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ORIGINAL ARTICLE

Sarcopenia definitions and their association with injurious falls in older Swedish women from the Sahlgrenska University Hospital Prospective Evaluation of Risk of Bone fractures (SUPERB) study

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Abstract

Summary Associations between different sarcopenia definitions and the risk of injurious falls were investigated in 75–80-year-old women in the Swedish SUPERB cohort. Only sarcopenia according to the Sarcopenia Definitions and Outcomes Consortium (SDOC) definition was associated with incident injurious falls with and without fractures in older women.

Purpose To investigate the association between three commonly used sarcopenia definitions and the risk of injurious falls in a population of older Swedish women.

Methods A total of 2,883 75–80-year-old women with complete data on relevant sarcopenia definitions from the Swedish SUPERB cohort were studied. Sarcopenia was defined based on the Sarcopenia Definitions and Outcomes Consortium (SDOC: low handgrip strength and gait speed), revised European Working Group on Sarcopenia in Older People (EWGSOP2: low appendicular lean mass index (ALMI, dual-energy X-ray absorptiometry (DXA)-derived), appendicular lean mass (kg)/height (m^2), hand grip strength (kg), or low chair stand time (s)), and Asian Working Group for Sarcopenia (AWGS: low ALMI and hand grip strength (kg) or low gait speed (m/s)). Questionnaires captured the occurrence of falls in the past 12 months. Incident injurious falls were identified using national registers. Cox regression (hazard ratios (HR) and 95% confidence intervals (CI)) analyses were performed without adjustment and after adjustment for age, body mass index, previous falls, and the Charlson comorbidity index.

Results During a median (IQR) follow-up time of 7.06 (6.2–7.9) years, there were 491 injurious falls without fracture and 962 injurious falls when also including falls resulting in a fracture. Sarcopenia according to EWGSOP2 and AWGS was not associated with an increased risk of injurious falls. Individuals with sarcopenia defined by SDOC had a higher risk of injurious falls with and without fracture (HR 2.11; 95% CI, 1.63–2.73 and HR, 2.16; 95% CI, 1.55–3.02, respectively).

Conclusion Sarcopenia definitions confined to muscle function and strength such as SDOC, rather than including DXA-determined ALMI (EWGSOP2 and AWGS), are associated with incident injurious falls with and without fractures in older women.

Keywords Falls · Older adults · Sarcopenia

Introduction

Falls in the aging population have significant negative health implications including functional decline and increased risk of subsequent fractures which lead to disability, frailty, and institutionalization [1–3]. Although non-injurious falls may not result in immediate physical harm, they can cause psychological distress, fear of falling, and a decline in mobility [4]. However, injurious falls on the other hand range from minor injuries to severe fractures and head trauma, evoking immediate medical attention [5]. Fall-related injuries are common with age as they negatively impact up to 40% of individuals aged more than 75 years and up to 50% of individuals aged more than 80 years [6]. Fall-related injuries are considered a significant healthcare issue in the elderly population due to the consequential economic ramifications associated with increased hospitalization [3, 7].

Sarcopenia is characterized as an age-associated loss of skeletal muscle mass and function which increases the risk

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of dependency, morbidity, falls, and fractures among older adults [8–10]. Despite its significant negative effects, the condition remains underdiagnosed and mismanaged, in part due to the lack of a consensus definition [1, 11–13]. Emerging studies have demonstrated that the prevalence of sarcopenia varies largely based on the definition used, age group, sex, and ethnicity and ranges from anywhere between 5 and 50% [14, 15]. Furthermore, it is unclear which definition of sarcopenia might best identify potential fallers among older adults [16–19].

Recent evidence has demonstrated that sarcopenia may exacerbate the risk of injurious falls among older adults [7, 20]. Furthermore, it is evident from a recent systematic review and meta-analysis that older adults with sarcopenia are at a higher risk for falls compared to individuals without sarcopenia [7, 20]. Although several definitions and diagnostic criteria have been previously proposed, no studies have investigated different definitions of sarcopenia and their association with the risk of injurious falls within a population of older women [21–24]. We have previously shown that sarcopenia, defined using the Sarcopenia Definitions and Outcomes Consortium (SDOC) [23], by the revised European Working Group on Sarcopenia in Older People (EWGSOP2) [22], an dby the revised Asian Working Group for Sarcopenia (AWGS) [25] definition, was associated with low bone mineral density (BMD) in a large cohort of older Swedish women [26]. Interestingly, only sarcopenia defined by the SDOC definition was associated with the risk of incident fractures (also including fractures not linked to falls) in this cohort [26]. However, it is important to evaluate the potentially underlying mechanisms, bone fragility or increased fall risk, associated with SDOC and fracture risk.

This study aimed to investigate if sarcopenia defined by SDOC, AWGS, and EWGSOP2 was associated with the risk of injurious falls, without or with a fracture, in a population of Swedish older women.

Methods

Study design and participants

Data from the Sahlgrenska University Hospital Prospective Evaluation of Risk of Bone Fractures (SUPERB) study was utilized for this analysis. Women residing in the greater Gothenburg area, Sweden, were included in the SUPERB study, which is a prospective population-based study including 3,028 older women. Women aged between 75 and 80 years were randomly recruited from the Swedish national population register. Women were formally invited to participate in the study through a mailed letter, which was followed by a subsequent telephone call. Participants were excluded from this study if they were unable to walk without walking aids, did not understand Swedish, and did not have at least one hip that could be evaluated for dual-energy X-ray absorptiometry (DXA)-determined BMD. All study participants provided written informed consent, and this study was approved by the regional Ethics Review Board in Gothenburg.

Incident injurious falls, with and without fracture

Data regarding incident injurious falls, with and without fracture, and comorbidity were collected through two primary sources: the National Patient Register (NPR) and a questionnaire administered at baseline. In the NPR, incident injurious falls resulting in hospital visits or admissions in Sweden were identified using ICD-10 codes W00-W19 and an S00-T14 diagnosis. The positive predictive value (PPV) or those accurately diagnosed to sustain an injury using the NPR has been reported to be 95% [27]. High agreement was found for falls (93.9%) than for other causes of injury with agreement of less than 50% [28]. Concurrently, participants completed a baseline questionnaire providing additional information on prevalent falls and comorbidities. The total follow-up time was 6.4 ± 1.3 (mean $\pm$ SD) years.

Questionnaires

Participants completed self-administered questionnaires at baseline including questions on physical activity, diseases, and the occurrence of falls in the previous 12 months. Clinical risk factors (CRFs) for injurious falls were based on medical history and included prior fractures (after the age of 50, excluding face and skull fractures), current smoking, and high alcohol consumption (three standard measures of alcohol per day or more). A questionnaire was also used to collect information on comorbidity, in addition to collected ICD-10 codes obtained from the NPR.

Charlson comorbidity index was used to evaluate comorbidity and consists of the following medical conditions with each condition assigned an integer weight from one to six (six representing the most severe morbidity): dementia (weight 1), ischemic heart disease (weight 1), heart failure (weight 1), cerebrovascular disease (weight 1), vascular disease (weight 1), chronic pulmonary disease (weight 1), chronic liver disease (weight 1), diabetes (weight 1), diabetes with end organ damage (weight 2), tumor without metastasis (weight 2), lymphoma or leukemia (weight 2), kidney disease (weight 1), kidney disease moderate or severe (weight 2), hemiplegia (weight 2), peptic ulcer disease (weight 2), and metastatic solid tumor (weight 6) [29].

Anthropometry

An electronic scale was used to measure weight (kg) to the nearest 0.1 kg (Seca GMBH, Hamburg, Germany), and a wall-mounted calibrated stadiometer (Seca GMBH, Hamburg, Germany) with footwear and heavy items of clothing removed was utilized to measure height (m) two consecutive times. If the two height measurements differed by ≥ 5 mm, a third measurement was performed. An average of the two height measurements or the two most similar measurements if three were taken was used. Weight (kg) / height (m^2) was used to compute BMI.

Functional performance evaluation

As previously described, hand grip strength was measured using a hydraulic dynamometer (Saehan dynamometer, model SH5001, Saehan Corporation, Masan, Korea) [30]. Participants were asked to grip the dynamometer with maximal force in a seated position. This measurement was repeated twice in both hands with a 30-s rest between trials. The mean force of the dominant hand from the two trials was then utilized to calculate average hand grip strength. In addition, gait speed was assessed twice and was measured over a 10-m distance, and the mean value of the two assessments was utilized. However, only the middle 6-m distance was utilized to calculate the average gait speed (m/s) to exclude the effects of acceleration and deceleration and to obtain the usual gait speed. A 30-s chair stand test was performed with participants in a seated position, with their arms across their chest. The number of times the participants could rise from a chair without aid from their arms within 30-s was recorded. This assessment was performed thrice, and an average of the measurements was taken.

Dual-energy X-ray absorptiometry (DXA)

Lean mass was determined from whole-body DXA scans using Hologic Discovery A (S/N 86491, Waltham, MA, USA) for a total of $n = 2{,}995$ participants. However, $n = 33$ scans were performed using another Hologic Discovery A device due to machine failure. A cross-calibration was performed between the two instruments and has been reported elsewhere [31]. Appendicular lean mass (ALM) was calculated as the sum of lean mass in the upper and lower limbs. The coefficient of variation (CV) for lean mass was 0.6%.

Sarcopenia definition

Three of the most common and recently developed sarcopenia definitions were utilized to evaluate differences in the prevalence of sarcopenia in this group of Swedish older women at baseline. Furthermore, their predictive value for the risk of injurious falls was assessed. Sarcopenia was defined using the SDOC, EWGSOP2, and AWGS definition [22, 23, 25]. The SDOC definition categorizes sarcopenia based on low hand grip strength (< 20 kg) and low gait speed (< 0.8 m/s) [23]. The EWGSOP2 definition identifies sarcopenia through a combination of low appendicular lean mass index (ALMI) (< 5.5 kg/m^2) and low grip strength (< 16 kg) or low chair stand time (> 15 s for five rises) [22]. The AWGS definition utilizes reduced ALMI (< 5.4 kg/m^2) along with low hand grip strength (< 18 kg) or low gait speed (< 1.0 m/s) [25].

Statistical analysis

All data analyses were performed using SPSS Statistics 25 (IBM, NY, USA). Participant characteristics were reported as mean ± standard deviations for continuous variables, or as percentages for categorical variables (Table 1). Independent sample *t*-tests or X^2 tests were performed to compare differences between individuals with and without sarcopenia. Cox regression analysis was performed to investigate the associations between three frequently used sarcopenia definitions (EWGSOP2, SDOC, and AWGS), mortality risk, and injurious falls with or without a fracture [21–23, 25], with fully adjusted models containing age, BMI, previous falls, and Charlson comorbidity index as covariates. Age and BMI were included as continuous variables whereas previous falls and Charlson comorbidity index were included as categorical variables for the primary analysis (Tables 2 and 3). Incidence per 1000 person-years was calculated as the number of events divided by total follow-up time (until fracture, death, or censoring) per 1000 years. To assess the implications of death as a competing risk, the Fine and Gray sub-distributed hazard for injurious falls was compared between individuals with/without sarcopenia using the Survival-Time Competing Risk Regression command in Stata 17.0 [32]. For all analyses, $p < 0.05$ or 95% confidence intervals not including the null point were considered statistically significant.

Results

A total of 2,883 older women with a mean age of 77.8 ± 1.6 years were included. Among older women, sarcopenia prevalence was the highest when defined by the EWGSOP2 definition (12.5%), followed by AWGS (10.3%), with the lowest prevalence by the SDOC definition (4.5%) (Table 1). Individuals with sarcopenia had higher BMI (29.2 kg/m^2) than those without sarcopenia based on the SDOC definition; in contrast, individuals with sarcopenia had lower BMI than those without sarcopenia when defined by both the EWGSOP2 and AWGS definitions (Table 1).

Table 1 Descriptive characteristics based on sarcopenia definitions

	SDOC		*p*-value	EWGSOP2		*p*-value	AWGS		*p*-value
	No (*n* = 2754)	Yes (*n* = 129)		No (*n* = 2523)	Yes (*n* = 360)		No (*n* = 2587)	Yes (*n* = 296)	
Age (years)	77.8 ± 1.6	78.5 ± 1.5	**0.023**	77.8 ± 1.7	77.9 ± 1.7	0.303	77.8 ± 1.6	77.9 ± 1.6	0.908
BMI (kg/m^2)	26.1 ± 4.3	29.2 ± 5.5	**< 0.001**	26.8 ± 4.3	22.3 ± 2.5	**< 0.001**	26.7 ± 4.3	21.7 ± 2.3	**< 0.001**
High alcohol consumption (%)	15 (0.5%)	0 (0.0%)	0.645	14 (0.6%)	1 (0.3%)	0.494	14 (0.5%)	1 (0.3%)	0.645
Current smoking (%)	138 (5.0%)	9 (6.8%)	0.401	116 (4.6%)	31 (8.6%)	**0.001**	117 (4.5%)	30 (10.1%)	**< 0.001**
Previous self-reported fracture[A] (%)	1011 (36.7%)	62 (48.1%)	**0.006**	933 (37.0%)	140 (38.9%)	0.260	956 (37.0%)	117 (39.5%)	0.386
Previous falls injury (%)	366 (13.3%)	39 (30.2%)	**0.001**	357 (14.1%)	48 (13.3%)	0.737	364 (14.1%)	41 (13.9%)	0.988
Falls in the past 12 months (%)	53 (1.9%)	7 (5.4%)	**0.016**	53 (2.1%)	7 (1.9%)	1.000	53 (2.0%)	7 (2.4%)	0.884
Charlson comorbidity index (%)			**0.001**			0.282			0.811
0	1470 (53.4%)	35 (27.1%)	-	1324 (52.4%)	181 (50.3%)	-	1349 (52.1%)	156 (52.7%)	-
1	564 (20.5%)	34 (26.4%)	-	527 (20.9%)	71 (19.7%)	-	547 (21.1%)	51 (17.2%)	-
2	455 (16.5%)	29 (22.5%)	-	421 (16.7%)	63 (17.5%)	-	430 (16.6%)	54 (18.2%)	-
3 or more	265 (9.6%)	31 (24.0%)	-	251 (9.9%)	45 (12.5%)	-	261 (10.2%)	35 (11.8%)	-
Gait speed (m/s)	1.29 ± 0.21	0.66 ± 0.12	-	1.27 ± 0.25	1.24 ± 0.25	-	1.26 ± 0.25	1.28 ± 0.24	-
Grip Strength (kg)	15.0 ± 5.4	9.9 ± 4.7	-	15.3 ± 5.5	11.2 ± 4.1	-	15.2 ± 5.52	11.3 ± 3.8	-
30-s chair stand test (*n*)	11.0 ± 4.0	3.4 ± 4.1	-	10.8 ± 4.3	9.8 ± 4.1	-	10.7 ± 4.3	10.4 ± 4.1	-
Appendicular lean mass index (kg/m^2)	6.26 ± 0.82	6.62 ± 1.12	-	6.43 ± 0.78	5.18 ± 0.27	-	6.4 ± 0.78	5.1 ± 0.2	-

A selection of baseline characteristics according to sarcopenia definitions has been published previously [26]. Data presented as mean ± standard deviation or number (percent). Abbreviations: *EWGSOP2* European Working Group on Sarcopenia in Older People revised definition, *SDOC* Sarcopenia Definitions and Outcomes Consortium, *AWGS* Asian Working Group for Sarcopenia. [A]After 50 years of age, fractures of the skull and face are excluded

Individuals classified as having sarcopenia based on the SDOC definition exhibited a notably higher proportion of previous fall injuries, experienced falls in the past 12 months, and demonstrated higher Charlson commodities index scores compared to those without sarcopenia (all $p < 0.05$). Individuals with sarcopenia defined by SDOC also had significantly poorer muscle strength/function but had higher lean mass compared to those without sarcopenia (all $p < 0.05$). Individuals with sarcopenia defined by both the EWGSOP2 and AWGS definitions had significantly lower hand grip strength and appendicular lean mass compared to individuals without sarcopenia (both $p < 0.05$). The Charlson comorbidity index was similar in those with and without sarcopenia according to AWGS and EWGSOP2, but women with sarcopenia defined by SDOC had a higher Charlson comorbidity index than those without (Table 1).

During a median (IQR) follow-up time of 7.06 (6.2–7.9) years, there were 491 injurious falls without fracture and 962 injurious falls when also including falls resulting in a fracture. Sarcopenia defined by the AGWS and EWGSOP2 definitions was neither associated with injurious falls without fractures nor with injurious falls resulting in fractures (all, $p > 0.05$, Tables 2 and 3). However, sarcopenia defined by the SDOC definition was associated with injurious falls both with and without fractures included (Tables 2 and 3) with an approximately doubled risk in those with SDOC-defined sarcopenia. These associations did not materially change after adjustment for previous falls and the Charlson comorbidity index. The cumulative incidence of injurious falls was considerably higher only in those with sarcopenia defined by SDOC than in those without (Fig. 1).

Individuals with sarcopenia defined by the EWGSOP2 and SDOC definition had, as previously reported [26], an increased risk of death. Therefore, an analysis to consider the competing risk of mortality according to the Fine and Gray analysis was performed. In this analysis, sarcopenia defined by the SDOC definition was significantly associated with injurious falls without fracture in both unadjusted and fully adjusted models (Table 4). Similarly, sarcopenia defined by the SDOC definition was significantly associated with injurious falls, including fractures in both unadjusted and fully adjusted models (Supplemental Table 1).

A sensitivity analysis to investigate if the association observed between sarcopenia by SDOC and injurious falls including fractures was dependent on the length of follow-up; we investigate the association during the first 2 years of follow-up. Highly similar results (HR 2.55 95% CI (1.71, 3.80)) for injurious falls, adjusted for age and BMI, were observed as compared to the analysis using the complete follow-up (Supplemental Table 2).

Discussion

In this population of Swedish older women, sarcopenia defined by SDOC was the only definition associated with an increased risk of injurious falls without fracture. Sarcopenia defined by both the EWGSOP2 and AWGS definitions failed

Table 2 Associations between sarcopenia definitions and risk of injurious falls without fracture

	SDOC		EWGSOP2		AWGS	
	No (*n* = 2754)	**Yes (*n* = 129)**	**No (*n* = 2523)**	**Yes (*n* = 360)**	**No (*n* = 2587)**	**Yes (*n* = 296)**
Injurious falls						
n (%)	452 (16.4%)	39 (30.2%)	431 (17.1%)	60 (16.7%)	443 (17.1%)	48 (16.2%)
Rate per 1000 person-years	23.8	47.8	25.0	23.8	25.2	23.2
HR (95% CI):						
Model 1	REF	**2.21 (1.59, 3.07)**	REF	0.94 (0.72, 1.24)	REF	0.91 (0.68, 1.23)
Model 2	REF	**2.16 (1.55, 3.02)**	REF	1.00 (0.75, 1.34)	REF	0.98 (0.71, 1.34)
Model 3	REF	**1.88 (1.34, 2.64)**	REF	0.98 (0.73, 1.30)	REF	0.95 (0.69, 1.30)
Model 4	REF	**1.85 (1.32, 2.60)**	REF	0.97 (0.73, 1.29)	REF	0.94 (0.69, 1.30)

Data were presented as hazard ratios (HR) and 95% confidence intervals (CI). Bold indicates significance at $p < 0.05$. Abbreviations: *SDOC* Sarcopenia Definitions and Outcomes Consortium, *EWGSOP2* European Working Group on Sarcopenia in Older People revised definition, *AWGS* Asian Working Group for Sarcopenia

Model 1 Adjusted for age

Model 2 Adjusted for age, and body mass index

Model 2 Adjusted for age, body mass index, and previous falls

Model 3 Adjusted for age, body mass index, previous falls, and Charlson comorbidity index

Table 3 Associations between sarcopenia definitions and risk of injurious falls (with or without a fracture)

	SDOC		EWGSOP2		AWGS	
	No (*n* = 2754)	**Yes (*n* = 129)**	**No (*n* = 2523)**	**Yes (*n* = 360)**	**No (*n* = 2587)**	**Yes (*n* = 296)**
Injurious falls						
n (%)	897 (32.6)	65 (50.4%)	839 (33.3%)	123 (34.2%)	864 (33.4%)	98 (33.1%)
Rate per 1000 person-years	47.3	79.6	48.6	48.9	48.8	47.3
HR (95% CI):						
Model 1	REF	**2.00 (1.55, 2.57)**	REF	1.03 (0.85, 1.24)	REF	0.99 (0.80, 1.21)
Model 2	REF	**2.11 (1.63, 2.73)**	REF	0.98 (0.80, 1.19)	REF	0.93 (0.74, 1.16)
Model 3	REF	**1.86 (1.41, 2.42)**	REF	0.96 (0.78, 1.17)	REF	0.91 (0.73, 1.14)
Model 4	REF	**1.82 (1.40, 2.37)**	REF	0.94 (0.73, 1.16)	REF	0.90 (0.72, 1.13)

Data were presented as hazard ratios (HR) and 95% confidence intervals (CI). Bold indicates significance at $p < 0.05$. Abbreviations: *SDOC* Sarcopenia Definitions and Outcomes Consortium, *EWGSOP2* European Working Group on Sarcopenia in Older People revised definition, *AWGS* Asian Working Group for Sarcopenia

Model 1 Adjusted for age and body mass index

Model 2 Adjusted for age, body mass index, and previous falls

Model 3 Adjusted for age, body mass index, previous falls, and Charlson comorbidity index

to be predictive of injurious falls. These results indicate that fall prediction and prevention methods may be improved by assessing physical performance and/or muscle strength using the SDOC sarcopenia definition among older adults and also questions the utility of other sarcopenia definitions if injurious falls are seen as a relevant clinical outcome of sarcopenia.

Sarcopenia increases the risk of falls among older adults, regardless of the definition used [3, 7, 20, 33]. A possible explanation is that individuals with sarcopenia have a delayed reaction time along with decreased agility and flexibility as a result of a decline in the number of types of motor neurons [3, 20]. In the current study, the risk of injurious falls varied depending on the definition of sarcopenia used. Individuals with sarcopenia according to the SDOC definition, which predicates the condition on physical function and muscle strength, rather than low ALMI, had a greater risk for injurious falls compared to those without sarcopenia [7]. In contrast, the two sarcopenia definitions using ALMI as the gateway did not predict the risk of injurious falls in this population, consistent with previous observations relating to fracture outcomes [34–36]. Age-related decline in overall physical function and performance leads to impairments in postural reflexes adversely affecting walking speed, balance, and endurance therefore increasing the chances of a fall during daily activities [7]. Emerging studies have demonstrated that muscle strength and physical performance are key risk

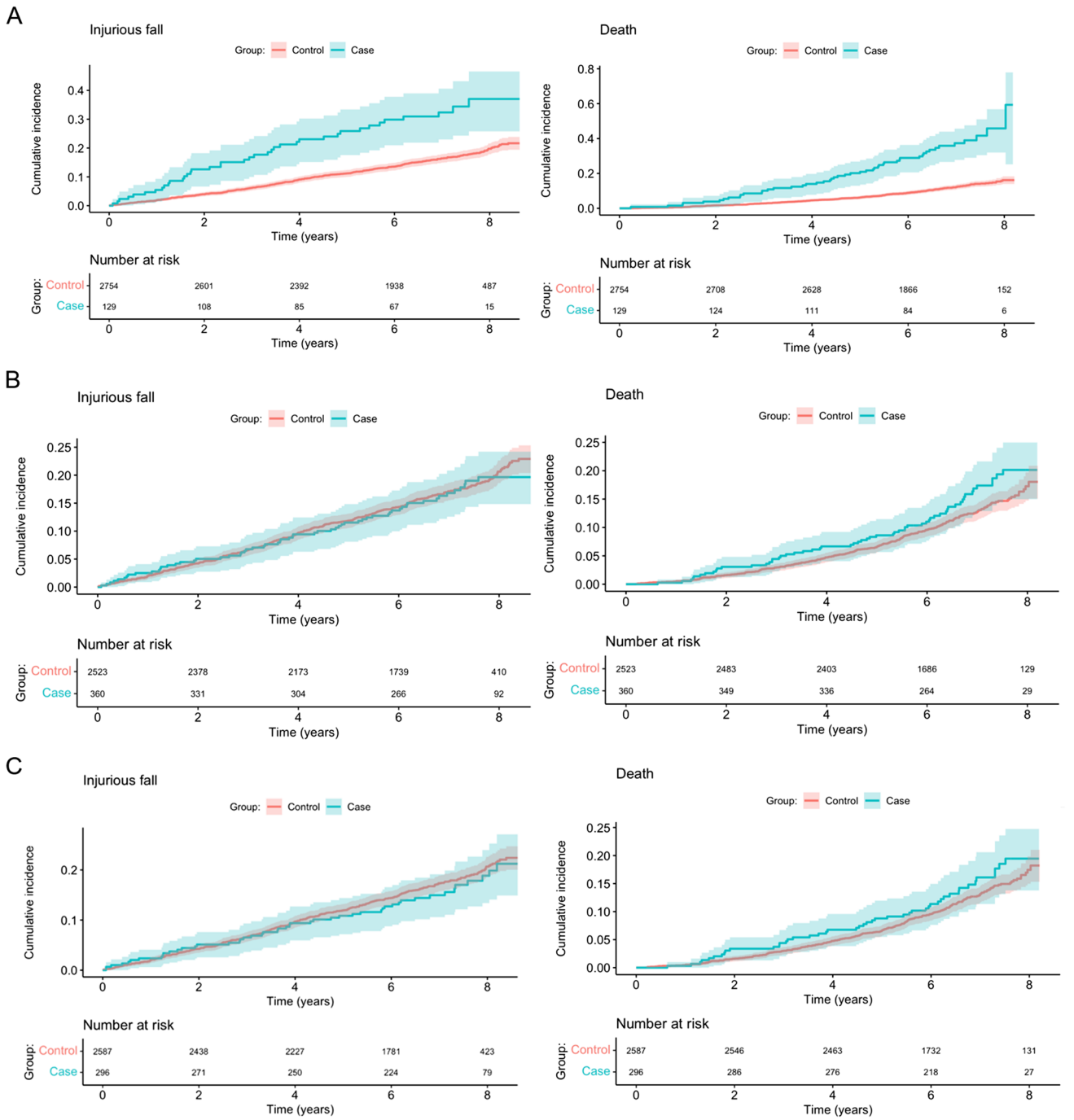

Fig. 1 Cumulative incidence of injurious falls and death based on sarcopenia definitions: **A** SDOC, **B** EWGSOP2, and **C** AWGS. Abbreviations: SDOC, Sarcopenia Definitions and Outcomes Consortium; EWGSOP2, European Working Group on Sarcopenia in Older People revised definition; AWGS, Asian Working Group for Sarcopenia

factors associated with falls [33, 37]. In a study including 108 older adults aged 77 to 79 years, gait speed was utilized to identify individuals at risk of functional decline and those at higher risk of falls [38]. In the abovementioned study, a higher risk for falls was observed in individuals with a gait speed < 1.0 m/s [38]. Therefore, the incorporation of gait speed according to the SDOC definition might enhance its ability to better predict the risk of injurious falls compared to the EWGSOP2 and AWGS definitions. Likewise, in a study including 1,067 Taiwanese older adults aged 65 years and over, hand grip strength was utilized as a measure of muscle strength which was found to be an independent risk factor

Table 4 Associations between sarcopenia definitions and risk of injurious falls without fracture, adjusted for competing risk of death

	SDOC		EWGSOP2		AWGS	
	No ($n = 2754$)	Yes ($n = 129$)	No ($n = 2523$)	Yes ($n = 360$)	No ($n = 2587$)	Yes ($n = 296$)
Model 1	REF	**1.92 (1.37–2.68)**	REF	0.99 (0.74–1.31)	REF	0.95 (0.69–1.32)
Model 2	REF	**1.69 (1.20–2.38)**	REF	0.96 (0.72–1.27)	REF	0.93 (0.68–1.29)
Model 3	REF	**1.68 (1.19–2.37)**	REF	0.95 (0.71–1.27)	REF	0.93 (0.67–1.28)

Data presented as Fine and Gray sub-distribution hazard ratios (SHR) and 95% confidence intervals (CI). Bold indicates significance at $p < 0.05$. Abbreviations: *EWGSOP2* European Working Group on Sarcopenia in Older People revised definition, *SDOC* Sarcopenia Definitions and Outcomes Consortium, *AWGS* Asian Working Group for Sarcopenia

Model 1 Adjusted for age and body mass index

Model 2 Adjusted for age, body mass index, and previous falls

Model 3 Adjusted for age, body mass index, previous falls, and Charlson comorbidity index

for fall episodes [39]. This study also demonstrated that individuals with a greater hand grip had a lower risk for falls [39]. Hand grip strength and gait speed are feasible yet cost-effective measures of poor muscle strength/function which should therefore be assessed among older adults who are at risk of falls compared to other functional measures [39, 40].

Sarcopenia defined by EWGSOP2 and AWGS was not associated with an increased risk of injurious falls in this population of older women. In contrast, in a study including 260 individuals aged 80 years, individuals with sarcopenia defined by EWGSOP were over three times more likely to fall during a 2-year follow-up period compared to individuals without sarcopenia [7]. These differences in findings might reflect the use of the EWGSOP2 sarcopenia definition with modified cut points of muscle mass and strength as opposed to the EWGSOP definition which was utilized in the abovementioned study [7]. In addition, differences in the study populations and specific measures used to define fall risk could also explain these inconsistent findings. It is also important to note that the abovementioned study investigated falls defined as an abrupt loss of balance resulting in any part of the body above the feet making contact with the floor unlike the current study which identified injurious falls contributing to the differences in the findings [7]. Additionally, in a recent systematic review and meta-analysis including 10,073 individuals, it was evident that older adults with sarcopenia according to the AWGS definition exhibited the highest risk of falls compared to individuals without sarcopenia [20]. This risk surpassed that of individuals identified with sarcopenia by the EWGSOP and FNIH definitions [20]. However, only one study was included in the meta-analysis, and therefore, further studies are warranted to confirm this finding. These inconsistencies in the associations between sarcopenia definitions may be explained by the fact that age-related declines in muscle strength occur at a much faster rate compared to declines in muscle mass [41]. Therefore, the SDOC definition which assesses muscle strength and physical performance/function may be more closely associated with fall risk in this population of older women compared with EWGSOP2 and AWGS definitions which also assess DXA-derived muscle mass in addition [42]. Therefore, there could be potential inadequacy of relying on sarcopenia definitions including measures of muscle mass obtained through DXA or creatine dilution [43], given that these methods may not fully capture the functional aspects of muscle health. Future research might therefore benefit from exploring other more comprehensive approaches that include assessments of muscle strength and physical performance to better inform fall risk evaluation in older populations. However, it is important to note that the differences in the cut points of hand grip strength between the definitions could also contribute to the disparities in the findings; therefore, further studies are warranted to investigate these findings.

Strengths of this study include its large, population-based setting with no loss to follow-up and all participants followed using regional registers. However, this study is subject to limitations including the relatively low number of injurious falls without fracture in this population of older women. Furthermore, only injurious falls reported in hospitals in Sweden were recorded leaving out; therefore, incidents were only notified in primary care. In addition, this study included ambulatory women with a narrow age span of 75 years to 80 years which may therefore limit the generalisability to men, other age groups, and other populations.

In conclusion, sarcopenia defined by the SDOC definition was the only definition associated with injurious falls, with and without fractures. These findings highlight the critical role of integrating assessments of physical performance and/or muscle strength into fall risk assessments for older adults in the clinical setting. Moreover, the findings suggest that prioritizing muscle function over muscle mass may yield greater insights into fall susceptibility. Nevertheless, the adequacy of sarcopenia definitions warrants careful consideration, recognizing the need for ongoing refinement and standardization in order to enhance the precision and relevance of sarcopenia in clinical practice.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00198-024-07196-0.

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Declarations

Conflict of interest M. Lorentzon has received lecture fees from Amgen, Astellas, Lilly, Meda, Renapharma, and UCB Pharma and consulting fees from Amgen, Radius Health, UCB Pharma, Parexel International, and Consilient Health. J. A. Kanis is a director of Osteoporosis Research Ltd. N Harvey has received consultancy, lecture fees, and honoraria from the Alliance for Better Bone Health, Amgen, MSD, Eli Lilly, Servier, Shire, UCB, Kyowa Kirin, Consilient Healthcare, Theramex, Radius Health, and Internis Pharma. E. McCloskey has received research funding, consultancy, lecture fees, and/or honoraria from Amgen, AstraZeneca, Consilient Healthcare, Fresenius Kabi, GSK, Hologic, Internis, Lilly, Merck, Novartis, Pfizer, Roche, Sanofi-Aventis, Servier, Synexus, UCB, Unilever, and Warner Chilcott. Dr Axelsson has received lecture fees from Lilly, Meda/Mylan, and Amgen. Dr. L Johansson has received lecture fees from UCB. Dr. B Larsson has received lecture fees from Boeringer-Ingelheim and consulting fees from Praktisk Medicin. All other authors have no conflicts of interest.

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