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Published in:
Maturitas

DOI:
10.1016/j.maturitas.2015.08.006

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1. INTRODUCTION

Sarcopenia is a geriatric syndrome associated with ageing that is characterised by a progressive loss of skeletal muscle mass and muscle function.[1] It is known to increase the risk of disability, falls and falls-related injuries, loss of independence, hospitalisation, and mortality [2-5].

In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) recommended that both low muscle mass and low muscle function (muscle strength or physical performance) must be present for an individual to be diagnosed with sarcopenia.[1] Recently, the International Sarcopenia Initiative confirmed the applicability of the EWGSOP measurement tools for varied populations and highlighted a shortcoming in research looking at prevalence and risk factors among populations that are highly vulnerable to sarcopenia, such as within an acute or institutional setting.[6]

Until the development of a consensus definition and measures, the prevalence of sarcopenia has varied widely from 7% to over 50% in middle to old aged adults.[7] A review of studies employing the EWGSOP criteria has shown prevalence to be from 1% to 29% in community living adults, and 14% to 33% among Dutch and Italian adults residing in nursing homes.[6, 8] Among older adults living in Italian nursing homes, Landi et al. using the EWGSOP criteria reported a high prevalence of 33%, with body mass index (BMI), gender, daily exercise and osteoarthritis identified as predictive risk factors.[8] Supporting this, Smoliner et al. confirmed BMI as a dominant risk factor to sarcopenia among in-patients in an acute geriatric hospital ward.[9] However, work in this area is still sparse, especially in populations of very old adults with low capacity in activities of daily living. The aim of the study was to assess the prevalence of sarcopenia, and identify the risk factors associated with sarcopenia among older adults permanently living in the long-term nursing home setting.

2. METHODS

2.1 Study Design and Recruitment

A cross-sectional survey to measure the prevalence of sarcopenia and associated risk factors in older people permanently living in nursing homes located in Australia. The homes were within one large aged care provider. A detailed account of the recruitment and assessment methods has been published previously.[10] In brief, eleven facilities agreed to participate. Facility residents were included if they were (i) aged ≥ 60 years, (ii) residing in a nursing home and (iii) could provide informed consent, or if unable, proxy-informed consent could be obtained from their substitute decision maker. They were excluded if they (i) had a pacemaker, (ii) were end-stage palliative or terminal (iii), had difficult or dangerous behaviours or (iv), had medical or other issues that would limit data collection. Of all eligible residents, a representative sample was randomly selected to the study using a random number generator within the strata of level of care (low care, high care, or people with dementia residing in a secure dementia unit) to ensure a representative sample across strata. The levels of care are categorised according to the Australian Government Aged Care Funding Instrument (ACFI). Approval for the study was provided by the Human Research Ethics Committees of the participating aged care organisation and Universities.

2.2 Measures

Data were collected in a single assessment at each facility by an accredited exercise physiologist (AEP). All measures have been validated for use among the older population.[10] Data collected from facility records included demographics, ACFI level of care, date of admission, and facility recorded history of falls over the previous six months, number and type of diseases and medications, hospital admissions over the previous 12 months, current and past smoking status. A fall was defined as ‘an event resulting in a person coming to rest unintentionally on the ground or lower level’.[11] Body weight and height

were measured using calibrated electronic scales and stadiometer to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI, kg/cm^2) was calculated from weight and height.

2.2.1 Primary Outcome: Sarcopenia

Sarcopenia was defined according to the EWGSOP criteria. This requires the presence of both low muscle mass and low muscle function (muscle strength or physical performance).[1] Under these criteria, sarcopenia can be categorised as pre-sarcopenia (low muscle mass alone), sarcopenia (low muscle mass with low muscle strength or physical performance) and severe sarcopenia (low muscle mass with low muscle strength and physical performance). The cut-off points for diagnosis are (1) low muscle mass (SMI < 8.87 kg/m^2 in men and < 6.42 kg/m^2 in women), (2) low muscle strength from handgrip strength (< 30 kg in men and < 20 kg in women), and (3) low physical performance assessed by the short physical performance battery (SPPB) 2.4m walk test of ≤ 0.8m/s.[1] Body resistance (Ohms - Ω) was measured using a Maltron BF-906 bioelectrical impedance analysis (BIA) device (Maltron International Ltd, UK). Body resistance was converted to skeletal muscle mass (SMM) using the Janssen et al.[12] validated equation:

$$\text{SMM (kg)} = [\text{height (cm)}^2 / \text{BIA resistance } (\Omega) \times 0.401) + (\text{gender} \times 3.825) + (\text{age (years)} \times -0.071)] + 5.102.$$

The skeletal muscle mass index (SMI) was calculated by dividing SMM by height squared (kg/m^2).[1] In addition, muscle mass (kg) and percent body fat data were generated by BIA assessment.[13] Muscle strength was measured by Jamar handgrip dynamometer (Sammons Preston Rolyan, IL). Physical performance was assessed using the SPPB 2.4 metre walk (metres per second).[14]

2.2.2 Secondary Outcomes

In addition to the 2.4 m walk, the remaining SPPB measures were collected, namely, the hierarchical test of standing balance, and the five-time repeated chair stand measures.[14] Nutritional status was assessed by the Mini-Nutritional Assessment Instrument (MNA) short form.[15] A score greater than 12 from 14 points were deemed to have normal nutritional status, 8-11 as risk of malnutrition, and less than 8 as malnourished.[16, 17] Mood and cognitive status were rated using the Geriatric Depression Scale (GDS-15)[18] and the Mini-Mental State Examination tool (MMSE)[19] respectively. The level of physical activity was assessed by the International Physical Activity Questionnaire-Short Form (IPAQ) which assesses four levels of activity (vigorous, moderate, walking, sitting) over a 7-day period.[20] Total physical activity (MET-minutes/week) was determined by summing the estimated metabolic equivalent energy expenditure within each activity level.

2.3 Statistical Analysis

Assuming a proportion of 30% based on the study by Landi etal.[8], a precision of 10%, and an estimated design effect of 2 to account for differences between the nursing home facilities, a sample size of 161 participants was required. Participant characteristics were analysed using descriptive statistics and presented as mean and SD for continuous variables, and counts and percentages for categorical variables. The characteristics of participants with sarcopenia and without sarcopenia were compared according to data distribution by one-way analysis of variance or the Mann-Whitney test. Categorical variables were compared using the Chi-square test. A $p < 0.05$ was considered to be statistically significant. Risk factors were determined by the use of logistic regression with sarcopenic status as the outcome. Univariable analysis was used initially to identify predictors of sarcopenia. Those factors that were significant at the 0.10 level were included in a multivariable model to determine which combination of factors best predicts sarcopenic status. Backwards stepwise regression was

used, with a statistical significance level of $p < 0.05$ for the final set of factors. All analyses were conducted using Stata 11.2 (StataCorp).

3.0 RESULTS

3.1 Recruitment and Characteristics of Study Participants

Of the 709 adults living in the 11 participating facilities, 328 were ineligible due to having a fitted pacemaker (3%), end-stage disease (8%), dangerous behaviours (31%), medical or other problems that made participation challenging (58%). From the 381 eligible residents, 273 were randomly selected within the strata of high (58%) and low (29%) health care needs, and residing in a dementia unit (13%), and invited to participate, of which 102 individuals consented to participate, including 11 by proxy. A detailed overview of participant recruitment and characteristics has been presented elsewhere.[10] Participants were aged 84.5 ± 8.2 years with 70% female. On average, participants had resided for 39.8 ± 40.3 months with 85 individuals (83%) classified as high care by the ACFI. Over a quarter of participants had experienced a fall in the previous 6 months, and over a third had a hospitalisation in the previous year. Participant characteristics are depicted in Table 1.

3.2 Sarcopenia

Participants had a mean SMI of 7.7 ± 2.3 kg/m^2, hand grip strength of 16.5 ± 7.7 kg and gait speed of 0.37 ± 0.23 m/s. Forty one (40.2%) participants were classified as being sarcopenic, among whom 95% had severe sarcopenia (Fig. 1). Males (48%) were more likely to be sarcopenic than females (37%). The majority of residents had below normal physical performance (97%) and below normal muscle strength (87%). Compared to non-sarcopenic participants (Table 2), sarcopenic individuals had a lower BMI (24.8 ± 1.9 kg/m^2 vs 29.0 ± 4.8 kg/m^2, $p<0.001$), hand grip strength (14.2 ± 6.6 kg vs 17.9 ± 8.1 kg, $p=0.02$), and SPPB summary scores (2.9 ± 1.9 vs 3.8 ± 2.6, $p=0.05$). In addition, sarcopenic individuals had

higher GDS scores (6.3 ± 3.7 vs 4.6 ± 3.7, p = 0.04), reported more sitting time (13.7 ± 2.2 hours/day vs 12.4 ± 3.3 hours/day, p=0.04), were less likely to report being currently physical active (25.6% vs 74.3%, p=0.04) and were more likely to be malnourished (p=0.03).

3.3 Secondary outcomes

Anthropometric measures showed the cohort had a BMI approaching obesity (27.3 ± 5.7 kg/m^2), high body fat (35.7 ± 11.7%) and a low SPPB summary score (3.5 ± 2.4). Only 77 participants could complete the standing balance test, and 27 were able to complete the chair standing task (20.9 ±5.4 sec). Eighty-four percent had a low IPAQ categorical score, with an average sitting time of 12.9 ± 3.0 hours per day. Participants overall had mild cognitive impairment (MMSE 20.9 ± 6.4) and mild depression (GDS 5.2 ± 3.8), with 44 (45.9%) participants having moderate to severe cognitive impairment. The majority of participants were at risk of malnourishment (48.5%), and 14.9% were malnourished.

A number of variables (Age category, sex, hospital admissions in previous 12 months, length of hospital stay (mths), smoking status, BMI, SPPB total, MMSE category, GDS category, whether physically active at <50 yrs, whether physically active post retirement, any diagnoses, falls in previous 6 months, sitting time (IPAQ), ACFI category) were considered for logistic regression to identify factors that could impact on risk of sarcopenia.

Variables entered as univariate predictors found an increased risk of sarcopenia (Table 3) for: BMI (Odds Ratio (OR) = 0.86; 95% Confidence Interval (CI) 0.78-0.94), SPPB summary score (OR = 0.83; 95% CI 0.69-1.00), MNA (OR = 0.19; 95% CI 0.05-0.68) and IPAQ sitting time (OR = 1.18; 95% CI 1.00-1.39). When the model was adjusted simultaneously for all variables in a multivariate logistic regression, only BMI remained significant (OR = 0.80; 95% CI 0.65 – 0.97).

4. DISCUSSION

Our findings demonstrate that the prevalence of sarcopenia is high (40.2%) among older adults living in nursing homes, with the majority presenting with severe sarcopenia. Sarcopenia was more prevalent in males than in females. Multivariate analysis identified decreasing BMI to be a significant predictor of increasing sarcopenic risk among the participants.

A high level of prevalence of sarcopenia within nursing homes using the EWGSOP criteria was also assessed in a study by Landi et al.[8] at 32.8% (n=122, age = 84.1± 4.1 years). Few other studies have investigated institutional settings, those that have reported prevalence as low as 14.3 – 17.3%, have been based on substantially younger populations.[6, 21] In comparison, community-dwelling older adults have a prevalence of 1 – 29%.[6] Our findings demonstrate that residents in nursing homes have at least double the prevalence of sarcopenia compared to community-dwelling adults and those in acute geriatric hospital wards. Gianoudis and colleagues found in community-dwelling adults that for each 1-hour increment in overall daily sitting time, there was a 33 % increased risk of having sarcopenia.[22] Our study found that older adults living in nursing homes have high levels of sedentary behaviour.[23] Sedentary behaviour in older adults has been associated with reduced functional fitness required to perform normal everyday activities [24], and increased disability in activities of daily living (ADL)[25].

Low lower limb strength, malnourishment, and poor physical performance were identified risk factors for sarcopenia in studies prior to the development of the EWGSOP criteria.[4] In our study, we assessed self-reported nutritional status, with 15% reporting malnourishment, and 49% being at risk of malnourishment. The mean BMI was 27 kg/m^2, but was 24.8 kg/m^2 in residents with sarcopenia. Univariate regression analyses after control of potential confounders showed BMI, physical performance, sitting time, and nutritional status were associated with the presence of sarcopenia. The association of these factors with sarcopenia

could be the effect of inactivity on muscle strength and physical performance. In addition, there may be inadequate protein intake for the formation and maintenance of fat-free muscle mass.[26] After incorporating these variables into a multivariate regression analyses, only BMI remained predictive of sarcopenic status. BMI has previously been identified as a risk factor independently associated with sarcopenia among institutionalised and hospitalised older adults. [8, 9]

Given the high prevalence of sarcopenia in nursing home residents, it is imperative to develop and implement evidence-based interventions into clinical practice.[27] Interventions to prevent or reduce sarcopenia include exercise interventions to increase muscle strength and improve physical performance, and nutritional interventions to increase protein synthesis, or a combination. A recent Cochrane review (2013) of physical rehabilitation in long-term care [28] found a small improvement on gait speed and a beneficial effect on muscle strength. The authors concluded that physical rehabilitation may be effective, but effects are small, and large scale trials of interventions are required.[28] A strength of the current study is that it recruited across eleven nursing homes, and all participants were randomly selected within strata of high and low care needs to achieve a representative sample. By employing the EWGSOP algorithm, this study can be compared to other prevalence studies across settings that utilise this criterion.

That two-thirds of randomly selected residents declined to participate may limit the generalizability of this study and under-estimate the prevalence of the sarcopenia in this setting. The EWGSOP selected BIA as it is the most valid, reliable and feasible method of measuring muscle mass within field settings.[29] However, compared to Dual-energy X-ray absorptiometry, BIA may overestimate muscle mass, leading to an underestimation of the prevalence of sarcopenia.[29, 30] Due to the extent of missing data on disease status and medications during data collection, this data was considered unreliable and not included in

the logistic regression analyses. However, hospital admission and length of stay was included which could be regarded to act as a surrogate for disease status. The absence of these variables from the model may reduce the strength of the model in predicting sarcopenia.

This study is only of a few to evaluate the prevalence and risk factors of sarcopenia within the nursing home setting using the EWGSOP criterion and the first in Australia. In conclusion, sarcopenia is highly prevalent in nursing homes, with low BMI being a significant risk factor, and provides a rationale for the development and evaluation of effective, feasible, transferable and sustainable interventions (exercise and nutritional interventions alone or in combination) implemented in nursing home settings.

Acknowledgements: This work was supported by an internal grant of Bond University.

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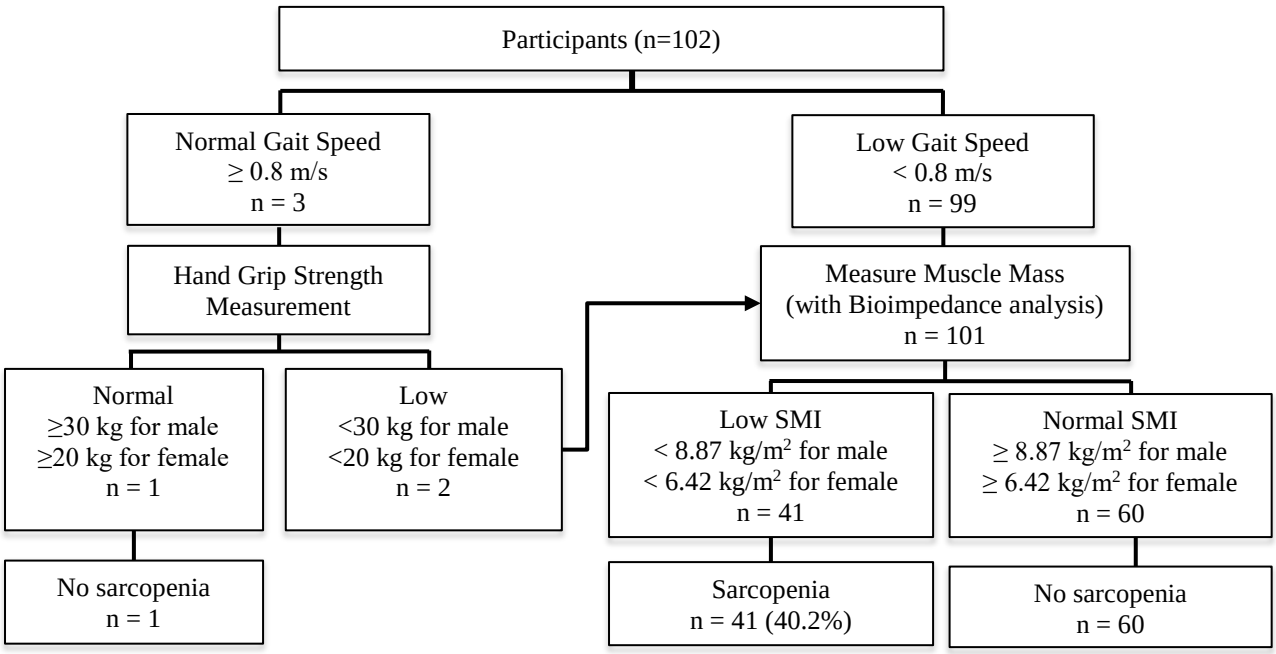

Fig 1. Diagnosis of Sarcopenia according to the EWGSOP algorithm
Notes: SMI, skeletal mass index.

Table 1: Characteristics of residential aged care participants

			Total (n= 102)	Female (n= 71)	Male (n= 31)
Age (years)			84.5 ± 8.2	85.8 ± 8.0	82.1 ± 8.3
Smoking Status (n, %)		Current	10 (10.2)	7 (10.4)	3 (9.7)
		Former	42 (42.9)	23 (34.3)	19 (61.3)
		Never	46 (46.9)	37 (55.2)	9 (29.0)
Median length of stay in facility (mo)			29.7 (2.1-236.9)	34.7 (2.1-236.9)	18.8 (2.5-128.6)
High Care by ACFI (%)			83.3	87.1	81.7
Falls History in past 6 mths (%)			26.4	29.6	19.4
Hospitalisation in past 12 mths (%)			34.3	35.4	33.8
BMI (kg/m^2)			27 ± 5.7	28 ± 6.1	26 ± 4.4
Fat Mass (%)			36 ± 11.7	38 ± 10.8	28 ± 10.4
Skeletal muscle mass index (kg/m^2)			7.7 ± 2.3	7.2 ± 2.2	8.9 ± 1.9
Hand grip strength (kg)			16.5 ± 7.7	14.7 ± 6.5	20.7 ± 8.9
Gait speed (m/s)			0.37 ± 0.23	0.39 ± 0.23	0.31 ± 0.21
Chair Stands (s)[1]			20.9 ± 5.4	20.3 ± 6.0	22.1 ± 4.1
SPPB summary score			3.5 ± 2.4	3.8 ± 2.6	2.7 ± 1.9
Physically active (n,%)		Current	39 (39.8)	30 (44.8)	9 (29.0)
		Post-retirement	78 (76.5)	55 (77.5)	23 (74.2)
IPAQ (N)	Low (< 600)		81	53	28
	Mod (600-1499)		12	10	2
	High (≥ 1500)		4	3	1
IPAQ Total (Met-mins/wk)			369.5 ± 729.9	406.8 ± 715.8	288.8 ± 765.1
IPAQ sitting time (hours/day)			12.9 ± 3.0	12.7 ± 3.3	13.3 ± 2.3
MMSE	Severe (n)		4 (4.2)	3 (4.5)	1 (3.3)
	Moderate (n)		40 (41.7)	24 (36.4)	16 (53.3)
	Mild (n)		16 (16.7)	13 (19.7)	3 (10.0)
	Normal (n)		36 (37.5)	26 (39.4)	10 (32.3)
	Total		20.9 ± 6.4	21.3 ± 6.6	20.2 ± 5.9
GDS			5.2 ± 3.8	4.6 ± 3.4	6.6 ± 4.3
MNA (n, %)	Malnourished		15 (14.9)	12 (17.1)	3 (9.7)
	At risk		49 (48.5)	31 (44.3)	18 (58.1)
	Normal		37 (36.6)	27 (38.6)	10 (32.3)
ABC			67.0 ± 32.2	69.7 ± 34.7	61.0 ± 24.0
Sarcopenia (n, %)			41 (40.2)	26 (36.6)	15 (48.4)

Results are expressed as means ± SD unless otherwise stated. BMI = body mass index; SPPB = Short Physical Performance Battery; IPAQ = International Physical Activity Questionnaire; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; MNA = mini-nutritional assessment, ABC = Activity-Specific Balance Scale

Table 2: Characteristics of Older Adults by Sarcopenia Status

	No sarcopenia (n= 61)	Sarcopenia (n= 41)	*p*-value
Age (years)	83.5 (8.3)	86.0 (7.8)	0.14
Education (n, %)			
Primary school	30 (65.2)	16 (34.8)	0.88
High school	20 (55.6)	16 (44.4)	
Tertiary	9 (64.3)	5 (35.7)	
Unknown	3	3	
Smoking Status (n, %)	8 (80)	2 (20)	0.47
Falls History in past 6 mths (%)	22 (57.9)	16 (42.1)	0.76
Hospitalisation in past 12 mths (%)	20 (57.1)	15 (42.9)	0.59
BMI (kg/m^2)	29.0 (4.8)	24.8 (1.9)	<0.001
Hand grip strength (kg)	17.9 (8.1)	14.2 (6.6)	0.02
Gait speed (m/s)	0.39 (0.03)	0.33 (0.03)	0.16
Total SPPB score	3.8 (2.6)	2.9 (1.9)	0.05
Physically active (n,%)			
Current	29 (74.3)	10 (25.6)	0.04
Post-retirement	49 (62.8)	29 (37.2)	0.82
IPAQ Categorical Score (Met-mins/wk)			
Low (< 600)	50 (61.7)	31 (38.3)	0.84
Mod (600-1499)	7 (58.3)	5 (41.7)	
High (≥ 1500)	3 (75.0)	1 (25.0)	
IPAQ sitting time (hours/day)	12.4 (3.3)	13.7 (2.2)	0.04
MMSE	21.6 (6.3)	19.9 (6.4)	0.20
MMSE Level of Cognitive Impairment			
Severe	25 (69.4)	11 (30.6)	0.64
Moderate	9 (56.3)	7 (43.8)	
Mild	23 (57.5)	17 (42.5)	
Normal	3 (75.0)	1 (25.0)	
GDS	4.6 (3.7)	6.3 (3.7)	0.04
MNA Category			
Malnourished	5 (33.3)	10 (66.7)	0.03
At risk	30 (61.2)	19 (38.8)	
Normal	27 (73.0)	10 (27.0)	

Results are expressed as means (SD) unless otherwise stated. BMI = body mass index; SPPB = Short Physical Performance Battery; IPAQ = International Physical Activity Questionnaire; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; MNA = mini-nutritional assessment.

Table 3 Logistic Regression Models of Risk of Sarcopenia

Factor	**Univariate Odds Ratio (95% CI)**	**p-value**
BMI	0.86 (0.78-0.94)	0.001
Total SPPB	0.83 (0.69-1.00)	0.05
IPAQ sitting time	1.18 (1.00-1.39)	0.05
MNA	0.19 (0.05-0.68)	0.01
MNA Category		
Poor	1.0 (referent)	
At risk	0.32 (0.09-1.07)	0.06
Good	0.19 (0.05-0.68)	0.01
Factor	**Multivariate (Adjusted) Odds Ratio (95% CI)**	**p-value**
BMI	0.80 (0.65-0.97)	0.03
Total SPPB	0.82 (0.49-1.37)	0.45
IPAQ sitting time	1.20 (0.78-1.83)	0.40
MNA Category		
Poor	1.0 (referent)	
At risk	2.52 (0.10-61.3)	0.57
Good	2.91 (0.09-94.7)	0.55

Notes: BMI, body mass index; SPPB, Short Physical Performance Battery; IPAQ, International Physical Activity Questionnaire; MNA, Mini-Nutritional Assessment, OR, odds ratio.