J Nutr Health Aging. 2019;23(1):51-59

BODY COMPOSITION CHANGES AND 10-YEAR MORTALITY RISK IN OLDER BRAZILIAN ADULTS: ANALYSIS OF PROSPECTIVE DATA FROM THE SABE STUDY

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Abstract: *Introduction:* Aging related alterations in body composition are associated with higher all-cause mortality risk. *Objective:* To examine the associations between 10-year mortality risk with both BMI and body composition, as well as to establish whether these relationships are modified by age and gender, using data from community-dwelling older Brazilian adults. *Methods:* We used data from two waves i.e., 2000 and 2010 of the SABE (Health, Well-being, and Aging) study conducted in São Paulo, Brazil, involving a probabilistic sample of community-dwelling older adults aged 60 years and older. The variables of the study were: mortality (in 10-year follow-up period), body mass index (BMI), body composition (waist circumference, waist hip ratio, triceps skinfold thickness, mid-upper arm circumference, calf circumference, and arm muscle area) and covariables (sociodemographic characteristics, life style, self-reported health conditions, number of chronic diseases, Mini mental state exam, and Geriatric depression scale). Poisson regression estimates with STATA statistical software were used for statistical analyses, considering all p-values < 0.05. *Results:* Over the 10-year follow-up period, there were 769 deaths (40.2%). The mortality rate was 61.0 for men and 111.8 for the ≥80 age group. In the fully adjusted model, statistically significant hazard ratios were found for low muscle mass (IRR: 1.33), underweight (IRR: 1.29), and low fat mass (IRR: 1.31) with mortality. Men in extreme BMI categories (underweight - IRR: 1.47; obesity I - IRR: 1.66; and obesity II - IRR: 1.91) and women with low muscle and low fat mass were significantly associated with mortality risk. In the ≥80 age group it was observed that low muscle mass (IRR: 168.7), inadequate body reserves (IRR: 1.63), low fat mass (IRR: 140.7), and underweight (IRR: 142.9) were associated with mortality risk. Waist circumference demonstrated protection for mortality in the high-risk categorization for the ≥80 age group. *Conclusion:* Our results showed that underweight, low fat mass, and low muscle mass were associated with mortality risk, presenting different roles considering gender and age in older Brazilian adults over a 10-year follow-up period.

Key words: Aging, body composition, mortality, community-dwelling.

Introduction

Aging related alterations in body composition are associated with higher all-cause mortality risk (1, 2). However, the majority of evidence comes from developed countries (1-4). In addition, longitudinal data from nationally representative aging cohorts from low and middle income nations are scarce. The social changes affecting Brazil in recent years have also impacted on health, with increases in the proportion of older adults, currently over 11%, and an increasing number of overweight and obese Brazilians, over 51% of the population (5, 6).

Epidemiological research showed that being overweight or obese increases both morbidity and mortality risks in younger and middle-aged individuals, however, in older adults, this relationship is still not fully explained (7, 8). A recent debate indicates that overweight and obesity seem to be associated with decreased mortality rates in older adults (7, 9). On the other hand, undernutrition remains a concerning condition in later life since it can contribute to the development of functional limitations, disability, and death (10).

The body mass index (BMI) is the most widely used anthropometric measure to investigate mortality risk. However, BMI does not capture important alterations in body composition that occur in later life (2, 7, 11). Therefore, other body composition measures, such as fat mass and muscle mass, could be better indicators to investigate mortality risk in older adults (12). Few studies have examined the association between fat or muscle mass and mortality (12, 13). In addition, different methods have been employed to define body composition,

Received March 22, 2018
Accepted for publication June 6, 2018

Published online October 17, 2018, http://dx.doi.org/10.1007/s12603-018-1118-1

such as bioelectrical impedance analysis, dual-emission X-ray absorptiometry, and anthropometric measures; the latter being considered more accessible for use in developing countries (14). Thus, the aim of the present study was to examine the associations between 10-year mortality risk and both BMI and body Composition, as well as to establish whether these relationships are modified by age and gender, using data from community-dwelling older Brazilian adults.

Methods

Study Population

We used data from two waves i.e., 2000 and 2010 of the SABE (Health, Well-being, and Aging) study conducted in São Paulo, Brazil, involving a probabilistic sample of community-dwelling older adults aged 60 years and older. SABE is a multicenter survey with respondents from seven capital/major cities throughout the countries of Latin America and the Caribbean (LAC), investigating the health and well-being of older adults (15).

The baseline sample was obtained from the 1995 Brazilian National Household Survey master sampling frame. The sampling process for SABE was conducted in two stages: the first, a probabilistic sample of 1,568 individuals, and the second, a further 575 individuals, to compensate the higher rate of male mortality and lower population density of the group aged 75 and older. At baseline, in 2000, information was collected on 2,143 individuals in the city of São Paulo/Brazil (15).

Data collection was performed in two steps. The first involved a household interview conducted by a single interviewer using a standardized questionnaire that included questions about living conditions and health status, proposed by the Pan American Health Organization (PAHO), translated and adapted for use in Brazil. The second step was a household visit by a pair of interviewers who collected anthropometric and physical performance measurements. Each questionnaire was reviewed by a specialized technical group. Detailed information about the sampling procedures and data collection process has been described elsewhere (15, 16).

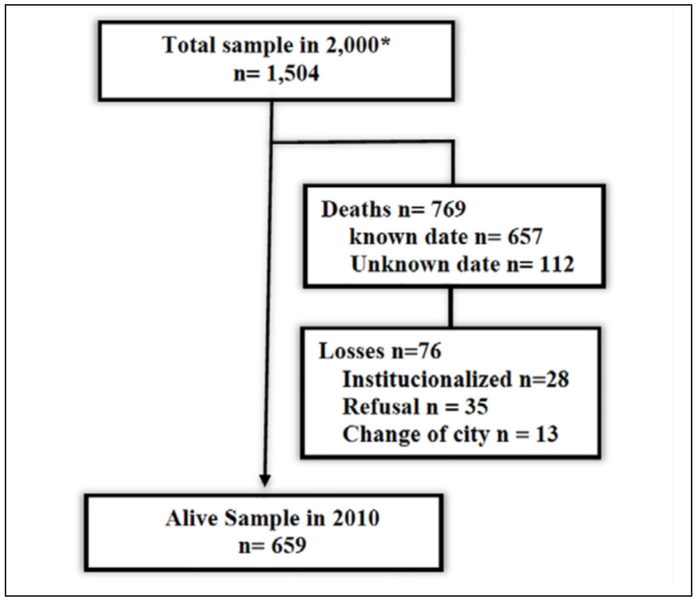
In 2010, the surviving participants from the 2000 cohort comprised 659 individuals. Reasons for the reduction in participants included losses (institutionalization, refusal, change of city) and deaths. Our analytical sample comprised 1,504 participants who presented complete information on all variables investigated. Figure 1 shows the study design.

The SABE survey was approved by the Ethics in Research Committee of the Faculty of Public Health of the University of São Paulo (control number 475,455) and the National Committee for Ethics in Research (CONEP) and all participants gave written informed consent prior to participation (15).

Mortality Follow-Up

Deaths assigned to all-cause were obtained from the data provided by the Fundação Sistema Estadual de Análise de Dados (the SEADE foundation) and Programa de Aprimoramento das Informações de Mortalidade (Program of Improvement of Information on Mortality, PRO-AIM), which are responsible for collecting and organizing data on deaths for the city of São Paulo, Brazil. The SABE research team identified the deaths occurring from 2000 to 2010 through a search based on name, sex, date of birth, and address listed in the 2000 database.

Figure 1
Study design (SABE 2000-2010)



Note: *Exclusion of 639 individuals from the 2,000 total sample, because of missing anthropometric and other studied variables data.

BMI and Body Composition Assessment

The BMI (kg/m^2) was classified according to: undernutrition = BMI ≤ 23 kg/m^2; adequate weight = BMI > 23 and < 28 kg/m^2; overweight = BMI ≥ 28 and < 30kg/m^2, and obesity, class I BMI ≥ 30 kg/m^2< 35kg/m^2, classes II and III ≥ 35kg/m^2. Body composition was measured using a wide range of indicators: waist circumference (WC), waist hip ratio (WHR), triceps skinfold thickness (TSF), mid-upper arm circumference (MAC), calf circumference (CC), and arm muscle area (AMA). High abdominal adiposity was categorized as WC ≥ 94 for men and ≥ 80 for women and WHR ≥ 1 for men and ≥ 0.85 for women; <25th percentile for low body fatness and ≥ 25th percentile for adequate body fatness; adequate reserves of muscle mass, body fat, water, and bone when ≥ 25th percentile and < 25th percentile for inadequate reserves; low muscle mass when <31cm and <25th percentile when ≥ 31 cm and ≥ 25th percentile, respectively, considering the percentiles of the same population.

In addition, the AMA was calculated according to the equations proposed by Heymsfield et. al.17(1982), presented below, subtracting the area corresponding to bone mass from the muscle mass value, 10 cm^2 for men and 6.5 cm^2 for women. In this way, it is possible to obtain a more reliable estimate of muscle mass.

Men

$$AMA\ (cm^2) = \frac{\{MAC\ (cm) - [\pi * (TSF\ (mm) / 10)]\}^2}{4*\pi} - 10\ cm^2$$

Women:

$$AMA\ (cm^2) = \frac{\{MAC\ (cm) - [\pi * (TSF\ (mm) / 10)]\}2}{4*\pi} - 6{,}5\ cm^2$$

$\pi = 3.1416$

Covariates

The following covariates were included in the analysis: sociodemographic characteristics (age in years, gender, marital status - married and not married; schooling years - 0 to 11 and 12 or more years; currently working - yes or no; and income - > US$808.70 < 323.5 - US$ ≤808.70 and ≤ US$ 323.50); life style (weekly alcohol intake - none, once a week, two to six days a week, and every day; practice of physical activity - identified by the International Physical Activity Questionnaire -IPAQ, short version, and individuals classified as active if they practiced ≥150 minutes of moderate physical activities per week in different domains leisure, transportation, work, and household activities and as sedentary if they practiced <150 minutes per week in these different domains; and smoking habit - non-smoking, smoking and ex-smoking); doctor diagnosed self-reported health conditions (hypertension, diabetes mellitus, cardiovascular diseases, lung diseases, stroke, and cancer - yes or no), number of chronic diseases - none, one, and two or more, Mini mental state exam - ≤ 12 and > 12 points, and Geriatric depression scale - < 6 and ≥ 6 points).

Statistical analyses

Means, standard deviations (continuous variables), and percentages (categorical variables) were reported for descriptive data at baseline.

Age and sex adjusted incidence rate ratios (IRR) and their 95% confidence intervals were estimated for the association between nutritional status and body composition and death using Poisson regression estimates instead of Cox proportional hazards since the proportional hazards assumption was not detected. The results were expressed in the multivariate analysis that included only 2 models (unadjusted and fully adjusted) for a wide range of sociodemographic, lifestyle, health conditions variables, according to gender and age groups. Statistical analyses were conducted using version 13.0 of STATA statistical software (Stata Corp, College Station, Texas). All p-values were 2-tailed ($p < 0.05$).

Data analysis was conducted using the "survey" command, which permits the incorporation of features related to the complex design of the sample, namely, disproportionate stratification, drawing in clusters, and weighting. The weighting variable, created to examine the data, was defined by the inverse of the sampling fraction and adjusted so that the sample did not present distortions regarding age and sex.

Results

Over the 10-year follow-up period, there were 769 deaths (40.2%), 48% in men and 35% in women, with 31% and 73% from the 60-74 and ≥ 75 age groups, respectively. Mortality rates of 61.0 (95% CI 53.5 – 69.6) and 39.5 (95% CI 35.1-44.6), were found for men and women respectively; and 34.3 (95% CI 30.2 – 39.1) and 111.8 (95% CI 102.9 - 121.5) for the 60-79 and ≥80 age groups respectively.

Table 1

Selected baseline characteristics of participants. The SABE (Health, Well-Being, and Aging) Study, Brazil, 2000

Characteristics	**SABE (n=1.504)**
Sociodemographic variables	
Age	67.2 ± 0.19
Gender (female)	57.7 (n=861)
Marital status (married)	58.4 (n=802)
12 or more years of schooling	9.78 (n=125)
Currently working (yes)	27.7 (n=301)
Income	
>US$808.70	21.7 (n=264)
> 323.5 US$ ≤808.70	27.3 (n=403)
≤US$≤323.50	51.0 (n=771)
Lifestyle	
Weekly alcohol intake	
None	68.1 (1.056)
Once a week	19.7 (n=275)
Two to six days a week	6.2 (n=92)
Everyday	6.0 (n=81)
Sedentary lifestyle	73.5 (n=1,168)
Smoking	15.9 (n=205)
Health conditions	
Hypertension (yes)[1]	52.0 (n=797)
Diabetes (yes)[1]	17.4 (n=264)
Cardiovascular diseases (yes)[1]	18.0 (n=303)
Lung diseases (yes)[1]	10.2 (n=169)
Stroke (yes)[1]	6.0 (n=96)
Cancer (yes)[1]	3.1 (n=49)
Number of diseases[2]	
None	27.1 (n=384)
One	31.6 (n=466)
Two or more	41.3 (n=654)
Mini Mental State exam (≤ 12 points)	11.1 (n=232)
Geriatric depression Scale (≥ 6 points)	18.3 (n=234)

Note: Data are given as mean ± SD (standard deviation) or number and percentage. Means and proportions were calculated considering the weight of the sample. 1. Self-reported doctor diagnosed for all diseases. 2. Hypertension, diabetes, cancer, osteoporosis, respiratory, cardiovascular, and osteoarticular diseases.

Table 2
Body mass index and body composition characteristics of the included participants by 10-year mortality. The SABE (Health, Well-Being, and Aging) Study, Brazil, 2000

	10-year Mortality			
Characteristics	**Survived=659**		**Died=769**	
	Mean (SD)	**95% CI**	**Mean (SD)**	**95% CI**
Weight (kg)	62.56 (0.49)	61.60 – 63.53	66.59 (0.44)	65.73 – 67.46
Height (meters)	1.57 (0.01)	1.56 – 1.58	1.56 (0.01)	1.56 – 1.57
Body mass index (kg/m^2)	27.20 (0.17)	26.86 – 27.54	25.36 (0.18)	25.00 – 25.70
Waist circumference	0.78 (0.15)	0.75 – 0.81	0.67 (0.17)	0.64 – 0.71
Waist to hip ratio	0.93 (0.01)	0.92 – 0.93	0.95 (0.13)	0.93 – 0.98
Triceps skinfold (mm)	23.61 (0.36)	22.91 – 24.31	18.64 (0.34)	17.97 – 19.31
Mid-upper arm circumference (cm)	31.36 (0.14)	31. 10 – 31.63	29.08 (0.15)	28.78 – 29.38
Calf circumference (cm)	36.29 (0.13)	36.03 – 36.56	34.61 (0.16)	34.29 – 34.93
Arm muscle area (cm^2)	38.53 (0.39)	37.77 – 39.29	35.39 (0.38)	34.64 – 36.14

Note: Data are given as mean ± SD (standard deviation) or confidence interval (CI) calculated considering the weight of the sample.

At baseline, the mean age (SD) was 69.3 (0.30) years for men and 68.4 (0.26) years for women. The mean values by gender for the anthropometric variables for men and women, respectively were: BMI 24.9 (0.16) and 27.2 (0.17) kg/m^2; WC 100.8 (2.84) and 100.7 (2.60) cm; WHR 0.97 (0.01) and 0.91 (0.001); AMA 38.9 (0.42) and 35.5 (0.34) cm^2; CC 35.4 (0.17) and 35.5 (0.13) cm; and STF 14.6 (0.28) and 25.9 (0.29) mm (data not shown). The majority of participants were married, had low education, were not currently working, had a low income, did not regularly ingest alcohol, had a sedentary lifestyle, and were not current smokers. Hypertension and having 2 or more chronic diseases were the most common health conditions (Table 1). The mean values for weight, height, BMI, and body composition indicators were lower for those participants who died compared to those who survived over the 10-year period (Table 2).

The total mortality rate was higher in individuals with low muscle mass (110.4), underweight (74.1), and low fat mass (66.6). In the Poisson regression analysis, statistically significant unadjusted and adjusted hazard ratios were found for low muscle mass (IRR: 1.88; IRR: 1.33), underweight (IRR: 1.53; IRR: 1.29), and low fat mass (IRR: 1.39; IRR: 1.31) with mortality rate. Some anthropometric variables, such as high abdominal fat and inadequate muscle mass, lost significance in the fully adjusted model (Table 3).

Considering gender differences, men with low muscle and fat mass and inadequate body reserves had a higher mortality rate (136, 89.7, and 104.1, respectively) than women (98.8, 52.8, and 57.9, respectively). In the fully adjusted model, men in extreme BMI categories (underweight – IRR: 1.47; obesity I – IRR: 1.66; and obesity II – IRR: 1.91) presented higher mortality risk. In women, low muscle mass and low fat mass were significantly associated with mortality risk. For women, the underweight BMI category (IRR: 1.34) was associated with mortality only in the unadjusted model and obesity I (IRR: 0.66) only in the fully adjusted model (Table 4).

Regarding age group differences, a higher mortality rate was observed for those in the ≥80 age group who had low muscle mass (IRR: 168.7), inadequate body reserves (IRR: 1.63), low fat mass (IRR: 140.7), and were underweight (IRR: 142.9) compared to individuals in the 60 to 79 age group. The variables associated with mortality risk in the fully adjusted model were the same for both age groups. WC was significantly associated with mortality only in the ≥80 age group, demonstrating protection for mortality in the high-risk categorization. The AMA indicator lost significance after adjustment for both age group and gender (Tables 4 and 5).

Discussion

The main findings from this longitudinal aging study of community-dwelling older Brazilian adults showed that the underweight BMI category, and low muscle and fat mass were associated with all-cause mortality risk during a 10-year follow-up period. The highest mortality rate was observed in individuals with low muscle mass, independent of their gender or age group. Moreover, no significant association was found between overweight/obesity and abdominal adiposity with mortality risk.

BMI and body composition differ according to age, gender, and ethnicity. Older adults tend to lose water, muscle mass, and body fat (10, 11). Many factors are associated with these alterations, such as the normal ageing process, level of physical activity, functional capacity, nutrition, and chronic health conditions (1, 18). Furthermore, comparisons with other studies are difficult due to differences in the methods of measurement

Table 3
Mortality rates and incidence rate ratios (IRR) for 10-year mortality in older Brazilian adults, by body mass index, waist circumference, waist to hip ratio, triceps skinfold, mid-upper arm circumference, calf circumference, and arm muscle area. The SABE (Health, Well-Being, and Aging) Study, Brazil, 2000-2010

Variables	Mortality rate (95% CI)	Unadjusted IRR (95% CI)	Fully adjusted IRR (95% CI)
Body mass index (kg/m2)			
Adequate weight	42.9 (37.3 - 49.5)	1.00	1.00
Underweight	74.1 (63.3 – 86.8)	1.53 (1.30-1.79)	1.29 (1.07 – 1.55)
Overweight	45.9 (35.8 - 59.4)	1.07 (0.84-1.35)	1.11 (0.88-1.41)
Obesity I	40.2 (31.1 – 52.4)	0.96 (0.76-1.23)	0.98 (0.76 – 1.28)
Obesity II	31.5 (20.7- 49.8)	0.78 (0.53-1.15)	1.07 (0.72-1.61)
Waist circumference			
Adequate abdominal fat	58.6 (49.9-68.9)	1.00	1.00
High abdominal fat	43.9 (39.5-48.9)	0.81 (0.70-0.94)	0.96 (0.80 -1.14)
Waist to hip ratio			
Adequate fat	48.6 (42.4-55.8)	1.00	1.00
High fat	47.0 (41.9-52.9)	0.98 (0.85-1.13)	1.04 (0.87-1.23)
Triceps skinfold			
Adequate fat mass[a]	43.5 (39.3- 48.3)	1.00	1.00
Low fat mass[a]	66.6 (56.3- 79.0)	1.39 (1.19-1.61)	1.31 (1.10-1.55)
Mid-upper arm circumference			
Adequate	42.9 (38.7-47.6)	1.00	1.00
Inadequate	73.5 (62.1-87.2)	1.51 (1.30-1.75)	1.40 (1.17-1.66)
Calf circumference			
High muscle mass	44.3 (40.3-48.8	1.00	1.00
Low muscle mass	110.4 (87.5-139.1)	1.88 (1.60-2.19)	1.33 (1.08-1.64)
Arm muscle area			
Adequate muscle mass[a]	45.8 (41.7-50.4)	1.00	1.00
Inadequate muscle mass[a]	70.8 (55.3-90.9)	1.38 (1.14-1.68)	1.21 (0.96-1.59)

Note: Models unadjusted and fully adjusted by age, gender, marital status, schooling, working status, income, weekly alcohol intake, sedentary lifestyle, smoking, hypertension, diabetes, cardiovascular and lung diseases, stroke, cancer, number of diseases, Mini Mental State exam, and Geriatric Depression Scale. a. Percentile of the studied population. Poisson regression analysis.

and covariates used, reference values, and population characteristics, that might affect mortality risk (14, 19).

Undernutrition has frequently been reported as the nutritional condition that most impacts on mortality risk in later life. This could be attributed to multiple factors such as chronic diseases, polypharmacy, and psychosocial and physiologic alterations associated with aging. Underweight is associated with respiratory disease, cancer, depression, chronic kidney disease, and non-circulatory diseases, whereas excessive-weight is associated with hypertension, hyperlipidemia, heart disease, and diabetes (20, 21).

It is also important to consider the possibility of reverse causality. Older adults often lose weight because of a fatal illness and, consequently, mortality appears to be higher among people with low weight when the real cause is the presence of disease (19). To clarify this, it is necessary to evaluate whether low BMI is a result of disease-related weight loss or reflects a stable unmodified weight, each option having different prognostics (7). In the present study, weight change was not analysed. However, the nutrition assessment was not limited to only one measure of BMI or weight, but also included body fat and muscle mass.

We did not find an association between overweight and obesity with mortality, which is consistent with findings from several previous cohort studies (7, 19, 22-23). However, by stratifying our analyses by gender, it was observed that the mortality risk in men was significantly associated with the extreme BMI categories. The mortality risk was 47% greater in underweight men when compared to the ideal weight group (≥23 and <28 kg/m^2) and 60% greater for obesity; as the obesity grade increased so did the mortality risk. In women, an association was observed between underweight and mortality in the unadjusted model. Underweight did not remain significant in the fully adjusted model. However, in the obesity grade I

Table 4
Mortality rates and incidence rate ratios (IRR) for 10-year mortality in older Brazilian adults, by body mass index, waist circumference, waist to hip ratio, triceps skinfold, mid-upper arm circumference, calf circumference, arm muscle area and gender. The SABE (Health, Well-Being, and Aging) Study, Brazil, 2000-2010

Variables	Men			Women		
	Mortality rate (95% CI)	Unadjusted IRR (95% CI)	Fully adjusted IRR (95% CI)	Mortality rate (95% CI)	Unadjusted IRR (95% CI)	Fully adjusted IRR (95% CI)
Body mass index						
Adequate weight	47.5 (38.8 - 58.5)	1.00	1.00	38.5 (32.1 – 47.2)	1.00	1.00
Underweight	96.9 (78.2 - 117.7)	1.72 (1.40-2.12)	1.47 (1.14-1.87)	56.5 (44.5 - 72.1)	1.34 (1.05-1.70)	1.06 (0.80-1.41)
Overweight	48.6 (32.8 - 73.5)	1.03 (0.72-1.46)	1.11 (0.78-1.57)	43.7 (31.9 - 60.6)	1.12 (0.82-1.53)	1.05 (0.76-1.45)
Obesity I	82.8 (52.8 - 131.8)	1.49(1.07-2.09)	1.60 (1.14-2.23)	29.5 (21.7 - 40.8)	0.81 (0.59-1.11)	0.66 (0.46-0.95)
Obesity II	77.2 (31.1-210.5)	1.47 (0.76-2.85)	1.91 (1.11-3.31)	25.8 (16.2 – 42.9)	0.71 (0.45-1.12)	0.80 (0.49-1.32)
Waist circumference						
Adequate abdominal fat	64.7 (53.4 - 78.6)	1.00	1.00	46.9 (35.0 - 63.3)	1.00	1.00
High abdominal fat	57.9 (48.3 - 69.5)	0.91 (0.75-1.11)	1.03 (0.84-1.28)	37.7 (33.1 - 43.1)	0.86 (0.66-1.11)	0.80 (0.59-1.09)
Waist to hip ratio						
Adequate abdominal fat	60.4 (51.5 – 71.0)	1.00	1.00	29.3 (22.6 – 38.6)	1.00	1.00
High abdominal fat	61.4 (48.7 – 78.0)	1.00 (0.81-1.23)	0.95 (0.76-1.18)	42.7 (37.4 – 44.9)	1.37 (1.06- 1.77)	1.09 (0.80-1.45)
Triceps skinfold						
Adequate fat massa	54.5 (46.7-63.8)	1.00	1.00	36.2 (31.5- 41.6)	1.00	1.00
Low fat massa	89.7 (70.6-114.3)	1.45 (1.19-1.78)	1.24 (0.97-1.59)	52.8 (41.7- 67.1)	1.34 (1.08-1.67)	1.31 (1.03-1.67)
Mid-upper arm circumference						
Adequate	53.8 (46.1-64.8)	1.00	1.00	35.3 (30.8-40.6)	1.00	1.00
Inadequate	104.1 (82.3-131.7)	1.63 (1.35-1.97)	1.38 (1.07-1.78)	57.9 (45.8-73.6)	1.46 (1.18-1.81)	1.41 (1.10-1.81)
Calf circumference						
Adequate muscle mass	57.8 (50.3 – 66.5)	1.00	1.00	35.3 (31.0- 40.2)	1.00	1.00
Low muscle mass	136.0 (91.0- 200.0)	1.72 (1.36-2.16)	1.13 (0.85-1.50)	99.8 (74.4- 133.9)	2.13 (1.72-2.62)	1.45 (1.07-1.96)
Arm muscle area						
Adequate muscle mass[a]	57.1 (49.6-65.8)	1.00	1.00	38.2 (33.7-43.5)	1.00	1.00
Low muscle mass[a]	105.8 (75.0-149.5)	1.52 (1.21-1.92)	1.28 (0.95-1.72)	51.4 (33.6-72.8)	1.26 (0.95-1.69)	1.04 (0.72-1.47)

Note: Models unadjusted and fully adjusted by age, gender, marital status, schooling, working status, income, weekly alcohol intake, sedentary lifestyle, smoking, hypertension, diabetes, cardiovascular and lung diseases, stroke, cancer, number of diseases, Mini Mental State exam, and Geriatric Depression Scale. a. Percentile of the studied population. Poisson regression analysis.

group the mortality risk was reduced by 44%. This protective effect was lost with a BMI ≥35kg/m^2.

Some studies have found a lower mortality risk associated with overweight and obesity (7, 23, 24). This supports the existence of a kind of obesity paradox, although in the present study, as in other Brazilian and international cohort studies, this effect was not proven (7, 19). The effect of the obesity paradox on mortality in older adults, if present, may be modest. A possible explanation for this is that weight gain may indicate the absence of underlying wasting conditions or additional energy reserves that could be helpful to brain and muscle, able to be mobilized in the event of acute catabolic or chronic illness (7).

Considering the age groups, a greater mortality rate was found in the oldest group (≥80), and, therefore, the underweight status presented greater risk in the youngest group (IRR: 1.37,1.03-1.83). This phenomenon was also observed in other study where the mortality for those aged between 60 and 64 was about 15-fold higher compared to individuals from the general population, whereas for those aged 84 and older, mortality was only 3-fold higher (25). This may be explained by the fact that individuals who survive to old age present characteristics that protect them from the adverse effects of aging.

The association between abdominal and whole body adiposity with mortality in later life remains unclear (26, 27). Abdominal adiposity assessed by both WC and WHR has been reported as a risk factor for mortality in older adults (28). However, our findings do not support this association since

Table 5
Mortality rates and incidence rate ratios (IRR) for 10-year mortality in Brazilian older adults, by body mass index, waist circumference, waist to hip ratio, triceps skinfold, mid-upper arm circumference, calf circumference, arm muscle area and age groups. The SABE (Health, Well-Being, and Aging) Study, Brazil, 2000-2010

Variables	60 – 79 years			80 years and more		
	Mortality rate (95% CI)	Unadjusted IRR (95% CI)	Fully adjusted IRR (95% CI)	Mortality rate (95% CI)	Unadjusted IRR (95% CI)	Fully adjusted IRR (95% CI)
Body mass index						
Adequate weight	30.3 (24.8-37.4)	1.00	1.00	107.1 (94.5-121.5)	1.00	1.00
Underweight	51.2 (40.0-66.3)	1.58(1.21-2.06)	1.37 (1.03-1.83)	142.9 (124.1-164.4)	1.15 (1.04-1.27)	1.17 (1.01-1.35)
Overweight	36.1 (25.8-51.5)	1.18 (0.84-1.65)	1.18 (0.85-1.64)	94.9 (73.4-123.3)	0.93 (0.76-1.13)	0.93 (0.74-1.17)
Obesity I	30.2 (21.1-44.3)	1.01 (0.71-1.45)	1.07 (0.75-1.55)	88.5 (67.7-116.6)	0.89 (0.74-1.08)	0.83 (0.65-1.06)
Obesity II	21.7 (12.1-42.6)	0.76 (0.43-1.36)	1.03 (0.57-1.85)	130.4 (78.5-215.2)	1.08 (0.83-1.41)	1.18 (0.86-1.61)
Waist circumference						
No risk	41.2 (32.5-52.6)	1.00	1.00	141.3 (123.5-161.7)	1.00	1.00
High risk	32.0 (27.4-37.4)	0.81 (0.64-1.03)	0.99 (0.76-1.28)	99.8 (91.9-113.0)	0.83 (0.75-0.91)	0.84 (0.73-0.96)
Waist to hip ratio						
No risk	35.5 (29.4- 43.3)	1.00	1.00	126.4 (111.8-142.9)	1.00	1.00
Risk	33.3 (28.1- 39.9)	0.94 (0.75-1.17)	1.05 (0.84-1.34)	104.0 (93.1-116.3)	0.88 (0.81-0.98)	0.86 (0.74-0.99)
Triceps skinfold						
Adequate fat mass[a]	30.8 (26.5-36.0)	1.00	1.00	104.1 (94.5-114.7)	1.00	1.00
Low fat mass[a]	49.1 (38.6-63.2)	1.48 (1.17-1.88)	1.34 (1.04-1.73)	140.7 (119.5-165.4)	1.16 (1.05-1.28)	1.20 (1.05-1.38)
Mid-upper arm circumference						
Adequate	30.4 (26.2-35.5)	1.00	1.00	100.0 (90.8-110.1)	1.00	1.00
Inadequate	53.3 (42.0-68.2)	1.60 (1.27-2.02)	1.38 (1.06-1.79)	173.9 (148.2-203.4)	1.32 (1.21-1.44)	1.35 (1.18-1.55)
Calf circumference						
Adequate muscle mass	32.4 (28.3-37.2)	1.00	1.00	104.4 (95.3-114.4)	1.00	1.00
Low muscle mass	77.4 (52.1-116.6)	1.96 (1.46-2.64)	1.65 (1.15-2.36)	168.7 (137.3-206.2)	1.25 (1.12-1.39)	1.22 (1.05-1.42)
Arm muscle area						
Adequate muscle mass[a]	32.4 (28.2-37.4)	1.00	1.00	107.6 (98.4-117.6)	1.00	1.00
Low muscle mass[a]	53.3 (38.1-75.8)	1.49 (1.12-1.99)	1.17 (0.85-1.60)	157.2 (122.0-201.1)	1.23(1.08-1.41)	1.21(0.99-1.47)

Note: Models unadjusted and fully adjusted by age, gender, marital status, schooling, working status, income, weekly alcohol intake, sedentary lifestyle, smoking, hypertension, diabetes, cardiovascular and lung diseases, stroke, cancer, number of diseases, Mini Mental State exam, and Geriatric Depression Scale. a. Percentile of the studied population. Poisson regression analysis.

we did not find significant associations between adiposity and mortality risk after adjustments for multiple indicators. An inverse association between abdominal adiposity and mortality was observed in the oldest group suggesting that higher abdominal adiposity in addition to whole body fat might be beneficial for survival in participants aged 80 and older. Based on these considerations our results suggest that cut-off points for older individuals should be defined using WC and WHR values. In the present study, low fat mass assessed by the TSF measure was associated with mortality risk. These results suggest that fat mass may not have detrimental effects in later life, conversely to what is generally reported in middle age, in that body stores contribute to the development of cardiovascular diseases and metabolic consequences (26).

Circumference of the extremities (CC and MAC) has been used for muscle mass assessment in older adults (29, 30). However, the relationships between these variables and mortality are still inconsistent. Decreases in muscle mass are associated with higher levels of cytokines and inflammatory markers. It has been hypothesized that loss of muscle mass is a physical sign of underlying inflammation related to a higher risk of mortality (31). The majority of studies present results based on MAC and CC values (29, 30). We used AMA to assess muscle mass and found that this indicator was not associated with mortality. Another study, also with older community-dwelling individuals, found results contrary to these (32).

Our results showed that both CC and MAC seem to be reliable indicators of muscle mass to predict mortality risk. The associations between CC and MAC with health outcomes and mortality have been investigated in several studies (29, 30, 32). CC under 31 cm is associated with greater frailty, impaired physical function, and mortality in older individuals (29). Moreover, low CC and MAC have been proposed as an indicator of malnutrition in older adults (33, 34). The present study also verified that low muscle mass measured by CC and inadequate reserves through MAC were associated with mortality risk. The mortality risk associated with low muscle mass could be due to low levels of physical activity in the population studied.

The CC and MAC are particularly relevant to clinical practice as they are readily accessible, non-invasive, inexpensive, and relatively easy to measure (compared to weight and height measurements), particularly for frail or hospitalized individuals who require regular monitoring, added to which a healthcare provider can assess muscle mass using only a tape measure. Furthermore, a decline in muscle mass is a condition of clinical importance in older persons, which needs to be identified early to prevent the development of sarcopenia and disabilities in this group (33-35).

This study has some limitations. First, we did not have data on specific cause of mortality in this population. Second, we did not consider recent weight changes of the participants. Third, individuals without data on anthropometric measures were excluded, resulting in a younger and healthier sample. This could have led to underestimation of the results found.

The strengths of this study are the representative sample of the general Brazilian elderly population and the longitudinal design with a 10-year follow-up period. As the relation between BMI and body composition with mortality may be different among institutionalized, hospitalized, and community-dwelling individuals, in the present study only individuals living in the community were included. The use of easy-to-assess anthropometric measures enhances the potential applicability of our findings to clinical and public health practices.

Conclusions

Our results showed that underweight, low fat mass, and low muscle mass were associated with mortality risk in older Brazilian adults over a 10-year follow-up period. It seems that body composition performs a different role regarding the risk of mortality considering gender and age. Further studies are needed to assess the potential protective role of high body fat using data from other countries.

Acknowledgments: In memory of Professor Maria Lúcia Lebrão, coordinator of the SABE study. We also thank all the staff working on SABE and all its participants.

Funding: The Sao Paulo Research Foundation - FAPESP (grant numbers: 99/05125-7, 05/54947-2, and 09/53778-3) and CAPES (Coordenação deAperfeiçoamento de Pessoal de Nível Superior) funds SABE survey. Manuela de Almeida Roediger receive a Research Fellowship grant from the Sao Paulo Research Foundation (FAPESP/ grant numbers: 15/15224-7), Jair Licio Ferreira Santos and Yeda Aparecida de Oliveira Duarte receive a Research Fellowship grant from the National Council for Scientific and Technological Development (CNPq).

Data availability: The SABE datasets used in this analysis are under license and are not publicly available, based on a policy adopted by the SABE Survey.

Authors' contributions: MAR conceived the study. MAR and DAQSD performed the statistical analyses. MAR, DAQSD, and CO drafted the first manuscript. MAR, YAOD, MFNM, CO, and JLFS substantially contributed to the design of the study, and analyses and interpretation of these data; approved its final version; and critically reviewed the manuscript for important intellectual content.

Competing interests: None declared.

Conflict of interest: None declared.

Ethical Standards: This research followed the required ethical standards.

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