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The prevalence of sarcopenia in community-dwelling older adults, an exploration of differences between studies and within definitions: a systematic review and meta-analyses

A. J. Mayhew[1,2,3], K. Amog[1,2,3], S. Phillips[4], G. Parise[4], P. D. McNicholas[5], R. J. de Souza[1,6], L. Thabane[1,7], P. Raina[1,2,3]

[1]Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada
[2]Labarge Centre for Mobility in Aging, Hamilton, Ontario, Canada
[3]McMaster Institute for Research on Aging, Hamilton, Ontario, Canada
[4]Department of Kinesiology, McMaster University, Hamilton, Ontario, Canada
[5]Department of Mathematics & Statistics, McMaster University, Hamilton, Ontario, Canada
[6]Population Genomics Program, Chanchlani Research Centre, McMaster University, Hamilton, Ontario, Canada
[7]Biostatistics Unit, Research Institute at St Joes, St. Joseph's Healthcare Hamilton, 50 Charlton Avenue E, Hamilton, Ontario L8N 4A6, Canada

Address correspondence to: P. Raina. Tel: 905-525-9140 x 22197. Email: praina@mcmaster.ca

Abstract

Background: sarcopenia in ageing is a progressive decrease in muscle mass, strength and/or physical function. This review aims to summarise the definitions of sarcopenia in community-dwelling older adults and explore similarities and differences in prevalence estimates by definition.
Methods: a systematic review was conducted to identify articles which estimated sarcopenia prevalence in older populations using search terms for sarcopenia and muscle mass. Overall prevalence for each sarcopenia definition was estimated stratified by sex and ethnicity. Secondary analyses explored differences between studies and within definitions, including participant age, muscle mass measurement techniques and thresholds for muscle mass and gait speed.
Results: in 109 included articles, eight definitions of sarcopenia were identified. The lowest pooled prevalence estimates came from the European Working Group on Sarcopenia/Asian Working Group on Sarcopenia (12.9%, 95% confidence interval: 9.9–15.9%), International Working Group on Sarcopenia (9.9%, 3.2–16.6%) and Foundation for the National Institutes of Health (18.6%, 11.8–25.5%) definitions. The highest prevalence estimates were for the appendicular lean mass (ALM)/weight (40.4%, 19.5–61.2%), ALM/height (30.4%, 20.4–40.3%), ALM regressed on height and weight (30.4%, 20.4–40.3%) and ALM / body mass index (24.2%, 18.3–30.1%) definitions. Within definitions, the age of study participants and the muscle mass cut points used were substantive sources of between-study differences.

Conclusion: estimates of sarcopenia prevalence vary from 9.9 to 40.4%, depending on the definition used. Significant differences in prevalence exist within definitions across populations. This lack of agreement between definitions needs to be better understood before sarcopenia can be appropriately used in a clinical context.

Keywords: *gait speed, grip strength, muscle mass, muscle loss, muscle wasting, older adults, sarcopenia, systematic review*

Sarcopenia is a progressive decrease in muscle mass, strength and physical function that occurs with age [1]. Beginning in approximately the fifth decade of life, muscle mass and strength decline at annual rates of 0.8 and 1–3%, respectively [2–4]. Functional declines, culminating in a loss of independence in self-care abilities, are not evident until later in life, but are related to decreases in strength and physical function. Sarcopenia is associated with a significantly greater risk for poor health outcomes including disability and functional impairments [5], increased risk of falls [6], longer hospital stays [7] and an increased risk of mortality [8, 9]. In 2000, it was estimated that the USA incurred $18.5 billion in direct healthcare costs related to sarcopenia alone [10].

Sarcopenia was first defined by Baumgartner using appendicular lean mass (ALM) adjusted for height (kg/m^2) [11]. Subsequent definitions of sarcopenia include measures of either muscle strength or function because muscle strength declines more rapidly than muscle mass during ageing [2], and muscle strength and function are more strongly associated with outcomes such as mortality [12]. The International Working Group on Sarcopenia (IWGS) defined sarcopenia as a combination of low muscle mass and low muscle function [13], while the European Working Group on Sarcopenia in Older People (EWGSOP) suggested that low muscle mass and either low muscle strength or low physical performance must be present [14].

Depending on the definition used, sarcopenia is estimated to affect between 1 and 29% of community-dwelling older adults [15] though some estimates are as high as 60% [16]. The wide range of prevalence estimates suggests that different sarcopenia definitions are not measuring the same underlying construct. Studies using the same population have found that sarcopenia estimates vary up to 40% by definition [17–19]. It is unclear how much of the prevalence variability is due to the operationalization of sarcopenia, the use of different cut points and/or the different techniques used for muscle measurement, study methodologies and participant populations. However, the lack of a standardised sarcopenia definition makes it challenging to accurately estimate the burden of the disease, thus limits the clinical usefulness of a sarcopenia diagnosis. With the introduction of sarcopenia into the International Classification of Disease [20], there is an even greater urgency to arrive at a unified definition for sarcopenia. The aims of this review are: (i) to identify definitions currently used to characterise sarcopenia in community-dwelling older adults and (ii) to document the similarities and difference between prevalence estimates by definition.

Methods

This review was conducted in accordance with the meta-analysis of observational studies in epidemiology guidelines (Supporting Information S1, available in *Age and Ageing* online) [21]. Ethics approval was not required for this research. The protocol for this systematic review has been published on PROSPERO (ID: ANONYMISED).

Data sources and searches

An electronic search strategy was developed to identify human studies with estimates of sarcopenia prevalence in community-dwelling older adults without specific health conditions. No restrictions on study design were imposed. Studies were limited to original English language articles. MEDLINE, EMBASE, CINAHL, AgeLine and SPORTDiscus were searched from inception to 19 December 2016 (Supporting Information S2, available in *Age and Ageing* online). The bibliographies of the retrieved articles were reviewed for additional studies.

Study selection

The title, abstract and full-text screenings were performed in duplicate by two independent reviewers. Discrepancies were resolved by discussion. A third author was consulted to reach consensus when necessary. Studies were excluded if they were a review, meeting abstract, commentary, letter to the editor, study protocol without data, exclusively used animal models, were not English language, had participants exclusively under the age of 60, or if the mean age minus one standard deviation was below 55 years. Other exclusion criteria include participants living in hospitals, long-term care facilities, nursing homes or retirement homes, the use of convenience sampling to recruit participants, sarcopenia measured at only a specific area of the body such as the thigh or tongue and sarcopenia exclusively defined as a change in muscle parameter(s).

Data extraction and quality assessment

Two authors independently extracted details of the study design, country the study was conducted in, sarcopenia definition including details of measures of muscle mass, muscle strength and physical function and participant characteristics such as age, sex and ethnicity. For each study, prevalence was calculated as the number of participants with sarcopenia divided by the entire sample size. If this information was

not provided, the prevalence reported in the paper was extracted. Discrepancies were resolved by discussion.

The 'Joanna Briggs Institute Prevalence Critical Appraisal Tool' [22] was used to assess risk of bias (ROB). Manuscripts and additional documentation referenced by the study were reviewed for the ROB assessment. Studies were categorised as low, moderate, high or very high ROB. Studies at low ROB scored all responses as either 'yes' or 'not applicable' with an allowance for one 'unclear' response for a total score of 8.5 or 9. Moderate ROB studies could have three 'unclear' responses or one response of 'no' and one response of 'unclear' for a score of 7.5 or 8.0.ROB. High ROB studies had scores between 5.0 and 7.5 and very high ROB studies had scores of less than 5.0.

Data synthesis and analysis

All studies were stratified by ethnicity and, when possible, by sex. Ethnicity was categorised as European if the study took place in North America, Europe or Australia/New Zealand or non-European. For all analyses, the EWGSOP/Asian Working Group on Sarcopenia (AWGS) were included together because they used identical algorithms for determining sarcopenia status. In cases where at least two studies provided combinable data, a DerSimonian and Laird's random effect meta-analysis was performed which yields conservative confidence intervals (CI) around the prevalence estimates in the presence of heterogeneity [23]. Heterogeneity was detected using Cochran's Q test (significant at $P < 0.10$) and quantified using the I^2 statistic (ranging 0–100%). All analyses were completed using Review Manager (version 5).

In the primary analyses, overall prevalence for each sarcopenia definition was estimated, stratified by sex and ethnicity. A subgroup analyses were conducted after removing studies that were poor or very poor quality. Four sensitivity analyses were conducted to assess the impact of age, muscle mass cut-offs, the method of measuring muscle mass and gait speed/course length on sarcopenia prevalence. Studies were first stratified by sarcopenia definition, sex and ethnicity, then further categorised by the sensitivity analyses variable. For age and muscle mass cut-offs, studies were categorised by approximate tertiles for each sex and ethnicity group, and the results of groups were pooled together. The method of muscle mass determination was categorised as dual X-ray absorptiometry (DXA), bioelectric impedance analysis (BIA) or other. Only the EWGSOP/AWGS definitions had sufficient data on gait speed/course length. Categories included all possible combinations of speed and length. For each sensitivity analysis, prevalence estimates for each of the sensitivity analysis categories within each age/ethnicity strata were calculated. These estimates were then pooled together to determine the overall prevalence for that category across all age/ethnicity strata for a given definition.

Results

Literature flow

Of the 13,191 potentially eligible articles, 777 remained after removing duplicates and screening the titles and abstracts and 109 after the full-text review (Supporting Information S3, available in *Age and Ageing* online).

Study characteristics

Table 1 summarises the characteristics and results of the 109 articles categorised by definition. The articles

Table 1. Summary of study characteristics.

Definition, year that definition was developed	Cohorts included	Number of estimates, number of participants	Range of measures of sarcopenia	Range of measures of sarcopenia prevalence
EWGSOP, 2009	AGES Reykjavik [1], BEFRAIL [2], BRHS [3], EPIC [4], Hertfordshire Cohort Study [5, 6], Hertfordshire Sarcopenia Study [5], HSHD [7], Sumukadas, 2015—Scotland [8], COMO VAI? [9, 10], Quilombola Elderly [11], Lafaiete Coutinho-BA [12], SABE—Brazil [13, 14], COURAGE/SAGE [15, 16], EPIDOS [17], I-Lan [18], Lin, 2014—Taiwan [19], Taichung Community Health [20, 21], TOP Study [22], IlSirente [23–27], InCHIANTI Study [28, 29], Kashiwa Cohort Study [30–33], Japan Murakami [34], OSHPE [35], ROAD Study [36], KLoSHA [37, 38], MaSS [39–41], Wen, 2015 – China [42], Mexico City [43, 44], MrOS and SOF [45], SABE – Colombia [46], SARIR [47, 48], SMAS [49], CHAMP [50], The FORMoSA Project [51, 52]	210, 58,442	Muscle mass: thigh muscle surface area (<116.5 cm^2 males, <83.2 cm^2 females), mid arm muscle circumference area (lowest 40% of participants at risk for sarcopenia, or <21.1 cm males and <19.2 cm in females), calf circumference (31–34 cm males, 31–33 cm females), skinfold thickness (lowest third), ALM/$height^2$ measured with dual energy X-ray absorptiometry (DEXA) and BIA (5.58–10.75 kg/m^2 males, 4.32–6.75 kg/m^2 females), ALM/BMI (country-specific lowest quintile), unadjusted lean body mass (lowest tertile), ALM/body weight (<27.1–29.9% males, <22.3–25.1% females), ALM regressed on height and weight (lowest tertile), total ASM (<19.75 kg males). Muscle strength: HGS (< 25–30 kg males, < 16–20 kg females or <33 nm, or BMI-based cut points, or <0.75Nm males, <0.79 Nm females, or lowest quantiles,).	Males: 0% −36.7% Females: 0–62.2%

Continued

Table 1. Continued

Definition, year that definition was developed	Cohorts included	Number of estimates, number of participants	Range of measures of sarcopenia	Range of measures of sarcopenia prevalence
			Physical performance: Walk speed (<0.8 m/s, <1.0 m/s, 1.26 m/s, age/sex or height-specific cut-offs, course distance of 2.44–10 m) or SPPB (score of less than 8)	
AWGS, 2014	Chinese Elderly Study [53], No-Name China [42], I-Lan [54], ROAD Study [36, 55]	30, 2,835	Muscle mass: calf circumference (cut-off of 31 cm), DEXA measured ALM/height (cut-offs of 7.0 kg/m^2 for males, 5.4 kg/m^2) for females. Muscle strength: Handgrip strength (cut-offs of 28 kg for males and 16 kg for females) Physical function: gait speed (cut- offs of 0.8 m/s (n = 3 cohorts) and 1.0 m/s (1 cohort)	Males: 0–27.0% Females: 0–23.9%
IWGS, 2009	EPIDOS [17], Hertfordshire Cohort Study [6], NHANES [56], Wen, 2015 – China [42], Tramontano – Peru [57], FORMoSA Project [52], Gouveia, 2016—Portugal [58]	37, 10,383	Muscle mass: DXA or BIA measured ALM/height^2 (<7.23 kg/m^2 <10.76 kg/m^2 males, <5.67 kg/m^2 – 6.75 kg/m^2 females), ALM/BMI (<0.789 males, <0.512 females). Muscle strength: handgrip strength (<26 kg males, <12 kg females) Physical function: gait speed (<0.8 m/s or 1.0 m/s, course length 4 m, 6 m, 10 m or 50 feet)	Males: 0–35.9% Females: 0–24.2%
FNIH, 2014	Hertfordshire Cohort Study [6]HSHD [7], NHANES [59, 60], CHAMP [50, 61]	85, 10,979	Muscle mass: DXA measured ALM/height^2 (7.23 kg/m^2 males, 5.67 kg/m^2 females), unadjusted ALM (<19.75 kg males, <15.02 kg females), ALM/BMI (<0.789 males, <0.512 females) Muscle strength: handgrip strength <26 kg males, <16 kg females Physical function: gait speed (<0.8 m/s or <1.0 m/s)	Males: 3.1–72.8% Females: 0–63.6%
ASM divided by height, 1998	SMAS [49], NHANES [62–64], Cardiovascular Health Study[65, 66], Health ABC [67, 68], NMAPS [69], Buehring, 2013—US [70], STORM [71], The Framingham Study [72], New Mexico Elder Health [73], WHAS II [74], KNHANES [37, 75–83], KLoSHA [37, 84], Ansan Geriatric Study [85], No-Name China [42], Taichung Community Health [86], MINOS [87], EPIDOS [17, 88–90], Portuguese centenarians [91], No-Name Germany [92], EXERNET [93], NuAge [94], Quilombola Elderly [11], SPAH [95, 96]	147, 32,732[a]	Muscle mass: measured by DEXA or BIA with cut points ranging from 6.52 kg/m^2 to 10.65 kg/m^2 for males and 4.59 kg/m^2 to 8.5 kg/m^2 for females	Males: 9.9–70.7% Females: 0.7–58.1%
ASM/weight, 2002	KLoSHA [37, 84], KNHANES [37, 54, 78, 83, 97–104], NHANES [105,106],Wen, 2015 – China [42], SMAS [49]	56, 21,219[b]	Muscle mass: ASM measured using DEXA, BIA or densitometry divided by total weight. Cut points range from 25.72 to 27.6% in males and 19.43 to 37.0% in females	Males: 3.1–56.1% Females: 3.2–52.3%
ASM regressed on height and weight, 2003	EPIDOS [17], Health ABC [67, 68], Mr OS [107], The Framingham Study [72], SMAS [49], TASOAC [108], SPAH [95, 96],	31, 15,289	Muscle mass: measured by DEXA and regressed on weight and height. Lowest quintile considered sarcopenic	Males: 8.2–27.1% Females: 8.1–30.5%
ALM/BMI, 2014	NHANES 1999–2004 [60]	60, 3,880	Muscle mass: ALM/BMI. Cut-off of <0.789 for males and <0.512 for females	Males: 4.0–47.3% Females: 3.6–51.2%
Other	Cardiovascular Health Study [65], Rancho Bernardo Study [109], EPIDOS [17], SMAS[49]	6, 8,824	Muscle mass: BIA fat free mass of <47.9 kg for men and <34.7 kg for women Muscle strength: Handgrip strength adjusted for height using regression (lowest tertile), handgrip strength only (<30 kg males, <20 kg females), knee extensor strength (<23.64 males, <15.24 females)	Males: 6.2,% no upper estimate Females: 5.9%, no upper estimate

[a]Assumed that the 2008–2010 KNHANES study included all participants in the 2008–2009 grouping. The sample size for KNHANES 2008–2011 was disregarded (n = 463) because of the small sample size an impossibility of knowing which participants were included in other samples. Therefore this is an underestimation of the sample size.

[b]Assumed that the 6,949 participants reported for KNHANES (2008–2011) encompass the participants from all KNHANES studies using a subset of that data. This will be resulted in an underestimation of the number of participants

represented 58 unique cohorts from 26 countries with 656 individual estimates of sarcopenia prevalence. Across all studies, the minimum age was 55 years, and the earliest year of data collection was 1988. Sarcopenia estimates were available for eight common definitions-ALM/body mass index (BMI), AWGS, ALM divided by weight, ALM regressed on height and weight, ALM divided by height, EWGSOP, Foundation for the National Institute of Health (FNIH) and IWGS-and three uncommon definitions that measured sarcopenia using absolute muscle mass, fat mass, handgrip strength or knee extensor strength (Supporting Information S4, available in *Age and Ageing* online).

ROB assessment

According to the *Joanna Briggs Institute Prevalence Critical Appraisal Tool*, 10.6% (n = 10) of studies were at low ROB, 20.4% (n = 29) were at moderate risk, 52.8% (n = 75) of studies were at high risk and 16.2% (n = 23) were at very high risk.

Overall sarcopenia prevalence estimates

After merging studies where two or more manuscripts provided an estimate for sarcopenia using identical measurement methods in the same population, 227 individual prevalence estimates remained (Table 2). The most frequently used definitions were the EWGSOP/AWGS criteria (n = 83), ALM/height (n = 68) and ALM/weight (n = 27). The remaining definitions had fewer than 20 estimates. The lowest pooled prevalence estimates were for the EWGSOP/AWGS (12.9%, 95% CI: 9.9, 15.9%), IWGS (9.9%, 95% CI: 3.2, 16.6%) and FNIH (18.6%, 95% CI: 11.8, 25.5%) definitions. The highest prevalence estimates were for the ALM/weight (40.4%, 95% CI: 19.5, 61.2%), ALM/height (30.4%, 95% CI: 20.4, 40.3%), ALM regressed on height and weight (30.4%, 95% CI: 20.4, 40.3%) and ALM/BMI (24.2%, 18.3, 30.1%) definitions. All definitions except for IWGS had a significant between-study heterogeneity (I^2 > 87%, Cochrane's Q, P-value < 0.00001) (Supporting Information S5, available in *Age and Ageing* online).

Prevalence estimates varied between males and females. In Europeans and non-Europeans, prevalence was higher in males for EWGSOP/AWGS, ALM/height and ALM/BMI. For FNIH, ALM/weight and ALM/BMI, sarcopenia prevalence was higher in females. For ALM regression, prevalence was higher in European males than European females, but equal in non-European males and females. When comparing Europeans versus non-Europeans, sarcopenia prevalence was similar (<5% difference) for EWGSOP/AWGS and ALM/BMI in males and females. Compared to non-Europeans, prevalence was higher in Europeans for ALM/height, ALM/weight and ALM regression and lower for FNIH. For IWGS, sarcopenia prevalence was higher in European males compared to non-European males but lower in European females compared to non-European females. When studies with high or very high ROB were removed, 76 studies remained. Prevalence estimates decreased for the EWGSOP/AWGS, FNIH, ALM/height, ALM/weight, ALM regression and other definitions and increased for IWGS (5.5%) and ALM/BMI (1.1%).

Prevalence estimates stratified by age groups

After including all age categories, there were 363 unique estimates of sarcopenia prevalence. Prevalence increased across age groups from youngest to oldest for EWGSOP/AWGS, FNIH and ALM/BMI. For the ALM/height, ALM/weight and ALM/regression definitions, prevalence estimates differed by <10% between age groups, but did not increase across increasing age groups. The prevalence of IWGS varied by 13.8% between age groups but did not demonstrate an increase with age (Table 3).

Prevalence estimates stratified by muscle mass threshold

A total of 123 estimates of sarcopenia from the EWGSOP/AWGS, IWGS, ALM/height and ALM/weight definitions were included in this analysis. Definitions with less than three cut points were excluded. Two definitions (EWGSOP/AWGS and ALM/height) had studies in different muscle mass groups depending on whether the prevalence was ranked according to the cut-offs in males or females for the pooled analyses. When groups were based on female cut points, EWGSOP/AWGS and ALM/height

Table 2. Overall sarcopenia prevalence estimates.

Definition	Number of studies	Participants (n)	Forest plot	Prevalence estimate (%)	95% CI	Heterogeneity
EWGSOP/AWGS	83	58283		12.9	9.9, 15.9	93% (P < 0.001)
IWGS	12	10381		9.9	3.2, 16.6	52% (P = 0.100)
FNIH	16	6467		18.6	11.8, 25.5	75% (P = 0.003)
ALM/height	68	39135		30.4	20.4, 40.3	87% (P < 0.001)
ALM/weight	27	18985		40.4	19.5, 61.2	100% (P < 0.001)
ALM regression	6	16899		30.4	20.4, 40.3	87% (P < 0.001)
ALM/BMI	8	4984		24.2	18.3, 30.1	92% (P < 0.001)
Other	6	9243		18.0	7.3, 28.8	100% (P < 0.001)
			0% 40% 80%			

Table 3. Sarcopenia prevalence stratified by definition and age groups

Definition	Age Group	Number of studies	Number of participants	Forest Plot	Prevalence Estimate (%)	95% CI	Heterogeneity
EWGSOP/AWGS	Youngest	48	24244		9.9	5.4, 14.4	94% ($P < 0.001$)
	Middle	47	35553		15.1	13.5, 16.7	8% ($P = 0.370$)
	Oldest	46	12393		19.4	15.6, 23.2	70% ($P = 0.006$)
IWGS	Youngest	5	3143		14.8	3.7, 33.2	0% ($P = 0.360$)
	Middle	6	4493		1.0	0.0, 3.3	88% ($P = 0.004$)
	Oldest	5	3553		6.7	3.1, 10.3	0% ($P = 0.500$)
FNIH	Youngest	15	8208		12.5	7.6, 17.4	0% ($P = 0.650$)
	Middle	15	4129		25.3	11.3, 39.3	79% ($P < 0.001$)
	Oldest	15	2911		29.0	14.9, 43.0	92% ($P < 0.001$)
ALM/height	Youngest	33	14079		28.9	16.8, 41.0	87% ($P < 0.001$)
	Middle	31	24697		27.9	14.7, 41.2	92% ($P < 0.001$)
	Oldest	32	15183		34.5	24.0, 45.0	30% ($P = 0.220$)
ALM/weight	Youngest	11	8735		51.1	38.0, 64.3	94% ($P < 0.001$)
	Middle	11	5113		48.5	33.6, 63.5	96% ($P < 0.001$)
	Oldest	11	4266		51.1	34.3, 67.8	97% ($P < 0.001$)
ALM regression	Youngest	4	8976		20	19.1, 20.9	0% ($P = 0.330$)
	Middle	2	1401		27	24.2, 19.9	0% ($P = 0.750$)
	Oldest	2	3299		19.1	8.8, 29.3	94% ($P < 0.001$)
ALM/BMI	Youngest	8	2129		18.4	12.0, 24.8	98% ($P < 0.001$)
	Middle	8	1635		27	18.1, 35.8	92% ($P < 0.001$)
	Oldest	8	1173		33.6	22.5, 44.8	71% ($P < 0.020$)
				0% 40% 80%			

Table 4. Sarcopenia prevalence stratified by definition and muscle mass measure groups.

Definition	Muscle mass group	Number of studies	Number of participants	Forest Plot	Prevalence Estimate (%)	95% CI	Heterogeneity
EWGSOP/AWGS[a]	Lowest	14	6573		9.4	4.6, 14.1	93% ($P < 0.001$)
	Middle	18	6763		10.2	7.5, 12.9	65% ($P = 0.020$)
	Highest	18	10644		18.4	14.7, 22.1	23% ($P = 0.260$)
EWGSOP/AWGS[b]	Lowest	16	11355		8.7	4.2, 13.2	92% ($P < 0.001$)
	Middle	18	10642		9.5	7.2, 11.9	65% ($P = 0.020$)
	Highest	15	18045		18.4	14.7, 22.1	23% ($P = 0.260$)
IWGS	Lowest	2	3427		7.9	0.0, 20.3	100% ($P < 0.001$)
	Middle	1	1325		3.3	2.3, 4.3	N/A
	Highest	1	2500		24.2	22.5, 25.9	N/A
ALM/height[c]	Lowest	15	12334		26.3	0.0, 55.1	100% ($P < 0.001$)
	Middle	19	11619		17.2	8.2, 26.2	85% ($P < 0.001$)
	Highest	15	18045		47.3	22.1, 72.6	93% ($P < 0.001$)
ALM/height[d]	Lowest	15	6797		8.7	4.2, 13.2	92% ($P < 0.001$)
	Middle	17	6572		9.5	7.2, 11.9	61% ($P = 0.020$)
	Highest	18	10611		18.4	14.7, 22.1	23% ($P = 0.260$)
ALM/weight	Lowest	7	6949		9.9	8.0, 11.8	0% ($P = 0.390$)
	Middle	9	3984		39.3	35.4, 43.1	0% ($P = 0.640$)
	Highest	4	3718		43	40.8, 45.1%	93%, ($P < 0.001$)
				0% 40% 80%			

[a]For the EWGSOP/AWGS definition, the ordering of the studies in the European males and females combined differed based on if the prevalence estimates were ordered according to the male cut points or the female cut points. These prevalence estimates are when the male ordered cut points were used.
[b]For the EWGSOP/AWGS definition, the ordering of the studies in the European males and females combined differed based on if the prevalence estimates were ordered according to the male cut points or the female cut points. These prevalence estimates are when the female ordered cut points were used.
[c]For the ALM/height definition, the ordering of the studies in the European males and females combined differed based on if the prevalence estimates were ordered according to the male cut points or the female cut points. These prevalence estimates are when the male ordered cut points were used.
[d]For the ALM/height definition, the ordering of the studies in the European males and females combined differed based on if the prevalence estimates were ordered according to the male cut points or the female cut points. These prevalence estimates are when the female ordered cut points were used.

as well as ALM/weight showed trends for sarcopenia prevalence increasing as muscle mass increased (Table 4).

Comparison of gait speed, length of gait speed test

Only the EWGSOP/AWGS definitions provided sufficient data for gait speed analysis. For European males and females, a gait speed cut-off of 0.8 m/s was used for course lengths of 3 , 4 and 6 m. Prevalence was lowest for the 3 m distance (12.1% (95% CI: 0.0, 24.3%) males, 4.8% (95% CI: 0.0, 9.9%), females) and highest for the 4 m distance (20.4% (95% CI: 17.3, 23.4% males), 32.1% (26.8, 37.4%, females). Pooled estimates for European males and females used a cut-point of 0.8 m/s with course lengths of 3, 4, 6 and 10 m.

Prevalence ranged from 4.5% (95% CI: 3.3, 5.6%) for the 10-m course to 21.5% (95% CI: 17.5, 25.5%) for the 6-m course. In non-Europeans, the shortest course length was 2.4 m and the longest course length was 20 m and gait speed cut-offs were between 0.8 and 1.26 m/s. As the course length increased for a given cut-point, the prevalence of sarcopenia decreased in both sex strata with the exceptions of the 20-m walk course in males and females and the 4.0 m to 4.572 m/s gait speed for females only.

Comparison of methods of measuring muscle mass

Across all definitions, 158 sarcopenia estimates used DXA to measure muscle mass, 39 used BIA and 21 used methods such as muscle circumference or a formula-based estimate of muscle mass. Of the definitions using both BIA and DXA, the prevalence of sarcopenia was between 2.0 (EWGSOP/AWGS) and 8.5% (IWGS) higher when measured by BIA than DXA.

Discussion

Recognising and screening for sarcopenia and developing steps for its treatment has become an important public health challenge in light of the recent development of International Classification of Disease code. This review critically evaluated 656 individual estimates of sarcopenia from 109 articles, representing 58 unique cohorts from 26 countries. Eight common definitions of sarcopenia used in community-dwelling older adults (ALM/BMI, AWGS, ALM/weight, ALM regressed on height and weight, ALM divided by height, EWGSOP, FNIH and IWGS) were identified. Surprisingly, sarcopenia prevalence was markedly dependant on the operationalized definition, ranging from 9.9 to 40.4%. This more than fourfold difference suggests that there are crucially important differences between the definitions of sarcopenia in regard to muscle parameters, the operationalization of variables and study populations. We explored some of these differences in this review.

The clinical implications of a lack of standardised definition for sarcopenia are of particular concern with the introduction of International Classification of Disease code for sarcopenia in 2016 [20]. With issuance of the code came no guidance for clinicians about which definition to use or how to treat individuals identified as sarcopenic, which appears to encompass many different phenotypic presentations and pursuant treatment strategies [24]. It is also unknown if the participant characteristics vary in those considered sarcopenic and if different treatment strategies may be more or less effective based on the sarcopenia definitions used. Understanding which interventions to employ for composite definitions is further complicated by the inclusion of multiple variables and an absence of an outcome for treatment. From a public health perspective, the lack of a standard definition makes it impossible to understand the burden of sarcopenia.

A key difference between definitions was whether sarcopenia was operationalized using a single measure of muscle mass (ALM/BMI, ALM/weight, ALM regressed on height and weight and ALM/height) or a composite measure of muscle mass and muscle strength and/or physical function (AWGS, EWGSOP, FNIH, IWGS). Sarcopenia prevalence was between 24.2 and 40.4% for single measure definitions and 9.9 and 18.6% using composite definitions (Table 3). This suggests that there are more people with lower indices of muscle mass but fewer with lower muscle mass in conjunction with poor strength or function. However, people with low muscle mass and poor strength or function are more likely to experience disability compared to those with low muscle mass alone [25, 26].

Within definitions, muscle mass thresholds and the use of BIA versus DXA may explain some of the differences in prevalence estimates. For most definitions, prevalence increased across increasing age groups indicating studies including older participants are likely to report a higher prevalence. Twenty of the 22 studies with different age groups within the same population reported increased prevalence in the older age groups. However, it is unlikely that potential differences in age distribution of participants by definition explains the difference in prevalence estimates between definitions. The difference in prevalence within definition by age tertiles tended to be smaller than the difference between definitions for the same age tertile. Prevalence also increased as muscle mass cut-offs increased within definitions. The same trend was found in studies that used multiple cut points. For all definitions with both BIA and DXA measures, BIA yielded higher prevalence estimates than DXA. Conclusions about gait speed and course length were less clear due to lack of evidence. However, the results suggested that for a given gait speed, prevalence of sarcopenia generally increases with increasing course length. However, the cause of this trend is unclear and may be attributable to differences in methods of measurement such as when timers are started or the speed at which participants are instructed to walk.

A challenge encountered in this review was that subsets of the same population were used to estimate sarcopenia in multiple publications. This occurred when either a single study such as National Health and Nutrition Examination Survey or the Korean National Health and Nutrition Examination Survey had multiple publications using overlapping but not identical participant populations. Whenever possible, sample size estimates were adjusted to better reflect the number of unique estimates contributing to the pooled data.

Our review provides a comprehensive synthesis of the literature, building upon previous systematic reviews which have only included a subset of definitions, have been restricted to specific diseases or looked at sarcopenia in relation to another outcome. This is the first systematic review that has investigated prevalence estimates for sarcopenia definitions in community-dwelling older adults, which allows for comparisons to be made between and within

definitions. Our subgroup analyses revealed factors that may contribute to differences in prevalence estimates within studies including the age distribution of the study population, muscle mass cut points, the use of BIA versus DXA and gait speed cut-offs that require further investigation.

Our study has limitations. First, the literature search was last updated in December 2016 and does not reflect the most recent literature. Second, though this review highlights variables that potentially contribute to differences in prevalence, it is impossible to isolate the unique contribution of these variables due to other between-study differences including variables not investigated in this review such as study inclusion and exclusion criteria for physical performance tasks. Another limitation is the use of sex and ethnicity-specific tertiles for muscle mass cut points and age opposed to the same cut points for each sarcopenia definition. This was done to allow for internal comparisons to be made for these variables within a definition by maximising the number of studies included in each of the groups. More primary research is required to better understand what drives the differences in study prevalence. In addition to the current literature [27, 28], more studies are required to empirically test which sarcopenia definitions are predictive of future health status. There is also a need for further exploration of the effect of different methods of adjusting lean mass for body size on sarcopenia. Four methods of adjustment were captured in this review, ALM/height, ALM/weight, ALM regression and ALM/BMI. Adjustment of muscle parameters for body size has been shown to increase the strength of the association between muscle with function and disability [29], but it is unknown which of the four adjustment techniques is most appropriate. This review provides evidence that the prevalence of sarcopenia is also impacted by the method of adjustment with prevalence estimates ranging from 24.2 to 40.4%. This research will provide the information necessary for researchers and clinicians to determine what the standard definition of sarcopenia might be.

Conclusions

In this review, the pooled prevalence of sarcopenia pooled ranged between 9.9 and 40.4%, depending on the definition used. The differences in sarcopenia prevalence suggest that the definitions are not measuring the same underlying construct. In general, definitions that include measures of muscle function or physical performance in addition to muscle mass provide lower estimates of sarcopenia compared to measures of muscle mass only. Our findings also suggest that, within definitions, there are multiple sources of between-study differences including participant age, the muscle mass cut points used in definitions and the use of DXA versus BIA. Most importantly, this review emphasises the need for further development and refinement of the definition of sarcopenia to allow for greater comparability between future studies examining sarcopenia and its treatment.

Key points

- Estimates of sarcopenia prevalence vary from 9.9 to 40.4% depending on the definition used.
- The lack of agreement between sarcopenia definitions needs to be understood before sarcopenia can be used clinically.
- Sarcopenia in ageing is a progressive decrease in muscle mass, strength and/or physical function.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

Conflict of interest

PR holds the Raymond and Margaret Labarge Chair in Research and Knowledge, is the Scientific Director of the McMaster Institute for Research on Aging and holds a Tier 1 Canada Research Chair in Geroscience.

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