Comparison of methods to identify individuals with obesity at increased risk of functional impairment among a population of home-dwelling older adults.

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Abbreviations used: HGS: Handgrip strength; BIA: Bioelectrical impedance analysis; DXA: Dual-energy X-ray absorptiometry, WC: Waist circumference; FM: Fat mass FM%: Percentage body fat mass, FFM: Fat free mass; BMI: Body mass index; SPBB: The Short Physical Performance Test

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Abstract

Obesity is associated with increased muscle mass and muscle strength. Methods taking into account the total body mass to reveal obese older individuals at increased risk of functional impairment are needed. Therefore, we aimed to detect methods to identify obese older adults at increased risk of functional impairment. Home-dwelling older adults (n 417, ≥ 70 years of age) were included in this cross-sectional study. Gender-specific cut-off points for two obesity phenotypes (waist circumference [WC] and body fat mass [FM %]) were used to divide women and men into obese and non-obese groups, and within-gender comparisons were performed. Obese women and men, classified by both phenotypes, had similar absolute handgrip strength (HGS), but lower relative HGS (HGS/total body mass) ($P < 0.001$) than non-obese women and men, respectively. Women with increased WC and FM %, and men with increased WC had higher appendicular skeletal muscle mass ($P < 0.001$), lower muscle quality (HGS/upper appendicular muscle mass) ($P < 0.001$) and spent longer time on the stair climb test and the repeated sit-to stand test ($P < 0.05$) than non-obese women and men, respectively. Absolute muscle strength was not able to discriminate between obese and non-obese older adults. However, relative muscle strength in particular, but also muscle quality and physical performance tests, where the total body mass was taken into account or served as an extra load, identified obese older adults at increased risk of functional impairment. Prospective studies are needed to determine clinically relevant cut-off points for relative HGS in particular.

Introduction

Aging and inactivity are associated with loss of muscle mass, muscle strength and muscle quality (1–4). Obesity and low muscle strength are strong predictors of functional decline among older adults (5), and serious health consequences such as limitations in daily living activities (6), disability, risk of falling, fracture and mortality (7,8). Aging is characterized by changes in body composition where loss of muscle mass is often accompanied by increased fat mass. Age-related changes in body composition also include fat redistribution, with reduction in peripheral subcutaneous fat and increased visceral fat, and fat deposition in non-adipose tissue such as e.g. skeletal muscles (3,9). Along with the rising number of older adults aged above 65 years, the prevalence of obesity among older adults is expected to increase (10,11). Obesity, excessive accumulation of body fat, is associated with higher muscle mass (12–14), suggesting that the strength production capacity is higher in obese than non-obese individuals (15–17). Additionally, since obesity is related to reduced muscle function and mobility limitation (18–20), muscle strength and physical performance tests where the total body mass is taken into account or serve as an extra load, may be useful tests to identify obese individuals at increased risk of functional impairment

Handgrip strength (HGS) is widely used as an indicator of overall muscle strength, especially among older people (21). Low HGS in older adults has consistently been linked to poor health outcomes such as long-term disability onset, low quality of life (22,23), functional decline and mortality (24). However, in individuals with obesity, where fat mass serves as an extra load while moving, a limitation with measuring the absolute HGS is the reduced ability to reflect the actual physical performance capacity. Relative HGS (HGS/total body mass) has been suggested as a more sensitive method than absolute HGS to discriminate between obese and non-obese older adults at risk of impaired physical performance (25). Further, muscle quality, defined as the ratio of muscle strength or power per unit muscle mass (26) is another suggested parameter to identify muscle function in older adults, and the use of muscle quality is expected to grow in importance (27,28).

To prevent negative health outcomes and to enable older adults to remain living independently in their homes, effective and low-cost strategies to early identify functional impairment related to obesity are needed. In the present study, we aimed to detect methods to identify obese older adults at increased risk of functional impairment. By using two common phenotype definitions of obesity, we wanted to compare muscle strength (absolute HGS, relative HGS, and stair climb test), muscle quality (absolute HGS/upper body appendicular skeletal muscle mass) and physical performance (balance test, repeated sit-to-stand test, and gait speed) between obese and non-obese home-dwelling older adults.

Methods

Participants

The present study was conducted in 2014-15 at Oslo and Akershus University College of Applied Sciences, Norway. Invitation letters were sent to home-dwelling women and men (≥ 70 years) living in the area of Skedsmo, Norway, listed in the National Population Register. In total, 2860 older adults (≥ 70 years of age) were invited to participate, of which 477 (17%) responded to the invitation and thus 438 (16%) participated. One participant withdrew the informed consent. Bioimpedance analyzer (BIA) measurements were only available in 417 individuals, thus 417 were included in this study. There were no exclusion criteria. Cognitive health and nutritional status were measured using the Mini-Mental State Examination (MMSE) test form and the Mini Nutritional Assessment form® (MNA), respectively. Both the MMSE and MNA have a maximal score of 30 points, and high scores indicate a high cognitive function and good nutritional status, respectively. In a previous study, data on cognitive health (MMSE-score), nutritional status (MNA-score), co-morbidities and dietary intake (2 x 24 hour dietary recall method) in the same study population (n 417) have been shown (29). The data included in the current study were obtained from a cross-sectional study which served as a screening visit for a randomized controlled study (Clinicaltrials.gov, ID no. NCT02218333) (30). The present study was conducted according to the guidelines in the Declaration of Helsinki and all procedures involving human subjects were approved by the Regional Committees for Medical and Health Research Ethics, Health Region South East, Norway (2014/150/REK). Written informed consent was obtained from all participants. Extracts from the National Population Registry were used according to, and with approval by the Norwegian Tax Administration.

Study design

In this cross-sectional study, gender-specific cut-off points for two obesity phenotypes (waist circumference [WC] and percentage of body fat [FM %]) were used to create groups that allowed within-gender comparisons of muscle strength, muscle mass, muscle quality and physical performance between obese and non-obese. For women the cut-off points were > 35 % FM and ≥ 88 cm (obese) or ≤ 35 % and < 88 cm (non-obese). For men the cut-off points were > 25 % FM and ≥102 cm (obese) or ≤ 25 % and < 102 cm (non-obese) (31).

Body composition and waist circumference

Body composition was measured by a single frequency BIA (BC-418 MA, Tanita Corp., Tokyo Japan), operating at 50 kHz, providing measurements of fat-free mass (FFM), body fat mass (FM) and FM % for the whole body. The participants were standing barefoot on the instrument platform. Four pairs of electrodes were positioned at each hand and foot, in which the low-voltage current entered the limbs. Appendicular skeletal muscle mass was derived from the sum of the fat-free mass of the four limbs based on equations incorporated in the software by the manufacturer. In-house validation of BIA against dual-energy X-ray absorptiometry (DXA) was performed in 47 individuals of the current study population, showing comparable estimates of appendicular skeletal muscle mass measured with BIA on group level. Between-day CV % (SD/mean) of the BIA measurement of fat-free mass was calculated in a subgroup (n 46). Each subject was measured twice, on separate days. The between day CV % was 1.8 %. To identify subjects with low appendicular skeletal muscle mass, gender specific cut-off points (< 15 kg in women and < 20 kg in men) were used (28,32). WC (centimeters) was measured with the use of a measuring band in standing position with arms hanging loosely, and on exhalation at the midpoint between the top of the iliac crest and the lower margin of the last palpable rib. The measurement was performed with the abdomen relaxed at the end of expiration (33).

Muscle strength, muscle quality and physical performance

HGS of both hands was measured using a digital handheld dynamometer (KE-MAP80K1, Kern MAP, Elstra, Germany). Participants were placed in a sitting position, elbow in 90° flexion and wrist in a neutral position. The participants were asked to squeeze the dynamometer as hard as possible simultaneously by breathing out. The maximal HGS of three measurements was registered from each hand. Absolute HGS was defined as the maximal HGS, regardless of dominant or non-dominant hand. Low absolute HGS was defined as < 16 kg in women and < 27 kg in men (28,34). Relative HGS was defined as the absolute HGS (kg)/total body mass (kg). Upper body muscle quality was calculated by absolute HGS/upper body appendicular skeletal muscle mass (26,35–38). As described elsewhere, in a subgroup of 47 participants the between-day CV of absolute handgrip strength was 5.0 % (29). Low muscle quality was defined as muscle quality < 5.475 in women and < 5.760 in men (36). The stair climb test (16 steps, 18 cm height) has been found to be a relevant measure of leg power (force and speed) impairments (39). The test was performed where each participant was given two attempts with at least two minutes rest in between, and the best performance was registered. The time was recorded to the nearest 100th of a second. No cut-off points for slow stair climb exits. The Short Physical Performance Battery (SPPB) tests (balance test, repeated sit-to-stand test and gait speed) were performed according to the SPPB protocol (40). According to SPPB, Scores of 0-4 of the three tests were summed to give a maximal total score of 12 points, and a total score ≤ 8 points indicates poor physical performance. To describe subjects with reduced muscle strength in the lower body and reduced gait speed, cut-off points for the repeated sit-to-stand test (> 15.0 sec) and gait speed (≤ 0.8 m/sec) were used (28).

Statistic

All continuous normally distributed data were presented as mean (standard deviation, SD), not normally distributed data were presented as median (25-75 percentiles) and categorical data as number and percentage. For continuous variables, independent sample t-test or Mann-Whitney U test were used in normally distributed and not normally distributed data, respectively, and for categorical variables, the chi-square test was used. Cohen´s kappa (κ) was used to determine the agreement between the two phenotypes (WC and FM%) of obesity used to define women and men as either obese or non-obese. The level of significance was defined as $P < 0.05$. All analysis were performed using SPSS for Windows (version 26.0; SPSS, Inc., Chicago, IL, USA).

Results

Characteristic of the study population

In this study, 417 community-dwelling older women (n =217, 52 %) aged 74 (71-77) years, and men (n = 200, 48 %) aged 78 (74-82) years were included. The MMSE and MNA scores were skewed towards high values, and the median scores were 28 (26-30) and 28 (27-29) in women, and 29 (26-30) and 28 (27-29) in men, respectively. As shown in **Table 1**, using WC and FM % to define obesity, 59 % and 62 % of the women, respectively, were obese. In men, 38 % and 49 % were defined as obese, respectively. Agreement between WC and FM % classification was κ= 0.62 (95% CI 0.51-0.73) $P < 0.001$ in women and κ=0.54 (95% CI 0.43-0.65) $P < 0.001$ in men. Mean (SD) absolute HGS was 21.8 (4.7) kg in women, and 38.1 (7.0) kg in men. Few women and men had low absolute HGS (7 % and 6 %, respectively), low SPPB score (6 % and 8 %, respectively) and low appendicular skeletal muscle mass (7 % and 8 %, respectively). Despite this, low muscle quality was observed in 64 % and 34 % of the women and men, respectively. Data on relative HGS, muscle quality, physical performance and body composition in women and men are further outlined in Table 1.

Body composition, muscle strength, muscle quality and physical performance

As shown in **Table 2**, older women with obesity defined by increased WC or FM %, had significantly higher appendicular skeletal muscle mass, but similar absolute HGS than non-obese women. However, the obese women had significantly lower relative HGS and muscle quality, and they spent significantly longer time performing the stair climb test and the repeated sit-to-stand test than the non-obese women (Table 2). As shown in **Table 3,** obese men defined by WC or FM % had similar absolute HGS, but lower relative HGS compared to non-obese men. Further, obese men defined by WC had higher appendicular skeletal muscle mass, lower muscle quality, spent longer time on the stair climb test and the repeated sit-to-stand test than the non-obese men. The only difference between obese and non-obese men defined by FM % was lower relative HGS among obese men.

Discussion

In the present study, where home-dwelling older adults had high cognitive function and good nutritional status, we show that the absolute muscle strength was not able to discriminate between obese and non-obese older adults. However, relative muscle strength in particular, but also muscle quality and physical performance tests where the total body mass was taken into account or served as an extra load, identified the obese older adults at increased risk of functional impairment.

Obesity is associated with higher fat mass and muscle mass (12–14,41), and HGS produced by obese individuals is higher than in non-obese (16,17). HGS is widely used for the measurement of muscle strength, and cut-off points for low HGS has been lowered by the European Working Group on Sarcopenia in Older People (EWGSOP) (28) compared to previous recommendations (42). Thus, the probability to misclassify obese individuals has increased. To identify obese older individuals with low muscle strength, the total body mass must also be taken into account. Further, this may incorrectly lead to the suggestion that the actual muscle strength in obese individuals is sufficient. The present study shows that obese and non-obese older adults had similar absolute HGS, but the obese individuals had poorer physical performance where total body mass served as an extra load (repeated sit-to-stand and stair climb tests) than the non-obese. Even though absolute HGS is a highly efficient screening tool (43), it may misclassify individuals as it only accounts for ~ 40% of the variance in lower body strength (44). Thus, caution should be taken into account when estimating overall strength from absolute HGS in obese individuals and from one single measurement tool (45–47). Since strength production capacity relative to body mass was lower among the obese than non-obese, it may indicate that relative HGS is a more sensitive method than absolute HGS to identify obese older adults at the risk of functional impairment. Furthermore, relative HGS has been associated with cardiometabolic disease risk factors (48–50). Currently, no population specific cut-off points for low relative HGS exist. Future prospective studies are needed to establish gender specific cut-off points that predicts clinically relevant impaired muscle function.

Despite finding a higher appendicular skeletal muscle mass in obese compared to non-obese individuals, differences were not observed in absolute HGS between the two groups. It is well known that obesity leads to fat infiltration into muscle tissue, causing decline in muscle strength to a greater extent than loss of muscle mass (2). Previous studies in older adults have shown that increased fat mass contributes to a deterioration of muscle strength and lower absolute HGS (51,52). Muscle quality, expressing muscle strength relative to muscle mass, declines with age and obesity (14,53), and marked inter-individual differences in rates of loss have been reported (26,35,54). In accordance with previous studies, lower muscle quality was observed in obese women and men, which may explain the lack of differences in absolute HGS between obese and non-obese individuals (14,55). By definition, muscle quality provides a good indication of muscle function. However, muscle quality referring both to micro- and macroscopic changes in muscle architecture and composition (27,56) and may thus be technically difficult to measure accurately (27,57–59). Further, previous studies have shown that both muscle mass, obesity and age affect the relationship between muscle quality and physical function (54). Consequently, despite similar values of muscle quality, obese individuals may have poorer muscle function than non-obese. Muscle quality measurement is suggested to grow in importance, but cut-off points for low values needs to be established and validation of muscle quality as an assessment tool is needed. However, since the active muscle mass may only be a small part of the total muscle mass, it is important to emphasize that both relative HGS and muscle quality estimated by absolute HGS/upper body muscle mass have limitations. Further, muscle quality (HGS/upper body muscle mass) would not necessarily be a good measure of overall muscle quality because the muscle mass may be differently distributed on the body. Thus, implementation of muscle quality as a screening measurement for functional impairment in older adults, especially among obese, should be done with caution.

Absolute HGS has traditionally been used as a measure of muscle strength in the assessment of muscle function in older adults. However, as previously shown, lower body strength may better reflect the functional capacity compared with absolute HGS, that are necessary for activities of daily living such as mobility, gait speed and stairs climbing (41,60,61). In addition, although absolute HGS has been shown to strongly correlate with leg strength in older adults, absolute HGS does not provide valid results when evaluating the efficacy of exercise intervention programs to increase muscle mass or strength in an older population (47). The repeated sit-to-stand and stair climb tests are widely used as lower extremity strength measurement (21,62), and have been shown relevant measures of leg power impairments (39).

Further, these methods take total body mass into account and are affected by muscle strength, dynamic balance and cardiorespiratory endurance, and thus represent overall physical performance rather than overall muscle strength (63,64). The short gait speed test (4m), may not be as sensitive as repeated sit-to-stand and stair climb tests in older obese adults, but studies where longer walking distances have been used (20m and 500m) (65,66) show differences between the obese and non-obese. In a clinical context, repeated sit-to-stand test and stair climbing test are simple tests that could be easily implemented.

More women than men were classified as obese, and a substantial agreement between WC and FM % was observed among women. A moderate agreement between the methods was observed in men, and only obesity defined by WC identified individuals at increased risk for functional impairment. In a previous study, where the two obesity phenotypes WC and FM % were compared, WC were more sensitive to identify older adults at the risk of functional impairment than FM % (67). However, in our study, more men were defined as obese by FM % than WC. Thus, the lower agreement between the obese-phenotypes in men than in women, could be explained by the cut-off point to define obesity by FM % in men is too low. Furthermore, WC is a surrogate measure of visceral adiposity and may reflect greater inflammatory potential (68) and insulin resistance (69), which may contribute to progressive loss of muscle mass, muscle strength, and muscle quality (69–71). In a clinical context, WC measurement may be preferred because it is easier to implement than FM %. Moreover, increased WC is associated with lower quality of life, a decline in physical function, and a slightly higher risk of disability over time (65). Thus, WC has been suggested to be measured routinely in clinical practice (72).

There are, however, some limitations in this study. Food intake and physical activity may affect BIA measurements. Due to practicalities, non-fasting measurement of body composition BIA was performed in this study. To reduce the effect of physical activity, all physical tests were performed after the BIA measurement was performed. However, the participants had no restrictions on physical activity the last 24 hours prior to the study visit. Thus, the non-fasting measurement and the activity level may thus have influenced the estimation of fat free mass and fat mass in our study. Whether this has contributed to the reduced agreement between WC and FM % is plausible, but uncertain. Furthermore, the majority of older adults had high SPPB score, and the study population included was relatively healthy having high cognitive function, adequate nutritional status and dietary intake, and only a few had severe inflammatory disease (9%) or respiratory diseases (5%) as further described elsewhere (29). Despite this, we cannot exclude the possibility that diseases, pain or motivation may have affected the ability to perform the physical tests in some individuals. Unfortunately, we were not able to reveal age-related intra-muscular changes which affect the muscle quality. The participants included in the present study had high muscle mass and physical performance, and thus, the results may not be generalized to obese older frail or sarcopenic older adults. A strength of the present study was the large number of participants, and the fact that several tests were included to assess body composition and muscle function.

In conclusion, methods to identify obese older adults with increased risk of functional impairment are needed. We show that neither muscle mass nor absolute muscle strength, was able to discriminate between obese and non-obese older adults at increased risk of functional impairment. However, relative muscle strength, muscle quality, and physical performance tests where body mass serves as an extra load, identified obese older adults with an increased risk of functional impairment. Relative HGS is a simple and an effective method that is easy to implement for routine clinical practice. Thus, prospective studies are needed to investigate clinically relevant cut-off points for relative HGS in relation to functional impairment in older adults.

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Statement of authorship

SMU, KBH and IO conceived and designed the study, LKLØ and IO conducted the research, and ALN and IO interpreted and performed statistical analysis. ALN, and IO wrote this paper and had the primary responsibility for the final content. All authors have critically reviewed the manuscript.

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Table 1. Antropometric measurements, muscle strength, -quality and physical performance in women and men.

	Women (*n* 217)		Men (*n* 200)	
	Mean/median/*n*	SD/Q1-Q3/%	Mean/median/*n*	SD/Q1-Q3/%
Waist circumference (cm)	91.4	12.5	99.2	10.3
women ≥ 88 cm, men ≥ 102 cm (*n*)	128	59	75	38
Fat mass (%)	36.2	7.0	25.2	6.1
women > 35%, men > 25% (*n*)	135	62	97	49
Absolute hand grip strength (kg)†	21.8	4.7	38.1	7.0
women < 16 kg, men < 27 kg (*n*)	16	7	11	6
Relative handgrip strength (kg/kg)[†]	0.32	0.07	0.47	0.09
Muscle quality (kg/kg)[†]	5.2	1.0	6.2	1.0
women < 5.475, men < 5.760 (*n*)	138	64	68	34
Appendicular skeletal mucsle mass (kg)	17.8	2.6	24.3	3.3
women < 15 kg, men < 20 kg (*n*)	16	7	15	8
Stair climb test (sec)ǂ	7.9	2.3	6.7	1.8
Repeated sit-to-stand test (sec)[\$]	11.7	3.3	11.1	2.4
> 15.0 sec (*n*)[\$]	26	12	12	6
Gait speed (m/sec)	1.2	0.1	1.3	0.2
≤ 0.8 m/sec (*n*)	13	6	5	3
Balance test < 10 sec (*n*)[¢]	35	16	20	10
SPPB (score)	11	11-12	11	11-12
≤ 8 points (*n*)	13	6	8	4
BMI (kg/m^2)	26.3	4.5	26.0	3.5
> 30 kg/m^2 (*n*)	40	18	24	12
Fat free mass (kg)	43.5	5.6	60.0	7.2
Fat mass (kg)	25.7	8.7	20.8	7.2
Body weight (kg)	69.2	12.9	80.8	12.0

Height (cm)	162	6.0	176	6.5

†Two women and four men missing.

ł Three women missing.

$ Two women missing.

¢ One women missing.

Table 2. Absolute and relative handgrip strength, muscle quality and -mass, and physical performance in obese and non-obese older women.

	FM % > 35 *n* 135	FM % ≤ 35 *n* 82	WC ≥ 88 cm *n* 128	WC < 88 cm *n* 89	*P*-value*	*P*-value**
Absolute HGS (kg)	21.7 (4.6)†	21.8 (4.9)†	22.1 (4.6)†	21.4 (4.7)†	0.89	0.27
Relative HGS (kg/kg)	0.29 (0.06)†	0.37 (0.08)†	0.29 (0.06)†	0.36 (0.08)†	< 0.001	<0.001
Muscle quality (kg/kg)	5.0 (0.1)†	5.5 (1.1)†	4.9 (0.9)†	5.5 (1.0)†	< 0.001	<0.001
Appendicular skeletal muscle mass (kg)	18.4 (2.5)	16.7 (2.4)	18.8 (2.6)†	16.3 (1.7)†	<0.001	<0.001
Stair climb test (sec)	8.2 (2.1)ǂ	7.4 (2.5)†	8.3 (2.4)ǂ	7.4 (2.1)†	0.01	0.01
Repeated sit-to-stand test (sec)	12.2 (3.5)ǂ	11.0 (2.7)	12.2 (3.3)ǂ	11.1 (3.2)	0.01	0.02
Gait speed (m/sec)	1.2 (0.2)	1.3 (0.2)	1.2 (0.2)	1.3 (0.2)	0.08	0.10

FM, Total body fat mass; WC, Waist circumference; HGS, Handgrip strength.

* Between women with FM > 35 % vs ≤ 35%.

** Between women with WC ≥ 88 cm vs < 88 cm.

† One missing.

ǂ Two missing.

Table 3. Absolute and relative handgrip strength, muscle quality and -mass, and physical performance in obese and non-obese older men.

	FM % > 25	FM % ≤ 25	WC ≥ 102 cm	WC < 102 cm		
	n 97	*n* 103	*n* 75	*n* 125	*P*-value[*]	*P*-value[**]
Absolute HGS (kg)	38.0 (6.8)[ǂ]	38.1 (7.2)[ǂ]	38.6 (6.7)[ǂ]	37.7 (7.2)[ǂ]	0.91	0.38
Relative HGS (kg/kg)	0.44 (0.08)[ǂ]	0.50 (0.09)[ǂ]	0.43 (0.07)[ǂ]	0.50 (0.08)[ǂ]	<0.001	<0.001
Muscle quality (kg/kg)	6.1 (0.9)[ǂ]	6.3 (1.0)[ǂ]	5.8 (0.8)[ǂ]	6.5 (1.0)[ǂ]	0.23	<0.001
Appendicular skeletal muscle mass (kg)	24.6 (3.4)	24.1 (3.2)	26.2 (2.8)	23.2 (3.1)	0.21	<0.001
Stair climb test (sec)	7.0 (1.9)	6.5 (1.8)	7.2 (1.9)	6.5 (1.7)	0.06	0.004
Repeated sit-to-stand test (sec)	11.1 (2.2)	11.1 (2.7)	11.6 (2.4)	10.8 (2.5)	0.96	0.04
Gait speed (m/sec)	1.3 (0.2)	1.3 (0.2)	1.3 (0.2)	1.3 (0.2)	0.30	0.63

FM, Total body fat mass; WC, Waist circumference; HGS, Handgrip strength.

[*] Between men with FM > 25 % vs ≤ 25%.

[**] Between women with WC ≥ 102 cm vs < 102 cm.

[ǂ] Two missing.