Sarcopenia and mortality risk in community-dwelling Brazilian older adults

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We estimated the impact of sarcopenia parameters on mortality risk and assessed its prevalence and associated factors in the older adults according to the European Working Group on Sarcopenia in Older People's 2010 (EWGSOP1) and 2018 (EWGSOP2) criteria. This was a 10-year follow-up cohort study. Low muscle mass (MM) was defined as low skeletal muscle mass index (SMI) using dual-energy X-ray absorptiometry (DXA), and low calf circumference (CC). Cox regression and the Kaplan–Meier method were performed. The prevalence of sarcopenia and associated factors were influenced by the MM measurement method and diagnostic criteria used [6.8% (SMI and EWGSOP2), 12.8% (CC and EWGSOP2; and SMI and EWGSOP1) and 17.4% (CC and EWGSOP1)]. While a low BMI was associated with sarcopenia regardless of the sarcopenia definitions, diabetes, and high TGs were associated with sarcopenia only when using the EWGSOP1 criteria. Low SMI increased mortality risk (EWGSOP1: HR = 2.01, 95% CI 1.03–3.92; EWGSOP2: HR = 2.07, 95% CI 1.05–4.06). The prevalence of sarcopenia was higher according to EWGSOP1 than EWGSOP2. A low BMI, diabetes, and high TGs were associated with sarcopenia. A low SMI doubled the risk of mortality in community-dwelling older adults.

Sarcopenia was originally characterized by the loss of muscle mass associated with advancing age1,2. Recent definitions define sarcopenia as a reduction in mass, strength, and muscle function3–9. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP1) criteria recommended diagnosing sarcopenia based on a low muscle mass (MM) combined with low muscle strength and/or poor physical performance. A new consensus on sarcopenia was published, i.e., the EWGSOP2 criteria, wherein low muscle strength was defined as “probable sarcopenia” with low MM confirming the diagnosis. The new definition does not consider muscle function as a component of sarcopenia diagnosis but rather to classify the severity of the disease. Another difference between the two criteria was the modification of the diagnostic criteria to define both low MM and strength4.

Few studies in older adults applied both criteria to estimate the prevalence of sarcopenia. They found its prevalence to be significantly lower using the EWGSOP2 than the EWGSOP110–15. Because the diagnosis of sarcopenia was reviewed by the EWGSOP24, it is important to assess the impact of this new diagnostic criteria in clinical practice to understand the associated factors and mortality risk of sarcopenia in community-dwelling older adults.

Sarcopenia and its separate components have been associated with adverse health outcomes such as increased mortality risk16–18, diabetes19,20 and reduced weight21 later in life. Its diagnosis is highly relevant, both in research and clinical practice, although the evaluation of muscle mass is one of the major challenges22,23. The muscle mass measurement tools proposed by the EWGSOP1, such as Dual-energy X-ray absorptiometry (DXA), have limited clinical application. Conversely, the EWGSOP2 proposed the use of calf circumference (CC), as an alternate measure5.

The new recommendations of the EWGSOP24 should be used to assess sarcopenia prevalence, its associated factors and mortality risk. They should also be compared with the previous diagnostic criteria. The new criteria changes are likely to result in different findings in the identification of cases in clinical practice and, consequently, in associated factors. Therefore, we aimed to assess the impact of sarcopenia and its parameters on mortality over a 10-year follow-up period in community-dwelling older adults. We also estimated the prevalence of sarcopenia and identified the factors associated with it using two methods for measuring MM and both EWGSOP1 and EWGSOP2 diagnostic criteria.

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Results

The study population consisted of 132 community-dwelling older adults (60.6% women) with a mean age of 70.0 ± 6.3 years. A positive gradient of increasing prevalence of sarcopenia with age was observed for all definitions evaluated. We highlight that the proportion of participants with sedentary physical activity change according to the different methods and definitions used. Older adults with low CC have a higher prevalence of sedentary lifestyle (EWGSOP1: 20%; EWGSOP2: 14%) than those with low skeletal muscle mass index (SMI) (EWGSOP1: 16%; EWGSOP2: 4%) in the definition of both criteria. The prevalence of sarcopenia was higher in underweight older adults ranging from 14.3% (using SMI and EWGSOP2) to 42.4% (using CC and EWGSOP1). Approximately one third (28%) of older adults with diabetes mellitus and more than half with hypertension (56.8%) had sarcopenia (using CC and EWGSOP1) (Table 1).

Prevalence of sarcopenia. Considering EWGSOP1, the prevalence of sarcopenia was 17.4% (CC) and 12.8% (skeletal muscle mass index [SMI]). Considering EWGSOP2, the prevalence was 12.8% (CC) and 6.8% (SMI). The prevalence of "pre-sarcopenia" was 28.3% (EWGSOP1), and the prevalence of "probable sarcopenia" was 34.4% (EWGSOP2).

Factors associated with sarcopenia. Factors associated with sarcopenia according to the EWGSOP1 criteria using CC in the evaluation of low muscle mass were diabetes mellitus (DM) (p < 0.016), low body mass index (BMI) (p < 0.001), high triglycerides (TG's) (< 0.018), and fasting glycemia (p < 0.044). Factors associated with sarcopenia according to the EWGSOP1 criteria using SMI were DM (p < 0.021), low BMI (p < 0.002), and fasting glycemia (p < 0.021). According to the EWGSOP2, the only factor associated with sarcopenia was a low BMI, when using either CC (p < 0.001) or SMI (p < 0.019) for the muscle mass evaluation (Table 1).

Mortality risk: association with sarcopenia and its parameters. The proportion of deaths was significantly higher in older adults with "probable sarcopenia" (p < 0.043). Low muscle mass by CC was observed in 32.6% individuals (Table 2). Low SMI was associated with increased mortality risk, considering the two criteria (EWGSOP1: hazard ratio [HR] = 2.01, 95% confidence interval [CI] 1.03–3.92; EWGSOP2: HR = 2.07, 95% CI 1.05–4.06). Sarcopenia, low CC, and low Handgrip strength (HS) were not associated with mortality (Table 3). There was no multicollinearity between the independent variables (variance inflation factor [VIF] < 10.0) (Table S1). Results of the survival curves according to sarcopenia status by the EWGSOP1 and EWGSOP2 criteria showed no significant differences (Fig. 1).

Discussion

Our findings showed that the use of different diagnostic criteria for sarcopenia and different methods of measuring muscle mass (MM) resulted in variability of estimates of the sarcopenia prevalence and its associated factors in community-dwelling older adults. Overall, the risk factors identified were diabetes, low BMI, serum glycemia alterations, and high triglycerides. We would like to highlight that low SMI indicated a two-fold higher all-cause mortality risk than low calf circumference (CC). The proportion of individuals with obesity in the study sample may account for this finding. Compared with individuals in the lowest tertile, participants in the highest CC tertile had a higher prevalence of higher BMI values (Table S2).

To the best of our knowledge, this is the first study to compare the impact of sarcopenia and low muscle mass in community-dwelling older adults in a 10-year follow-up by applying the two methods of measuring muscle mass (CC and SMI) and the diagnostic criteria of the EWGSOP1 and EWGSOP2.

In this study, the overall prevalence of sarcopenia was 6.8–17.4%. This figure corroborates previous studies that reported a prevalence of 5–13% at 60–70 years of age and 11–50% at ≥ 80 years of age24. A recent meta-analysis reported a prevalence of sarcopenia ranging from 8.6 to 36.5% in community-dwelling older adults35. The variability in prevalence observed in the present study is due to the different diagnostic criteria for sarcopenia and the two methods of measuring muscle mass applied, which is in accordance with some of the previous studies26,27.

We observed that the prevalence of sarcopenia, regardless of the muscle mass measurement method (CC or SMI), was higher applying the EWGSOP1 criteria in relation to the EWGSOP2. Previous studies on the prevalence of sarcopenia comparing the two criteria found similar results to ours12–17. A study using CC observed the prevalence of sarcopenia to be more than double for the EWGSOP1 (8.8%) than the EWGSOP2 (3.4%) criteria38.

The differences in prevalence between EWGSOP1 and EWGSOP2 criteria can be explained by the change in algorithm and cutoff points. According to the new algorithm (EWGSOP2), older adults with reduced muscle mass but with normal strength and function are classified without sarcopenia1. A previous study stated that the use of EWGSOP2 may not be appropriate as a diagnostic tool for sarcopenia in high prevalence settings such as care homes and hospitals29. In the present study, a 0.5 T-score (EWGSOP1: − 2.0 T-scores and EWGSOP2: − 2.5 T-scores) difference in cut-offs resulted in relatively large differences in the prevalence between these individual criteria, which translated to large differences in sarcopenia and "pre-sarcopenia" or "probable sarcopenia" (Table 2).

The choice of tools for diagnosing sarcopenia depends on the characteristics of the individual, access to technical resources, and the main objective, i.e., monitoring the progression, rehabilitation and recovery4,30.

In the present study, a BMI value lower than 25.0 kg/m² was a risk factor associated with sarcopenia considering the two diagnostic criteria and the two methods of measuring muscle mass (CC and SMI). Our results confirm the conclusions of other similar studies31–36. A cohort study with community-dwelling older adults showed that a BMI < 18.5 kg/m² was associated with a higher prevalence of sarcopenia37. A similar association was observed in another study with a BMI < 22 kg/m² with institutionalized individuals38. Being overweight has been associated with improved survival, occasionally called the "obesity paradox"38.
## Prevalence of sarcopenia

| Variables                   | EWGSOP1 | EWGSOP2 |
|-----------------------------|---------|---------|
| **Muscle mass measurement method** |         |         |
| CC                          | SMI     | CC      | SMI     |
| Yes, n (%)                  | p       | Yes, n (%) | p       |
| Men                         | 52 (39.4) | 9 (17.3) | 0.977   | 8 (15.4) | 0.488 | 8 (15.4) | 0.488 |
| Women                       | 80 (60.6) | 14 (17.5) | 0.479   | 7 (13.7) | 0.796 | 9 (17.6) | 0.072 |
| Age groups                  |         |         |         |         |         |         |         |
| 60–69                       | 69 (52.3) | 10 (14.5) | 0.796   | 5 (7.3) | 0.072 | 5 (9.8) | 0.079 |
| 70–79                       | 51 (38.6) | 19 (9.6) | 0.479   | 7 (13.7) | 0.796 | 9 (17.6) | 0.072 |
| 80 and older                | 12 (9.1) | 3 (25.0) | 0.796   | 2 (16.7) | 0.072 | 3 (25.0) | 0.072 |
| **Skin colour**             |         |         |         |         |         |         |         |
| White                       | 68 (51.5) | 10 (14.7) | 0.396   | 11 (17.2) | 0.152 | 9 (14.1) | 0.694 |
| Not white                   | 64 (48.5) | 13 (20.3) | 0.396   | 6 (8.8) | 0.694 | 8 (11.8) | 0.258 |
| **Schooling years**         |         |         |         |         |         |         |         |
| Illiterate                  | 32 (26.2) | 4 (12.5) | 0.717   | 2 (6.3) | 0.493 | 3 (9.4) | 0.675 |
| 1–4 years                   | 45 (36.9) | 9 (20.0) | 0.479   | 8 (17.8) | 0.493 | 6 (13.3) | 0.493 |
| 5–8 years                   | 30 (24.6) | 7 (23.3) | 0.717   | 5 (16.7) | 0.493 | 6 (20.0) | 0.493 |
| 9 years or more             | 15 (12.3) | 3 (20.0) | 0.717   | 2 (13.3) | 0.493 | 3 (20.0) | 0.493 |
| **Socioeconomic class**     |         |         |         |         |         |         |         |
| A/B/C                       | 34 (26.4) | 5 (14.7) | 0.717   | 5 (14.7) | 0.717 | 4 (11.7) | 0.717 |
| D/E                         | 95 (7.6) | 18 (18.9) | 0.717   | 12 (12.6) | 0.717 | 13 (13.7) | 0.717 |
| **Living with a partner**   |         |         |         |         |         |         |         |
| No                          | 76 (57.6) | 11 (14.5) | 0.298   | 10 (13.2) | 0.911 | 10 (13.2) | 0.911 |
| Yes                         | 56 (42.4) | 12 (21.4) | 0.298   | 7 (12.5) | 0.911 | 7 (12.5) | 0.911 |
| **Smoking status**          |         |         |         |         |         |         |         |
| Never                       | 64 (48.5) | 11 (17.2) | 0.135   | 8 (12.5) | 0.585 | 7 (10.9) | 0.179 |
| Current                     | 14 (10.6) | 5 (35.7) | 0.135   | 3 (21.4) | 0.585 | 4 (28.6) | 0.179 |
| Ex-smoker                   | 54 (40.9) | 7 (13.0) | 0.135   | 6 (11.1) | 0.585 | 6 (11.1) | 0.585 |
| **Alcohol consumption**     |         |         |         |         |         |         |         |
| No                          | 103 (78.0) | 19 (18.5) | 0.392   | 14 (13.6) | 0.459 | 14 (13.6) | 0.459 |
| Yes                         | 29 (22.0) | 4 (13.8) | 0.392   | 3 (10.3) | 0.459 | 3 (10.3) | 0.459 |
| **Physical activity**       |         |         |         |         |         |         |         |
| Sedentary                   | 107 (81.1) | 5 (20.0) | 0.706   | 15 (14.0) | 0.419 | 4 (16.0) | 0.605 |
| Active                      | 25 (18.9) | 18 (16.8) | 0.706   | 2 (8.0) | 0.419 | 13 (12.2) | 0.535 |
| **Daily consumption of fruits and vegetables** |         |         |         |         |         |         |         |
| No                          | 79 (59.8) | 13 (16.5) | 0.720   | 8 (15.1) | 0.534 | 8 (15.1) | 0.534 |
| Yes                         | 53 (40.2) | 10 (18.8) | 0.720   | 9 (11.4) | 0.534 | 9 (11.4) | 0.534 |
| **Comorbidities**           |         |         |         |         |         |         |         |
| Diabetes mellitus           | 37 (28.0) | 2 (5.4) | 0.016   | 1 (2.7) | 0.021 | 2 (5.4) | 0.090 |
| Hypertension                | 75 (56.8) | 13 (17.3) | 0.975   | 12 (16.0) | 0.219 | 9 (12.0) | 0.700 |
| **Nutritional status**      |         |         |         |         |         |         |         |
| Low weight**                | 56 (42.4) | 20 (35.7) | <0.001  | 14 (25.0) | <0.001 | 15 (26.8) | <0.001 |
| Overweight                  | 44 (33.3) | 3 (6.8) | <0.001  | 2 (4.5) | <0.001 | 2 (4.5) | <0.001 |
| Cholesterol total, mean (DP)| 201.99 (± 41.12) | 197.17 (± 34.78) | 0.538 | 199.12 (± 34.05) | 0.758 | 195.47 (± 31.11) | 0.486 |
| HDL, mean (DP)              | 45.37 (± 12.36) | 49.39 (± 15.93) | 0.232 | 47.17 (± 16.35) | 0.932 | 47.29 (± 12.88) | 0.461 |
| LDL, mean (DP)              | 124.24 (± 34.87) | 123.13 (± 33.11) | 0.867 | 124.47 (± 28.99) | 0.977 | 122.41 (± 28.55) | 0.817 |
| TG, mean (DP)               | 149.85 (± 62.51) | 137.65 (± 58.49) | 0.018 | 137.65 (± 58.49) | 0.566 | 128.59 (± 57.77) | 0.100 |
| Fasting glucose, mean (DP)  | 107.72 (± 38.48) | 100.87 (± 38.87) | 0.044 | 94.82 (± 28.93) | 0.021 | 105.88 (± 44.28) | 0.302 |
Based on the EWGSOP1 criteria, we found that the risk factors associated with sarcopenia were diabetes and altered serum levels of glycemia and triglycerides. These results confirmed findings from previous studies. Although the association between diabetes and the prevalence of sarcopenia is not fully understood, several mechanisms have been proposed for the acceleration of sarcopenia in older diabetic adults. Insulin resistance is one of the mechanisms involved in the development of sarcopenia. The loss of muscle mass contributes to impaired insulin metabolism, since muscle tissue is a target organ for insulin actions.

### Table 1
Prevalence and factors associated with sarcopenia defined by the EWGSOP1 and EWGSOP2 criteria and two methods of measuring muscle mass (n = 132). EWGSOP European Working Group on Sarcopenia in older people, CC calf circumference, DXA X-ray double absorption bone densitometry, BMI body mass index, HDL high density lipoprotein (mg/dL) (high density lipoprotein), LDL low density lipoproteins (mg/dL) (low density lipoprotein), TG triglycerides (mg/dL), SD standard deviation, SMI skeletal muscle mass index.

| Variables | EWGSOP1 | EWGSOP2 |
|-----------|---------|---------|
| CC        |         |         |
| Normal    | 89 (67.4) | 23 (25.8) | 0.180 |
| Low       | 43 (32.6) | 16 (37.2) |         |
| Pre-sarcopenia |         |         |
| EWGSOP1   | 37 (28.3) | 15 (40.5) | 0.084 |
| EWGSOP2   | 32 (24.2) | 14 (43.8) | 0.043 |
| Probable sarcopenia |         |         |
| EWGSOP1   | 71 (54.2) | 19 (26.7) | 0.538 |
| EWGSOP2   | 45 (34.4) | 11 (24.4) | 0.405 |
| Sarcopenia |         |         |
| EWGSOP1a  | 23 (17.4) | 9 (39.1) | 0.268 |
| EWGSOP1b  | 17 (12.8) | 6 (35.3) | 0.578 |
| EWGSOP2  | 17 (12.8) | 7 (41.2) | 0.260 |
| EWGSOP2b  | 9 (6.8) | 4 (44.4) | 0.254 |

### Table 2
Prevalence of sarcopenia, pre-sarcopenia and probable sarcopenia by the EWGSOP1 and EWGSOP2 criteria, two muscle mass assessment methods (n = 132) and association with all-cause mortality (n = 39). Statistical analysis: Chi-square test. CC calf circumference, EWGSOP European Working Group on Sarcopenia in older people, SD standard deviation. Significant values are in bold.

| Variables | EWGSOP1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|-----------|---------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC        |         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Normal    | 1.47 (0.78–2.80) | 0.235 | 1.45 (0.74–2.85) | 0.278 |
| Low       | 1.81 (1.00–3.47) | 0.035 | 2.01 (1.03–3.92) | 0.041 |
| Sarcopenia |         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CC  | 1.61 (0.76–3.40) | 0.214 | 1.33 (0.58–3.03) | 0.503 |
| SMI | 1.53 (0.64–3.67) | 0.340 | 2.16 (0.86–5.39) | 0.100 |

### Table 3
Crude and adjusted cox regression analysis between the parameters of sarcopenia, by the EWGSOP1 and EWGSOP2 sarcopenia criteria, according to two muscle mass measuring methods and 10-year all-cause mortality risk. Adjusted for: age, sex, smoking, physical activity, and diabetes mellitus. HR hazard ratio, CI confidence interval, CC calf circumference, SMI skeletal muscle mass index, HS handgrip strength, EWGSOP European Working Group on Sarcopenia in older people. Significant values are in bold.

| Variables | EWGSOP1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|-----------|---------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC        |         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Normal    | 1.61 (0.76–3.40) | 0.214 | 1.33 (0.58–3.03) | 0.503 |
| Low       | 1.53 (0.64–3.67) | 0.340 | 2.16 (0.86–5.39) | 0.100 |

Based on the EWGSOP1 criteria, we found that the risk factors associated with sarcopenia were diabetes and altered serum levels of glycemia and triglycerides. These results confirmed findings from previous studies. Although the association between diabetes and the prevalence of sarcopenia is not fully understood, several mechanisms have been proposed for the acceleration of sarcopenia in older diabetic adults. Insulin resistance is one of the mechanisms involved in the development of sarcopenia. The loss of muscle mass contributes to impaired insulin metabolism, since muscle tissue is a target organ for insulin actions.
Previous evidence suggested that reduced skeletal muscle mass increases the risk of developing dyslipidemia\textsuperscript{37,45-47}. The infiltration of cholesterol in muscle tissue, which may be caused by elevated plasmatic triglycerides levels, may contribute to increased oxidative stress on muscles\textsuperscript{48} and, consequently, muscle damage\textsuperscript{49,50}. In this study, low skeletal muscle mass index (SMI) was associated with increased all-cause 10-year mortality risk. Our results are in agreement with a Chinese study in centenarian women in which SMI was a predictor of mortality\textsuperscript{40}. Previous studies have shown that the evaluation of muscle mass alone is not enough to predict mortality\textsuperscript{51,52}, and yet muscle strength is a better predictor of adverse outcomes such as mortality, than muscle mass\textsuperscript{53-55}. However, in the present study, muscle strength, i.e., handgrip strength was not associated with an increased mortality risk. However, low SMI showed a two-fold increase in mortality risk over the 10-year follow-up period in community-dwelling older adults. Our finding that low HS in the absence of low SMI did not increase the risk of all-cause mortality may cause controversy when compared with previous studies. The mechanisms that explain the association of low muscle strength with increased risk of mortality in community-dwelling older adults are not well understood\textsuperscript{56}. Studies are needed to verify whether the association between low muscle strength and mortality is direct or whether muscle strength is a marker of other factors underlying mortality\textsuperscript{57}. Results from previous studies are similar to ours, in which they showed that initial grip strength was not associated with mortality\textsuperscript{56,57}. This study presents baseline muscle strength results; therefore, it is believed that for this reason muscle strength was not associated with mortality\textsuperscript{56,57}. A clinical trial study with a senescent population of mice showed that loss of muscle quality preceded loss of absolute function because of maintaining larger and poorer quality muscles, which increases the metabolic demand to maintain larger muscles, and exacerbation of catabolism age-related muscle growth in older muscles if the metabolic energy needs of skeletal muscles are not met\textsuperscript{58}.

Although this study showed a decreased survival rate in sarcopenic participants after a long-term follow-up, this finding was not significant. Previous studies presented divergent results in relation to a lower probability of survival in sarcopenic patients\textsuperscript{18,25,59}. These conflicting findings can be explained by the age of participants, older individuals than in our study, shorter follow-up times, use of different muscle mass measurement methods such as bioelectrical impedance analysis (BIA) and the use of cutoff points for diagnosis of low muscle mass (CC < 31 cm) different from our study. A longitudinal study with methodological characteristics similar to ours regarding its sample size, age and use of DXA to measure muscle mass, observed similar results as those in the present study, i.e., sarcopenia was not associated with mortality in older women\textsuperscript{59}.

As a potential limitation of this study, we could mention small number of participants since the DXA test was performed in a sub-sample of the study population. However, some strengths of this analysis were its long follow-up period allowing us to assess the impact of sarcopenia parameters on mortality risk, the inclusion of...

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**Figure 1.** Survival curves according to sarcopenia status according to EWGSOP1 (A,B) and EWGSOP2 (C,D) criteria. *EWGSOP* European Working Group on Sarcopenia in Older People. (A) EWGSOP1\textsuperscript{a}: Low Calf circumference + Low Handgrip strength. (B) EWGSOP1\textsuperscript{b}: Low Skeletal muscle mass index + Low Handgrip strength. (C) EWGSOP2\textsuperscript{c}: Low Handgrip strength + Low Calf circumference. (D) EWGSOP2\textsuperscript{d}: Low Handgrip strength + Low Skeletal muscle mass index.
community-dwelling older adults with a wide age range (60–98 years), and the use of two methods to assess muscle mass, i.e., the DXA and CC that has applicability in clinical practice.

Future research should focus on exploring the mechanisms underlying the association between low muscle mass and mortality risk. The use of muscle mass assessment either by DXA or a more accessible technique such as CC is suggested in routine clinical practice, to reduce the occurrence of sarcopenia and to develop preventive intervention. Older adults with low BMI, elevated blood glucose and triglyceride levels should be under greater surveillance with enrollment in intervention programs to preserve muscle mass. Muscle mass reduction should be considered as one of the potential triggers of geriatric syndromes such as sarcopenia and mortality.

In summary, this study showed that the estimation of the prevalence of sarcopenia, associated factors and its impact on mortality risk depends on the criteria adopted and method of measuring muscle mass. The prevalence of sarcopenia was higher using the EWGSOP1 criteria than the EWGSOP2 one and when using CC instead of SMI. Low BMI was a risk factor for sarcopenia regardless of the definitions used. Using the EWGSOP1 criteria, we found that the presence of diabetes and changes in serum glycemia and triglyceride levels were also associated with the development of sarcopenia. Low SMI doubled the all-cause mortality risk in the 10-year follow-up in community-dwelling older adults. However, low muscle strength and low CC did not impact on mortality risk.

Methods
Study population. The Goiânia Ageing Project is a prospective cohort involving 418 community-dwelling older adults living in Goiania city, Midwestern Brazil, which started in 2008. In the first wave of the cohort (2009) biochemical tests and body composition assessments were performed on 132 older adults. The sample selection was probabilistic and stratified according to the health regions linked to the health districts used in the organization and management of the Brazilian Unified Health System (SUS) of the municipality. This analysis included only those who participated in 2009. The ethical review committee at the Medical School, Federal University of Goiás, Goiania, Brazil (2,500,044/2018) approved this study. All participants provided an informed written consent. This study was conducted in accordance with the declaration of Helsinki.

Data collection procedures. Data collection was conducted in a specialized diagnostic imaging clinic for DXA analysis and blood collection. The inclusion criteria to perform these tests were fasting for at least 4 h, no alcohol or caffeine consumption in the last 24 h, no physical activity performed in the last 12 h, emptying the bladder 30 min before the data collection, and no use of diuretics in the last 24 h. The blood samples were collected after 12-h fasting.

Muscle mass (MM) assessment. MM was assessed through DXA (software version 7.52.002, GE-Lunar DPX-MD PLUS) and calf circumference (CC). Using the arms and legs MM estimated by DXA, skeletal muscle mass index (SMI) was calculated as follows: appendicular skeletal muscle mass of the arms + appendicular skeletal muscle mass of the legs/height. A low MM was defined according to EWGSOP1 as SMI ≤ 7.26 kg/m² for men and ≤ 5.5 kg/m² for women and by EWGSOP2 as SMI ≤ 7.0 kg/m² for men and ≤ 5.5 kg/m² for women.

CC was measured on the left leg with an inelastic tape measure (CESCORF), in its most protruding part, with the participant in an upright position. The anthropometric evaluation was performed by qualified nutritionists according to the Habicht’s technique. A CC of < 34 cm for men and < 33 cm for women were used as indicators of low MM, and these cutoff points were previously validated in the present study sample.

Muscle strength assessment. Handgrip strength (HS) was measured using a manual hydraulic dynamometer (JAMAR). The test was performed with the individual sitting on a chair, upright vertical back without arm support, elbow flexed at 90° and forearm in a neutral position. Three HS measurements for the dominant hand were obtained and the highest value was used. According to the EWGSOP1, a HS < 30 kg for men and < 20 kg for women, and the EWGSOP2, a HS < 27 kg for men and < 16 kg for women, were indicative of low muscle strength.

Sarcopenia assessment. Considering the criteria of the EWGSOP1, the EWGSOP2, and the evaluation of muscle mass by SMI and CC, sarcopenia was defined as: (1) EWGSOP1 A: Low CC + Low HS; (2) EWGSOP1 B: Low SMI + Low HS; (3) EWGSOP2 A: Low HS + Low CC; and (4) EWGSOP2 B: Low HS + Low SMI.

Mortality ascertainment. All-cause mortality registers in the last 10 years (July 2009 to March 2019) were obtained through the Brazilian Mortality Information System (SIM) for the Municipal Health Secretariat (SMS).

Sociodemographic characteristics, lifestyle and health conditions. The following covariates were included: sociodemographic (age, gender, ethnicity, level of education, socioeconomic class, living with a partner), lifestyle (smoking status, of alcohol consumption, physical activity level, daily consumption of fruits and vegetables), comorbidities (diabetes [DM] and hypertension), BMI (weight in kg/height in m²) categorized according to the World Health Organization cutoff points, and biochemical tests (total cholesterol, HDL-cholesterol, LDL-cholesterol, triglycerides [TG], and fasting glycemia in mg/dL).

DM was diagnosed when the fasting glycemia level was ≥ 126 mg/dL and/or when hypoglycemic drugs were used. Hypertension was diagnosed when the systolic pressure ≥ 140 mm Hg and the diastolic pressure ≥ 90 mm Hg and/or when hypotensive drugs were used.
Statistical analysis. The prevalence of sarcopenia and its associated factors were estimated according to the four definitions of sarcopenia used in this study. Their association with sociodemographic variables, lifestyle, and health conditions including biochemical tests were assessed.

To analyze the factors associated with the prevalence of sarcopenia we used independent t tests for continuous variables with a normal distribution, and the Mann–Whitney U test for continuous data with an abnormal distribution; and Pearson chi-square test or Fisher exact test (with the expected cell count of < 5) for categorical variables. The association analysis between sarcopenia, pre-sarcopenia and probable sarcopenia with all-cause mortality was performed using the chi-square test.

Unadjusted and fully adjusted Cox regression analyses were performed to estimate the association between low muscle mass (CC and SMI), low hand grip strength, sarcopenia, and 10-year mortality risk. Age, gender, smoking status, physical activity, and DM were included as covariates.

Kaplan–Meier survival curves were plotted, and the comparison between the groups with and without sarcopenia was performed using the log-rank test. For all tests, a 5% significance level was considered. Statistical analyses were performed using the Stata/SE version 12.0.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions
The authors’ contributions are as follows: conceptual idea of E.A.S.; E.A.S. and V.P. conducted the research; E.A.S., V.P., C.C.P. and C.O. analyzed the data, interpreted the results and wrote the article. All authors read and approved the final work.

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Competing interests
The authors declare no competing interests.

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