

Prevalence of sarcopenia and sarcopenic obesity in older German men using recognized definitions: high accordance but low overlap!

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Abstract

Summary The relevance of sarcopenia and sarcopenic Obesity (SO) is rising in our aging societies. Applying recognized definitions to 965 community-dwelling Bavarian men 70 years+ resulted in a prevalence for sarcopenia between 3.7 and 4.9 and between 2.1 and 4.1% for SO. Despite this high consistency, the overlap between the definitions/approaches was <50%.

Introduction The relevance of sarcopenia and sarcopenic obesity (SO) is rising steadily in the aging societies of most developed nations. However, different definitions, components, and cutoff points hinder the evaluation of the prevalence of sarcopenia and SO. The purpose of this contribution was to determine the prevalence of sarcopenia and SO in a cohort of community-dwelling German men 70+ applying established sarcopenia (European Working Group on Sarcopenia in Older People, Foundation National Institute of Health, International Working Group on Sarcopenia) and obesity definitions. Further, we addressed the overlap between the definitions.

Methods Altogether, 965 community-dwelling men 70 years and older living in Northern Bavaria, Germany, were assessed during the screening phase of the Franconian Sarcopenic Obesity project. Segmental multi-frequency bio-impedance analysis (BIA) was applied to determine weight and body composition.

Results Applying the definitions of EWGSOP, IWGS, and FNIH, 4.9, 3.8, and 3.7% of the total cohort were classified as sarcopenic, respectively. When further applying body fat to diagnose obesity, SO prevalence in the total cohort ranged from 4.1% (EWGSOP + body fat >25%) to 2.1% (IWGS + body fat >30%). Despite the apparently high consistency of the approaches with respect to prevalence, the overlap in individual sarcopenia diagnosis between the sarcopenia definitions was rather low (<50%).

Conclusion The prevalence of sarcopenia and SO in community-dwelling German men 70 years+ is relatively low (<5%) independently of the definition used. However, consistency of individual sarcopenia diagnosis varies considerably between the three definitions. Since sarcopenia is now recognized as an independent condition by the International Classification of Diseases, a mandatory definition must be stated.

Trial registration number: ClinicalTrials.gov: NCT2857660.

Keywords 70+ · Germany · Men · Prevalence · Sarcopenia · Sarcopenic obesity

Introduction

Due to current demographic trends, sarcopenia and sarcopenic obesity (SO) is becoming increasingly important for our fast aging societies. Indeed, the synergistic negative effect of decreased muscle mass combined with increased fat mass may be the most prominent component of disability, frailty, morbidity, and mortality in older people [1–4]. Although the general meaning, underlying conditions, and consequences of these geriatric symptoms [5] are comprehensible, their definition, components, and classifications are yet not finally

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specified, and hence, the prevalence of sarcopenia and SO is difficult to evaluate. However, with respect to definitions and components, there is at least some consensus in that morphometric and functional components are more adequate to characterize sarcopenia than the application of morphometric components alone. Indeed, the most prominent expert panels, the European Working Group on Sarcopenia in Older People (EWGSOP [6]), International Working Group on Sarcopenia (IWGS [7]), and Foundation National Institute of Health (FNIH [8]) have suggested a combined sarcopenia definition using one morphometric parameter and one (IWGS, FNIH) or two (EWGSOP, AWGS) functional parameters. All definitions focus on the evaluation of grip strength and/or gait velocity to determine the functional sarcopenia aspect and use appendicular skeletal muscle mass (ASMM) to determine the morphometric component of sarcopenia. Thus, one should expect that the application of these definitions should result in comparable sarcopenia prevalence in a given cohort. However, the devil lies in the detail(s): Apart from the different adjustment of ASMM either on body height (i.e., EWGSOP [6], IWGS [7]) or body mass index (FNIH [8]), the cutoff points for grip strength, gait velocity, and muscle mass index are far from consistent. Additionally, the different population characteristics may contribute to the enormous differences between the prevalence rates given.

The main reasons for these differences may be the different understanding of sarcopenia, along with the approach to adjust cutoff points based on more comprehensible conditions (i.e., “weakness” [8]).

As if this were not complicated enough, with respect to SO, the identification of the additional prevalence of obesity within the SO is not trivial.

The primary aim of this study was to evaluate and describe the prevalence of sarcopenia and sarcopenic obesity (SO) in a cohort of community-dwelling (CDW) German men 70+ applying (different) applicable sarcopenia (EWGSOP, IWGS, and FNIH) and obesity definitions (i.e., BMI and body fat). The secondary study aim was to determine and describe the degree of overlap of sarcopenia and SO prevalence using the different recognized approaches.

Methods

The Franconian¹ Sarcopenic Obesity (FRANSO) study focuses on the prevalence and non-pharmacologic therapy of sarcopenia and sarcopenic obesity in community-dwelling men 70+. In this contribution, we address the prevalence issue of the project and focus on the screening period that was conducted between February and May 2016. The Institute of Medical Physics and the Institute of Biomedicine of Aging,

University of Erlangen-Nürnberg (FAU), Germany, initiated the project, which was approved by the University Ethics Committee of the FAU (Ethikantrag 67_15b). After detailed information, all study participants gave written informed consent. The entire FRANSO project is registered under ClinicalTrials.gov: NCT2857660.

Participants

Young male adult reference group

We applied the T-score-based approach suggested by the EWGSOP [6] in order to generate the most valid and appropriate cutoff point for low-muscle mass for this cohort. To realize this aim, body composition data of 1189 healthy Caucasian men 18–35 years old living in Northern Bavaria were used as a young male reference cohort. Participants were either collected in former studies with young males, or health promotion projects conducted in close cooperation with the Siemens-Betriebskrankenkasse (Erlangen, Germany) during 22 different campaigns between 2014 and 2016. Apart from age and male gender, eligibility criteria in the young adult reference cohort were (exclusion) (a) systemic diseases that relevantly affect muscle or fat mass (e.g., hypogonadism, Cushing syndrome: $n = 18$); (b) medication/drugs that relevantly affect muscle or fat mass (doping with anabolic substances or prednisolone >5 mg for >6 months: $n = 23$); (c) total or partial amputation of limbs (except fingers or toes); and (d) non-Caucasian origin ($n = 61$). All subjects were assessed using modern bio-impedance analysis (BIA) technique (InBody770, Biospace Ltd., Seoul, Korea).

Community-dwelling men 70+

Using citizen registers provided by the municipality, 6800 men 70+ living independently in the area of Erlangen-Nürnberg, Germany, were contacted by personal letters that already included the most important eligibility criteria (i.e., age, independency) in tranches of 500 letters. Interested persons were contacted and reviewed for other, more detailed eligibility criteria (i.e., contraindication for assessments) by phone calls and structured interviews. After each tranche, baseline characteristics that may affect sarcopenia and SO prevalence (e.g., BMI, physical activity, nutrition, education) of the participants were analyzed and compared with data reported for the corresponding German population of males 70+. Finally, 1045 persons replied to the letter. Following our inclusion criteria, (a) male 70 years and older, (b) living independently at home, (c) able to visit our lab, (d) no total or partial amputation of the limbs (except fingers or toes) and (e) no contraindication for BIA (e.g., cardiac pacemaker), altogether 987

¹ Franconia is the northern part of Bavaria.

were screened. Subjects were invited independently of their ethnicity, but only the data of Caucasians ($n = 965$) were included in the analysis.

Measurements

All assessments were performed by qualified research assistants using calibrated devices.

Body composition

Height was determined using a Harpenden stadiometer (Holtain, Crymych, Great Britain), and weight and body composition were determined using multi-frequency, multi-segmental BIA device analysis (BIA; InBody770, Biospace Ltd., Seoul, Korea). This device measures impedance of the trunk, arms, and legs separately with a tetrapolar eight-point tactile electrode system that applied six frequencies (1, 5, 50, 250, 500, and 1000 kHz). Participants were asked to avoid severe physical activity and to fast 3 h prior to the BIA assessment. Body mass index (BMI) was calculated body mass/body height² (kg/m²), and skeletal muscle mass index (SMI) was calculated using appendicular skeletal muscle mass (ASMM)/body height² (kg/m²) or, when applying the FNIH definition of sarcopenia, ASMM/BMI. In two previous studies with males 30–50 and 25–65 years old, we determined a good agreement for lean (intraclass correlation (ICC) 0.89; 95% CI 0.86–0.91 (males 30–50 years) and 0.92; 95% CI 0.89–0.95 (males 25–65 years) and fat mass (0.87; 95% CI 0.83–0.90 (males 30–50 years) and 0.91 95% CI 0.87–0.94 (males 25–65 years)) between the InBody770 and our Hologic 4500a DXA Scanner with a narrow limit of agreement on Bland-Altman for LBM and fat mass. Reliability of the BIA device to determine ASMM was checked by a test-retest approach with 25 participants who were assessed twice within 1 h while restraining from food, beverages, and physical activity. Resulting ICC was 0.91 (95% CI 88–94) in the young reference cohort and 0.86 (95% CI 84–88) in the cohort 70+. ICCs for percent body fat were comparably high (0.89 and 0.88).

Gait velocity

A standardized assessment of habitual gait speed was performed using the 10-m protocol recommended for research [9]. Participants started in an upright position 3 m before the first photosensor (HL 2-31, TagHeuer, La Chaux-de-Fonds, Switzerland), started walking, and stopped 2 m after the second photosensor. Tests were performed without any specific walking aids wearing regular shoes. The standardized

instruction to the participants was consistently “walk at a speed just as if you were walking along the street to go to the shops.”

Handgrip strength

Handgrip strength was tested three times for the dominant and non-dominant hand using a Jamar Hand Dynamometer (Sammons Preston Inc., Bollington, USA) with a break of 30 s between the tests. Grip width was adjusted individually to participant hand size. Tests were performed while standing upright, arms down by the side [10]. The standardized instruction to the participants was consistently “squeeze as strongly as possible.” The average result of the three trials for the dominant hand was included in the analysis.

Questionnaires and interviews

Reference cohort of young male adult

In order to determine the most relevant anthropometric, socio-demographic, health-related, and lifestyle parameters of this cohort, a standardized interview was conducted immediately before the body height and BIA assessment. Data were collected in order to check representativeness of the corresponding data for Germany (or at least Southern Germany).

Male adults 70+

General characteristics (e.g., family and educational status, occupational career), medication (type, dose, duration); diseases (e.g., hypertension, hypercholesterolemia, diabetes mellitus II); physical limitations (i.e., amputations of fingers or toes, hip, knee, and shoulder TEP); lifestyle with special emphasis on physical activity, exercise, and nutrition [11]; falls and injuries within the last year; low traumatic fractures; and pain severity and frequency at different skeletal sites were determined using a standardized questionnaire completed by the participants while visiting our lab. We also used the abridged version of the Late Life Function and Disability Instrument (LLFDI) [12]. Prior to the tests, participants were asked to list their medication and diseases in order to generate completeness and accuracy of the questionnaire, and this was checked by research assistants together with the participants. During this interaction, degree of independence and autonomy, family status, social network, and use of ambulatory nursing services was inquired more distinctly.

Sarcopenia definitions according to the different expert panels

We applied three Sarcopenia definitions recommended for European and US American cohorts.

The European Working Group on Sarcopenia in Older People (EWGSOP) [6] used an algorithm that included gait velocity, handgrip strength, and skeletal muscle mass index (SMI).

Cutoff values for gait velocity (<1.0 m/s [13] or <0.8 m/s [14]) and grip strength (men <30 kg [14]) (Table 1) were defined according to the results of preceding studies; with respect to gait velocity, we applied the lower cutoff points (<0.8 m/s) used by the majority of studies [15] that reported sarcopenia epidemiology according to EWGSOP. However, with respect to SMI, the authors did not give a specific recommendation for either DXA-based or BIA-based approaches. Different concepts of SMI calculations were listed, e.g., appendicular (ASMM) or absolute muscle mass (kg) divided by body height (m^2) and body mass index (kg/m^2) or adjusted for body fat (e.g., [16–18]). Cutoff points were based on either T-scores [16], Z-scores [19], or statistical calculation based on physical disability [20]. Thus, a large variety of possible SMI calculations with potential impact on sarcopenia prevalence exists. However, since most studies that refer to the EWGSOP sarcopenia definition used the T-score-based approach (-2 SD below “young references”) that focus on ASMM/height² (kg/m^2) (review in [15]), we also applied this approach (Table 1).

More clearly, the International Working Group on Sarcopenia (IWGS) [7] prescribed the ASMM/height², Z-score-based (lowest 20%) cutoff point for skeletal muscle mass index of ≤ 7.23 kg/m^2 for men calculated by Newman et al. [18] for a US population, and a gait velocity of less than 1.0 m/s [13, 21].

Finally, the Foundation for the National Institutes of Health (FNIH) [8] prescribed an SMI cut point based on an ASMM/BMI approach of <0.789 [22] and a handgrip strength below 26 kg for men [23]. Both cutoff points were generated using data of $30,772$ participants 65 years

and older participating in nine studies, which included (very) different populations, however. Cutoff points were calculated to optimally identify “clinically relevant weakness” [22, 23].

Table 1 summarizes the cutoff points according to EWGSOP, IWGS, and FNIH applied for this cohort.

Obesity definitions

There are three different types of obesity assessments applied for sarcopenic obesity: (a) the BMI-based method, (b) body fat assessment approaches, and (c) waist circumference or assessments of abdominal visceral fat [2, 24].

In consistence with the WHO criteria [25], BMI-based approaches for Caucasian cohorts used a cut point of 30 kg/m^2 . Body fat (%) cutoff points were less consistent and vary between 20.2 and 37.2% in men and from 31.7 to 42.9% in women (review in [2, 24]). Finally, waist circumference cutoff points vary between ethnicities; however, for a Caucasian cohort, 88 cm (women)/ 102 cm (men) is specified [26]. In this study, we applied the BMI- and body fat-based approaches to diagnose obesity.

Statistical analysis

Distribution of the characteristics and key parameters of the study cohort was graphically (QQ plots) and statistically (Shapiro-Wilk test) checked. Accordingly, data are described using mean values with standard deviation (MV \pm SD), median with minimum/maximum, and proportions (%). Differences between age groups (70 – 79 vs. ≥ 80 years) were calculated using Welch T-test for continuous variables and chi-square test for categorical variables. Scatterplots were used to graphically illustrate the overlap with respect of morphometric and functional parameters of a definition or between two SMI calculation approaches in our cohort. Simple Pearson-Bravais correlations were calculated to check the relationship between independent variables. All tests were two-sided with a p value of less than 0.05 considered as statistically

Table 1 Sarcopenia criteria, cutoff points, and diagnostic approach of the sarcopenia definitions of the European Working Group on Sarcopenia in Older People (EWGSOP), International Working Group on Sarcopenia (IWGS): appendicular muscle mass/body height² (kg/m^2), and Foundation for the National Institutes of Health (FNIH)

Definition/criteria	SMI ^a	Gait velocity	Handgrip strength
EWGSOP [6]	<7.18 kg/m^{2b} , and	<0.8 m/s or (when ≥ 0.8 m/s)	<30 kg
IWGS [7]	≤ 7.23 kg/m^{2c} , and	<1.0 m/s	–
FNIH [8]	$<0.789^c$, and	–	<26 kg

^a Appendicular muscle mass/body height² or appendicular muscle mass/body mass index (FNIH)

^b T-score-based approach suggested by the EWGSOP

^c Using the cut point defaults suggested by IWGS and FNIH

significant. SPSS 22.0 (SPSS Inc., Chicago, IL) was used for all statistical procedures.

Results

With respect to anthropometric characteristics (e.g., body height, body mass, BMI, body fat) as well as health-related (e.g., number and types of diseases), demographic (e.g., family and educational status), and lifestyle parameters (e.g., physical activity, exercise, smoking, alcohol consumption), we did not determine relevant differences to corresponding data given for the Bavarian and/or German population 18–35 years old; thus, we considered this cohort as largely representative for young Bavarian [27] and German males [28].

According to the recommended approach [16], we calculated the skeletal muscle mass index (SMI) by dividing ASMM by height². The mean value and corresponding standard deviation of the young reference cohort was exactly $8.765 \pm 0.794 \text{ kg/m}^2$. Thus, applying the T-score-based sarcopenia cut point of 2 SD below young reference data, the cutoff averaged 7.177 kg/m^2 . We called this morphometric sarcopenia cut point the *Weißenfels Score*.

Table 2 gives baseline characteristics of the 965 CDW men 70+, additionally structured according to age.

The age of the cohort ranged from 70 to 95 years, and BMI averaged $27.3 \pm 3.5 \text{ kg/m}^2$ (range 19.4 to 39.4 kg/m^2). Handgrip strength [29] and gait velocity [30] were consistent with normative data given for comparable male cohorts 70 to 79 and 80 to 95 years old. With respect to generalizability, anthropometric data, family status, lifestyle including physical

Table 2 Characteristics of the study participants

Variable	Total cohort (n = 965)	70–79 years (n = 690)	80–95 years (n = 275)
Age [years]	77.3 ± 4.9	74.8 ± 2.6	83.6 ± 3.4
Body height [cm]	173.5 ± 6.8	174.3 ± 6.6	171.6 ± 6.9
Body weight [kg]	82.2 ± 12.0	83.3 ± 11.8	79.2 ± 11.9
Body fat [%]	30.2 ± 6.5	29.8 ± 6.6	31.0 ± 6.2
Lean body mass [kg]	56.9 ± 7.1	58.1 ± 6.9	54.2 ± 6.6
Habitual gait velocity [m/s]	1.21 ± 0.22	1.25 ± 0.21	1.12 ± 0.23
Handgrip strength [kg]	36.2 ± 7.3	37.8 ± 6.9	32.2 ± 6.7
LLFDI ^a [Index]	1.50 ± 0.56	1.41 ± 0.48	1.71 ± 0.66
Number of diseases [n] ^b	2 (0–8)	2 (0–6)	2 (0–8)
Multi-morbidity (≥2 diseases) [%] ^b	69.5	67.1	75.6
Hypertension [%] ^b	50.4	51.5	50.1
Hypercholesterolemia [%] ^b	32.1	33.2	29.3
Type II diabetes mellitus [%] ^b	15.8	15.9	15.8
Hip/knee TEP [%]	3.3/2.6	3.2/2.5	3.7/2.8
Glucocorticoids >5 mg/day [%] ^c	2.6	2.5	2.7
Upper/middle/lower class [%] ^c	21/64/15	20/65/15	22/63/15
High educational level [%] ^c	18	19	17
Moderate educational level [%] ^c	25	26	23
Low educational level [%] ^c	57	55	60
Physical activity [index] ^d	4.01 ± 1.10	4.13 ± 1.09	3.97 ± 1.11
No sports or exercise [%] ^e	32.3	30.5	36.6
≥2 × 30 min exercise/week [%] ^e	29.0	31.6	22.7
Vegetarians [%] ^c	3.7	4.1	2.9

TEP total endoprosthesis as assessed by standardized questionnaires and interviews

^a Late Life Function and Disability Instrument (LLFDI) [12] (1: no complaints to 5: impossible)

^b As assessed and structured by the list of Schäfer et al. [52]

^c As assessed from baseline questionnaires and interviews

^d As assessed by physical activity questionnaires [11] on overall habitual physical activity (without exercise) with a scale from 1: very low/very bad to 7: very high/very good

^e As assessed by a specific exercise questionnaires [11]

activity and exercise, number and distribution of diseases, and medication of our cohort reflect corresponding data given by the most recent reports of the “Statistisches Bundesamt” for the male German population 70+ [28, 31, 32]. Further, the age distribution among our cohort was comparable with German data for CDW men 70 years and older. On the other hand, socio-economic status was slightly and educational status [28] was moderately higher compared with average German data reported for this age group. However, with respect to the latter parameters, there is a considerable variation between the Southern and especially the Eastern part of Germany, which may generally undermine a claim to overall representativeness for Germany.

Prevalence of sarcopenia and sarcopenic obesity according to different definitions

Table 3 shows the prevalence of sarcopenia in our cohort of CDW males 70+ according to the definitions of the EWGSOP, IWGS, and FNIH. Generally, all approaches show comparable, or at least non-significantly different ($p \geq .11$), results for Sarcopenia prevalence, ranging between 3.7 and 4.9%. Corresponding data were determined for the age group 70–79 years old (1.0–2.5%) and for men 80 years+ (8.0–10.9%).

Looking behind the covariates of the EWGSOP, IWGS, and FNIH definitions, the prevalence of “morphometric

sarcopenia” varied significantly (Table 3). Due to a diverse approach (i.e., ASMM/BMI vs. ASMM/height²), the FNIH definition differed considerably from the EWGSOP and IWGS criteria (21.7 vs. 14.6 and 12.9%), which were more closely related. Of relevance, as given, the cut point applying the EWGSOP criteria was calculated with a German cohort (≤ 7.177 kg/m²) that differ considerably from T-score-based cutoff points calculated for some other countries (e.g., Spain 8.25 kg/m², BIA [33]).

In parallel, the sarcopenia prevalence based on functional criteria differs between the definitions (Table 3). According to different cutoff points for grip strength (26 vs. 30 kg), the prevalence of “low-grip strength” was twice as high according to the EWGSOP approach compared with the FNIH definition. With respect to gait speed, the corresponding prevalence was 3.5-fold higher according to the IWGS criteria (<1.0 m/s) compared with the <0.8 m/s cut point suggested by the EWGSOP. However, since the EWGSOP uses an algorithm that additionally tested grip strength in subjects with normal gait speed, low gait speed is not a “killer criterion” for the prevalence of sarcopenia.

Overlap between the sarcopenia definitions

When applying the definitions pairwise, the sarcopenia prevalence falls considerably, suggesting a low to

Table 3 Sarcopenia and obesity prevalence and prevalence of underlying criteria according to different expert panel definitions

Sarcopenia	Total cohort (n = 965)	70–79 years (n = 690)	80–95 years (n = 275)	p value
EWGSOP (<7.18 kg/m ² ; <0.8 m/s; <30 kg)	4.9%	2.5%	10.9%	<.001
IWGS (7.23 kg/m ² ; <1.0 m/s)	3.8%	2.0%	8.0%	<.001
FINH (0.789 ASMM/BMI; <26 kg)	3.7%	1.0%	10.2%	<.001
Prevalence of morphometric sarcopenia criteria				
EWGSOP ^a (ASMM/height ² : ≤ 7.18 kg/m ²)	12.9%	9.9%	20.4%	<.001
IWGS (ASMM/height ² ≤ 7.23 kg/m ²)	14.6%	11.4%	22.2%	<.001
FINH (ASMM/BMI <0,789)	21.7%	18.0%	30.9%	<.001
Prevalence of functional sarcopenia criteria				
EWGSOP (gait speed <0.8 m/s) ¹	3.9%	2.2%	8.4%	<.001
EWGSOP (grip strength <30 kg)	16.9%	16.5%	32.4%	<.001
IWGS (gait speed <1.0 m/s)	14.9%	10.3%	26.2%	<.001
FINH (grip strength <26 kg)	8.6%	4.6%	18.2%	<.001
Obesity prevalence				
Body fat >25%	77.4%	75.2%	82.9%	.006
Body fat >28%	63.3%	61.0%	68.7%	.015
Body fat >30%	52.6%	50.3%	58.2%	.016
BMI >30 kg/m ²	19.9%	21.3%	16.4%	.048

EWGSOP European Working Group on Sarcopenia in Older People, IWGS International Working Group on Sarcopenia, FNIH Foundation for the National Institutes of Health, ASMM appendicular skeletal muscle mass, BMI body mass index

^a Cut point not clearly defined; we used the T-score-based approach described above

moderate overlap between the definitions (Table 4). Of 47 men 70+ classified as being sarcopenic according to EWGSOP, only 17 confirmed this diagnosis applying the FNIH criteria (36%); vice versa, only 17 of 36 men sarcopenic according to FNIH fell within the EWGSOP sarcopenia criterion (47%).

Figure 1 gives the relationship and overlap of morphometric and functional sarcopenia parameters in our cohort of 965 men 70+ together with cutoff points (vertical and horizontal lines, Fig. 1) according to different definitions. The lower left area represented the overlap, and the subjects identified with sarcopenia according to the corresponding definition(s). Applying simple correlation, the relationship between morphometric and functional parameters was at best low ($r = .368$). In parallel, the correlation between grip strength and gait speed was also rather low ($r = .387$). Figure 1 also gives the relationship ($r = .288$) and overlap between the two different morphometric sarcopenia approaches (ASMM/BMI vs. ASMM/height²) suggested by IWGS/EWGSOP and FNIH.

Sarcopenic obesity prevalence using different approaches and cutoff points

Table 3 shows the obesity prevalence according to different definitions. Less surprisingly, applying obesity criteria based on body fat content resulted in 3–4-fold higher prevalence rates compared with a BMI-based approach. All or almost all (95–100%) subjects with a BMI >30 kg/m² had body fat of 25, 28, and 30%, respectively. Body fat content was significantly higher, while BMI was significantly lower in the older subgroup.

Lastly, Table 5 gives the prevalence of sarcopenic obesity in our cohort applying different approaches. Using the EWGSOP criteria and a body fat content of >25% consequently resulted in the highest SO rate (4.1%), whereas the application of the WHO criteria for obesity generated the lowest SO rates ranging from 0.1 to 0.9% ($p \leq .01$ compared with the corresponding body fat-based approaches).

Discussion

The principal aim of the present study was to determine and describe the prevalence of sarcopenia and SO in German males 70+ and the corresponding agreement when applying recognized sarcopenia (and obesity) definitions. The two primary findings of this study were that (1) the prevalence of sarcopenia and sarcopenic obesity is relatively low in community-dwelling (CDW) older men. Further, (2) the prevalence of sarcopenia did not vary considerably when applying recognized definitions (3.7–4.9%); however, the corresponding overlap was at best moderate. The latter finding indicates that sarcopenia diagnosis of the individual still largely depends on the definition used. This unclear state should be resolved as soon as possible, also when considering that sarcopenia has been officially recognized as an independent condition by the ICD-10 code since October 2016.

Comparing sarcopenia and SO prevalence determined by the present study with a cohort of CDW women 70+ of a comparable background [34], the prevalence rate of sarcopenia according to EWGSOP was nearly identical (4.9 vs. 4.5%). On the other hand, although the prevalence of obesity was comparable between both genders (BMI-based 19.8 vs. 19.9%; body fat-based 63.6 vs. 63.3%) and independently of which model was applied, SO prevalence was considerably higher in the male cohort. With respect to sarcopenia prevalence, we confirmed data from the UK [35] that reported similar results at least when applying the EWGSOP (3.3%) and FNIH criteria (1.9%) in 156 CDW men 70–82 years old. Also, roughly comparable sarcopenia prevalence (EWGSOP 2.9%; FNIH 0.6%) was provided for CWD Dutch males and females 74 ± 3 years old [36], at least when bearing in mind that none of the participants suffered from multi-morbidity. However, Beudart et al. [37] who applied the identical EWGSOP sarcopenia criteria reported much higher prevalence rates (15%) for a CDW cohort ($n = 157$) of slightly younger but predominately multi-morbid male Belgians. One reason for these variations may be socio-economic differences with impact on earlier institutionalization despite poor health (e.g., family structures, public health system [38]) that may confound a proper comparison of sarcopenia prevalence in

Table 4 Sarcopenia prevalence when combining two different definitions

Variable	Total cohort ($n = 965$)	70–79 years ($n = 690$)	80–95 years ($n = 275$)	p value
EWGSOP and IWGS	2.5%	0.9%	6.5%	<.001
EWGSOP and FINH	1.8%	0.3%	5.5%	<.001
IWGS and FINH	1.0%	0.1%	2.9%	<.001

Percent of subjects with sarcopenia according to both definitions

EWGSOP European Working Group on Sarcopenia in Older People, IWGS International Working Group on Sarcopenia, FNIH Foundation for the National Institutes of Health

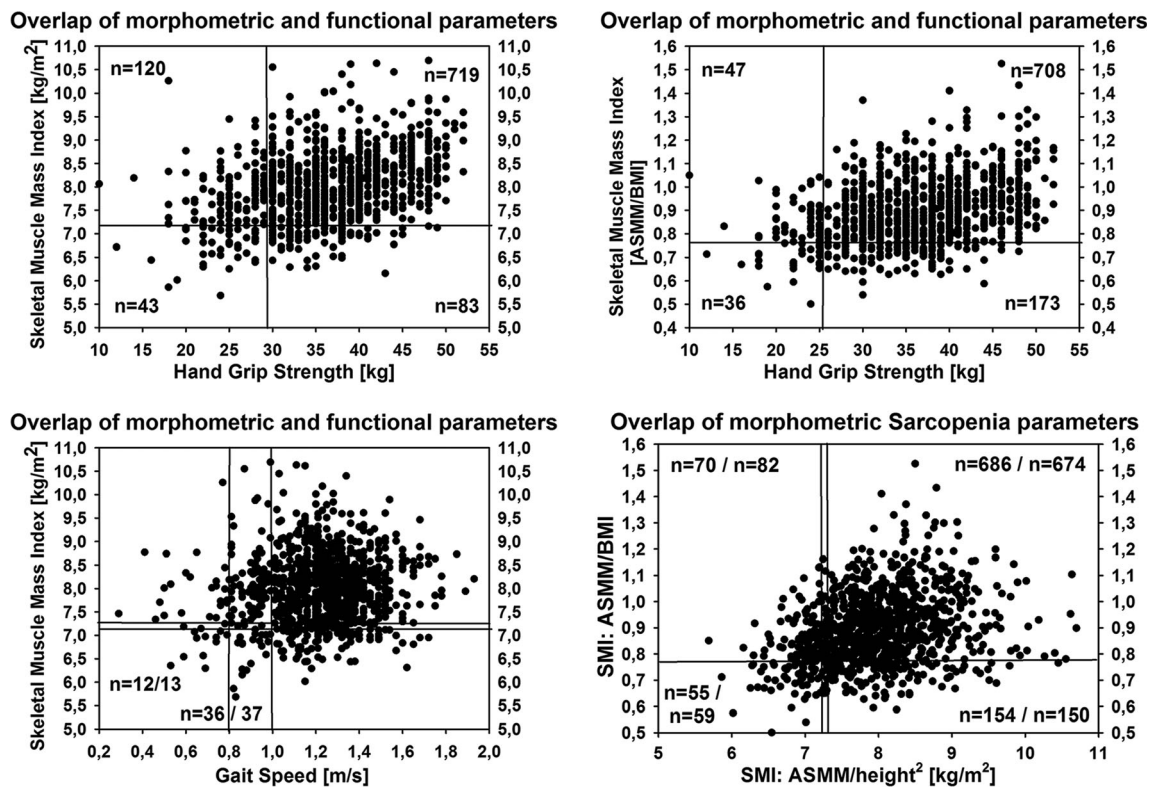


Fig. 1 Scatterplots of the overlap of morphometric and functional sarcopenia components and (*lower right corner*) of the two skeletal muscle mass index (SMI) criteria suggested by EWGSOP/IWGS (ASMM (kg)/height (m²) and FNIH (ASMM/BMI). Vertical and horizontal lines in the graph represent the cutoff points of the corresponding

sarcopenia criteria for SMI, handgrip strength, and gait speed. The number of subjects stated in the sectors also indicates the overlap between the different criteria. When two different cutoff points were applied (*lower graphs*), the corresponding numbers of subjects within the sectors were given separately (e.g., 12/13)

CWD people even between comparably developed, neighboring European nations.

The low diagnostic consistency between the applied sarcopenia definitions became comprehensive when looking

Table 5 Sarcopenic obesity prevalence applying different definitions and cutoff points

Variable	Total cohort (n = 965)	70–79 years (n = 690)	80–95 years (n = 275)	p value
Model I				
EWGSOP + body fat >25%	4.1%	2.0%	9.5%	<.001
EWGSOP + body fat >28%	3.6%	1.7%	8.4%	<.001
EWGSOP + body fat >30%	2.9%	1.6%	6.2%	<.001
EWGSOP + BMI > 30 kg/m ²	0.1%	0%	0.4%	.285
Model II				
IWGS + body fat >25%	3.4%	2.0%	6.5%	.001
IWGS + body fat >28%	2.9%	1.7%	5.5%	.003
IWGS + body fat >30%	2.1%	1.5%	3.3%	.061
IWGS + BMI > 30 kg/m ²	0.3%	0.3%	0.4%	.635
Model III				
FINH + body fat >25%	3.4%	1.0%	9.1%	<.001
FINH + body fat >28%	3.2%	1.0%	8.4%	<.001
FINH + body fat >30%	3.0%	1.0%	7.6%	<.001
FINH + BMI >30 kg/m ²	0.9%	0.3%	2.5%	.003

EWGSOP European Working Group on Sarcopenia in Older People, IWGS International Working Group on Sarcopenia, FNIH Foundation National Institute of Health, BMI body mass index

behind the covariates. As stated, definitions vary for criteria (i.e., gait speed [6, 7] and/or grip strength [6, 8]), calculation of skeletal muscle mass index (i.e., ASMM/height² [6, 7] or ASMM/BMI [8]), and computational procedures (algorithm [6] vs. “killer criteria” [7, 8]). Furthermore, cutoff points differ between the morphometric and functional criteria (grip strength 30 kg [6] vs. 26 kg [8]; gait speed 0.8 m/s [6] vs. 1.0 m/s) of the definitions. With respect to SMI, even when using the ASMM/height² criterion, the cutoff point differs not only between IWGS and EWGSOP but also within the EWGSOP [15, 39]. This finding becomes clearer when one bears in mind that most researchers applying the EWGSOP definition of sarcopenia used the T-score-based approach [15] (i.e., MV of young references—2 SD). However, when reviewing the literature, SMI cutoff points (DXA) for Caucasian or predominately Caucasian cohorts vary between 6.34 kg/m² [40] and 8.51 kg/m² [41, 42] for men and 4.32 kg/m² [43] to 6.29 kg/m² [41, 42] for women. Finally, apart from the DXA vs. BIA issue discussed below, even the application of different tools or methods to determine handgrip strength and/or gait velocity resulted in different results for the same cohort. Beaudart et al. [44] when determining the prevalence of sarcopenia in 250 CDW Belgians 65 years + reported that their pneumatic handgrip dynamometer diagnosed about twice as many sarcopenic subjects compared with their hydraulic device. The maximum handgrip strength difference between both devices averaged about 15 kg (12.2 vs. 27.5 kg), although both dynamometers were calibrated for 10, 40, and 90 kg prior to the study. Less pronounced and not undisputed [9], albeit potentially relevant, even differences in the walking distance (4 m vs. 10 m) were reported to significantly affect gait speed [45] and may thus possibly affect sarcopenia prevalence according to EWGSOP and IWGS.

Some limitations and features may decrease the degree of evidence of this study.

(a) Although we regularly (after each 500 letters) compared the most important characteristics of our cohort with corresponding German data during the screening process and did not detect relevant differences for confounding parameters, the regional character and the incomplete response (15%) may clash with our intention to generate data for sarcopenia and SO prevalence representative for German men 70+. From a biometrical point of view, it may be better to take representative samples of each German region and average the data to generate the corresponding sarcopenia and SO prevalence for the whole of Germany. However, federal data with relevant impact (e.g., BMI, physical activity, diet, education) on sarcopenia and SO prevalence vary considerably in this age group, especially between the former Eastern and Western parts of Germany [28, 46, 47]. Applying these average German data, the difference between characteristics of our cohort and corresponding German data was within the range

of the average difference between the German federal states; thus, we consider our results as representative at least for the Southern German population 70+. (b) One may argue that our approach of applying the SMI cut points was not consistent between the definitions. However, since the cutoff points of the IWGS and FNIH were mandatory, we directly applied these fixed SMI cutoff points (≤ 7.23 kg/m² [7, 18] and < 0.789 [8, 22]). On the other hand, the EWGSOP approach allows much more scope for the generation of a more dedicated SMI cutoff point. Therefore, we applied the most popular [15] and suitable approach of calculating a T-score based SMI cutoff based on a large young national reference cohort. (c) We used the BIA method for the body composition assessment of our cohort. Although the assessment of ASMM by BIA is reliable and Ling et al. [48] in particular reported an “excellent agreement” of BIA (InBody720, Biospace Ltd., Seoul, Korea)² compared with the gold standard “dual-energy X-ray absorptiometry” (DXA), some authors are concerned that BIA systematically overestimates SMI [44, 49]. Even if there were an overestimation, this problem should not affect our result since we apply a T-score-based cut point. However, due to time and cost efficiency and the lack of X-ray exposure, the modern BIA technique may be the more favorable choice for determining body composition in larger cohorts. (d) With respect to handgrip strength, we tested both hands, but only the mean value of the three trials of the dominant hand was included in the analysis. Although the strength of the dominant hand may be more important for independent living [50] from a functional point of view, this approach slightly affects our results. Indeed, we observed a difference of 2.2% when comparing mean grip strength of the dominant hand with the mean value of the six trials for both hands. When applying this cumulative grip strength data, 17.8% (vs. 16.9%, Table 3) fell within the EWGSOP and 9.4% fell within the FNIH (vs. 8.6%, Table 3) definition of low grip strength, resulting in a slight increase in overall sarcopenia prevalence according to EWGSOP and FNIH of 5.0% (4.9%) and 3.9% (3.7%), respectively.

Based on the strengths and limitations of this study, we strongly suggested considering the following aspects: (a) When using a T-score-based SMI approach, the reference data of young adults should regionally correspond to the targeted older population. The application of Korean or (New-) Mexican SMI cutoff points for Caucasian cohorts, for example, may lead to inadequate sarcopenia prevalence rates. (b) Since even slight variations in testing may affect prevalence rates, functional tests have to be strictly applied according to the prescribed test protocol. (c) With respect to obesity, it is evident that BMI-based approaches were absurd when addressing sarcopenic obesity. Unfortunately, there is no clear

² We used the identical DXA scanner and the succeeding model of their BIA device (i.e., InBody770).

body fat-based cutoff point for obesity in (older) men [2, 24], although most researchers applied cutoff points of 27 or 28% total body fat [2].

Conclusion

In conclusion, using established definitions, the prevalence of sarcopenia and SO in CDW German men 70+ averaged in the “reasonable” range of 3.7 to 4.9% for sarcopenia and 2.1 to 4.1% for SO, at least when body fat-based approaches were applied. However, the relative consistency of prevalence rates between the EWGSOP, IWGS, and FINH definitions does not necessarily imply a corresponding overlap with respect to individual sarcopenia diagnosis (Table 4). For example, only 50 and 36% subjects that fulfill the EWGSOP criteria were diagnosed sarcopenic according to IWGS or FNIH. Differences between EWGSOP/IWGS and FNIH can be predominately related to the varying SMI calculations (Table 1). Regarding the overlap of morphometric and functional parameters (Fig. 1), our data confirmed existing data that reported low correlations between morphometric and functional sarcopenia parameters (e.g., [22, 51]).

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Conflicts of interest None.

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