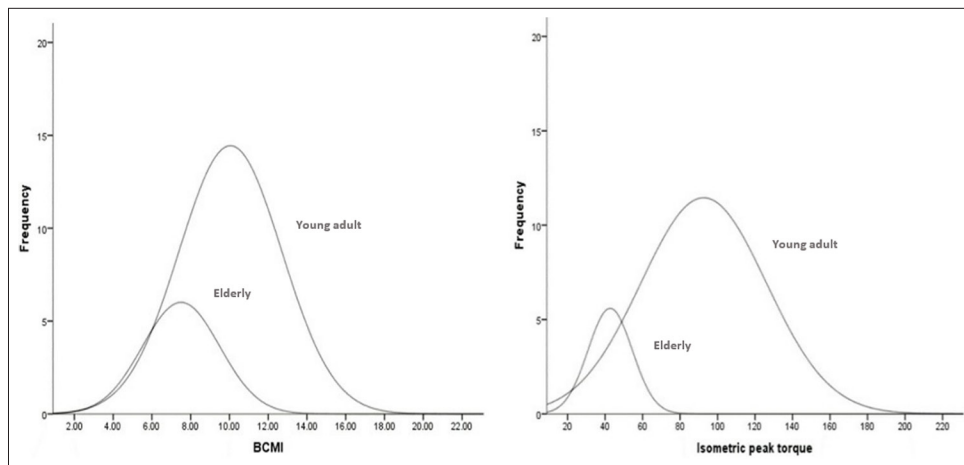


Figure 3: Representation of distribution of muscle mass (body cell mass index [BCMI]) and muscle strength (isometric peak torque) between the young adult and elderly participants.

that genetic, environmental and lifestyle factors can influence muscle parameters, and these factors vary across different populations. Therefore, relying solely on universal cut-off values might not accurately capture the true prevalence of sarcopenia in specific populations.

This emphasises the need for further research to develop large cohorts to validate population-specific cut-off values, accounting for diverse demographic and cultural factors. The clinical implications of utilising population-specific reference data are significant. Accurate sarcopenia diagnosis enables early intervention strategies, such as exercise interventions and nutritional supplementation, to prevent or mitigate the adverse consequences of sarcopenia. By incorporating population-specific reference data, healthcare professionals can optimise treatment plans tailored to individual needs, resulting in improved outcomes and enhanced quality of life for older adults.

Our study highlights the importance of considering population-specific reference data for sarcopenia diagnosis in the Indian population by demonstrating the discrepancies with the AWGS cut-off values. Incorporating population-specific reference data enhances the accuracy of sarcopenia diagnosis and enables tailored interventions to address this prevalent geriatric syndrome effectively. Future research should focus on recruiting large cohorts to develop and validate population-specific cut-off values, taking into account the diverse demographic and cultural factors that influence muscle parameters in specific populations.

To place the rationale for deriving population-specific cut-offs into perspective, Figure 3 illustrates the age-related trajectory of muscle mass (demonstrated by the BCMI) and strength (demonstrated by the isometric peak torque) in the Indian population. This representation highlights an important finding that demonstrates a negative shift in the

isometric peak torque with advancing age, with a lesser shift in the BCMI, pointing towards better preservation of mass compared to strength in the elderly Indians. This pattern illustrates a trend previously noted in the Indian population consisting of prediabetic individuals by Sambashivaiah *et al.*^[8] Such trends support the argument that cut-offs grounded in the young, locally representative, healthy individuals may offer greater diagnostic sensitivity for detecting early sarcopenia in ageing Indian adults.

Despite the methodological strengths of this study, certain limitations must be acknowledged. First, while the WBKC is considered a gold standard for measurement of BCM, it is not easily available in the country. It requires special infrastructure, which may restrict its use in routine clinical and especially community settings, thereby affecting its translational applicability. Second, the relatively small sample size limits the statistical power and generalisability of the results. This might be one of the reasons for the significant difference observed in the agreement between the AWGS data and the population-specific data outputs. However, as this is a preliminary finding, it allows us to have a glimpse at the status of sarcopenia diagnosis in India and sets the precedent for larger studies with a larger representative sample of elderly Indians to get a better picture of this often-overlooked health condition.

CONCLUSION

This study underscores the significance of using population-specific reference data for sarcopenia diagnosis in the Indian elderly, contrasting with AWGS cut-offs. Implementing tailored diagnostic criteria can enhance accuracy and facilitate timely interventions, crucial for optimising outcomes and quality of life in ageing populations.

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Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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