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Predictive value of percentage body fat in aging people with low muscle mass: A 2.2-year longitudinal study

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ABSTRACT

Background: The aim of this study was to evaluate the usefulness of percentage body fat (PBF) in screening for the risk of low muscle mass (LMM) in elderly people.
Methods: A prospective study was carried out in Chinese PLA General Hospital with 413 participants who underwent baseline and an average 2.2-year follow-up health check-up examinations.
Results: The average age of the participants at baseline was 63.6 years. The incidence of newly developed LMM was 10.3% in men and 18.2% in women during follow-up. Linear regression demonstrated that baseline PBF were negatively correlated with follow-up total muscle mass index (TMMI) in both men and women (β = -0.124 for men and -0.233 for women, all $P < 0.001$). The cut-off points of baseline PBF in elderly people for future LMM were 25.45% in men and 30.95% in women and were identified by Receiver Operator Curves (ROC).
Conclusions: Elderly people with a high PBF had a higher risk of new LMM, which suggested that baseline PBF had a close relationship with future LMM and the screening of high PBF should be paid enough attention in health care management in the senior people.

1. Introduction

Body composition analysis, namely bioelectric impedance analysis (BIA), is largely based on the perspective that the electric resistance varies in different human body tissues, thus low-level and safe current which passes through tissues can be detected specifically, quickly and painlessly (Zeng, Dong, Sun, Xie, & Cui, 2012). The technique has drawn much attention over the past years.

Previous studies indicated that percentage body fat (PBF) was a better predictor of hypertension, hyperglycemia and hyperlipidemia than body mass index (BMI) (Zeng, Sun, Fan, & Ye, 2008). The reason maybe related to overestimate or underestimate adiposity by using BMI (Carpenter et al., 2013). However, the value of it remains controversial. Several reports suggested that the trend of total body fat and BMI differed in adults with different age (Flegal et al., 2009), thus there was no agreement about the potential application of total body fat in various diseases.

Age-related muscle mass reduction, as one aspect of sarcopenia, is a process characterized by gradual loss of skeletal muscle during aging and may lead to adverse health outcomes, such as falls, disability and poor quality of life (Van Ancum et al., 2018). Severely low muscle mass (LMM) has been shown to be a risk factor of poor prognosis (Lin, Peng, Hung, & Tarng, 2018). In an aging population, LMM is becoming more prevalent among elderly people (Giglio et al., 2018). Total muscle mass, measured by BIA, is widely used as a indicator in assessing muscular condition in older people (Hars et al., 2016).

Although total body fat has been demonstrated previously (Scott et al., 2018), little is known about its role in LMM assessment. It is necessary to determine whether high PBF, namely total body fat with adjustment of weight, is a risk factor for LMM, which may lead to sarcopenia and decrease the quality of life in elderly people. Therefore, the aim of the study was to evaluate the usefulness of PBF in screening for the risk of LMM in elderly people.

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2. Methods

2.1. Subjects

Ambulatory elderly people aged between 60 and 81 years who underwent a routine health examination in Chinese PLA General Hospital from February 2013 to December 2015 were enrolled in this study. The inclusion criteria were elderly people aged over 60 who accepted BIA, anthropometric measurements (e.g. height, weight) and biochemical tests. Participants were excluded if they had any of the following: (a) diseases of the extremities, such as musculoskeletal diseases and joint diseases; (b) diseases which may affect bone mass, such as parathyroid diseases, renal dysfunction; (c) diseases which may lead to malnutrition, such as anorexia, malignant tumors, a history of gastrointestinal surgery, an acute phase of a chronic disease, immune diseases; (d) thyroid disorders; (e) previous LMM: One hundred and thirty two participants with LMM at baseline were actually excluded after screening. The total muscle mass index (TMMIs) in excluded LMM participants were 64.39 ± 1.60 (%) in men and 58.92 ± 1.81 (%) in women which were below to the cut-off points in men (66.38%) and women (61.53%, Table S1). A reference group for LMM of 199 healthy young adults aged between 20 and 40 years (mean age 33.5 ± 5.4 years, 33.7% were men) was also recruited. Healthy was defined as without any obvious diseases according to the person's medical history. The TMMIs in young reference group were 74.84 ± 4.23 (%) in men and 70.63 ± 4.55 (%) in women.

Four hundred and thirteen participants screened from health check-up people were recruited at baseline. Visits were performed at baseline and next check-ups between February 2016 and February 2017. We took the check-up results which were nearest before the end of study as follow-up data. The shortest follow-up was 0.6 year and the longest follow-up was 4.0 year. Meanwhile, height, body composition and waist-hip ratio (WHR) were recorded during the follow-up visits. Finally, all participants completed the average 2.2 years' follow-up. All participants gave informed consent to take part in the study. The study protocol was approved by the Institutional Review Board of Chinese PLA General Hospital.

2.2. Sample size calculation

The sample size was calculated using the formula of prospective study and the following statistical assumptions: according to the previous study (Woo & Leung, 2018), the incidence of sarcopenia in high total body fat group was 0.8%, and the incidence of sarcopenia in normal total body fat group was 6.5%. The necessary number was at least 226 ($\alpha = 0.05$, $\beta = 0.1$) which was analyzed by Power Analysis and Sample Size (PASS, version 11.0). But considering 20% drop-out rate, the sample size required was at least 283.

2.3. Data collection and measurements

The medical history (e.g., obesity, diabetes) and personal history (e.g., smoking habit) of each subject were collected by trained health-care providers. Muscle mass data was collected with a body composition analyzer (X-Scan Plus-II, SELVAS Healthcare Inc., Geumcheon-gu, Seoul, South Korea), which has been validated to measure body composition (Berker et al., 2010) and has been reported to measure muscle mass in the young population before (Yadav, Kim, Kim, & Cho, 2018). All subjects wore light clothes and stepped onto the device in bare feet before measurement. They stood on the plate electrodes and gripped the handle electrodes for 5 min without moving, following the instructions of a gauger. The analysis was performed by body composition management software (Body Pass Plus II). Body mass, height, waist circumference(WC) and hip circumference(HC) were measured according to the standard protocol (Lohman, Roche, & Martorell, 1988). The 10 h fasting forearm vein blood was obtained in the early morning and an Architect Ci8200-intergrated system (Abbott Laboratories, USA) was used to detect the level of blood glucose, whole-blood glycohemoglobin A1c (HbA1c) and albumin. Postprandial glucose was determined at 2 h after the administration of 75 g glucose.

2.4. Diagnostic definitions

BMI, WHR, PBF and TMMI were calculated from the following equations:

$$BMI = \text{body mass}/\text{height}^2$$

$$WHR = WC/HC$$

$$PBF = \text{total body fat}/\ \text{body mass} \times 100$$

$$TMMI = \text{total muscle mass}/\text{body mass} \times 100$$

Total muscle included trunk and appendicular muscle. LMM was defined as two standard deviations (SD) below to the mean TMMI of young reference group. In our study, the cut-off points of TMMI using 2SD method was 66.38% in men and 61.53% in women. Smoking history was defined as daily smoking more than one cigarette, cigar or pipe and accumulating 100 or more cigarettes, cigars or pipes for at least six months (National Center of Cardiovascular Diseases, China, 2011). Obesity was defined as a BMI ≥ 28 kg/m^2 (Sub-Committee of Obesity of Chinese Society of Endocrinology of Chinese Medical Association, 2011). Diabetes was defined as fasting blood glucose ≥7.0 mmol/L, or blood glucose ≥ 11.1 mmol/L at 2 h after loading glucose, or HbA1C ≥ 6.5%, or previously diagnosed diabetes (Chinese Society of Diabetes, 2014).

2.5. Statistical analysis

All the data were analyzed using the Statistical Package for the Social Sciences, version 22.0 (SPSS, Inc., Chicago, IL, USA). All continuous variables were approximately under normal distribution, and were expressed as a *mean (SD)*. Categorical data were expressed as a *count (percentage)*. Linear regressions with or without adjustments were constructed to assess the effect of baseline PBF on follow-up TMMI. Receiver Operator Curves (ROC) were created to determine the predictive value of baseline PBF for future LMM. A two-sided P value < 0.05 was considered statistically significant.

3. Results

3.1. Participants' clinical characteristics

The average age at baseline was 63.6 years. The minimum age was 60 and the maximum age was 81. The incidence of LMM was 10.3% in men and 18.2% in women during follow-up. Participants were divided into normal MM group and LMM group based on the last BIA tests' results. Subjects with LMM had higher baseline PBF than those with normal MM ($P < 0.001$ for men and $P = 0.003$ for women, Table 1).

3.2. Effect of baseline PBF on follow-up TMMI

Linear regression demonstrated that baseline PBF were negatively correlated with follow-up TMMIs in both men and women (β=-0.124 for men and -0.233 for women after adjustment for height, baseline total muscle mass, follow-up WHR and obesity history, all $P < 0.001$, Table 2).

3.3. Cut-off points of baseline PBF for future LMM

According to Youden index, the most suitable cut-off points of baseline PBF in elderly people for future LMM were 25.45% (72.4% sensitivity, 78.2% specificity) in men and 30.95% (70.8% sensitivity,

Table 1
Participants' clinical characteristics.

	Normal MM		Newly low MM	
	Male (n = 252)	Female (n = 108)	Male (n = 29)	Female (n = 24)
Age (years)	63.6 (4.1)	63.2 (3.4)	64.7 (4.8)	63.5 (2.6)
Smoking history (n, %)	151 (59.9)	6 (5.6)	14 (48.3)	2 (8.3)
BMI (kg/m^2)	24.34 (2.25)	22.60 (2.15)	27.10 (2.27)**	24.73 (1.67)††
Follow-up BMI (kg/m^2)	24.48 (2.33)	22.70 (1.96)	27.84 (2.00)**	25.52 (1.49)††
WHR	0.93 (0.04)	0.81 (0.04)	0.97 (0.02)**	0.84 (0.03)†
Follow-up WHR	0.94 (0.03)	0.82 (0.03)	1.00 (0.04)**	0.86 (0.01)††
PBF (%)	22.47 (3.73)	28.28 (4.01)	26.01 (1.71)**	30.88 (3.06)†
Follow-up PBF (%)	22.75 (3.55)	29.38 (2.73)	29.20 (0.94)**	34.15 (1.02)††
TMMI (%)	71.95 (3.68)	66.28 (4.01)	68.51 (1.50)**	63.76 (2.99)†
Follow-up TMMI (%)	71.48 (3.52)	64.91 (2.70)	65.08 (0.92)**	60.18 (0.99)††
Albumin (g/L)	45.17 (2.57)	45.73 (2.17)	44.86 (2.34)	45.25 (2.40)
Follow-up albumin (g/L)	44.70 (2.44)	44.83 (2.58)	44.95 (2.47)	45.03 (2.06)
Calcium (mmol/L)	2.31 (0.08)	2.34 (0.08)	2.31 (0.09)	2.33 (0.11)
Follow-up calcium (mmol/L)	2.30 (0.09)	2.35 (0.08)	2.32 (0.11)	2.34 (0.10)
Phosphorous (mmol/L)	1.09 (0.14)	1.22 (0.12)	1.15 (0.18)	1.20 (0.16)
Follow-up phosphorous (mmol/L)	1.09 (0.13)	1.24 (0.11)	1.15 (0.21)	1.20 (0.16)
Obesity (n, %)	84 (33.3)	21 (19.4)	18 (62.1)*	9 (37.5)
DM (n, %)	53 (21.0)	25 (23.1)	10 (34.5)	6 (25.0)

Continuous data were shown as *mean (SD)* and categorical data were *n (%)*.
Abbreviations: MM: muscle mass; BMI: body mass index; WHR: waist-hip ratio; PBF: percentage body fat; DM: diabetes mellitus.
Normal MM versus Newly low MM: Male: $^{*}P < 0.05$, $^{**}P < 0.001$; Female: $^{†}P < 0.05$, $^{††}P < 0.001$.

Table 2
Effect of baseline PBF on follow-up TMMI.

	Male β (SE)	P value	Female β (SE)	P value
Model 1	−0.709 (0.045)	< 0.001	−0.456 (0.055)	< 0.001
Model 2	−0.121 (0.030)	< 0.001	−0.236 (0.036)	< 0.001
Model 3	−0.124 (0.031)	< 0.001	−0.233 (0.038)	< 0.001

Abbreviations: SE: standard error; TMMI: total muscle mass index; PBF: percentage body fat; WHR: waist-hip ratio.
Model 1 was not adjusted for any factor. Model 2 was adjusted for height, baseline total muscle mass and follow-up WHR. Model 3 was adjusted for height, baseline total muscle mass, follow-up WHR and obesity history.

74.1% specificity) in women. Baseline PBF showed a predictive value for future LMM without adjustment [*Area Under Curve* (AUC) = 0.818 for men and 0.773 for women separately, all $P < 0.001$]. Based on the cut-off points, high PBFs were defined as PBF over 25.45% in men and 30.95% in women (Fig. 1).

4. Discussion

This study reported for the first time that the usefulness of PBF in screening for the risk of LMM in elderly people.

As is known to us, body fat mass was negatively correlated with muscle mass. With people aging, more fat without completely consumed will deposit as adipose tissues in different body parts especially in abdomen. One large-scale study involved Chinese population have elucidated that with aging, PBF exhibited a U-shape curvilinear trend for male. In 18–19 age, PBF related indicator declined to the valley. But

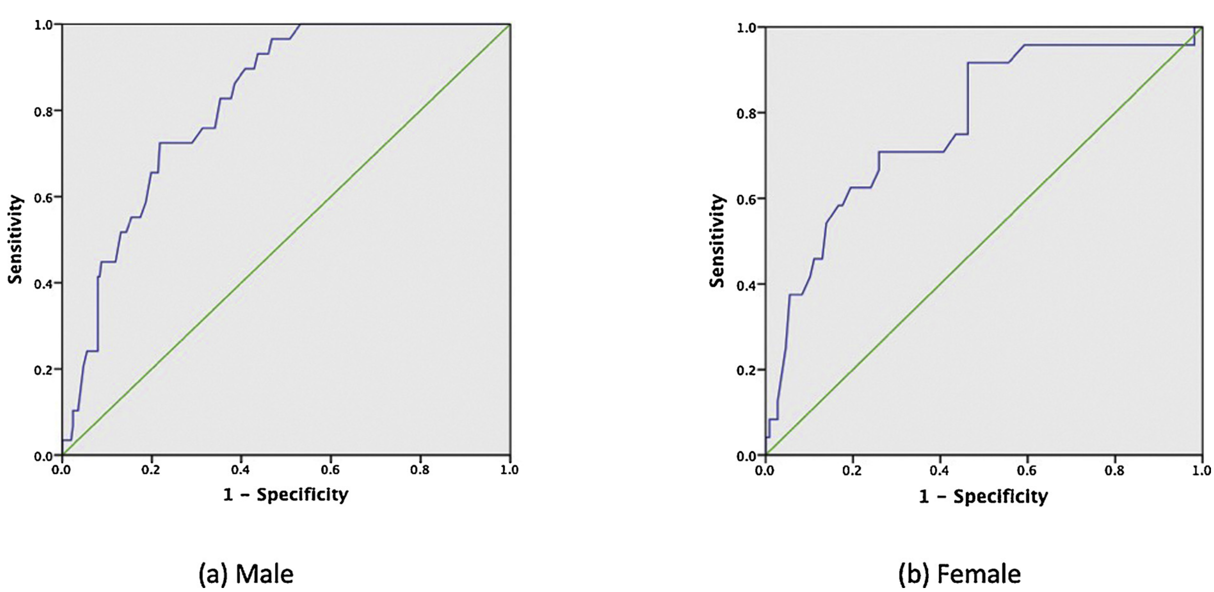

Fig. 1. Receiver Operator Curve of baseline PBF as a predictor for newly LMM.
Abbreviation: PBF: percentage body fat; LMM: low muscle mass.

PBF changed in a linear trend for female (Xu, Zhu, & Han, 2015).

The occurrence and development of LMM involved a wide range of fields, including age, gender, hormone levels, drugs and co-morbidities, such as malnutrition, stroke et al. (Tian et al., 2017). However, in our study, besides traditional causes, we found that high PBF was another important factor for newly developed LMM. The cut-off points of baseline PBF in elderly people for future LMM were 25.45% in men and 30.95% in women, which have not been determined before. The *AUCs* of PBF were nearly between 0.7 and 0.9, which manifested median value in predicting future LMM.

The relationship between body fat mass and muscular indicators has been widely discussed, but how much influence the fat may have in human muscle declining is still in exploration. It has been well demonstrated that as individuals age, body fat increases and lean mass decreases, even without concomitant change in body weight and BMI (St-Onge & Gallagher, 2010). Previous animal study has shown that inflammatory adipokines secreted by ectopic accumulation of fat leads to insulin resistance of muscle (Romacho, Elsen, Röhrborn, & Eckel, 2014). It was also reported that free fatty acid impact the secretion of myokines. Importantly, fat deposition affects muscle homeostasis. Mice with excess ectopic fat accumulation inhibit impaired muscle regeneration possibly due to lipid toxicity, pro-inflammatory cytokines and compromised muscle satellite cell function (Akhmedov & Berdeaux, 2013). In our study, we explored the effect of baseline PBF on follow-up TMMI. With baseline PBF increased one percent, follow-up TMMI decreased 0.124 percent for men and 0.233 percent for women after adjustment.

However, the work had inevitable limitations. Firstly, as a single center study, its biases were unavoidable since the sample was taken from people in one center without amplified. Secondly, we did not evaluate hormone levels, which could be confounding factors that affect muscle mass. A further limitation was that we did not evaluate muscle function, namely muscle strength and physical performance, thus we could not use EWGSOP's definition of 'presarcopenia' in this study (Cruz-Jentoft et al., 2010). Besides, the relationship between high PBF and low TMM may be moderated by physical activity. However, we did not arrange physical activity measurement during data collections. Last but not least, PBF and TMM just demonstrate the whole-body fat and muscle condition separately which did not indicate to a specific body part, therefore a large and longitudinal cohort is warranted to further demonstrate the cause-and-effect relationship between certain body fat and muscle mass.

5. Conclusion

Elderly people with a high PBF had a higher risk of new LMM, which suggested that baseline PBF had a close relationship with future LMM and the screening of high PBF should be paid enough attention in health care management in the senior people.

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Authors' contributions

ZYJ participated in the design of the study and drafted the manuscript. FSH helped the interpretation of data and the statistical analysis. LXY, ZQ and WJX contributed to the conception of the study design and are the guarantors of the work. ZX contributed to the data collection process. All authors read and approved the final manuscript.

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Competing interests

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archger.2019.02.005.

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