ORIGINAL ARTICLE

JCSM Clinical Reports 2020; **5**: 89–98
Published online 3 July 2020 in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/crt2.22

Definition-specific prevalence estimates for sarcopenia in an Australian population: the Geelong Osteoporosis Study

Sophia X. Sui[1]*, Kara L. Holloway-Kew[1], Natalie K. Hyde[1], Lana J. Williams[1], Monica C. Tembo[1], Sarah Leach[2] & Julie A. Pasco[1,3,4,5]

[1]*Deakin University, Geelong, Victoria, Australia,* [2]*GMHBA, Geelong, Victoria, Australia,* [3]*Department of Medicine—Western Campus, The University of Melbourne, St Albans, Victoria, Australia,* [4]*Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Victoria, Australia,* [5]*University Hospital Geelong, Geelong, Victoria, Australia*

Abstract

Background We aimed to compare prevalence estimates for sarcopenia in an Australian sample of older men and women by using different criteria.

Methods Women (n = 323) and men (n = 342) aged 60–96 years from the Geelong Osteoporosis Study were included. Handgrip strength (HGS) was measured by dynamometer (Jamar or Vernier) and appendicular lean mass (ALM) by whole-body densitometry (Lunar). Sarcopenia definitions included European Working Group on Sarcopenia in Older People (EWGSOP) 1, EWGSOP2, and US Foundation for the National Institutes of Health (FNIH). Sarcopenia was identified as low HGS and low ALM/height^2 or low muscle performance, and low HGS and low ALM/body mass index (BMI). Prevalence estimates were standardized to the Australian population and agreement between definitions assessed using the Cohen kappa statistic (κ).

Results Low HGS was identified in 13.7–29.9% of women and 2.1–14.1% of men. Low ALM/height^2 was identified in 7.1–11.8% of women and 6.0–8.4% of men, while 21.7% of women and 21.1% of men had low ALM/BMI. Mean age-standardized prevalence estimates for sarcopenia were 5.9% (95% confidence interval 3.4–8.4) for women and 2.9% (1.9–4.0) for men (EWGSOP1), 2.3% (1.1–3.4) for women and 0.5% (0.2–0.9) for men (EWGSOP2), and 4.0% (2.1–5.8) for women and 1.1% (0.6–1.5) for men (FNIH). There was moderate agreement between EWGSOP1 and EWGSOP2 (κ = 0.58 women, 0.30 men) and poor agreement between FNIH and EWGSOP1 (κ = 0.16 women, 0.12 men) and EWGSOP2 (κ = 0.19 women, 0 men).

Conclusions Sarcopenia prevalence differed according to definition applied. Point estimates for sarcopenia prevalence according to EWGSOP2 identified fewer individuals than EWGSOP1, with FNIH estimates between the two; however, there were overlapping 95% confidence intervals across definitions.

Keywords Sarcopenia definitions; Sarcopenia prevalence; Muscle mass; Muscle strength; Muscle function; Aged

Received: 21 December 2019; Revised: 28 May 2020; Accepted: 31 May 2020
**Correspondence to: Sophia X. Sui, Epi-Centre for Healthy Ageing, IMPACT Strategic Research Centre, School of Medicine, Deakin University, PO Box 281 (Barwon Health), Geelong, Victoria 3220, Australia. Tel: +61 3 42153306, Fax +61 3 42153491, Email:* ssui@deakin.edu.au

Introduction

Sarcopenia is characterized as age-related low muscle mass in conjunction with muscle weakness or poor physical performance[1–4] and is associated with disability, functional impairment, frailty, and mortality in elderly populations.[5,6] The prevalence estimates of sarcopenia vary across studies to date, arguably owing to differences in population demographic characteristics in different geographic areas[7,8] but also as a consequence of using different criteria for identifying cases. There is currently no universally recognized definition of sarcopenia, and reports reveal that with the

application of different definitions to the same population, prevalence estimates vary by up to 40%.[2,7,9–13]

Baumgartner *et al.*[14] initially defined sarcopenia as age-associated loss of muscle mass. Subsequently, the importance of muscle strength and performance in association with health outcomes in the elderly led to a change in the definition for sarcopenia to consider low muscle mass in combination with either low grip strength or low gait speed.[1,3,4,7,15,16] There is further confusion regarding inconsistencies in the thresholds applied to identify low muscle mass, muscle strength, and muscle function.

Two of the most widely employed definitions for sarcopenia are those from the European Working Group on Sarcopenia in Older People (EWGSOP) [3] and the US Foundation for the National Institutes of Health (FNIH).[4] EWGSOP definition released in 2010 (EWGSOP1) suggested a conceptual stage as pre-sarcopenia (low muscle mass only), sarcopenia (low muscle mass and muscle strength or muscle performance), and severe sarcopenia (low muscle mass muscle strength and performance).[3] In 2019, EWGSOP1 was updated to EWGSOP2, with muscle strength replacing muscle mass as the primary muscle indicator for probable sarcopenia.[15] In EWGSOP2, confirmed sarcopenia is determined by low muscle mass and muscle strength, and severe sarcopenia as the presence of low muscle strength, muscle mass, and muscle performance.[4,15,17] In contrast, the aim of developing the FNIH definition was to assist clinicians in making a differential diagnosis of people who have low physical function due to sarcopenia (low muscle mass and strength) and those with low physical function due to other causes.[4,17,18] The FNIH definition used mobility impairment measured using gait speed as their primary outcome in the analyses determining what the clinically relevant cut-off points of grip strength should be. Therefore, with the use of the FNIH definition, sarcopenia can be identified as low muscle mass with low grip strength and 'slowness with weakness and low lean mass' can also be identified, which represents the concept of severe sarcopenia in the EWGSOP definitions, although is not labelled as such by the FNIH.[17] However, the suggested cut-off points across these definitions differ.

A large variance in sarcopenia prevalence is expected if multiple definitions are used with diverse samples.[7] However, little is known whether the variance would be reduced when multiple definitions are applied for one sample of individuals. There are papers that have already compared with the two EWGSOP definitions[19,13] and ones that have compared between the original EWGSOP definitions with the FNIH definition.[2] These papers have also compared agreement between the definitions. To our knowledge, no studies have compared the prevalence estimates of sarcopenia in Australia using definitions from the EWGSOP1, EWGSOP2, and FNIH. Thus, we aimed to determine the prevalence and the degree of agreement in a sample of older men and women from a population-based sample in Australia.

Materials and methods

Study design

In this study, we only included people aged ≥60 (ages 60–96 years). This cross-sectional analysis involved data at the 15 year follow-up phases collected from 2010 to 2014 for women and from 2016 to 2019 for men participating in the Geelong Osteoporosis Study, a population-based, prospective cohort study in Australia. Detailed information about the Geelong Osteoporosis Study is published elsewhere.[20] Briefly, age-stratified samples of women and men were selected at random using the electoral roll as the sampling frame. In total, 1494 women were recruited 1993–1997 (ages 20–93 years, 77% participation), and 1467 men were recruited 2001–2006 (ages 20–96 years, 67% participation) and assessed at subsequent follow-up phases. Data for identifying sarcopenia were obtained from 323 women and 342 men aged ≥ 60 years who were thus eligible for these analyses. The cohorts are essentially Caucasian (99%). The study was approved by the Barwon Health Human Research Ethics Committee. Written informed consent was obtained from all participants.

Measures

Weight and height were measured to the nearest ±0.1 kg and ±0.001, m and body mass index (BMI) was calculated as weight/height^2 (kilograms per square metre). BMI was calculated as weight/height^2, and BMI ≥ 30.0 kg/m^2 was recognized as obesity.[21] Lean mass (kilogram), a proxy measure for muscle mass, was obtained from whole-body dual-energy X-ray absorptiometry (Lunar Prodigy-Pro, Madison, WI, USA), which provided lean mass measures for appendicular lean mass (ALM), equivalent to the sum of lean mass for the arms and legs. ALM was expressed relative to height as ALM/height^2 (kilograms per square metre) or BMI as ALM/BMI (square metre). Handgrip strength (HGS, kilogram) was measured using an analogue hand-held dynamometer (Jamar, Sammons Preston, Bolingbrook, IL, UK) for women and an electronic hand-held dynamometer for men (Vernier, LoggerPro3). Trained researchers explained and demonstrated the testing procedure to each participant before measurement trials. With the participant seated in a comfortable position and the arm holding the dynamometer flexed at the elbow to 90°, the participant was asked to squeeze the device as hard as possible for several seconds, and the peak reading was recorded. For women, this procedure was duplicated for each hand, and there was no time interval between trials. For men, the protocol was similar, except they squeezed the device using each hand three times at their maximum for 3 s with a 5 s interval between trials. HGS values measured with the Vernier device were transformed to Jamar equivalent values according to the following equation: HGS_{Jamar}

(kg) = 9.50 + 0.818 * $HGS_{Vernier}$ (kg) + 8.80 * Sex, where sex = 1 for men, which was developed by measuring maximum HGS on each device for 45 men and women aged 21–67 years. The maximum value was used for analysis. Usual gait speed (waking at normal speed) with shoes was determined by measuring how many seconds the participant took to walk a distance of 4 m and recorded as walking speed (metre per second). Timed up-and-go (TUG), a test of mobility that involves static and dynamic balance,[22] involved measuring the time (seconds) taken by the participant to stand up from a chair (without arm rests), walk to a marked line (3 m distance), turn around, and then return to the chair and sit down. Tests were performed by women and men, except for gait speed, which was measured for men only. The Charlson co-morbidity index (CCI)[23,24] was calculated for 312 women and 342 men to indicate their disease burden. Scores were categorized into two groups: 0 = zero to one co-morbid condition and 1 = two or more co-morbid conditions.

Sarcopenia definitions

Table 1 details the sarcopenia criteria from the EWGSOP (1, 2) and FNIH. Low ALM/height^2 (EWGSOP1), low HGS (EWGSOP2), or slow gait speed (FNIH) are the primary indicators for sarcopenia.[3,4,16,25] The presence of a single criterion defined pre-sarcopenia (EWGSOP1),[3] probable sarcopenia (EWGSOP2),[16] or slowness (FNIH).[18,25] Sarcopenia was deemed present if an individual had both low HGS and low ALM/height^2 or slow TUG/gait speed, or low HGS and low ALM/BMI (FNIH).[3,4,16,25] The criteria were presented as (i) low HGS + low ALM/height^2 for EWGSOP1 or EWGSOP2 or (ii) low HGS + slow TUG/gait speed for EWGSOP1, and (iii) low HGS + low ALM/BMI for FNIH. EWGSOP suggests using ALM adjusted for height^2, while FNIH recommends using ALM adjusted for BMI. Severe sarcopenia was determined if the participant had low HGS, low ALM/height^2, and slow gait speed (EWGSOP1, 2) or low HGS, low ALM/BMI, and slow gait speed (FNIH).[3,4,16,25]

TUG was used as a proxy for gait speed in women and men for EWGSOP1 (an approach adopted from Sim *et al*. 2019[2]) because gait speed was not measured in our sample of women at this follow-up phase.[2,26] The cut-off point for slow TUG was >8.30 s for both men and women on the basis of the criteria of EWGSOP1.[2,26] This threshold was obtained by applying the numbers at two standard deviations (SDs) below the young reference range (aged 20–39 years) for women. We applied the same cut-offs for TUG in both sexes.

Statistical analysis

Data normality was checked using histograms. Normalized data were presented as means and SDs and skewed data as medians and inter-quartile ranges. Descriptive analyses were performed for prevalence (*n*, %) of sarcopenia parameters and sarcopenia. The age-standardized prevalence estimates [mean and 95% confidence interval (CI)] were calculated according to the 2011 census data for Australia from the Australian Bureau of Statistics.[27] The kappa coefficient (κ) was used to measure the level of agreement between the sarcopenia definitions: poor ($\kappa < 0.40$), medium ($\kappa = 0.40$–0.75), and high ($\kappa > 0.75$). χ^2 tests and multivariable logistic regression models were used to identify sex differences in the numbers of participants identified with sarcopenia, before and after accounting for differences in age. Analyses were performed using IBM SPSS Version 24 and Minitab (v18, USA).

Results

Table 1 presents details for each definition of sarcopenia (EWGSOP1, EWGSOP2, and FNIH) and the proportion (*n*, %) of low sarcopenia (muscle) parameters in women and men. *Table* 2 presents participant characteristics.

Low lean mass (n, %)

Low lean mass was identified in 7.1–12.7% of women and 8.2–21.1% of men. More men and women with low lean mass were identified using FNIH criteria, compared with criteria for EWGSOP1 and EWGSOP2. It was observed that a small difference in cut-off point resulted in a large difference in prevalence estimate. For example, the cut-off points for ALM/height^2 (EWGSOP1 and EWGSOP2) were <5.67 and <5.50 kg/m^2 in women, and despite this small difference (0.17 kg), the proportion varied from 11.8% to 7.1%. Similarly, the difference of cut-off points in men was 0.23 kg (EWGSOP1 7.23 kg/m^2 and EWGSOP2 7.0 kg/m^2), and the corresponding proportions were 12.3% and 8.2% (*Table* 1).

Low handgrip strength (n, %)

In *Table* 1, participants with low HGS ranged from 13.7% to 29.9% for women and 2.1% to 14.1% for men. Owing to the difference (3 kg for men and 4 kg for women) in low HGS thresholds between EWGSOP1 and EWGSOP2, the prevalence estimates varied from 13.7% to 29.9% for women and 2.9% to 14.1% for men. EWGSOP2 revised the cut-off point for HGS from 20 to 16 kg for women, consistent with FNIH.[4,15,28] The low HGS proportions in women were the same for EWGSOP2 and FNIH. There was a 1 kg difference between EWGSOP2 and FNIH in cut-off point in men, which resulted in the proportion varying between 2.1% and 2.9%. The proportion of low HGS was lower for men than for women across all the definitions.

DOI: 10.1002/crt2.22

Table 1 Sarcopenia definitions and the proportions of sarcopenia indicators

Muscle parameters	Techniques	Diagnostic criteria	Cut-off point		Reference	Proportions *n* (%)	
			Men	Women		Women *n* = 323	Men *n* = 342
EWGSOP1							
ALM/height^2 Cruz-Jentoft 2010[3]	DXA	Lowest 20%	<7.23 kg/m^2	<5.67 kg/m^2	Newman 2003[34]	38 (11.8)	42 (12.3)
HGS Cruz-Jentoft 2010[3]	Hand-held dynamometer	Below optimal cut point	<30 kg	<20 kg	Lauretani 2003[35]	107 (29.9)	48 (14.1)
Gait speed Sim 2019[2]	TUG	2 SDs below the young reference (aged 20-39 years)	>8.30 s	>8.30 s	Bischoff 2003[26]	226 (68.9)	231 (67.9)
	4 m walking test (men only)	Based on statistical analysis of study group	<0.8 m/s	<0.8 m/s	Lauretani 2013[35] Cruz-Jentoft 2010[3]	—	102 (30.4)
EWGSOP2							
HGS Cruz-Jentoft 2019[15]	Depending on the multiple studies descriptions	2.5 SDs below the gender-specific peak mean (31 kg at age 2642 years)	<27 kg	<16 kg	Dodds 2014[28]	49 (13.7)	10 (2.9)
ALM/height^2 Cruz-Jentoft 2019[15]	DXA	2 SDs below the young reference (20–39 years)	<7.0 kg/m^2	<5.5 kg/m^2	Gould 2014[36]	23 (7.1)	28 (8.2)
Gait speed Cruz-Jentoft 2019[15]	TUG	Chosen between the performance of community-dwelling and institutionalised elderly	≥20 s	≥20 s	Bischoff 2003[26]	9 (2.7)	10 (2.9)
	4 m walking test (men only)	Based on statistical analysis of study group	GS < 0.8 m/s	GS < 0.8 m/s	Lauretani 2013[35] Cruz-Jentoft 2010[3]	—	102 (30.4)
FNIH							
HGS Alley[18] 2014 Breiman 1984[37]	Hand-held dynamometer	Regression analysis (CART analysis)	<26 kg	<16 kg	Studenski[4] 2014	49 (13.7)	7 (2.1)
ALM/BMI Studenski 2014[4] Breiman 1984[37]	DXA	Regression analysis (CART analysis)	<0.789 m^2	<0.512 m^2	Cawthon 2014[25]	70 (21.7)	72 (21.1)
Gait speed	4 m walking test (men)	Not given	≤0.8 m/s	≤0.8 m/s	Dam 2014[17]	—	110 (32.8)

—, no data/information available. Missing data: TUG *n* = 3 women, *n* = 2 men; HGS *n* = 1 men; gait speed *n* = 325 women, *n* = 7 men.
ALM, appendicular lean mass; ALM/BMI, appendicular lean mass/body mass index; ALM/ht^2, appendicular lean mass/height^2; DXA, whole-body dual-energy X-ray absorptiometry; EWGSOP1,2, European Working Group on Sarcopenia in Older People; FNIH, United States Foundation for the National Institutes of Health; GS, gait speed; HGS, handgrip strength; TUG, timed up-and-go test.

Table 2 Participant characteristics

	Women (n = 323)	Men (n = 342)
Age (year)	70 (64–75)	70 (66–78)
Weight (kg)	73.9 (±15.4)	83.9 (±13.8)
Height (m)	1.59 (±0.06)	1.73 (±0.07)
BMI (kg/m^2)	29 (±6)	28 (±4)
Obese n (%)	133 (41.2%)	96 (28.1%)
HGS (kg)	23 (±6)	37 (±6)
ALM/height^2 (kg/m^2)	6.59 (±0.79)	8.25 (±0.93)
ALM/BMI (m^2)	0.59 (±0.10)	0.89 (±0.12)
TUG (s)	9.1 (7.9–10.8)	9.2 (8.0–10.7)
Gait speed (m/s)	—	0.9 (±0.2)
Co-morbid conditions (CCI ≥ 2) n (%)	57 (18.3%)	100 (29.2%)

Data are expressed as mean (±SD) or median (IQR) and n (%). Missing data: TUG n = 3 women, n = 2 men; CCI n = 11 women; HGS n = 1 men; gait speed n = 323 women, n = 7 men.
ALM, appendicular lean mass; ALM/BMI, appendicular lean mass/body mass index; ALM/ht^2, appendicular lean mass/height^2; CCI, Charlson co-morbidity index; HGS, handgrip strength; TUG, timed up-and-go test.

Low timed up-and-go or walking speed (n, %)

In *Table* 1, participants with poor physical performance, evaluated by TUG, ranged from 2.7% (EWGSOP2) to 68.9% (EWGSOP1) for women and ranged from 2.9% (EWGSOP2) to 67.9% (EWGSOP1) for men and from 30.4% to 32.8% for men assessed by gait speed.

Prevalence of sarcopenia

Table 3 shows that the proportion (n, %) of any level of sarcopenia using the three definitions ranged from 0.3% to 13.7% for women and 0.6% to 32.8% for men. Proportions defined by single muscle parameters were higher than those defined by multiple muscle parameters. Participants identified by a single sarcopenia criterion ranged from 11.8% to 13.7% for women and 2.9% to 32.8% for men; sarcopenia identified by two criteria ranged from 2.5% to 10.3% for women and 0.6% to 10.3% for men; and severe sarcopenia identified by three criteria from 0.3% to 5.6% for women (FNIH was not calculated as there were no reference cut-off points for TUG) and 0.6% to 2.7% for men. Compared with EWGSOP1 using ALM/height^2 as the first indicator for pre-sarcopenia, EWGSOP2 uses HGS as the primary muscle indicator. Consequently, the proportion of pre-sarcopenia was similar from 11.8% (EWGSOP1) to 13.7% (EWGSOP2) in women but varied in men from 12.3% (EWGSOP1) to 2.9% (EWGSOP 2). EWGSOP2 identified the smallest proportion of sarcopenia in comparison with EWGSOP1 and FNIH for both women and men for all three levels of sarcopenia.

Table 3 and *Figure* 1 show the prevalence estimates for sarcopenia (age standardized) for each level of sarcopenia. Depending on the definition used, the prevalence of all levels of sarcopenia in the Australian population was low with 0.2–13.4% in women and 0.5–36.7% in men.

Sarcopenia and age

To explore the relationships between age and the prevalence of sarcopenia using the different definitions, the prevalence of sarcopenia was stratified by age decades (*Figure* 2). The prevalence of sarcopenia was higher in older age groups for each definition. However, the results were not consistent across all definitions. Additionally, analyses were not possible for some definitions owing to low numbers of participants identified with sarcopenia.

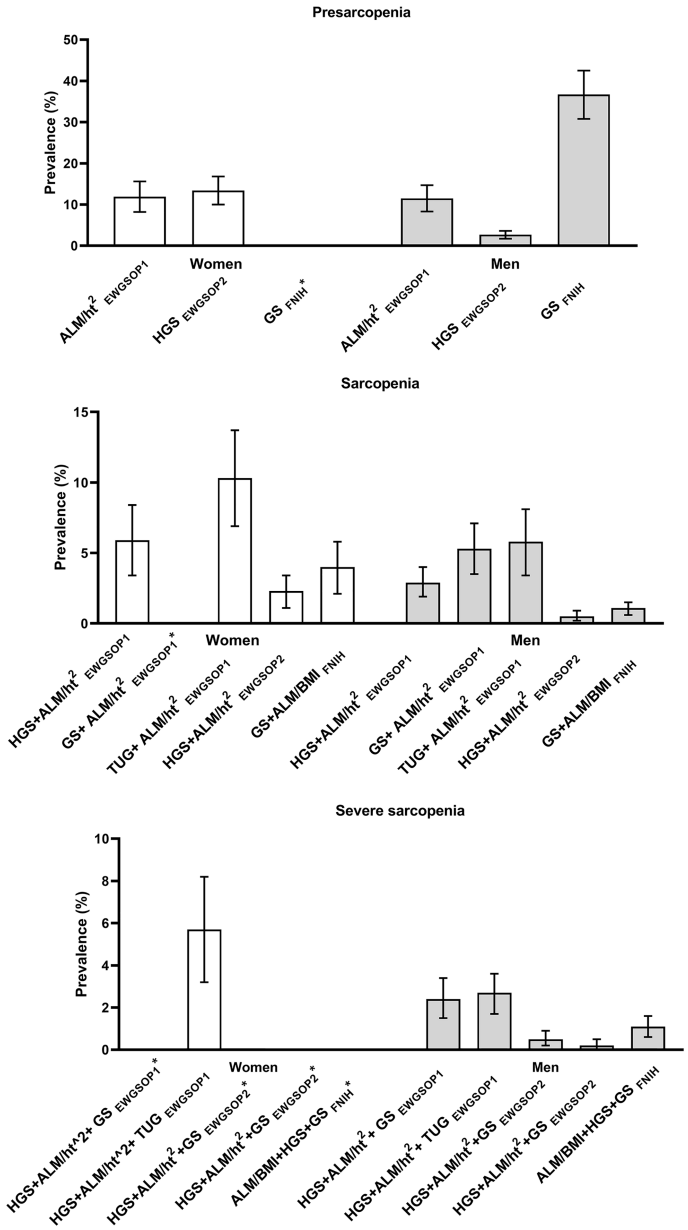
Table 3 Definition-specific propositions of sarcopenia and the age-standardized estimated prevalence rate

	Criteria	Proportion n (%)		Prevalence (mean% and CI)	
		Women	Men	Women	Men
EWGSOP1					
Pre-sarcopenia	ALM/ht^2	38 (11.8)	42 (12.3)	11.9 (8.2–15.6)	11.5 (8.3–14.7)
Sarcopenia	HGS + ALM/ht^2	19 (5.9)	11 (3.2)	5.9 (3.4–8.4)	2.9 (1.9–4.0)
	GS + ALM/ht^2	—	20 (6.0)	—	5.3 (3.5–7.1)
	TUG + ALM/ht^2	33 (10.3)	35 (10.3)	10.3 (6.9–13.7)	5.8 (3.4–8.1)
Severe sarcopenia	HGS + ALM/ht^2 + GS	—	9 (2.7)	—	2.4 (1.5–3.4)
	HGS + ALM/ht^2 + TUG	18 (5.6)	10 (2.9)	5.7 (3.2–8.2)	2.7 (1.7–3.6)
EWGSOP2					
Probable sarcopenia	HGS	49 (13.7)	10 (2.9)	13.4 (10–16.8)	2.7 (1.7–3.6)
Confirmed sarcopenia	HGS + ALM/ht^2	8 (2.5)	2 (0.6)	2.3 (1.1–3.4)	0.5 (0.2–0.9)
Severe sarcopenia	HGS + ALM/ht^2 + GS	—	2 (0.6)	—	0.5 (0.2–0.9)
	HGS + ALM/ht^2 + TUG	1 (0.3)	0	0.2 (0–0.5)	0
FNIH					
Slowness	GS	—	110 (32.8)	—	36.7 (30.8–42.5)
Weakness and low lean mass	HGS + ALM/BMI	11 (3.4)	4 (1.2)	4.0 (2.1–5.8)	1.1 (0.6–1.5)
Slowness with weakness and low lean mass	GS + HGS + ALM/BMI	—	4 (1.2)	—	1.1 (0.6–1.6)

ALM, appendicular lean mass; ALM/BMI, appendicular lean mass/body mass index; ALM/height^2, appendicular lean mass/height^2; EWGSOP1, using EWGSOP1 criteria and their recommended cut-off points; EWGSOP2, using EWGSOP2 criteria and its recommended cut-off points; FNIH, using FNIH criteria and their recommended cut-off points; GS, gait speed; HGS, handgrip strength; TUG: timed up-and-go test.

DOI: 10.1002/crt2.22

Figure 1 Levels of sarcopenia estimates for women and men. EWGSOP1, using European Working Group on Sarcopenia in Older People 1 criteria and their recommended cut-off points; EWGSOP2, using EWGSOP2 criteria and its recommended cut-off points; FNIH, using US Foundation for the National Institutes of Health criteria and their recommended cut-off points; ALM, appendicular lean mass; GS, gait speed; HGS, handgrip strength; ALM/ht^2, appendicular lean mass/height^2; ALM/BMI, appendicular lean mass/body mass index; TUG, timed up-and-go (TUG) test. Error bars are 95% confidence interval.

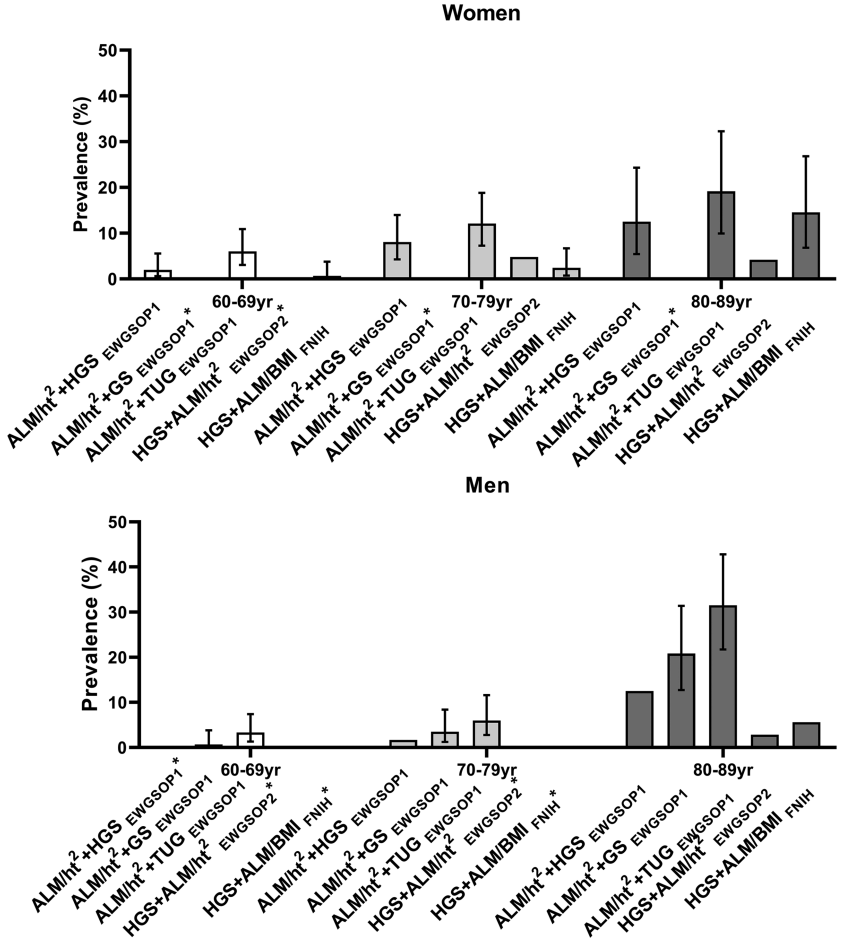


Sarcopenia and sex

We pooled data for women and men to statistically assess sex differences for the definition of EWGSOP1, EWGSOP2 (both HGS + ALM/height^2), and FNIH (HGS + ALM/BMI). Sarcopenia was more common in women than in men across all definitions [EWGSOP1: women 19 (5.9%) vs. men 11 (3.2%); $x^2(1) = 2.72$, $P = 0.10$; EWGSOP2: 8 (2.5%) vs. 2 (0.6%); $x^2(1) = 4.00$, $P = 0.05$; and FNIH 11 (3.4%) vs. 4 (1.2%); $x^2(1) = 3.75$, $P = 0.05$]. After age was adjusted, the sex differences were sustained across all definitions (EWGSOP1 OR 2.14, 95% CI 1.00–4.61, $P = 0.05$; EWGSOP2 OR 1.03, 95% CI 1.01–1.05, $P = 0.007$; and FNIH OR 1.03, 95% CI 1.01–1.05, $P = 0.005$).

DOI: 10.1002/crt2.22

Figure 2 Prevalence of sarcopenia for women and men by age group. EWGSOP1, using European Working Group on Sarcopenia in Older People 1 criteria and their recommended cut-off points; EWGSOP2, using EWGSOP2 criteria and its recommended cut-off points; FNIH, using US Foundation for the National Institutes of Health criteria and their recommended cut-off points; ALM, appendicular lean mass; GS, gait speed; HGS, handgrip strength; ALM/ht^2, appendicular lean mass/height^2; ALM/BMI, appendicular lean mass/body mass index. TUG, timed up-and-go (TUG) test. Error bars are 95% confidence interval.



Sarcopenia and co-morbidity

With the use of EWGSOP1, EWGSOP2, and FNIH criteria, 7/18 (38.9%), 3/8 (37.5%), and 2/10 (20.0%) of women with sarcopenia had two or more co-morbid conditions. For men, the numbers were 5/11 (45.5%) for EWGSOP1, 1/2 (50.0%) for EWGSOP2, and 0/4 (0.0%) for FNIH. For those with sarcopenia and a CCI $\geq$ 2, the most common co-morbid conditions were tumours [(33/57 (57.9%) for women and 77/100 (77.0%) for men] and diabetes [16/57 (28.1%) for women and 24/100 for men].

Sarcopenia and obesity

With the use of EWGSOP1, EWGSOP2, and FNIH criteria, 0/19 (0.0%), 0/8 (0.0%), and 6/11 (54.5%) of women with sarcopenia were also obese. For men, the numbers were 2/11 (18.2%) for EWGSOP1, 0/2 (0.0%) for EWGSOP2, and 2/4 (50.0%) for FNIH.

Agreement

Table 4 presents the degree of agreement between sarcopenia (low muscle mass + low muscle strength) using two criteria for women and men. Kappa coefficients (κ) ranged from 0.12 to 0.58.

Discussion

This study provides prevalence estimates for sarcopenia according to different criteria and cut-off points in a sample

Table 4 Agreement of sarcopenia definitions

	EWGSOP1	EWGSOP2
EWGSOP2		
Women	0.578	
Men	0.301	—
FNIH		
Women	0.164	0.187
Men	0.118	0

EWGSOP1: using EWGSOP1 criteria and their recommended cut-off points; EWGSOP2: using EWGSOP2 criteria and its recommended cut-off points; FNIH: using FNIH criteria and their recommended cut-off points.

of men and women from the Australian population. We applied three definitions that were applicable to the Australian population profile. Using these definitions, we obtained substantial differences in prevalence estimates for sarcopenia and sarcopenia parameters, and the level of agreement between definitions varied widely. Regardless, the prevalence of sarcopenia increased with advancing age across all definitions.

The different cut-off points used in EWGSOP1 and EWGSOP2 resulted in a large range in the prevalence estimates for low ALM/height^2 and slow TUG. Previous researchers have highlighted that the prevalence of these sarcopenia parameters is determined by the cut-off points, which in turn are determined by different reference ranges, measurement techniques, and diagnostic criteria.[12,17,19] Bischoff *et al*. suggested the cut-off point of ≥12 s for slow TUG. The EWGSOP2 definition cites Bischoff *et al*. but uses a higher threshold for slow TUG of ≥20 s.[2,15] Owing to the inconsistency in the threshold for TUG and the apparent lack of normalized data for TUG in the USA, we did not apply TUG to the FNIH criteria.

We report large differences in the prevalence estimates for three levels of sarcopenia. The prevalence of pre-sarcopenia was consistently higher than for confirmed sarcopenia; and the prevalence of confirmed sarcopenia was higher than for severe sarcopenia. This was consistent with a cross-sectional study that used different definitions for sarcopenia in 132 older community-dwelling Brazilians.[12] The prevalence estimates for sarcopenia were lower if based on definitions using muscle mass and strength (6.1–36.6%) rather than definitions using muscle mass (8.3–60.6%) or muscle strength (48.8–54.2%) alone.

In our study, the prevalence of confirmed sarcopenia increased with advancing age. This pattern is in agreement with a population-based study of 329 Dutch women aged 38–78 years, using seven diagnostic criteria (muscle mass + HGS). The authors reported that the prevalence of sarcopenia ranged from 0% to 15.6% in women aged <60 years, 0.0–21.8% in women aged 60–69 years, and 0.0–25.8% in women aged ≥70 years.[11]

The low agreement we identified between most definitions replicates previous literature. Dam et al[17] from FNIH examined the difference between FNIH definitions and other operational sarcopenia definitions, including EWGSOP1. The agreements between the FNIH criteria and other criteria ranged from 0.07 to 0.32 in men and 0.05 to 0.19 in women.[17] Definitions recognized globally may not be suitable for application in populations residing in different geographic areas. Large datasets from representative populations are needed in the future, to aid in determining cut-points for the corresponding population.

A recent study by Yang *et al*.[29] examined the prevalence and factors associated with sarcopenia in community-dwelling older adults in China using the definitions of EWGSOP2 in comparison with EWGSOP1, Asian Working Group for Sarcopenia, International Working Group on Sarcopenia, and FNIH. The agreement between prevalence estimates for EWGSOP2 and other definitions ranged from 0.16 to 0.60 in men and 0.19 to 0.51 in women.

Poor agreement between the FNIH and EWGSOP definitions likely reflects the adjustment of lean mass for by BMI (for FNIH) or height^2 (for EWGSOP), if not the cut-off values themselves. Usually, a low ALM/BMI is associated with higher fat mass and likely presents as sarcopenic obesity or accompanying metabolic disease, while people with low ALM/height^2 are leaner and have lower body weight. Dufour *et al*.[30] and Spira *et al*.[31] both recommended indexing lean mass to BMI rather than height as low values are more likely to be associated with negative physical outcomes. Indeed, our results indicate that according to EWGSOP criteria, just over one third of women and approximately one half of men with sarcopenia had two or more co-morbid conditions, but this proportion was much lower for FNIH criteria. By contrast, approximately one half of individuals with sarcopenia by FNIH criteria were obese, but this was much lower for EWGSOP. Of note, none of the men with sarcopenia by FNIH had two or more co-morbidities, and none of the women with sarcopenia by EWGSOP were obese. Thus, our study suggests that FNIH criteria are more likely to identify individuals with sarcopenic obesity, while EWGSOP criteria are more likely to identify sarcopenic individuals with multiple co-morbid conditions.

The strength of our cross-sectional study was the use of a large population-based data set to minimize the variance that arises naturally from differing participant characteristics in multiple samples. Nonetheless, our findings cannot be generalized to other geographic areas. Furthermore, gait speed was not available for women. We acknowledge that for EWGSOP2, we did not start the case finding process with a screening questionnaire such as SARC-F[32] or as a result of clinical suspicion, which could have impacted on the prevalence estimates for sarcopenia reported here. Although we pooled the data to identify sex differences in the numbers of men and women identified with sarcopenia, we note that our male and female participants were assessed at different times.

To conclude, in our sample of men and women aged 60 years and older, EWGSOP1 criteria identified the highest sarcopenia prevalence estimates, while EWGSOP2 identified the lowest. We report large variations in agreement between sarcopenia definitions and correspondingly large variations in the prevalence estimates of sarcopenia derived from the same sample of older women and men using these definitions.

Acknowledgements

The authors acknowledge the men and women who participated in the study and the staff who contributed to the data collection. The authors acknowledge James Gaston, who calculated the CCI scores that have been used in this manuscript. The authors of this manuscript certify that they comply with the ethical guidelines for authorship and publishing in the *Journal of Cachexia, Sarcopenia and Muscle*.[33]

Conflict of interest

Sophia X. Sui, Kara L. Holloway-Kew, Natalie K. Hyde, Lana J. Williams, Monica C. Tembo, Sarah Leach, and Julie A. Pasco declare that no competing interests exist.

Funding

The Geelong Osteoporosis Study was funded by the National Health and Medical Research Council (NHMRC) Australia (projects 251638 and 628582). S.X.S. was supported by a Deakin Postgraduate Scholarship in conjunction with Geelong Medical and Health Benefits Association (GMHBA). K.L.H.-K. was supported by an Alfred Deakin Postdoctoral Research Fellowship, N.K.H. by a Dean's Research Postdoctoral Fellowship (Deakin University), and L.J.W. by an NHMRC Career Development Fellowship (1064272) and an NHMRC Investigator grant (1174060). The funding organizations played no role in the design or conduct of the study; in the collection, management, analysis, and interpretation of the data; nor in the preparation, review, and approval of the manuscript.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study was approved by the Human Research Ethics Committee at Barwon Health.

Informed consent

Written, informed consent was obtained from all participants in the study.

References

1. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, et al. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc* 2011;**12**:249–256.
2. Sim M, Prince RL, Scott D, Daly RM, Duque G, Inderjeeth CA, et al. Sarcopenia definitions and their associations with mortality in older Australian women. *J Am Med Dir Assoc* 2019;**20**:76–82, e72.
3. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010;**39**:412–423.
4. Studenski SA, Peters KW, Alley DE, Cawthon PM, McLean RR, Harris TB, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. *J Gerontol A Biol Sci Med Sci* 2014;**69**:547–558.
5. Pasco JA, Mohebbi M, Holloway KL, Brennan-Olsen SL, Hyde NK, Kotowicz MA. Musculoskeletal decline and mortality: prospective data from the Geelong Osteoporosis Study. *J Cachexia Sarcopenia Muscle* 2017;**8**:482–489.
6. Pasco JA, Brennan Olsen SL. Low lean tissue mass and physical performance as markers of sarcopenia in older men and women. *J Gerontol Geriatr Res* 2016;**5**(3):1–4.
7. Mayhew AJ, Amog K, Phillips S, Parise G, McNicholas PD, de Souza RJ, et al. The prevalence of sarcopenia in community-dwelling older adults, an exploration of differences between studies and within definitions: a systematic review and meta-analyses. *Age Ageing* 2019;**48**:48–56.
8. Pasco JA, Holloway-Kew KL, Tembo MC, Sui SX, Anderson KB, Rufus-Membere P, et al. Normative data for lean mass using FNIH criteria in an Australian setting. *Calcif Tissue Int* 2019;**104**:475–479.
9. Reijnierse EM, Buljan A, Tuttle CSL, van Ancum J, Verlaan S, Meskers CGM, et al. Prevalence of sarcopenia in inpatients 70 years and older using different diagnostic criteria. *Nurs Open* 2019;**6**:377–383.
10. Locquet M, Beaudart C, Hajaoui M, Petermans J, Reginster JY, Bruyere O. Three-year adverse health consequences of sarcopenia in community-dwelling older adults according to 5 diagnosis definitions. *J Am Med Dir Assoc* 2019;**20**:43–46, e42.
11. Bijlsma AY, Meskers CGM, Ling CHY, Narici M, Kurrle SE, Cameron ID, et al. Defining sarcopenia: the impact of different diagnostic criteria on the prevalence of sarcopenia in a large middle aged cohort. *Age (Dordr)* 2013;**35**:871–881.
12. Pagotto V, Silveira EA. Applicability and agreement of different diagnostic criteria

for sarcopenia estimation in the elderly. *Arch Gerontol Geriatr* 2014;**59**:288–294.
13. Su Y, Hirayama K, Han TF, Izutsu M, Yuki M. Sarcopenia prevalence and risk factors among Japanese community dwelling older adults living in a snow-covered city according to EWGSOP2. *J Clin Med* 2019;**8**(3):1–13.
14. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* 1998;**147**:755–763.
15. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing* 2019;**48**:16–31.
16. Zanker J, Scott D, Reijnierse EM, Brennan-Olsen SL, Daly RM, Girgis CM, et al. Establishing an operational definition of sarcopenia in Australia and New Zealand: Delphi method based consensus statement. *J Nutr Health Ageing* 2019;**23**:105–110.
17. Dam TT, Peters KW, Fragala M, Cawthon PM, Harris TB, McLean R, et al. An evidence-based comparison of operational criteria for the presence of sarcopenia. *J Gerontol A Biol Sci Med Sci* 2014;**69**(5):584–590.
18. Alley DE, Shardell MD, Peters KW, McLean RR, Dam T-TL, Kenny AM, et al. Grip strength cutpoints for the identification of clinically relevant weakness. *J Gerontol A Biol Sci Med Sci* 2014;**69**:559–566.
19. Yoshida D, Suzuki T, Shimada H, Park H, Makizako H, Doi T, et al. Using two different algorithms to determine the prevalence of sarcopenia. *Geriatr Gerontol Int* 2014;**14**:46–51.
20. Pasco JA, Nicholson GC, Kotowicz MA. Cohort profile: Geelong Osteoporosis Study. *Int J Epidemiol* 2012;**41**:1565–1575.
21. Apóstolo J, Dixe MDA, Bobrowicz-Campos E, Areosa T, Santos-Rocha R, Braúna M, et al. Effectiveness of a combined intervention on psychological and physical capacities of frail older adults: a cluster randomized controlled trial. *Int J Environ Res Public Health* 2019;**16**:3125.
22. Podsiadlo D, Richardson S. The timed "up & go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;**39**:142–148.
23. Solbakken SM, Magnus JH, Meyer HE, Emaus N, Tell GS, Holvik K, et al. Impact of comorbidity, age, and gender on seasonal variation in hip fracture incidence. A NOREPOS study. *Arch Osteoporos* 2014;**9**:191.
24. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;**40**:373–383.
25. Cawthon PM, Peters KW, Shardell MD, McLean RR, Dam T-TL, Kenny AM, et al. Cutpoints for low appendicular lean mass that identify older adults with clinically significant weakness. *J Gerontol A Biol Sci Med Sci* 2014;**69**:567–575.
26. Bischoff HA. Identifying a cut-off point for normal mobility: a comparison of the timed 'up and go' test in community-dwelling and institutionalised elderly women. *Age Ageing* 2003;**32**:315–320.
27. Census of population and ageing: age by sex In. *2068*. www.abs.gov.au: Australian Bureau of Statistics 2011.
28. Dodds RM, Syddall HE, Cooper R, Benzeval M, Deary IJ, Dennison EM, et al. Grip strength across the life course: normative data from twelve British studies. *PLoS ONE* 2014;**9**:e113637.
29. Yang L, Yao X, Shen J, Sun G, Sun Q, Tian X, et al. Comparison of revised EWGSOP criteria and four other diagnostic criteria of sarcopenia in Chinese community-dwelling elderly residents. *Exp Gerontol* 2020;**130**:110798.
30. Dufour AB, Hannan MT, Murabito JM, Kiel DP, McLean RR. Sarcopenia definitions considering body size and fat mass are associated with mobility limitations: the Framingham study. *J Gerontol Series A* 2012;**68**:168–174.
31. Spira D, Buchmann N, Nikolov J, Demuth I, Steinhagen-Thiessen E, Eckardt R, et al. Association of low lean mass with frailty and physical performance: a comparison between two operational definitions of sarcopenia—data from the Berlin Aging Study II (BASE-II). *J Gerontol Series A* 2015;**70**:779–784.
32. Malmstrom TK, Morley JE. SARC-F: a simple questionnaire to rapidly diagnose sarcopenia. *J Am Med Dir Assoc* 2013;**14**:531–532.
33. von Haehling S, Morley JE, Coats AJS, Anker SD. Ethical guidelines for publishing in the Journal of Cachexia, Sarcopenia and Muscle: update 2017. *J Cachexia Sarcopenia Muscle* 2017;**8**:1081–1083.
34. Newman AKV, Visser M, Simonsick E, Goodpaster B, Nevitt M, Kritchevsky SB, et al. Sarcopenia: alternative definitions and association with lower extremity function. *J Am Geriatr Soc* 2003;**51**:1602–1609.
35. Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol* 2003;**95**:1851–1860.
36. Gould H, Brennan SL, Kotowicz MA, Nicholson GC, Pasco JA. Total and appendicular lean mass reference ranges for Australian men and women: the Geelong Osteoporosis Study. *Calcif Tissue Int* 2014;**94**:363–372.
37. Breiman LFJ, Stone CJ, Olshen RA. *Classification and Regression trees*. Belmont, CA: Wadsworth International Group; 1984.