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Comparison of the Two Algorithms of Skeletal Muscle Mass Index: An Observational Study in a Large Cohort of Chinese Adults

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Abstract

Objective: To compare the two skeletal muscle mass index (SMI) algorithms. One is SMM [SMM(%) = total skeletal muscle mass (kg)/body weight mass (kg) × 100%]; and the other is SMH [SMH (kg/m^2) = total skeletal muscle mass (kg)/height (m)^2]. **Methods:** Body composition, body mass index (BMI) and body fat percentage (BFP) were estimated using a bioelectrical impedance analyzer. SMI was calculated by the two algorithms described above, and measurement parameters were stratified by age, BMI and levels of physical activity. **Results:** Levels of BMI, BFP, SMM and SMH differed significantly between the sexes. BMI and BFP were positively associated with age, while SMM was negatively associated with age ($\beta = -0.2294$, $P < 0.001$). Furthermore, SMM was determined to have a negative association with BMI ($\beta = -0.5340$, $P < 0.001$), while a positive association between SMH and BMI ($\beta = 0.7930$, $P < 0.001$) was observed. Both SMM ($\beta = -0.9849$, $P < 0.001$) and SMH ($\beta = -0.0642$, $P < 0.001$) were negatively associated with BFP. In both men and women, SMM maintained the analogous correlation with other indicators. In the general population, SMM showed a gradual downward trend from low body weight to grade III obesity ($F = 9528.32$, $P < 0.001$), but SMH ($F = 34395.46$, $P < 0.001$) and BFP ($F = 9706.20$, $P < 0.001$) had a reciprocal association. BMI, BFP and SMM differences were observed based on levels of physical activity ($P < 0.001$). However, there was no significant difference in SMH based on exercise ($P > 0.05$). **Conclusions:** SMM may be a more ideal and accurate clinical algorithm for SMI because it is more tightly associated with other body composition indices, as compared with SMH.

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Keywords

Physical Examination, Body Weight, Muscle Mass, Skeletal Muscle Mass Index

1. Introduction

The prevalence of overweight and obesity is growing at an alarming rate in the global population, including in developing countries [1]. These clinical conditions not only increase the predisposition to multiple comorbidities [2], but also can lead to musculoskeletal impairments [3] via both systemic and mechanical effects [4]. For this reason, assessment of body composition remains a vitally important clinical criterion for health status and risk of disease. However, evaluation criteria and significance of human body composition indicators differ by age group and other factors, making the uniformity of this assessment a challenge [5] [6] [7]. Body composition parameters can be assessed by a number of methods, including weight (kg), BMI (kg/m^2), total body fat mass (TFM, kg) and lean mass (TLM, kg) which are commonly measured by dual-energy X-ray absorptiometry. Other parameters include body fat percent (BFP, body fat/weight × 100%) [8] and body fatness (TFM/weight) measured by bioelectrical impedance analysis (BIA) [9] [10]. Recently, the indicators based on BIA technology come under scrutiny by clinicians and investigators for a variety of reasons.

Muscle mass and strength in humans are closely related to the amount of exercise per person and the various functions of the human body. With the progressive aging of the general global population due to lengthening life spans, sarcopenia has emerged as a serious medical and socio-economic problem in recent years. Sarcopenia is linked with increased risk of diabetes [11], arthritis, osteoporosis, respiratory diseases, heart disease [12], Parkinson's disease [13] and cancer [14], leading to lower quality of life and contributing to mortality risk [15]. Sarcopenia severely hampers quality of life as it compromises ability for self-care, physical activity and recreation. Thus, it is an increasingly prominent issue of clinical concern, particularly in aging societies [16]. Diagnosis of sarcopenia in patients consists of both reduced skeletal muscle mass and decreased skeletal muscle function [17] [18]. Recent studies indicate that measures of body composition such as skeletal muscle mass index (SMI) can more accurately assess human physical status compared with BMI, height or weight, in order to gauge health and disease risk [19] [20].

There are two methods most commonly used for determining skeletal muscle mass index (SMI): one is SMM [SMM (%) = total skeletal muscle mass (kg)/ body weight mass (kg) × 100%] [21] [22]; the other is SMH (SMH (kg/m^2) = total skeletal muscle mass (kg)/height (m)^2] [23] [24]. Both procedures are called skeletal muscle mass index (SMI). Use of both methods has led to considerable confusion and discrepancies in clinical literature, which hamper clinicians' ability to provide risk assessment and guidance for patients.

Accurate analysis of body composition forms the basis of individualized treatment and intervention strategies. The present study aims to investigate the distribution of these two SMI algorithms in a large cohort of people undergoing health examinations, so as to explore the differences in SMM, SMH, BMI and BFP as they relate to age, gender, and levels of physical activity.

2. Methods

2.1. Participants

This study (S2017-003-02) was approved by the Ethics Committee of the PLA General Hospital, Beijing, China. Study participants (18 < age < 100 years) were **all** enrolled in the health medical center of General Hospital of the Chinese People's Liberation Army between September, 2014 and March, 2019. Participants were excluded if they had a diagnosis of severe debilitating diseases such as stroke-related paralysis, heart failure or renal failure, the inability for self-ambulation, history of major surgery including amputation, malignant tumor, or were <18 or >100 years of age. All participants were informed that their data could be used anonymously for scientific research. Written informed consent was obtained from all participants in this study.

2.2. Measures

Participants were subjected to physical examination and required to complete an investigator-administered questionnaire that covered basic demographic information. On a voluntary principle, some of these participants received a questionnaire containing details of exercise habits, which could reflect the average levels of physical activity. The judgement criteria for physical activity were based on WHO criteria as follows: 1) Adequate physical activity = engaging in vigorous activity for at least 3 days per week [with a minimum total physical activity of 1500 metabolic equivalents (METs)] or 7 days per week (achieving a total physical activity of at least 3000 METs per week); 2) Moderate physical activity = engaging in one of the following, at least 20 minutes of vigorous physical activity per day for a minimum of 3 days per week, or at least 30 minutes of non-vigorous physical activity per day for a minimum of 5 days per week, or at least 5 days of physical activity per week with weekly activity equivalents ranging from 600 to 3000 METs; 3) Inadequate physical activity = if the none of the abovementioned criteria are met [25].

Body mass and composition were estimated using a bioelectrical impedance analyzer (InBody 720 analyzer, InBody Co. Ltd, Seoul, Korea), which is comprised of a tetrapolar, 8-point tactile electrode system that separately measures impedance of the arms, trunk and legs at six different frequencies (1, 5, 50, 250, 500, and 1000 kHz). The InBody 720 automatically estimates weight, height, BMI and body fat percent (BFP, body fat/weight × 100%). SMM and SMH were also calculated.

2.3. Subject Classifications

Weight status was determined based on BMI as follows: underweight (BMI <

18.5 kg/m^2), normal weight (18.5 ≤ BMI < 24 kg/m^2), overweight (24 ≤ BMI < 28 kg/m^2), and obese (BMI ≥ 28 kg/m^2), in accordance with recommendations defined by the Working Group on Obesity in China [26] [27]. For purposes of our analysis, obese participants were divided into subgroups as follows: grade I obesity (28.0 - 31.9 kg/m^2), grade II obesity (32.0 - 35.9 kg/m^2), and grade III obesity (≥36.0). Participants were also divided into young group (age < 45 years), middle-age group (45 ≤ age < 60 years), older-age group (60 ≤ age < 80 years), and the oldest-age group (age ≥ 80 years).

2.4. Statistical Analysis

Statistical analysis was performed using STATA (version 11.0) for Windows (STATA, College Station, TX). Body measurement data were presented as mean ± standard deviation (SD), and the classifications data were expressed as rate. The Kolmogorov-Smirnov method or graphic method was used to test for data normality. Descriptive statistics were used to characterize the study participants. The two-sample Wilcoxon rank-sum test, single factor analysis, or χ^2 test was used to compare baseline characteristics of the participants. Differences in levels of BMI, BFP, SMM and SMH among different age groups or BMI groups were compared by using single factor analysis of variance (ANOVA) or analysis of covariance (ANCOVA), with Bonferroni method for pairwise comparison. Univariable analysis of age, BMI, BFP, SMM and SMH was performed to determine associations. Statistical significance was determined based on a P value < 0.05. Finally, we adopted t-test to compare age, gender, BMI, BFP, SMM, SMH between the physically active and inactive groups. Multivariable logistic regression was used to correct the related factors.

3. Results

3.1. Baseline Characteristics of the Study Population

A total of 141,451 participants were enrolled in the study, of which 90,526 (64%) were male and 50,925 (36%) were female. Mean age was 46.85 ± 9.81 years. Baseline characteristics are shown in **Table 1**. BMI (Z = 129.46, P < 0.001), BFP (Z = 154.91, P < 0.001), SMM (Z = 158.39, P < 0.001) and SMH (Z = 269.98, P < 0.001) were all significantly different between men and women using the two-sample Wilcoxon rank-sum test.

There were 57,896 participants who voluntarily finished the physical activity/exercise questionnaire. Of these, 4543 (7.85%) participants were determined to have adequate physical activity, 18,489 (31.93%) participants had no exercise habits and met the criteria of inadequate physical activity. The remaining 34,864 (60.82%) participants met the criteria of moderate physical activity. Participants within the moderate activity groups were sometimes difficult to define in the investigation because the diagnostic criteria were complex and not unified enough, especially for those who exercised occasionally. Comparing the two extreme groups (*i.e.*, adequate and inadequate) allowed for more clear delineation of outcomes. Therefore, this study only compared these two groups as shown in **Figure 1**.

Table 1. Results of body composition parameters in different groups.

characteristics	participants (%)	weight (kg)	muscle mass (kg)	BMI (kg/m^2)	BFP (%)	SMM (%)	SMH (kg/m^2)
Total	141,451 (100)	71.01 ± 12.98	49.26 ± 8.98	24.88 ± 3.47	25.37 ± 6.11	69.61 ± 5.94	17.21 ± 2.04
gender							
female	50,925 (36.00)	60.39 ± 9.02	39.68 ± 4.03	23.36 ± 3.40	28.69 ± 5.89	66.33 ± 5.62	15.33 ± 1.29
male	90,526 (64.00)	76.98 ± 10.89	54.65 ± 6.02	25.74 ± 3.21	23.50 ± 5.40	71.46 ± 5.28	18.27 ± 1.56
Age groups							
<45 years	55,627 (39.33)	70.63 ± 14.32	49.84 ± 9.37	24.42 ± 3.83	23.98 ± 6.01	70.97 ± 5.83	17.20 ± 2.18
45 ≤ age < 60 years	72,263 (51.09)	71.82 ± 12.07	49.43 ± 8.62	25.20 ± 3.18	26.04 ± 5.79	68.96 ± 5.63	17.29 ± 1.94
60 ≤ age < 80 years	13,503 (9.55)	68.28 ± 11.38	46.03 ± 8.52	25.06 ± 3.21	27.48 ± 6.93	67.53 ± 6.72	16.81 ± 1.88
age ≥ 80 years	58 (0.04)	65.78 ± 12.70	44.49 ± 8.99	24.44 ± 3.74	27.94 ± 7.93	67.77 ± 7.56	16.43 ± 2.21
BMI groups							
under weight	3677 (2.60)	48.11 ± 4.85	38.22 ± 5.46	17.50 ± 0.79	15.47 ± 5.74	79.26 ± 5.67	13.86 ± 1.00
normal	52,530 (37.14)	61.01 ± 7.58	44.09 ± 7.18	21.86 ± 1.44	22.78 ± 5.66	72.09 ± 5.51	15.74 ± 1.35
overweight	60,267 (42.61)	74.32 ± 7.76	51.21 ± 7.39	25.80 ± 1.12	26.32 ± 5.03	68.71 ± 4.91	17.72 ± 1.36
I obesity	21,221 (15.00)	85.43 ± 8.31	56.29 ± 7.79	29.42 ± 1.07	29.42 ± 4.92	65.71 ± 4.77	19.32 ± 1.44
II obesity	3230 (2.28)	96.61 ± 9.80	60.63 ± 8.77	33.30 ± 1.05	32.65 ± 4.91	62.56 ± 4.66	20.83 ± 1.58
III obesity	526 (0.37)	111.66 ± 13.54	65.87 ± 10.52	38.25 ± 2.45	36.42 ± 5.29	58.85 ± 4.95	22.47 ± 2.03

Notes: Data are presented as mean ± SD unless otherwise stated. Abbreviations: BMI: body mass index; BFP: body fat/weight × 100%; SMM: total muscular mass/weight × 100%; SMH: muscular mass/height^2.

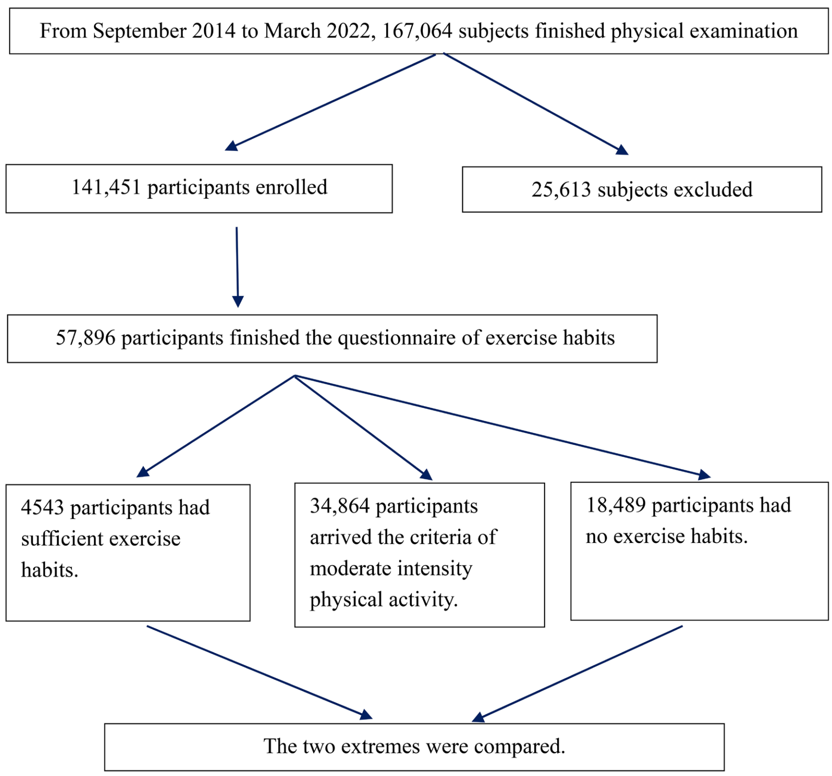
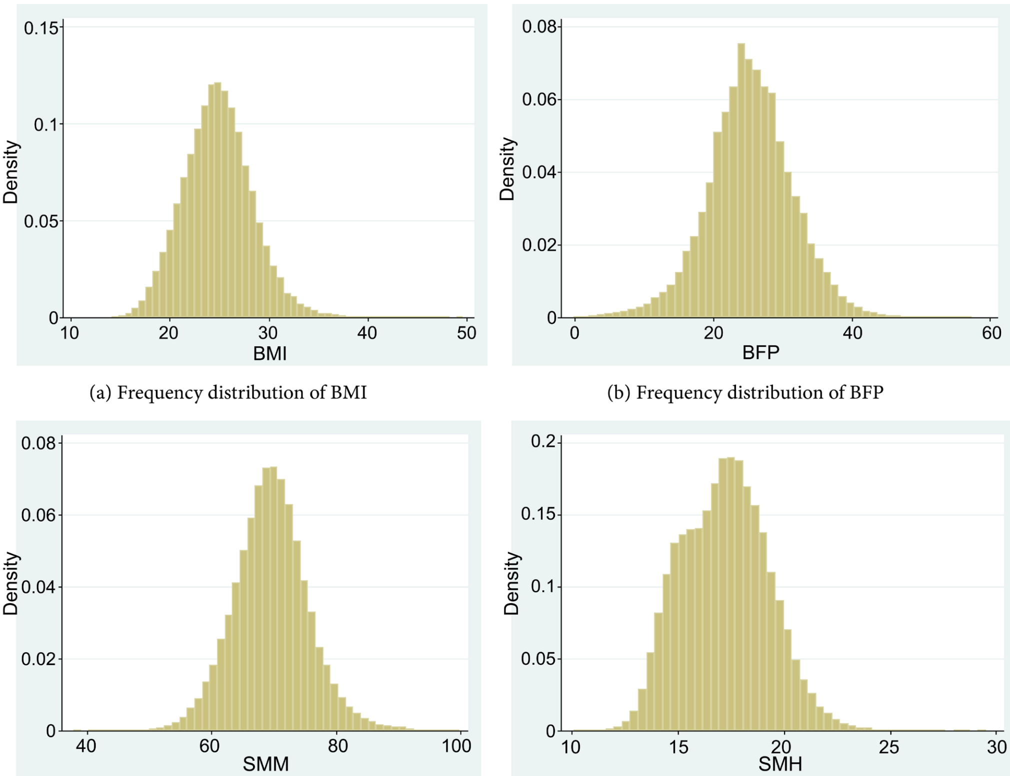


Figure 1. The sample flowchart of the study.

3.2. Frequency Distribution of BMI, BFP, SMM and SMH

In histograms, the distributions of BMI (Figure 2(a)) and SMM (Figure 2(c)) were very similar to normal distribution. However, the distributions of BFP (Figure 2(b)) and particularly SMH (Figure 2(d)) were skewed. The distribution of SMM seemed to be closer to normal distribution than others in different genders.



(a) Frequency distribution of BMI

(b) Frequency distribution of BFP

(c) Frequency distribution of SMM

(d) Frequency distribution of SMH

Figure 2. Frequency distribution of BMI, BFP, SMM and SMH. The distributions of age (a) and SMM (c) were very similar to normal distribution, but the distributions of BFP (b) and SMH (d) were not standard normal distribution, especially SMH.

3.3. The Relationship between Research Indicators in Different Genders

The association between age and the various body composition parameters is shown in Table 2. In all participants, BMI, BFP and SMM were significantly associated with age. BMI and BFP were positively associated with age, whereas SMM was negatively associated with age ($\beta = -0.2294$, $P < 0.001$). No significant association between SMH and age was determined. A negative association between SMM and BMI was observed ($\beta = -0.5340$, $P < 0.001$), while a positive association between SMH and BMI was observed ($\beta = 0.7930$, $P < 0.001$). Both SMM ($\beta = -0.9849$, $P < 0.001$) and SMH ($\beta = -0.0642$, $P < 0.001$) were negatively associated with BFP, with the correlation coefficient of the former significantly greater than the latter.

Table 2. Univariate correlation analysis between each parameters (β value and P value).

	Age	BMI	BFP	SMM	SMH
Total					
Age	1.0000				
BMI	0.1272 <0.001	1.0000			
BFP	0.2312 <0.001	0.5385 <0.001	1.0000		
SMM	−0.2294 <0.001	−0.5340 <0.001	−0.9849 <0.001	1.0000	
SMH	−0.0031 0.2434	0.7930 <0.001	−0.0642 <0.001	0.0809 <0.001	1.0000
In females					
Age	1.0000				
BMI	0.3444 <0.001				
BFP	0.4440 <0.001	0.8300 <0.001	1.0000		
SMM	−0.4513 <0.001	−0.8426 <0.001	−0.9816 <0.001	1.0000	
SMH	0.1612 <0.001	0.8555 <0.001	0.4570 <0.001	−0.4596 <0.001	1.0000
In males					
Age	1.0000				
BMI	0.0006 0.8657	1.0000			
BFP	0.1135 <0.001	0.7481 <0.001	1.0000		
SMM	−0.1101 <0.001	−0.7408 <0.001	−0.9822 <0.001	1.0000	
SMH	−0.0747 <0.001	0.8247 <0.001	0.2707 <0.001	−0.2448 <0.001	1.0000

Notes: β value and P values from the univariate correlations. Abbreviations: BMI: body mass index; BFP: body fat/weight × 100%; SMM: total muscular mass/weight × 100%; SMH: muscular mass/height^2.

In women, SMM was negatively associated with age but conversely, SMH was positively associated with age. SMM and SMH also showed negative associations among the two genders. In men, there was no significant association between BMI and age. Men differed from women in that both SMM and SMH were inversely associated with age in men. Figure 2 shows associations between SMM and SMH in both men and women. SMM was negatively associated with BFP and BMI in both genders, whereas SMH was positively associated with both BFP and BMI.

3.4 Trend of BMI, BFP, SMM and SMH Levels in Different Age Groups

Differences in body composition indices between age groups were compared by one-way ANOVA and the Bonferroni method as shown in Table 3. In the general population with both genders there were significant differences in BMI, BFP, SMM and SMH among the different age groups. Pairwise comparison analysis revealed that BMI showed an increase trend with age up to a certain point, then decreased, while BFP showed an increased trend with age continuously across the spectrum. SMH followed a similar track as BMI across the age spectrum. SMM in the whole population and in women showed a decreasing trend with age, while in the men the trend was variable across the age spectrum.

Table 3. Results of research parameters in the different age groups.

	n	BMI (kg/m^2)	BFP (%)	SMM (%)	SMH (kg/m^2)
Total	141,451				
<45 years	55,627	24.42 ± 3.83	23.98 ± 6.01	70.97 ± 5.83	17.20 ± 2.18
45 ≤ age < 60 years	72,263	25.20 ± 3.18*	26.04 ± 5.79*	68.96 ± 5.63*	17.29 ± 1.94*
60 ≤ age < 80 years	13,503	25.06 ± 3.21*#	27.48 ± 6.93*#	67.53 ± 6.72*#	16.81 ± 1.88*#
age ≥ 80 years	58	24.44 ± 3.74	27.94 ± 7.93*	67.77 ± 7.56*	16.43 ± 2.21*
F value		546.42	1853.18	1893.94	219.97
P value		<0.001	<0.001	<0.001	<0.001
In females	50,925				
<45 years	19,958	22.11 ± 3.25	26.02 ± 5.81	68.95 ± 5.55	15.09 ± 1.27
45 ≤ age < 60 years	24,887	23.98 ± 3.19*	29.95 ± 5.12*	65.08 ± 4.82*	15.48 ± 1.27*
60 ≤ age < 80 years	6068	24.88 ± 3.41*#	32.29 ± 5.44*#	62.83 ± 5.14*#	15.49 ± 1.34*
age ≥ 80 years	12	23.90 ± 3.83*	35.15 ± 5.84*	60.97 ± 5.74*#	14.47 ± 1.98#@
F value		1742.78	2949.06	3154.04	379.61
P value		<0.001	<0.001	<0.001	<0.001
In males	90,526				
<45 years	35,669	25.72 ± 3.51	22.84 ± 5.81	72.10 ± 5.68	18.38 ± 1.62
45 ≤ age < 60 years	47,376	25.84 ± 2.98*	23.98 ± 5.02*	70.99 ± 4.91*	18.24 ± 1.51*
60 ≤ age < 80 years	7435	25.21 ± 3.03*#	23.55 ± 5.36*#	71.36 ± 5.27*#	17.87 ± 1.54*#
age ≥ 80 years	46	24.57 ± 3.75#	26.05 ± 7.34*@	69.55 ± 6.98*	16.94 ± 1.98*#@
F value		87.66	307.97	303.06	240.36
P value		<0.001	<0.001	<0.001	<0.001

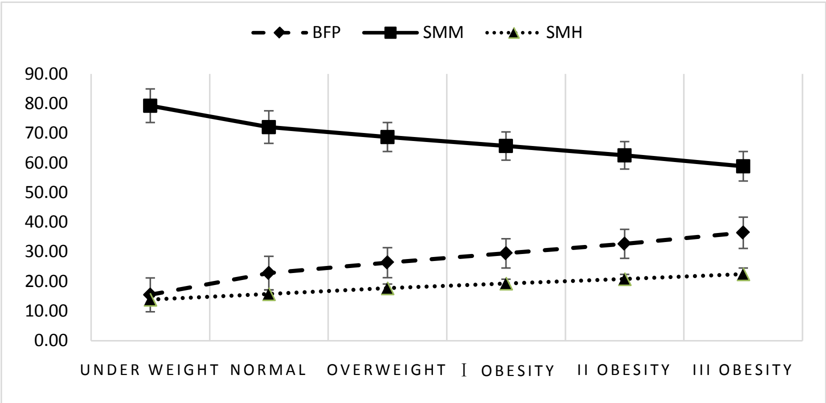
Notes: Data are presented as mean ± SD. *P* values from single factor analysis of variance or analysis of covariance and Bonferroni method for pairwise comparison. Abbreviations: BMI: body mass index; BFP: body fat/weight × 100%; SMM: total muscular mass /weight × 100%; SMH: muscular mass/height^2. *: Significant differences ($P < 0.05$), compared with young group; #: Significant differences ($P < 0.05$), compared with middle aged group; @: Significant differences ($P < 0.05$), compared with the older group.

3.5. Trends in BFP, SMM and SMH in Different BMI Groups

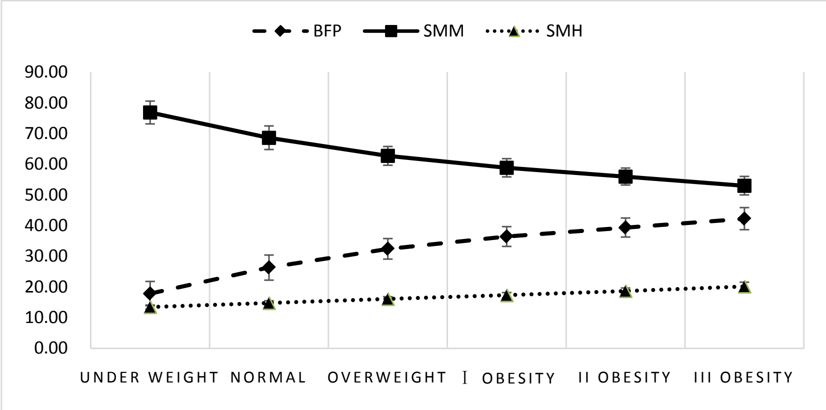
In the general population (both genders), there was a decline in the trend of the association between SMM and BMI, from low weight to third degree of obesity ($F = 9528.32$, $P < 0.001$), and pairwise comparison analysis revealed statistically significant differences by the Bonferroni method between every two groups. Conversely, an increasing trend in the association between SMH ($F = 34395.46$, $P < 0.001$) and BFP ($F = 9706.20$, $P < 0.001$) was observed among different BMI groups, and there were significant differences between every two groups ($P < 0.001$) (**Figure 3**).

3.6. Comparison of the Adequate and Inadequate Physical Activity Groups

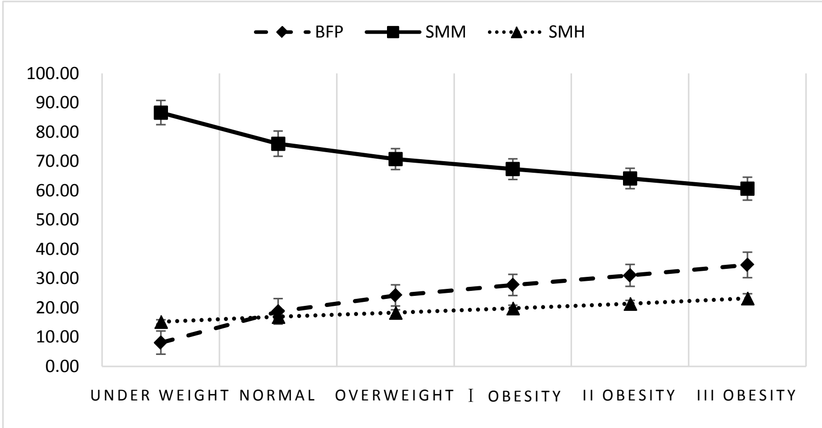
There was no significant difference in age and gender between the adequate and inadequate activity groups (**Table 4**). However, there were significant differences in BMI, BFP and SMM between the two groups ($P < 0.001$). Compared with inadequate physical activity group, we can see an obvious reduction in the proportion of body fat represented by BFP. Concurrently in the adequate activity group the SMM was markedly increased. However, no significant difference in SMH between the two groups was found. There were only subtle differences in mean values of BMI and SMH between the activity groups as compared with SMM.



(a)



(b)



(c)

Figure 3. Distribution trend of BFP, SMM and SMH in different BMI groups. (a) In total; (b) In females; (c) In males. It could be seen that, no matter in the total subjects, or in the males or females, SMM presented a gradual downward trend with BMI stratification. However, both BFP and SMH showed an upward trend with the stratification of BMI, and the increase of BFP was higher than that of SMH. All indicators showed significant difference between every two groups by Bonferroni method ($P < 0.001$).

Table 4. Comparison of related indexes between the two groups with different exercise volume.

	adequate physical activity (n = 4543)	inadequate physical activity (n = 18,489)	Total	*P* value
Gender				$P = 0.153$
male	3546	14,248	17,794	
female	997	4241	5238	
Age (years)	45.13 ± 6.12	44.98 ± 7.32	45.05 ± 6.48	$P = 0.202$
BMI (kg/m²)	25.32 ± 3.81	25.64 ± 3.48*	24.88 ± 3.47	$P < 0.001$
BFP (%)	23.98 ± 6.01	27.48 ± 6.93*	25.45 ± 5.14	$P < 0.001$
SMM (%)	70.67 ± 5.43	62.46 ± 6.62*	64.45 ± 7.46	$P < 0.001$
SMH (kg/m²)	17.14 ± 3.18	17.26 ± 6.88	17.20 ± 5.46	$P = 0.2518$

Notes: Data are presented as mean ± SD. *P* values from independent *t* tests, depending on the distribution of data. Abbreviations: BMI: body mass index; BFP: body fat/weight × 100%; SMM: total muscular mass/weight × 100%; SMH: muscular mass/height^2. *: compared between the two groups. Significant differences ($P < 0.05$).

4. Discussion

Skeletal muscle content and quality are major defining characteristics of body composition, and for many years there has been two algorithms used to define these parameters which has caused confusion and ambiguity. Since the mass of the human body is mainly comprised of muscle, fat and bone, any increase or decrease in weight could be due to changes in skeletal muscle mass or body fat as the bone mass is largely constant (assuming no severe osteoporosis). An increase in skeletal muscle mass tends to be accompanied by a relative decrease in body fat, although this is not always the case. Thus, given a constant body weight, skeletal muscle mass should be negatively correlated with body fat mass. In adults, body composition is drastically impacted by age, physical activity/exercise habits, diet, and more, which cause changes in total body weight but not height. For these and other reasons, SMM has remained a very appropriate clinical index of skeletal muscle quality and content, which have been recommended in different consensuses [28].

At the same time, application of SMH as a skeletal muscle index is still common in many countries [29]. There are even other methods of calculation such as ASM/BMI [30]. Despite the major differences that exist between these measurement parameters, all of them are viewed as representative of skeletal muscle mass index (SMI) by international sarcopenia study groups [31]. So far, there is no universal consensus on appropriate and uniform assessment methods for SMI which could be widely applied in research or clinical practice. However, determination of which of these operational algorithms are most appropriate to assess skeletal muscle mass has remained elusive [32]. In order to begin answering this question it is necessary to compare characteristics of the different algorithms currently and commonly used. Studies which have comprehensively compared SMM with SMH in large patient cohorts are sparse, and this is what makes the present study unique and well-needed.

4.1. Main Findings and Comparison with Other Studies

From the results of this study it has become clear there is a significant qualitative and quantitative difference between SMM and SMH as indices of skeletal muscle quality and content. The first example of how these indices are different involves the normality, concentration, and stability of the distribution variables which were expressed as SMM > BMI > BFP > SMH. Secondly, SMM and SMH showed significant differences between men and women. Across all age groups, BMI, BFP, SMM and SMH had different trends of association with age. We found the trends of SMH and SMM were different between men and women across age groups.

SMM was negatively associated with both BMI and BFP. SMH differed in that it was positively associated with BMI and BFP. Additionally, while the association between SMM and age, BMI and BFP remained constant, there was inconsistency in the relationship between SMH and these parameters. These findings suggest that SMM remains relatively stable in the population as a whole. Our study also determined that BFP is a reliable index of body fat as has been shown in other studies [33]. SMM proved to be superior to SMH as a reliable index of skeletal muscle content, as reflected in many ways by the association between SMM and body fat composition. The fact that SMM was determined to be negatively associated with BMI and BFP is not only in line with the laws of nature, but also consistent with contemporary research and theories on sarcopenia. In contrast, SMH was not consistent in its association with body fat parameter in the present study, which is different from previous reports [34].

No significant differences were found to exist in age, gender and SMH between the adequate activity and the inadequate activity group. However, BMI, BFP, and SMM were significantly different between the groups. This finding directly supports the notion that active exercise increases muscle and decreases body fat. In contrast, the comparison of SMH with BMI and BFP does not support this conclusion. The mean values of BMI and SMH in the two physical activity groups had only subtle differences. These findings collectively suggest that while BMI may be useful as a generalized index of body mass, BFP and SMM are more suitable as clinical guides for groups who expect to increase muscle and reduce fat through exercise.

4.2. Strengths and Limitations

This study has several strengths. First, we included data from a large population of Chinese adults covering all stages of the human lifespan. Secondly, the clinical and demographic characteristics of the participants were relatively comprehensive, including age, gender, and BMI. Thirdly, the number of study participants was larger than that of similar previous studies. Fourth, the comparison of the two major skeletal muscle algorithms can provide significant guidance for clinicians.

Our study also has some limitations. First, the study was limited to the Chinese population which is largely homogeneous with little representation of other ethnic groups. Secondly, most of the participants in our sample were healthy and excluded patients with missing limbs and most serious diseases. Thirdly, BFP, SMM and SMH were based solely on BIA measurements, not on more precise methods such as DXA, CT or MRI. Finally, as this was a cross-sectional study, selection and loss-to-follow up biases might have influenced accuracy of our modeling. Future prospective studies should consider optimum sampling strategies when SMI prediction formulas are developed based on BMI.

5. Conclusion

In conclusion, these findings are important from both theoretical and practical standpoints because they show that SMM is the most appropriate algorithm to assess skeletal muscle content and quality in the population across the age spectrum. Further studies with larger sample sizes using a prospective design are needed to confirm our findings.

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Authors' Contributions

All listed authors meet the requirements for authorship. Yansong Zheng wrote the review and prepared the figures. SuiYing and Zhen Huang provided the original drafts. Shengyong Dong assisted with information retrieval. All authors read and approved the final manuscript.

Availability of Data and Material

The original contributions presented in the study are included in the article/ supplementary material. Further inquiries can be directed to the corresponding author/s.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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