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Low Lean Tissue Mass and Physical Performance as Markers of Sarcopenia in Older Men and Women

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Abstract

Background: While declines in muscle mass and function occur in all individuals with advancing age, the extent and rate of decline vary in the general population. We aimed to determine the prevalence of low lean tissue mass combined with poor physical function as an indicator of sarcopenia among older men and women residing in south-eastern Australia.

Methods: The study involved men and women aged 60+ years from the Geelong Osteoporosis Study (GOS). Skeletal muscle mass was measured as total lean tissue mass by dual energy x-ray absorptiometry (DXA) and expressed as a percentage of body weight to generate the skeletal mass index (SMI); low lean mass was defined as SMI T-score <-1. Low muscle function was based on performance using "timed up-and-go" scores >10s. Physical activity scores were determined using a validated questionnaire for the elderly and falls were self-reported for the previous year. Associations between sarcopenia, physical activity and falls were determined using multivariable regression techniques.

Results: Among 624 men, 233 had low SMI, 169 had low muscle performance and 81 had both, thus meeting criteria for sarcopenia. Among 436 women, 143 had low SMI, 179 had low muscle performance and 70 had both. A general age-related increase in the observed prevalence of sarcopenia appeared to be driven by an age-related increase in low performance. Sarcopenia was associated with lower physical activity scores. No association was detected between sarcopenia and falls for men but an association was observed for women (age-adjusted OR 1.87, 95% CI 1.11, 3.14).

Conclusion: In our population, the prevalence of sarcopenia was 10.6% (95% CI 7.7, 13.4) for men and 14.5% (95% CI 10.8, 18.3) for women. Men and women with sarcopenia were habitually less active and, for women, sarcopenia was associated with increased likelihood of falls.

Keywords: Lean mass; Skeletal muscle mass; Muscle function; Physical performance; Sarcopenia; Ageing; Frailty; Falls

Abbreviations

BMI: Body Mass Index; CI: Confidence Interval; DXA: Dual Energy X-ray Absorptiometry; EWGSOP: European Working Group on Sarcopenia in Older People; GOS: Geelong Osteoporosis Study; IQR: Interquartile Range; NHMRC: National Health and Medical Research Council; OR: Odds Ratio; SD: Standard Deviation; SMI: Skeletal Mass Index; TUG: "Timed Up-and-Go" test

Introduction

The term "sarcopenia" (taken from the Greek to mean "poverty of flesh") was coined by Rosenberg to describe progressive changes in body composition that involve generalised loss of skeletal muscle mass [1]. While such a decline occurs in all individuals with advancing age, the extent varies on a continuum that gradually impacts on mobility, independence and frailty [2]. While there are several definitions of sarcopenia, we have referred to recommendations developed by the European working group on sarcopenia in older people (EWGSOP) that sarcopenia be defined in terms of loss of skeletal muscle mass and function [2]. In this study, lean tissue mass measures derived from dual-energy x-ray absorptiometry (DXA) and performance in the "timed up-and-go" (TUG) test served as indicators of skeletal muscle mass and function.

We aimed to determine the age-related prevalence of sarcopenia and its components in older men and women living in south-eastern Australia and to investigate this condition in association with habitual physical activity and falls.

Materials and Methods

Subjects

The study is set in the Barwon Statistical Division and forms part of the large prospective cohort study known as the Geelong Osteoporosis Study (GOS). Age-stratified samples of 1,540 men and 1,494 women were recruited at random from Commonwealth electoral rolls in the years 2001-2006 and 1994-1997, with 67% and 77% participation, respectively. Inclusion criteria were that the participants were registered on the electoral rolls for the Barwon Statistical Division and had resided in the region for at least six months. Participants were excluded if they were unable to provide written informed consent to participate in the study. Age at recruitment ranged from 20-97 years for men and 20-94 years for women. Participants are recalled every 2-5 years for re-assessment. Details of recruitment, follow-up and retention have been described elsewhere [3]. For this cross-sectional analysis, we included individuals aged 60 years and older, and utilised data for men at baseline and for women at 6-year follow-up. Among 651 men and 463 women who participated at these assessment phases and were of appropriate age, 624 men and 436 women provided data on both skeletal muscle mass and function, fulfilling inclusion criteria for this analysis. As a reference sample, we used lean tissue and whole body mass measures of men and women aged 20-39 years, for quantifying deficits in lean tissue muscle mass of the older participants. The study was approved by the Human Research Ethics Committee at Barwon Health. All participants gave informed, written consent.

Measures

Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, and body mass index (BMI) calculated as weight/height^2 (kg/m^2). DXA scans were performed using Lunar densitometers (DPX-L or Prodigy-Pro, Madison, WI, USA) to provide measures of lean tissue mass. Lean tissue assessed by this technology comprises non-fat and non-bone tissue, and this measure correlates well with skeletal muscle mass quantified by magnetic resonance imaging [4]. Our group has previously reported age-and-sex-specific normative data for lean tissue mass obtained from DXA [5]. We have used the skeletal mass index (SMI) which was calculated by expressing the lean tissue mass as a percentage of body mass [6]. SMI values for men and women aged 20-39 years were normally distributed and served as the young adult reference group in order to calculate T-scores for SMI values among older study participants. The younger individuals were also assessed as part of the GOS and comprised 377 men with mean SMI (SD) value of 74.6% (7.7) and 437 women with mean SMI (SD) value of 60.4% (8.6%). Low SMI for defining low lean tissue mass was T-score <-1.0, using sex-specific thresholds (cut-points) of 66.9% for men and 51.8% for women. Physical performance was assessed using the TUG test over a distance of 3 m, and a time >10s was used to indicate low performance [7]. By definition, the TUG measures the time taken to stand from a seated position in a chair, walk a measured distance of 3m, turn around, walk back and sit down again. While performing the TUG, participants wore normal shoes and used habitual walking aids. In this analysis we have designated individuals with sarcopenia as those with SMI T-score <-1 and TUG >10s.

Habitual physical activity levels were assessed using a questionnaire for the elderly [8] wherein a physical activity score was generated by combining scores for household, sport and leisure activities. For this group of older men and women, physical activity scores ranged from 0.2-66.9. Falls during the past 12 months were documented by self-report and those who reported one or more falls were classified as fallers.

Statistical analysis

To obtain the prevalence of sarcopenia, the age-stratified samples were standardised to the national age-profile (Australia, 2001). Characteristics of these older men and women were compared according to the presence or absence of sarcopenia using t-tests or Mann-Whitney tests for continuous data and the test for proportions for categorical data. The natural log of the TUG scores and the square root values of the physical activity scores were calculated to normalise the data before analysis.

The Pearson product moment correlation coefficient was used to describe the degree of linear relationship between transformed TUG scores, lean tissue mass and age. Associations between sarcopenia and transformed physical activity scores and falls were determined using multivariable regression techniques, adjusting for age. The models were checked for interaction terms. All statistical analyses were performed using Minitab (version 16; Minitab, State College, PA).

Results

Subject characteristics are shown in Table 1. Compared to individuals without sarcopenia, those with sarcopenia were older, heavier, had a higher mean BMI and poorer physical activity scores. Lean tissue mass was negatively correlated with age for both men ($r=-0.38$, $p<0.001$) and women ($r=-0.33$, $p<0.001$). Men with sarcopenia had lower lean tissue mass than those without sarcopenia, but this difference was not observed for women. The proportion of men with low SMI varied little across the age range for men; a similar pattern was observed for women in their 60s and 70s, but was reduced for women aged 80 years and older (Figure 1).

The log-transformed TUG scores were positively correlated with age for both men ($r=+0.44$, $p<0.001$) and women ($r=+0.53$, $p<0.001$); there was a marked age-related increase observed in the proportion of men and women with low physical performance (high TUG scores).

For men, 233 (37.3%) had low SMI, 169 (27.1%) had low physical performance and 81 (13.0%) had both, meeting criteria for sarcopenia. An overall increase in the prevalence of sarcopenia was observed for men, ranging from 3.8% (95% CI 1.0, 9.5) for age 60-64 years to 31.1% (95% CI 19.9, 44.3) for 85+ years (Figure 1).

The age-standardised prevalence of sarcopenia for men aged 60 years and older was 10.6% (95% CI 19.9, 44.3). Sarcopenia was associated with lower physical activity scores (Age-adjusted mean 8.8 (7.2-10.5) *vs* 14.7 (13.9-15.5), $p<0.001$) but no association was observed with falls (Age-adjusted OR 0.99 (95% CI 0.60, 1.63), $p=0.9$).

For women, 143 (32.8%) had low SMI, 179 (41.1%) had low physical performance and 70 (16.1%) had both, meeting criteria for sarcopenia. The age-specific pattern for the prevalence of sarcopenia in women differed to that seen in men, whereby the prevalence increased from 9.5% (95% CI 4.2, 17.9) for age 60-64 years to 25.8% (95% CI 17.1, 36.2) for age 75-79 years, followed by a decrease to 15.2% (95% CI 6.3, 28.9) for age 80-84 years and 19.0% (95% CI 10.2, 30.9) for age 85+ years (Figure 1).

The age-standardised prevalence of sarcopenia for women aged 60 years and older was 14.5% (95% CI 10.8, 18.3). Sarcopenia was associated with lower physical activity scores (age-adjusted mean 9.9

(8.5-11.5) vs 13.1 (12.4-13.9), p<0.001) and an increased likelihood falls (age-adjusted OR 1.87 (95% CI 1.11, 3.14), p=0.02). No interaction terms were identified for models developed for men and women.

Discussion

Sarcopenia is common among older individuals and data from our study reports a prevalence ranging of 7.7-13.4% for men and 10.8-18.3% for women aged 60 years and older. These prevalence figures are within the broad range of estimates reported from other community-based studies from across the world, which range from 1-29% [9], with higher prevalence estimates reported for clinical settings and aged-care institutions [9,10].

			Sarcopenia		
		All	**Yes**	**No**	
Men		n=624	n=81	n=543	P-value
	Age (yr)	74.3 (67.4-81.4)	79.0 (73.1-84.0)	73.7 (66.7-80.6)	<0.001
	Weight (kg)	81.0 (13.5)	86.8 (12.3)	80.1 (13.4)	<0.001
	Height (m)	1.72 (0.07)	1.70 (0.06)	1.72 (0.07)	0.01
	BMI (kg/m^2)[a]	27.3 (4.0)	29.9 (3.6)	27.0 (4.0)	<0.001
	Lean mass (kg)	55.5 (6.8)	53.4 (6.2)	55.9 (6.9)	0.001
	SMI (%)[b]	69.3 (6.8)	61.8 (3.8)	70.5 (6.4)	<0.001
	TUG (s)[c]	8.7 (7.6-10.2)	12.0 (10.9-13.7)	8.4 (7.4-9.6)	<0.001
	Physical activity[d]	14.1 (8.3-21.8)	7.8 (3.0-14.7)	15.1 (9.3-22.5)	<0.001
	Fallers	203 (32.5%)	30 (37.0%)	173 (31.9%)	0.3
Women		n=436	n=70	n=366	
	Age (yr)	73.6 (66.8-80.0)	77.0 (70.6-80.6)	72.8 (66.3-79.9)	0.006
	Weight (kg)	68.2 (13.2)	79.6 (14.2)	66.1 (11.9)	<0.001
	Height (m)	1.57 (0.06)	1.57 (0.07)	1.72 (0.06)	0.7
	BMI (kg/m^2)[a]	27.5 (5.0)	32.1 (4.7)	26.6 (4.6)	<0.001
	Lean mass (kg)	37.0 (4.4)	37.6 (5.8)	36.9 (4.1)	0.4
	SMI (%)[b]	55.4 (7.7)	47.5 (3.9)	56.9 (7.3)	<0.001
	TUG (s)[c]	12.4 (7.5-18.4)	12.0 (10.6-13.7)	8.8 (7.8-10.5)	<0.001
	Physical activity[d]	9.5 (8.0-11.6)	8.8 (5.8-14.0)	13.0 (7.9-19.2)	<0.001
	Fallers	175 (40.1%)	38 (54.3%)	137 (37.4%)	0.08

[a]Body Mass Index; [b]Skeletal Mass index; [c]Timed Up-and-Go; [d]Questionnaire scores [8]

Table 1: Subject characteristics for all men and women, and according to sarcopenia status. Data are shown as mean (±SD), median (interquartile range, IQR) or number (%).

After the age of about 50 years, skeletal muscle mass declines by an estimated 1-2% per year [11]. Our findings also showed an age-related decrease in lean tissue mass; however, the negative correlation between lean tissue mass and age was dissipated when the lean tissue mass was expressed as the SMI. It seems that for this group of older individuals, age-related changes in body composition have altered the relative proportions of fat and lean tissue that contribute to body mass [12,13]. While the reasons for this remain unclear, we might speculate that the fat-to-lean tissue mass ratio changes as a consequence of hormonal and lifestyle changes that might include increasingly sedentary behaviour and poor nutrition during ageing.

As factors that cause losses in skeletal muscle mass and function might differ [14], it is not perhaps surprising that age-related declines in muscle strength surpass expectations from corresponding declines in muscle mass [15]. Some reports highlight the substantial impact that losses of muscle strength and performance have on functional status, loss of independence and poor mobility associated with sarcopenia [11,16]. Ageing skeletal muscle is characterised by changes in composition and material properties, loss of motor units and conversion of the fast type II muscle fibres into slow type I fibres, which reduces muscle power [17]. Further, muscle atrophy that occurs in the face of obesity in a condition referred to as sarcopenic obesity, leads to lipid deposits in muscle fibres that reduce muscle strength [18] and this can occur without a net loss, and indeed sometimes a gain, in body weight. It is interesting to note that we report greater body weight and BMI among individuals with sarcopenia and that this difference persisted after adjusting for age. This finding corroborates other reports [19,20].

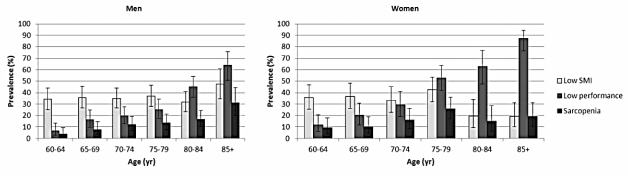

Figure 1: Age-related prevalence of low skeletal mass index (SMI), low performance and sarcopenia. Data are presented separately for men and women and error bars represent 95% confidence intervals.

We recognise several strengths and weaknesses in our study. Major strengths include the random selection of study participants from the broad population, and the clinical measures of skeletal muscle mass and function. In contrast to Janssen and colleagues who used estimates of skeletal muscle mass from bioimpedance analysis measurements to calculate SMI, we have used DXA measures while retaining the cut-point of one standard deviation below young adult values to identify low skeletal muscle mass (values below this cut-point being equivalent to type 1 sarcopenia) [6]. We cannot exclude the possibility that a higher TUG threshold might have better identified fallers and/or those with poorer physical function [21,22]. If alternative thresholds had

been employed to identify both low skeletal muscle mass from DXA measures, and low muscle function from TUG performances, or indeed if other clinical measures had been used to identify low skeletal muscle mass and function, individuals with and without sarcopenia might have been segregated differently. However, diverse criteria have been used extensively in the literature because of the absence of a widely-accepted operational definition for the condition. We also acknowledge that we cannot use our study findings to infer causality. Our cross-sectional analyses suggest that sarcopenia is associated with low levels of physical activity and high falls risk (at least in women) but it remains unclear whether or not the association is bi-directional. Further, it is possible that sarcopenia and the propensity to be physically inactive and/or a faller might share common risk factors.

In conclusion, we report that the prevalence of sarcopenia is greatest for women aged 70-79 years and affects one-third of elderly men, aged 85 years and older. Our data suggest that sarcopenia is detected in approximately 10.6% of men and 14.5% women aged 60 years and older. Men and women with sarcopenia are habitually less active and, for women, sarcopenia is associated with increased likelihood of sustaining a fall. Prospective data are now being sought to identify risk factors for sarcopenia and its components, low skeletal muscle mass and function.

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Author Contributions: All authors contributed to the interpretation of data, the writing and critical appraisal of the manuscript and approved the final version for submission.

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