REVIEW ARTICLE

Sarcopenia: Prevalence and associated factors based on different suggested definitions in community-dwelling older adults

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The age-related loss of muscle mass and/or strength and performance, sarcopenia, has been associated with geriatric syndromes, morbidity and mortality. Although sarcopenia has been researched for many years, currently there is a lack of consensus on its definition. Some studies define sarcopenia as low muscle mass alone, whereas other studies have recently combined low muscle mass, strength and physical performance suggested by the European Working Group on Sarcopenia in Older People, as well as the Asian Working Group for Sarcopenia. The arbitrary use of various available sarcopenia definitions within the literature can cause discrepancies in the prevalence and associated risk factors. The application of population-specific cut-off values in any sample population can be problematic, particularly among different ethnicities. Using commonly used cut-off points to define sarcopenia, including solely muscle mass and combined definitions, on a community-dwelling elderly Japanese population, the prevalence of sarcopenia ranged from 2.5 to 28.0% in men and 2.3 to 11.7% in women, with muscle mass measured by dual-energy X-ray absorptiometry, and 7.1–98.0% in men and 19.8–88.0% in women measured by bioelectrical impedance analysis. Body mass index was the most prominent related factor for sarcopenia across the definitions in this Japanese sample. However, other associated hematological and chronic condition factors varied depending on the definition. **Geriatr Gerontol Int 2016; 16 (Suppl. 1): 110–122.**

Keywords: muscle strength, sarcopenia, skeletal muscle mass, walking ability.

Introduction

Sarcopenia, a term proposed by Rosenburg in 1989 referring to the age-related decline in lean body mass, has become a relatively well-known condition among researchers and physicians.[1] Many investigators have attempted to clarify and establish a definition for the estimation of sarcopenia in older adults, as there is still a lack of consensus on components for the diagnosis of sarcopenia and the corresponding cut-off values.[2–8]

While some investigators maintain that sarcopenia should be characterized solely on muscle mass, since the publication of the European Working Group on Sarcopenia in Older People (EWGSOP) definition, more studies have used the combined definition of muscle mass, strength and performance to define sarcopenia.[9] The issue then, is that the reported prevalence of sarcopenia, or any outcome, varies depending on the definition used.[10–13] Furthermore, the differences in cut-off values used for the definition can also greatly affect the outcome of the results depending on the population on which said cut-off value is applied.[2,6,7,10] The different definitions of sarcopenia and their corresponding cut-off points might also have an effect on the risk factors associated with sarcopenia, which is an area that has not yet been explored. Understanding these risk factors can potentially assist in identifying early markers for sarcopenia prevention.

The purpose of the present review was to determine the differences in prevalence and factors associated with sarcopenia based on different definitions found in the literature, and to investigate how different sarcopenia definitions affect prevalence and associated factors

when applied to a population of community-dwelling Japanese older adults.

Criteria for sarcopenia diagnosis and cut-off points

Muscle mass

The loss of muscle mass and increase in fat mass with aging has been well established in numerous studies.[14–18] The age-related loss of much mass is strongly associated with impaired mobility, greater morbidity and mortality,[7,19,20] and is a principal component in the causal pathway leading to frailty.[21] Therefore, the proper measurement and evaluation of muscle mass in older adults is extremely important.

The most widely used muscle mass cut-off points are those suggested by Baumgartner *et al.*, which used skeletal muscle mass index cut-off points two standard deviations below the mean of a young reference group measured by dual x-ray absorptiometry (DXA), 7.26 kg/m^2 for men and 5.45 kg/m^2 for women.[2] As seen in Table 1, several methods and cut-off points have been used, although many follow Baumgartner's example. The range of cut-off values shown in Table 1 for skeletal muscle index (SMI) or appendicular skeletal muscle mass adjusted by height, was 5.72–8.81 kg/m^2 in men and 4.23–7.36 kg/m^2 in women measured by DXA.[2–6,10,11,14,15,22–36] In addition, although the golden standard method of measurement is dual DXA, bioelectrical impedance analysis (BIA) has also been used, as the method is convenient and cost-effective, making it a more desirable and perhaps appropriate method for large-scale population studies. The range of cut-off values for BIA measurements of muscle mass were 7.00–8.87 kg/m^2 in men and 5.75–6.42 kg/m^2 in women, which are smaller ranges as the number of studies are fewer relative to those using DXA.[7,8,12,19,31,37,38]

It is not uncommon to witness these previously established cut-off points applied to various populations and samples in the literature. However, whether these population-specific cut-points should be used for any sample is questionable.

Muscle strength

Loss of muscle strength can lead to a number of major geriatric syndromes in addition to sarcopenia including frailty, mobility impairment and falls.[20,21,39,44] Low muscle strength is an important public health issue, as it has been associated with poor future health outcomes, and some researchers insist that muscle quality and functionality might be more vital within the elderly population.[39,41,44,48,49] Generally, upper extremity strength is measured using hand grip strength,[20,39,50] and knee flexion or extension is used for lower extremity

strength assessments.[37,41] However, leg strength measurements might not be practical for large population studies or in clinical practice, as the equipment can be quite large and inconvenient, and the participants often require practice trials for accurate measurements. Therefore, grip strength is most often used in trials not only for the simplicity, reliability and affordability, but also because grip strength is a valid predictor of physical disability and mobility limitation. Grip strength cut-off points from the literature range from 26.0 to 37.0 kg in men and 18.0 to 21.0 kg in women.[9,13,19–21,31,35,38,39] One study suggested adjusting the cut-off values of grip strength based on body mass index (BMI).[21] Other measures of muscle strength included isokinetic knee extension torque and knee extension strength; however, these are not used as frequently (cut-off values summarized in Table 1).[40,41,48,51]

Physical performance

Among the commonly used available physical performance measures including the Short Physical Performance Battery, usual walking speed, 6-min walk test, timed get-up & go test and the stair climb power test,[52–54] usual walking speed is quick, inexpensive and a reliable measurement of physical function that can be easily implemented in clinical settings.[55] The predictive values of usual walking speed measurements for major health-related outcomes have been well established in the literature.[42,43,55] Determining the cut-off value for walking speed necessary to maintain a healthy, independent lifestyle is very important, which several researchers have investigated (Table 1).

The cut-point of gait speed ranged from 0.65 to 1.22 m/s.[9,19–21,31,38,41–43,45–47,55] Many of the studies found provided the same cut-off value for men and women, which does not take into account the likely height differences between the sexes. Fried *et al.* stratified walking speed by sex and height using the slowest 20% of a 15-ft walk as a cut-point.[21] The cut-points converted into m/s were 0.65 m/s for men ≤173 cm and women ≤159 cm, and 0.76 m/s for men >173 cm and women >159 cm.

Working definition of sarcopenia

The term sarcopenia was originally defined as the age-related loss of muscle mass.[1] Several cut-off points have been used to define sarcopenia based on muscle mass alone. The definition proposed by Baumgartner is the most commonly used definition of sarcopenia based on height-adjusted skeletal muscle mass measured by DXA.[2] Newman suggested a definition with similar cut-off values (7.23 kg/m^2 for men and 5.67 kg/m^2 for women) measured by DXA, defining sarcopenia as those whose muscle mass was in the lowest 20% of the

Table 1 Summary of cut-off values for components of sarcopenia and prevalence of people falling below the suggested cut-off values

Criteria	Country	Measurement and index of muscle mass	Cut-off values Male	Cut-off values Female	Cut-off value criteria	Prevalence Male	Prevalence Female	References
Muscle mass		*DXA*						
	USA	SMI (kg/m²)	7.26	5.45	2 SD below young reference mean	13.5–57.8	23.1–60.0	Baumgartner et al. (1998)[2]
	USA	Total SMI (kg/m²)	6.77	4.51	2 SD below young reference mean	11.3	7.3	Melton et al. (2000)a[3]
	USA	SMI (kg/m²)	7.26	5.45	2 SD below young reference mean	5.3	4.6	Melton et al. (2000)b[3]
	Denmark	LTM/height²	–	5.40	2 SD below young reference mean	–	12.3	Tanko et al. (2002)[4]
	USA	SMI (kg/m²)	7.26	5.45	2 SD below young reference mean	26.8	22.6	Iannuzzi-Sucich et al. (2002)[22]
	France	SMI (kg/m²)	7.26	5.45	2 SD below young reference mean	–	9.5	Rolland et al. (2003)[23]
	USA	SMI (kg/m²)	–	5.45	2 SD below young reference mean	–	23.8	Kenny et al. (2003)[24]
	France	SMI (kg/m²)	–	5.45	2 SD below young reference mean	–	8.9	Gillette-Guyonnet et al. (2003)[14]
	China (Hong Kong)	SMI (kg/m²)	5.72	4.82	2 SD below young reference mean	12.3	7.6	Lau et al. (2005)[25]
	China (Hong Kong)	SMI (kg/m²)	7.4	6.4	2 SD below young reference mean	2.2	2.6	Woo et al. (2009)[26]
	France	SMI (kg/m²)	–	5.45	2 SD below young reference mean	–	6.8	Rolland et al. (2009)[27]
	Korea	SMI (kg/m²)	7.40	5.14	2 SD below young reference mean	6.3	4.1	Kim et al. (2009)a[10]
	Canada	SMI (kg/m²)	8.51	6.29	2 SD below young reference mean	38.9	17.7	Bouchard et al. (2009)[28]
	Korea	SMI (kg/m²)	6.58	4.59	2 SD below young reference mean	6.3	4.1	Kim et al. (2010)[29]
	Japan	SMI (kg/m²)	6.87	5.46	2 SD below young reference mean	1.7	2.7	Sanada et al. (2010)[5]
	Japan	SMI (kg/m²)	6.58	4.59	2 SD below young reference mean	12.4	0.1	Kim et al. (2012)a[15]
	Brazil	SMI (kg/m²)	–	5.5	2 SD below young reference mean	–	3.7	Domiciano et al. (2013)a[30]
	Brazil	SMI (kg/m²)	7.26	5.40	2 SD below young reference mean	13.5	–	Figueiredo et al. (2014)a[11]
	Asian Consensus	SMI (kg/m²)	7.00	5.40	AWGS recommendation	–	–	Chen et al. (2014)[31]
	China	SMI (kg/m²)	5.85	4.23	2 SD below young reference mean	0.0	17.9	Wen et al. (2011)a[32]
	USA	aLM/height² (kg/m²)	7.23	5.67	Sex-specific lowest 20% of the distribution	0.0–50.4	0.0–51.9	Newman et al. (2003)a[6]
	USA	aLM/height² (kg/m²)	7.25	5.67	Sex-specific lowest 20% of the distribution	20.3	20.2	Delmonico et al. (2007)a[33]
	Italy	SMI (kg/m²)	–	5.70	Lowest 2 quintiles in recruited cohort	–	27.2	Zoico et al. (2004)[34]
	Korea	SMI (kg/m²)	8.81	7.36	Lowest 2 quintiles in recruited cohort	54.4	40.5	Kim et al. (2009)b[10]
	USA	Residuals method	–2.29	–1.73	Sex-specific lowest 20% of the distribution	11.5–32.8	14.4–23.0	Newman et al. (2003)b[6]
	USA	Residuals method	–	–	20th percentile of distribution of residuals	20.2	20.3	Delmonico et al. (2007)b[33]
	Korea	Residuals method	–1.87	–1.62	Sex-specific cut-off points of lower 20% of residuals	15.4	22.3	Kim et al. (2009)c[10]
	China	Residuals method	–	–	20th percentile of distribution of residuals	33.3	25.6	Wen et al. (2011)b[32]
	Brazil	ASM adjusted for fat mass and height	–	–1.45	20th percentile of distribution of residuals	–	19.9	Domiciano et al. (2013)b[30]
	Brazil	ASM adjusted for total fat mass	–2.06	–	20th percentile of distribution of residuals	19.8	–	Figueiredo et al. (2014)b[11]
	The Netherlands	ASM (kg)	loss >3%		Lowest 15% during 3-year follow up,		15.7	Visser et al. (2003)[35]
		BIA						
	Japan	(ASM/weight) × 100 (%)	29.1	23.0	2 SD below young reference mean	9.7	11.8	Kim et al. (2012)b[15]
	Korea	(ASM/weight) × 100 (%)	29.1	23.0	2 SD below young reference mean	12.1	11.9	Ryu et al. (2013)[36]
	USA	% SMI (muscle mass/body mass × 100)	31.5	22.1	2 SD below young reference mean	7.0	10.0	Janssen et al. (2002)[7]
	USA	SMI (kg/m²)	8.50	5.75	SMI below likelihood ratio for positive result	–	–	Janssen et al. (2004)[12]
	Taiwan	SMI (kg/m²)	8.87	6.42	2 SD below young reference mean	23.6	18.6	Chien et al. (2008)[8]
	Japan	SMI (kg/m²)	7.00	5.80	2 SD below mean young adult values	–	–	Tanimoto et al. (2012)[19]
	Japan	SMI (kg/m²)	6.42	6.42	Based on Chien's cut-off value	–	–	Kim et al. (2012)[37]
	Japan	SMI (kg/m²)	6.75	5.07	2 SD below young reference mean	21.1–75.0	24.5–71.4	Yamada et al. (2013)[38]
	Asian Consensus	SMI (kg/m²)	7.00	5.70	AWGS recommendation	–	–	Chen et al. (2014)[31]

	Country	Method of measurement	Cut-off value		Method / description	Prevalence		Reference
Muscle strength	USA	Grip strength (kg)	29.0–32.0	17.0–21.0	Frailty definition, stratified by BMI quartiles	–		Fried et al. (2001)[21]
	Italy	Grip strength (kg)	30.3	19.3	ROC curve identifying walking disability (speed <0.8 m/s)	–		Lauretani et al. (2003)a[20]
	The Netherlands	Grip strength (kg)	loss >40.0%		Lowest 15% during 3-year follow up	13.5		Visser et al. (2003)[35]
	European Consensus	Grip strength (kg)	30.0	20.0	EWGSOP recommendation based on Lauretani cut-off	–		Cruz-Jentoft et al. (2010)[9]
	Finland	Grip strength (kg)	37.0	21.0	Risk of mobility limitation	–		Sallinen et al. (2010)[39]
	Japan	Grip strength (kg)	30.3	19.3	The lowest quartile	–		Tanimoto et al. (2012)[19]
	Taiwan	Grip strength (kg)	22.4	14.3	Modified EWGSOP definition for Taiwanese population	–		Lee et al. (2013)[13]
	Japan	Grip strength (kg)	30.0	20.0	EWGSOP recommendation	31.9		Yamada et al. (2013)[38]
	Asian Consensus	Grip strength (kg)	26.0	18.0	AWGS suggestion for low hand grip strength	–		Chen et al. (2014)[31]
	USA	Knee extension torque (Nm/kg m^{-1})		2.5	Maximal voluntary muscle torque threshold	–		Cress et al. (2003)[40]
	Italy	Knee extension torque (N/dm)	390.9	266.4	ROC curve identifying walking disability (speed <0.8 m/s)	–		Lauretani (2003)b[20]
	USA	Knee extension strength (Nm/kg)	1.13	1.01	Deciles with high risk of mobility limitation	29.7	9.8	Manini et al. (2007)[41]
	Japan	Knee extension strength (Nm/kg)	–	1.01	Based on Manini's cut-off value	–		Kim et al. (2012)[37]
Gait speed	USA	Usual walking speed (m/s)	1.22		Speed allotted to cross signaled intersection	99.5		Langlois et al. (1997)[42]
	USA	Usual walking speed (m/s)	1.20		Future functional disability	77.9		Brach et al. (2001)[43]
	USA	Walking speed (m/s)	0.65 or 0.76‡		Slowest 20% of 15-ft walk	–		Fried et al. (2001)[21]
	Italy	Walking speed (m/s)	0.80		4-m course, ROC curve identifying walking disability	–		Lauretani et al. (2003)[20]
	USA	Usual walking speed (m/s)	1.00		Onset of persistent lower extremity limitation	24.0		Cesari et al. (2005)[55]
	USA	Walking speed (m/s)	0.98 or 1.06‡		6-m course. Based on Fried (2001) criteria	–	19.7	Cawthon et al. (2007)[45]
	USA	Usual walking speed (m/s)	1.22		Speed allotted to cross signaled intersection	38.5		Manini et al. (2007)[41]
	France	Gait velocity (m/s)	0.80		Based on systematic review	–		Abellan van Kan et al. (2009)[46]
	European Consensus	Gait velocity (m/s)	0.80		EWGSOP recommendation based on Lauretani cut-off	–		Cruz-Jentoft et al. (2010)[9]
	Japan	Walking speed (m/s)	1.27	1.19	The lowest quartile	–		Tanimoto et al. (2012)[19]
	Japan	Walking speed (m/s)	0.80		EWGSOP recommendation	4.1		Yamada et al. (2013)[38]
	Asian Consensus	Usual walking speed	0.80		6-m course, AWGS recommendation	–	3.8	Chen et al. (2014)[31]
	England	Usual walking speed (m/s)	0.78	0.72	3-m course, self-reported walking speed	5.0		Syddall et al. (2015)[47]

References with several methods and cut-off points within the same criteria have been differentiated using "a,b,c". †0.65 m/s for men ≤159 cm and women >159 cm; 0.76 m/s for men >173 cm and women >173 cm. ‡0.98 m/s for men ≤174 cm and 1.06 m/s for men >174 cm. aLM, appendicular lean mass. AWGS, Asian working group on sarcopenia; BIA, bioelectrical impedance analysis; DXA, dual-energy x-ray absorptiometry; EWGSOP, European Working Group on Sarcopenia in Older People; LTM$_A$, age- and menopause-related variations in appendicular lean tissue; ROC, receiver operating characteristic; SD, standard deviation; SMI, skeletal muscle index.

distribution.[6] Sanada *et al.* reported cut-off values for an Asian sample using Baumgartner's suggested method, two standard deviations below the sex-specific mean of a young population, 6.87 kg/m² in Japanese men and 5.46 kg/m² in women measured by DXA.[5]

In 2000, Janssen developed and published predictive equations for estimating skeletal muscle mass using BIA,[56] which has since been referred to by many researchers using BIA to define sarcopenia.[8,19,37,57] Janssen *et al.* used the common definition for sarcopenia (i.e. two standard deviations below the sex-specific mean for young adults), measured by BIA, where the muscle mass cut-off points were 8.50 kg/m² in men and 5.75 kg/m² in women.[12] Chien *et al.* reported muscle mass cut-off values of 8.87 kg/m² for men and 6.42 kg/m² for women in Taiwanese older adults.[8]

In 2010, the EWGSOP developed a practical clinical definition and consensus diagnostic criteria for age-related sarcopenia combining muscle mass, strength and physical performance.[9] As Manini and Clark summarized, muscle mass alone was not associated with mortality, and muscle strength is a crucial factor in the determination of physical disability and mortality.[58] The combined definition, which includes muscle mass and strength, as well as performance, might be more relevant for investigating the effects of sarcopenia on older adults. Based on the EWGSOP algorithm, walking speed below or equaling 0.8 m/s would be the first step in screening sarcopenic people. Followed by measures of muscle strength and muscle mass.

After the publication of the EWGSOP definition of sarcopenia in 2010, many investigators have applied this definition, even within trials studying populations of different ethnicities. Chen *et al.* summarized the Asian Working Group for Sarcopenia (AWGS), as Asian populations differ from Caucasians in ethnicity, adiposity, size and lifestyle, and the use of previous definitions obtained from varying ethnicities can be inappropriate.[31] The authors reported that a cohort effect might be observed in the use of a cut-off point derived from a young Asian population, as younger people lead a more Westernized lifestyle compared with the older generation, who most likely would have lived a more traditional lifestyle. Regardless, the AWGS recommended the traditionally used two standard deviations below the mean muscle mass of a young reference group or the lowest quintile for cut-off determination. The recommended cut-off value for height-adjusted skeletal muscle were 7.0 kg/m² in men and 5.4 kg/m² in women using DXA, and 7.0 kg/m² in men and 5.7 kg/m² in women measured by BIA.[31] Chen *et al.* specifically suggested the use of height-adjusted skeletal muscle mass, although research has shown that this method of measurement can underestimate the prevalence sarcopenia in Korean and Chinese populations.[15,32] The AWGS definition of sarcopenia further suggested low handgrip strength (<26 kg for men and <18 kg for women) in addition to muscle mass to screen for sarcopenia. A walking speed of ≤0.8 m/s was recommended as the cut-off for low physical performance in Asian people. Researchers should be aware and careful of the use of previous cut-off points, as they could have an effect on the prevalence rates of sarcopenia, as well as possible risk factors.

Risk factors of sarcopenia components

Muscle mass

Investigation into the risk factors and associated factors of muscle mass decline has been ongoing for several decades. Many of the risk factors assessed for declines in muscle mass, summarized in Table 2, include chronic conditions, such as diabetes, heart disease and hyperlipidemia; arterial stiffness, malnutrition and hematological factors.[57,59,60] Several hematological components have been linked to the loss of muscle mass, such as high creatinine, and high albumin concentration had protective effects.[57,61] BMI and inflammation have also been significantly associated with muscle mass loss.[57,75]

Muscle strength

Factors associated with muscle strength loss have also been investigated. Similar to muscle mass, the literature describes hematological factors including total free-testosterone, insulin-like growth factor-1, high parathyroid hormone, hemoglobin, low 25-hydroxy vitamin D and low serum albumin to be linked to grip strength decline in longitudinal studies.[35,62,63] One study by Stenholm *et al.* found that high concentrations of interleukin-6 and interleukin-1RA, and low levels of dehydroepiandrosterone sulfate were predictors of muscle strength loss over 22 years.[66]

Muscle strength loss has been associated with many chronic conditions and lifestyle factors, such as back pain, diabetes, cardiovascular disease, chronic kidney disease, hypertension, asthma, cognitive function, use of calcium channel blockers, caffeine intake, excess bodyweight, stress and smoking.[57,64,65,67,68,76]

Walking ability

Detailed study into hematological factors linked to declines in walking ability are more limited, and although walking speed decline has been studied extensively, few studies exist that have investigated blood component risk factors. In a recent letter to the editor of the *Journal of the American Geriatrics Society*, Onuoha outlined that red blood cell indices (red blood cell count, hematocrit, white blood cell count) were associated with gait rhythm, but not speed.[77] The author suggested that hematological mechanisms might cause disturbances in

Table 2 Summary of risk factors associated with sarcopenia components

Study design and Participants	Factors	Main results	References
Muscle mass			
Cross-sectional, 142 people aged 70 years and older	Diabetes, malnutrition, inflammation	The presence of diabetes mellitus was the strongest predictor of lean body mass loss (B = −2.302, $P < 0.001$). Malnutrition (B = 1.265, $P = 0.027$) and inflammation (B = −1.321, $P = 0.022$) were also significantly associated with lean body mass loss.	Pupim et al. (2005)[59]
Cross-sectional, 175 people aged 65 years or older	CAVI	Higher CAVI was significantly associated with low SMI (OR1.82, 95% CI 1.14–2.90).	Sampaio et al. (2014)[60]
Longitudinal (4 years), 3026 people aged 70–79 years	Serum creatinine	High serum creatinine was associated with loss of lean mass in men, but not women.	Fried et al. (2007)[61]
Longitudinal (4 years), 538 women aged 75 years or older	Age, BMI, calf circumference, albumin, heart disease, hyperlipidemia	Older age and BMI lower than 21 kg/m2 predicted muscle mass decline. High albumin had protective effects for SMI decline (OR 0.90, 95% CI 0.82–0.98). History of heart disease (OR 2.05, 95% CI 1.19–3.55) and hyperlipidemia (OR 1.74, 95% CI 1.10–2.77) were significant risk factors for decrease in SMI.	Kim et al. (2015)[57]
Muscle strength (Grip strength)			
Cross-sectional, 121 men and 180 women aged 65–97 years	Physical activity, IGF1, total free-testosterone	Grip strength had significant positive associations with physical activity, IGF1 and free-testosterone in men; and IGF1 in women.	Baumgartner et al. (1999)[62]
Longitudinal (3 years), 331 people aged 65 years or older at baseline	PTH, 25-hydroxy vitamin D	Low 25-OHD was associated with loss of strength (OR 2.57, 95% CI 1.4–4.7). Those with high PTH levels were 1.71-fold (95% CI 1.07–2.73) more likely to experience grip strength loss.	Visser et al. (2003)[35]
Longitudinal (3 and 6 years), 676 women and 644 men aged 65–88 years	Serum albumin	Low serum albumin was associated with grip strength decline over 3 years in men ($\beta = 0.57$, SE = 0.18) and women ($\beta = 0.37$, SE = 0.16). Weaker associations found over 6 years.	Schalk et al. (2005)[63]
Longitudinal (7 years), 321 men aged 51–84 years	Age, back pain, use of calcium channel blockers, caffeine intake, height, weight loss	Multivariate analysis showed that greater grip strength at baseline, higher lifetime caffeine intake, use of calcium channel blocker (OR 2.37, 95% CI 1.17–4.17), older age, height loss and back pain were associated with grip strength loss.	Forrest et al. (2005)[64]
Longitudinal (25 years), 3522 people aged 71–93 years at follow up	Age, glucose, cognitive function, BMI, hemoglobin	Handgrip strength was inversely associated with age and glucose. Cognitive function, BMI and hemoglobin levels were directly associated with strength.	Charles et al. (2006)[65]
Longitudinal (22 years), 716 people aged 65 years and older	IL-6, IL-1RA, DHEA-S	High concentrations of IL-6 and IL-1RA, and low levels of DHEA-S predicted muscle strength decline.	Stenholm et al. (2010)[66]
Longitudinal (22 years), 963 people aged 30–73 years at baseline	Excess body weight, smoking, CVD, hypertension, diabetes, asthma, weight loss	Over-weight/obese persons and current and former smokers had greater decline in handgrip strength as well as those with hypertension, diabetes and asthma. People who lost more than 10% of weight during follow-up had greater handgrip declines.	Stenholm et al. (2012)[67]
Longitudinal (22 years), 849 men and women aged 50–88 years at baseline	Stress, smoking, dementia, marital status, mean arterial pressure, physical activity at work, chronic disorders	Significant factors for women were stress, smoking and dementia. For men, factors associated with grip strength decline were marital status, mean arterial pressure, physical activity at work, and having a chronic disorder.	Sternang et al. (2015)[68]
Longitudinal (4 years), 538 women aged 75 years or older	Age, BMI, BMD, calf circumference, regular exercise habit	Age and low BMI were risk factors for muscle strength decline. Calf circumference (OR 0.65, 95% CI 0.52–0.83) had protective effects for strength. Greater BMD (OR 0.40, 95% CI 0.17–0.91) and regular exercise (OR 0.30, 95% CI 0.12–0.72) also had protective effects for grip strength declines.	Kim et al. (2015)[57]
Walking speed			
Cross-sectional, 1002 women aged 65 years and older (of which 129 women had severe walking disability)	Strength, balance	Greater knee extension strength (OR 0.91, 95% CI 0.86–0.97) and balance (OR 0.48, 95% CI 0.37–0.62) had protective effects for severe walking disability.	Rantanen et al. (1999)[51]
Cross-sectional, 3075 people aged 70–79 years	Cystatin C	Increase in cystatin C concentration was associated with 1.32 odds (95% CI 1.20–1.46) of walking difficulty (slow walking speed, not completing 400-m walk).	Odden et al. (2006)[69]
Cross-sectional and longitudinal (2.3 years), 333 people aged 70 years and older	IL-6	High IL-6 levels were associated with slow walking speed (estimate −4.90 cm/s, $P = 0.008$). Older adults in highest IL-6 quartile had a 1.75 cm/s/year faster decline in walking speed.	Verghese et al. (2011)[70]
Longitudinal (22 years), 840 people aged 32–72 years, with no walking ability at baseline	BMI, handgrip strength, physical function	Walking limitation after 22 years was significantly associated with BMI (OR 1.39, 95% CI 1.10–1.75) and grip strength (OR 0.56, 95% CI 0.38–0.81), as well as major difficulties with running and squatting.	Stenholm et al. (2007)[71]
Longitudinal (5 years), 909 people mean age 75.2 ± 2.8 years	Global function, verbal memory, memory, executive function	Poor performance in global function, verbal memory, and executive function was associated with walking speed declines.	Watson et al. (2010)[72]
Longitudinal (3 years), 434 women aged 63–76 years at baseline and after 3-year follow up	Fear of falling, sensory difficulties, CVD, diabetes, rheumatoid arthritis	OR for incident walking difficulty was 3.5 (95% CI 1.6–7.8) in those with fear of falls. Chronic conditions like CVD, diabetes and arthritis were also significant predictors of walking difficulty.	Viljanen et al. (2012)[73]
Longitudinal (mean follow up 6.6 years), 1226 older than 60 years and free of mobility disability at baseline	Chronic kidney disease (using cystatin C-based estimated glomerular filtration rate	Those with chronic kidney disease determined by cystatin C had greater odds of mobility disability (OR 1.55, 95% CI 1.05–2.31).	Liu et al. (2014)[74]
Longitudinal (4 years), 538 women aged 75 years or older	Age, BMI, BMD, calf circumference, TUG, albumin, HDL cholesterol, cystatin C, knee pain	Age and low BMI were predictive of walking speed decline. Longer TUG (OR 1.28, 95% CI 1.12–1.48) high HDL cholesterol (OR 1.01, 95% CI 1.00–1.03), cystatin c levels (OR 1.34, 95% CI 1.03–1.74), and knee pain (OR 1.73, 95% CI 1.08–2.76), were risk factors for walking speed decline. Greater BMD and albumin had protective effects.	Kim et al. (2015)[57]

25-OHD, 25-hydroxy vitamin D; BMD, bone mineral density; BMI, body mass index; CAVI, cardio-ankle vascular index; CI, confidence interval; CVD, cardiovascular disease; DHEA-S, dehydropiandrosterone sulfate; HDL, high-density lipoprotein; IGF, insulin-like growth factor; IL-1RA, interleukin-1 receptor antagonist; IL-6, interleukin-6; OR, odds ratio; PTH, parathyroid hormone; SE, standard error; SMI, skeletal muscle index; TUG, timed up & go.

separate aspects of gait, but not overall gait performance. Some studies have shown that kidney function, specifically the increase in cystatin C, was associated with increased risk of mobility disability.[57,69,74] Interleukin-6 was also associated with walking ability, being one of the hematological factors associated across all the components of sarcopenia.[70]

Reports have found that walking speed declines are associated with strength, balance, fear of falling, sensory difficulties, cardiovascular disease, diabetes, rheumatoid arthritis, global function, verbal memory and executive function (Table 2).[51,57,71–73]

Risk factors of sarcopenia

Sarcopenia is a systemic condition, and as such, the risk factors reported vary greatly. Age and BMI are evident risk factors for sarcopenia. Landi *et al.* found that sarcopenia was more likely seen in men,[78] whereas Yu *et al.* reported that the female sex was a risk factor for sarcopenia (Table 3).[83] Perhaps the difference in ethnicity between the populations might explain the conflicting results. Greater calf circumference has been reported to be protective against sarcopenia, whereas slow timed up & go test was associated with sarcopenia development longitudinally.[57] One investigation showed that higher education increased the likelihood of sarcopenia.[84] Chewing ability has also been reported to be associated with sarcopenia defined by the AWGS definition.[85] Murakami *et al.* state that while relationships between muscle strength, physical function and chewing ability have been reported previously, the association between muscle mass and chewing ability had not, and further suggested that the changes in general muscle mass and muscle mass related to chewing ability might have been the reason for the notable relationship between chewing ability in the study.[85] More detailed investigation into the causal relationship between sarcopenia and chewing-related muscle function decline are required.

Researchers have sought to identify blood biomarkers for sarcopenia. Currently in the literature, the associated hematological factors include low 25-hydroxy-vitamin D, insulin-like growth factor 1, albumin and testosterone, as well as high gamma-glutamyl transferase and cystatin C (Table 3).[22,35,57,62,79–81,84,86]

Several chronic conditions and lifestyle factors have also been associated with sarcopenia. As summarized in Table 3, older adults with high blood pressure, instrumental activities of daily living impairment, chronic obstructive pulmonary disease, chronic kidney disease, hyperlipidemia, osteoporosis and stroke are at risk for sarcopenia.[57,80,82,83,87] Furthermore, BMI, pain, being overweight, lacking exercise (sedentariness), and high fat and protein intake also increase the likelihood of being sarcopenic.[80,88]

Comparison of sarcopenia prevalence and risk factors associated with sarcopenia based on different suggested definitions

The literature is inconsistent in the application of sarcopenia definitions using previously established muscle mass cut-off points or the EWGSOP definition, which combines muscle mass, strength and physical performance. Some studies have examined the differences in prevalence rates using different sarcopenia definitions; however, there are few studies, if any, that investigate both sarcopenia prevalence and associated risk factors with differing definitions in a sample population.[3,10,11,15,30,32,33]

The prevalence of sarcopenia was determined in a sample of 1464 community-dwelling Japanese elderly men ($n = 246$) and women ($n = 1218$, mean age men 74.3 ± 5.17 years; women 79.9 ± 4.43 years) using each definition described in the previous section (Table 4). The data analyzed in the present review was obtained using protocol that has been approved by the Tokyo Metropolitan Institute of Gerontology Ethics Committee, and all participants gave informed consent. As seen in Table 4, sarcopenia prevalence in this sample varied greatly depending on the definition used. Within the DXA-measured definitions, the prevalence ranged from 2.5 to 28.0% in men and 2.3 to 11.7% in women, which is not unlike previously reported prevalence values.

The BIA-measured definitions, however, resulted in sarcopenia prevalence ranging from 7.1 to 98.0% in men and 19.8 to 88.0% in women. These largely wide ranges within the same population are problematic, as it brings into question the results of the existing studies, and the sarcopenia prevalence we understand as a research community. In the existing literature, some studies refer to these previously established definitions of sarcopenia without providing reasoning beyond its common use. Ideally, each trial should determine population-specific cut-off points; however, this would be very expensive and impractical. Large population-based studies are required for Japanese people to establish appropriate cut-off values for Japanese older adults. The seemingly arbitrary use of published cut-off values can affect the resulting prevalence rates of sarcopenia and associated factors.

We investigated the risk factors of sarcopenia in the same Japanese community-dwelling population using multiple step-wise logistic regressions. Table 5 shows that the risk factors associated with sarcopenia varied depending on the definition for sarcopenia assessment used.

BMI was predominantly associated with sarcopenia in men and women across most definitions, where greater BMI was inversely associated with the likelihood of

Table 3 Summary of risk factors associated with sarcopenia

Study design and Participants	Factors	Main results	References
Cross-sectional study			
Cross-sectional, 121 men and 180 women aged 65–97 years	Serum free-testosterone, physical activity, CVD, IGF1, fat mass	Muscle mass had significant positive associations with physical activity, IGF1 and free testosterone in men; and total fat mass and energy intake in women.	Baumgartner et al. (1999)[62]
Cross-sectional, 195 women aged 64–93 years and 142 men aged 64–92 years	BMI, serum estrone, estradiol, 25-hydroxy vitamin D, physical performance	Serum estrone, estradiol, and Physical Performance Test total score were significantly correlated with ASM/Ht^2. 25-OHD was inversely related to muscle mass.	Iannuzzi-Sucich (2002)[22]
Longitudinal (3 years), 331 people aged 65 years or older at baseline	PTH, 25-hydroxy vitamin D	Low 25-OHD was significantly associated with ASM loss (OR 2.25, 95% CI 1.11–4.56) Those with high PTH levels were 2.35 times (05% CI 1.05–5.28) more likely to have ASM loss.	Visser et al. (2003)[35]
Longitudinal (5 years), 1882 men and women aged 70–79 years	Albumin concentration	Lower albumin concentrations are associated with future loss of ASM and is a risk factor for sarcopenia.	Visser et al. (2005)[79]
262 community-dwelling men and 265 women aged over 70 years	BMI	BMI < 18.5 was a significant risk factor for sarcopenia in men (OR 39.1, 95% CI 11.3–134.6) and women (OR 9.7, 95% CI 2.8–33.8).	Lau et al. (2005)[25]
13 770 men and women aged over 20 years	Age; overweight; lack of exercise; low carbohydrate, fat, and protein intake; hyperglycemia; low 25- OHD3; high diastolic BP; insulin resistance	Prevalence of sarcopenia rose with declining kidney function. Older age; low income-to-poverty ratio; overweight; lack of exercise; low carbohydrate, fat and protein intake; hyper-calcemia; low 25-OHD3; higher diastolic BP; and insulin resistance were factors associated with sarcopenia for subjects with glomerular filtration rate <60 mL/min/1.73 m^2 or a urinary albumin-to-creatine ratio >30 mg/g.	Foley et al. (2007)[80]
1380 men and 1789 women aged 50 years or older, community-dwelling people	Vitamin D	The highest quartile (≥24.1), OR 0.47 (95% CI 0.30–0.73), strong inverse association between 25-OHD level and sarcopenia.	Kim et al. (2011)[81]
313 women (mean age 79.7 ± 7.4 years)	Osteoporosis	Sarcopenia was significantly associated with osteoporosis (OR 1.8, 95% CI 1.07–3.02).	Di Monaco et al. (2011)[82]
122 people aged 70 years and older living in nursing homes	Male sex, cerebrovascular disease, osteoarthritis, BMI	High risk of sarcopenia was seen in men (OR 13.39, 95% CI 3.51–50.63), those with cerebrovascular disease (OR 5.16, 95% CI 1.03–25.87), osteoarthritis (OR 7.24, 95% CI 2.02–25.95). High BMI had protective effects.	Landi et al. (2012)[78]
4000 community-dwelling Chinese men and women over 65 years or older	Age, stroke, physical activity, IADL impairments, BMI, female sex, COPD	Stroke OR 2.56 (95% CI 1.32–4.95); IADL impairment OR 2.12 (95% CI 1.49–3.02); COPD OR 1.84 (95% CI 1.02–3.31); physical activity and BMI had protective effects. Protein and vitamin D not associated with sarcopenia incidence.	Yu et al. (2014)[83]
730 participants 74% aged 65 years and older (age range 27–97 years)	Education, IGF-1, testosterone	Higher education (OR 0.85; 95% CI 0.74–0.98), low IGF-1 (lowest tertile: OR 3.89; 95% CI 1.03–14.1), low bioavailable testosterone (OR 2.67; 95% CI 1.31–5.44) were associated with the likelihood of being sarcopenic.	Volpato et al. (2014)[84]
761 community-dwelling people aged 65–85 years	Age, BMI, chewing ability	Sarcopenia was significantly associated with age (OR 2.37, 95% CI 1.52–3.70), BMI (OR 0.75, 95% CI 0.69–0.81) and chewing ability (OR 2.18, 95% CI 1.21–3.93).	Murakami et al. (In Press)[85]
3193 community-dwelling people aged ≥50 years	Gamma-glutamyl transferase	Overall, OR 1.35 (95% CI 1.15–1.58), elevated serum GGT activity was independently associated with sarcopenia.	Hong et al. (2015)[86]
11 625 community-dwelling people aged 40 years or older,	Chronic kidney disease	CKD 3–5, OR 1.93 (95% CI 1.02–3.68) in men, stage of CKD was associated with an increased prevalence of sarcopenia in men, but not women.	Moon et al. (2015)[87]
Longitudinal study			
2928 people aged 70–79 years at baseline (9 years follow up)	Age, pain, BMI	Increasing age (OR 1.12, 95% CI 0.80–1.18, $P < 0.001$), history of pain (OR 1.18, 95% CI 1.01–1.39) and higher BMI (OR 1.30, 95% CI 1.25–1.36) were predictive of transition from normal state into sarcopenic state.	Murphy et al. (2014)[88]
538 community-dwelling women aged >75 years (4 years follow up)	Age, BMI, calf circumference, TUG, hyperlipidemia, cystatin C	Low BMI and slow TUG were significantly associated with sarcopenia development. Cystatin C was significantly associated with severe sarcopenia (OR = 1.83, 95%CI = 1.08–3.12).	Kim et al. (2015)[57]

25-OHD, 25-hydroxy vitamin D; ASM, appendicular skeletal muscle mass; BMI, body mass index; BP, blood pressure; CI, confidence interval; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; GGT, gamma-glutamyl transferase; Ht, height; IADL, instrumental activities of daily living; IGF, insulin-like growth factor; OR, odds ratio; PTH, parathyroid hormone; TUG, timed up & go.

Table 4 Sarcopenia prevalence based on different suggested definitions in Japanese community-dwelling older adults

Reference study	SMI measurement	Cut-off values SMI Male	Female	Muscle strength Male	Female	Walking speed Male	Female	Prevalence Male	Female
Baumgartner *et al.* (1998)[2]	DXA	7.26	5.45	–	–	–	–	28.0	5.7
Newman *et al.* (2003)[6]	DXA	7.23	5.67	–	–	–	–	25.6	11.7
Sanada *et al.* (2010)[5]	DXA	6.87	5.46	–	–	–	–	11.0	6.3
EWGSOP (2010)[9]	DXA	7.26	5.45	30.0	20.0	0.8	0.8	13.2	3.2
AWGS (2014)[31]	DXA	7.00	5.40	26.0	18.0	0.8	0.8	2.5	2.3
Janssen *et al.* (2004)[12]	BIA	8.50	5.75	–	–	–	–	95.1	57.3
Chien *et al.* (2008)[8]	BIA	8.87	6.42	–	–	–	–	98.0	88.0
EWGSOP (2010)[9]	BIA	8.87	6.42	30.0	20.0	0.8	0.8	24.2	39.0
AWGS (2014)[31]	BIA	7.00	5.70	26.0	18.0	0.8	0.8	7.1	19.8

AWGS, Asian Working Group for Sarcopenia; BIA, bioelectrical impedance analysis; DXA, dual-energy X-ray absorptiometry; EWGSOP, European Working Group on Sarcopenia in Older People; SMI, skeletal muscle index (appendicular muscle mass/height^2).

Table 5 Risk factors (odds ratios and 95% confidence intervals) associated with sarcopenia based on differing definitions

Reference definition for sarcopenia	Risk factors Male	Female
DXA		
Baumgartner *et al.* (1998)[2]	BMI: 0.60 (0.48–0.75) TG: 1.01 (1.0–1.01) HbA1c: 3.34 (1.26–8.82)	BMI: 0.45 (0.35–0.57) Knee OA: 3.89 (1.27–11.91)
Newman *et al.* (2003)[6]	BMI: 0.65 (0.53–0.80) HbA1c: 2.04 (0.96–4.31)	BMI: 0.51 (0.43–0.60) TG: 1.01 (1.00–1.01)
Sanada *et al.* (2010)[5]	BMI: 0.52 (0.37–0.72) TG: 1.01 (1.00–1.01)	BMI: 0.52 (0.43–0.63)
EWGSOP (2010)[9]	BMI: 0.79 (0.66–0.94) HbA1c: 1.84 (0.96–3.52)	BMI: 0.48 (0.36–0.63) HDL-C: 0.95 (0.92–0.99) Falls: 3.84 (1.00–14.73)
AWGS (2014)[31]	BMI: 0.40 (0.21–0.78) HDL-C: 0.90 (0.82–0.99) Falls: 3.90 (2.82–5.40)	BMI: 0.56 (0.43–0.73) Falls: 5.05 (1.26–20.28)
BIA		
Janssen *et al.* (2004)[12]	BMI: 0.58 (0.37–0.90)	BMI: 0.66 (0.61–0.71) Creatinine: 4.36 (1.46–13.01)
Chien *et al.* (2008)[8]	–	BMI: 0.60 (0.53–0.68) Diabetes: 3.68 (1.53–8.84)
EWGSOP (2010)[9]	BMI: 0.87 (0.76–1.00) Diabetes: 2.99 (0.99–9.03)	BMI: 0.91 (0.87–0.96) Falls: 2.78 (1.71–4.50) Albumin: 0.31 (0.16–0.60)
AWGS (2014)[31]	Falls: 6.0 (1.81–19.99) Hypertension: 3.37 (1.02–11.14)	BMI: 0.79 (0.74–0.85) Falls: 2.21 (1.33–3.68) Albumin: 0.28 (0.13–0.61) Hyperlipidemia: 1.52 (1.00–2.30)

AWGS, Asian Working Group on Sarcopenia; BIA, bioelectrical impedance analysis; BMI, body mass index; DXA, dual-energy X-ray absorptiometry, EWGSOP, European working group on sarcopenia in older people, TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; OA, osteoarthritis.

sarcopenia (Table 5). In men, high glycated hemoglobin level was a significant risk factor for sarcopenia using the Baumgartner (OR 3.34, 95% CI 1.26–8.82) definition. High high-density lipoprotein cholesterol (OR 0.90, 95% CI 0.82–0.99) was protective from sarcopenia in Japanese men according to the AWGS definition using DXA. The chronic conditions associated with sarcopenia in men based on AWGS were falls (DXA: OR 3.90, 95% CI 2.82–5.40; BIA: OR 6.0, 95% CI 1.81–19.99) and hypertension (OR 3.37, 95% CI 1.02–11.14).

Based on the EWGSOP and AWGS definitions of sarcopenia using both DXA and BIA, falls were a significant risk factor for sarcopenia in women (Table 5). Similarly, high albumin levels had protective effects in the EWGSOP (OR 0.31, 95% CI 0.16–0.60) and AWGS (OR 0.28, 95% CI 0.13–0.61) definitions, although only using BIA. Other risk factors for sarcopenia in women included knee OA, TG levels, high-density lipoprotein cholesterol, creatinine, diabetes and hyperlipidemia.

The results presented in Table 5 show disparities in risk factors of sarcopenia vary greatly depending on the definition used to define sarcopenia in the same sample population. BMI was the only factor associated with sarcopenia across all definitions within the Japanese population studied, and a predominant risk factor for sarcopenia in previous studies (Table 5). Herein lies the problem with the many available definitions currently used in the literature. Without a clear consensus, the risk factors of sarcopenia differ, not only with varying definitions, but also with methods of measurement; that is, DXA or BIA. The discrepancies in prevalences and associated factors of sarcopenia in the existing literature can negatively affect the understanding of sarcopenia within the research community.

Conclusion

In summary, the inconsistencies in sarcopenia definitions, cut-off values and risk factors are apparent within the literature. Ideally, cut-off values should detect people with risk factors, and using cut-off values obtained from a vastly different population should be avoided. The application of the different sarcopenia definitions further shows that sarcopenia prevalence and risk factors vary greatly depending on the definition. Further studies and discussions are necessary in order to confirm the discrepancies in prevalence and particular risk factors, and develop a consensus definition or cut-off points for sarcopenia in Japanese older adults.

Disclosure statement

The authors declare no conflict of interest.

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