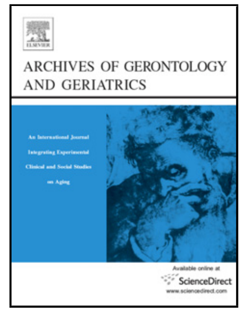

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Body composition as a predictor of physical performance in older age: a ten-year follow-up of the Helsinki Birth Cohort Study

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Highlights

- Greater adiposity predicted poorer physical performance ten years later.
- Measures of adiposity predicted physical performance better than those of lean mass.
- Lean mass was inversely associated with physical performance.

Abstract

Background

This study assessed how different measures of body composition predict physical performance ten years later among older adults.

Methods

The participants were 1076 men and women aged 57 to 70 years. Body mass index (BMI), waist circumference, and body composition (bioelectrical impedance analysis) were measured at baseline and physical performance (Senior Fitness Test) ten years later. Linear regression analyses were adjusted for age, education, smoking, duration of the follow-up and physical activity.

Results

Greater BMI, waist circumference, fat mass, and percent body fat were associated with poorer physical performance in both sexes (standardized regression coefficient [β] from -0.32 to -0.40, $p<0.001$). Lean mass to BMI ratio was positively associated with later physical performance (β=0.31 in men, β=0.30 in women, $p<0.001$). Fat-free mass index (lean mass/height^2) in both sexes and lean mass in women were negatively associated with later physical performance. Lean mass residual after accounting for the effect of height and fat mass was not associated with physical performance.

Conclusions

Among older adults, higher measures of adiposity predicted poorer physical performance ten years later whereas lean mass was associated with physical performance in a counterintuitive manner. The results can be used when appraising usefulness of body composition indicators for definition of sarcopenic obesity.

Key words: physical performance, body composition, obesity, lean mass

1. Introduction

It has been suggested that sarcopenic obesity is an important risk factor for morbidity and disability in older age (1,2). Sarcopenia refers to loss of muscle mass and strength (3) and sarcopenic obesity to the coexistence of high adiposity and low muscle mass (1,2). Older age is a susceptible time for developing sarcopenic obesity as muscle mass typically decreases with age while fat mass increases. Sarcopenic obesity, however, still lacks a widely accepted definition (4) as does its component, sarcopenia (3). Different measures have been suggested for determining sarcopenia such as appendicular skeletal muscle mass index (skeletal muscle mass of the limbs/height^2) (5,6), fat-free mass index (fat-free mass/height^2) (7), lean mass to total mass ratio (8), and appendicular lean mass to body mass index (BMI) ratio (6). Sarcopenic obesity, in turn, has been defined using various combinations between the above mentioned sarcopenia measures and different measures of obesity, such as BMI and percentage body fat (2).

To be clinically meaningful, a measure should predict later outcome relevant for health or functioning. However, most of earlier studies examining the relationship between body composition and physical performance among older adults have been cross-sectional. Previous cross-sectional studies have reported that lean mass without adjustment for obesity is not associated with physical performance (9) or functional limitation (10). Further, lean or fat-free mass adjusted for height has been found to correlate poorly with physical performance and functioning (9,11,12). A longitudinal study reported that low appendicular lean mass adjusted for height predicted better functioning (13), which is in contrast with the concept of sarcopenia. However, combined measures of lean mass and obesity, for example (appendicular) lean mass to BMI ratio (10,14), percent lean mass (9) or lean mass residual after accounting for fat mass (13), have been found to correlate positively with physical performance and functioning.

Only few studies have studied different measures related to sarcopenic obesity in a same study in a follow-up setting. Studying a variety of measures within the same study sample is important as estimates from different study samples cannot be directly compared to each other. Hence, it is not well known how different body composition measures related to sarcopenic obesity predict later objective measures relevant for functioning among older people and how these measures compare to each other. This information is needed when assessing the validity of measures in terms of sarcopenic obesity.

The aim of this study was to examine how different measures of body composition predict physical performance 10 years later among older adults. The ability of the body composition measures to predict later physical performance was tested separately for men and women.

2. Materials and Methods

This study is part of the Helsinki Birth Cohort Study (HBCS) that includes 13345 individuals born in Helsinki between 1934 and 1944. In the year 2000 of those born in the Helsinki University Central Hospital (n=8760), a random sample of 2902 individuals were invited to participate in a clinical examination conducted between the years 2001 and 2004 (15). From those who participated (n=2003), 1404 people who were alive and living within a 100 km distance from Helsinki were invited to participate in the second clinical examination in 2011-2013 (16). A total of 1094 participants attended and of these, 1076 had data on both physical performance and at least one of the body composition measures and were thus included in the analysis. Both among men and women, those who were included in the analysis were slightly younger, more educated, had lower percent body fat, and had better physical functioning than those excluded but they did not differ in the level of physical activity.

2.1. Body composition and anthropometry

Body composition was assessed by bioelectrical impedance analysis using the InBody 3.0 eight-polar tactile electrode system (Biospace Co, Ltd, Seoul, Korea) (17). The instrument estimates lean body mass and percentage body fat by segmental multi-frequency (5, 50, 250, and 500 kHz) analyses separately for trunk and each limb. The resistance measurements were made with the subject standing in light clothing on the 4-foot electrodes on the platform of the analyzer and gripping the two palm and thumb electrodes. Height was measured without shoes on to the nearest 0.1 cm and weight was measured in light indoor clothing to the nearest 0.1 kg. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Waist circumference was measured midway between the lowest rib and the iliac crest. We used the following anthropometric/body composition variables as predictors in the analyses: BMI, waist circumference (cm), lean mass (kg), fat mass (kg), percent body fat (=fat mass/total body mass), lean mass to BMI ratio (=lean mass/BMI) (14), fat-free mass index (=lean mass/height^2) (7), and lean mass residual (12). Lean mass residual was computed by regressing lean mass on height and fat mass i.e. it is the part of variation in lean mass not accounted for by height and fat mass (13). For the computation of lean mass residual, all available data were used (n=1918), including those who had no follow-up data.

2.2. Physical performance

Physical performance was assessed by using the Senior Fitness Test battery (SFT) (18,19). The test battery has been validated against the level of independence in physical functioning (e.g. self-care, household chores and walking outdoors) (20). The tests have also been shown to discriminate across different age groups and between individuals with low and high physical activity (19). We used a modified test battery consisting of five components of the

SFT: number of full stands in 30 s with arms folded across chest to assess lower-body strength; number of bicep curls in 30 s while holding a hand weight (3 kg for men and 2 kg for women) to assess upper-body strength; chair sit and reach to assess the lower-body flexibility (from sitting position with leg extended at front of chair and hands reaching toward toes, number of cm (+ or −) from extended fingers to tip of toe); number of meters walked in 6 min to measure aerobic endurance; and back scratch to assess upper-body flexibility (with one hand reaching over shoulder and the other one up middle of back, distance (cm) between extended middle fingers (+ or −). All measurements were performed by a team of trained research assistants. For each test, the scores of the participants were also classified with respect to percentile tables of normative data for each 5-year age group (18). A rating from 1 to 20 was given according to each five percentile range, with 1 being the worst performance (score below the fifth percentile), 2 the score from the 5th to the 9th percentile, and 20 the best performance (in or above the 95th percentile). Then we calculated an overall score, which was the sum of the normalized scores for the five SFT test components. The overall SFT score varied between 5 and 100.

2.3. Potential confounders

Date of birth was obtained from the hospital birth records. Completed years of education, smoking status, health characteristics, and medications used were assessed using questionnaires at the clinical examination in 2001-04. Of the diseases, cardio-vascular diseases, stroke, cancer and emphysema potentially affect both body composition and later physical performance and hence, these diseases were considered as potential confounders. Correspondingly, use of insulin, glucocorticoids or diuretics were considered as potential confounders. The participants also completed a validated Kuopio Ischemic Heart Disease

Risk Factor Study (KIHD) questionnaire on 12-month leisure-time physical activity (21). Total leisure-time physical activity, including both non-conditioning (e.g. housework) and conditioning (e.g. resistance training) physical activity, in metabolic equivalent (MET) values per week was computed based on the questionnaire.

2.4. Data analysis

Initially, the relationships between body composition measures and physical performance were visually inspected using scatter plots. Scatter plots presented no indications of non-linear associations and hence, linear models were deemed as sufficient. Linear regression analyses were used to analyze associations between body composition variable and physical performance 10 years later for each body composition variable separately. Analyses were stratified according to sex as men and women differ markedly in their typical body composition. First, crude models were run. Then age, years of education, smoking, duration of the follow-up, and physical activity were entered into the models. We also ran sensitivity analyses. First, we excluded participants with cardiovascular diseases, stroke, cancer or emphysema and participants those who reported using insulin, glucocorticoids or diuretics at baseline (excluded n=295). Second, we excluded those with BMI greater than 40 (excluded n=9) to make sure that these few extreme cases do not distort the results. The differences between the original and the sensitivity analyses were marginal and did not affect the conclusions made on the results and hence, we only present the original analyses comprising the whole analytical sample. To illustrate the contributions of fat and lean mass to physical performance, we regressed Senior Fitness Test score on quadratic functions of lean and fat mass, separately for men and women. The predicted Senior Fitness Test score was shown in five point intervals on the lean mass – fat mass scatter plots, only including the central 95% of observations. The analyses were carried out using IBM SPSS Statistics version 23.

3. Results

Characteristics of the study participants are shown in Table 1 and Table 2.

Table 1 Characteristics of the participants.

	Men			Women		
	N	Mean	SD	N	Mean	SD
Age at baseline (years)	473	61.2	2.6	603	61.3	2.9
Height (cm)	473	177.2	5.9	603	163.4	5.7
Weight (kg)	473	85.5	12.2	603	72.4	12.7
BMI (kg/m^2)	473	27.2	3.5	603	27.1	4.6
Waist circumference (cm)	473	99.6	10.3	603	89.3	11.7
Lean mass (kg)	452	62.1	7	585	44.9	5.1
Fat mass (kg)	452	20	7	585	24.6	8.9
Percent body fat (%)	452	22.9	5.5	585	33.2	6.6
Lean mass to BMI ratio (m^2)	452	2.3	0.2	585	1.7	0.2
Fat-free mass index[a] (kg/m^2)	452	19.7	1.6	585	16.8	1.5
Lean mass residual (kg)	452	0.9	6.3	585	0.1	4.2
SFT Sum Score at follow-up	473	42.5	16.6	603	46.9	17.9
Physical activity, (METhours/week)	445	36.8	25.4	558	38.5	26.9
Full-time studying (years)	458	13	3.8	590	12.2	3.5

Length of the follow-up (years)	473	9.6	0.8	603	9.8	0.9

Note. BMI, body mass index; SFT, Senior Fitness Test; MET, Metabolic equivalent

[a]lean mass/height^2

Table 2. Smoking, diseases, and medication among the participants at the baseline.

	Men			Women		
	n	yes, n	yes, %	n	yes, n	yes, %
Ever smoked	473	340	71.9	603	259	43
Current smoker	472	112	23.7	603	105	17.4
Cardiovascular disease	471	42	8.9	602	44	7.3
Stroke	471	9	1.9	602	3	0.5
Cancer	471	17	3.6	603	37	6.1
Emphysema	471	24	5.1	602	21	3.5
Insulin treatment	473	6	1.3	603	5	0.8
Systemic glucocorticoid treatment	473	2	0.4	603	5	0.8
Diuretics	473	45	9.5	603	78	12.9

Indicators of obesity i.e. BMI, waist circumference, absolute fat mass, and percent body fat were inversely associated with physical performance in both sexes (Table 3.) According to standardized regression coefficients, all these measures predicted physical performance equally well (β from -0.32 to -0.40).

Table 3. Linear regression models on baseline body composition explaining Senior Fitness Test result ten years later stratified according to sex.

	Men				Women			
	b	95% CI	β	Sig.	b	95% CI	β	Sig.
Height (cm)	0.28	0.02;0.55	0.10	0.032	0.009	-0.25;0.27	0.003	0.949
Body mass index (kg/m^2)	-1.51	-1.93;-1.09	-0.32	<0.001	-1.35	-1.64;-1.06	-0.35	<0.001
Waist circumference (cm)	-0.58	-0.72;-0.44	-0.36	<0.001	-0.57	-0.68;-0.45	-0.37	<0.001
Lean mass (kg)	-0.18	-0.4;0.04	-0.08	0.106	-0.64	-0.92;-0.36	-0.18	<0.001
Fat mass (kg)	-0.87	-1.08;-0.66	-0.37	<0.001	-0.80	-0.95;-0.65	-0.40	<0.001
Percent body fat (%)	-1.18	-1.44;-0.91	-0.39	<0.001	-1.06	-1.27;-0.85	-0.39	<0.001
Lean mass to BMI ratio (m^2)	20.82	14.87;26.76	0.31	<0.001	23.96	17.49;30.43	0.30	<0.001
Fat-free mass index[a] (kg/m^2)	-1.95	-2.92;-0.98	-0.19	<0.001	-2.72	-3.66;-1.78	-0.23	<0.001
Lean mass residual (kg)	0.00	-0.38;0.38	0.00	0.997	0.45	-0.06;0.96	0.07	0.085

Note. b, unstandardized regression coefficient; β, standardized regression coefficient

Adjusted for years of education, age, smoking (ever smoked and current smoker), physical activity, and duration of follow-up

[a]lean mass/height^2

Absolute lean mass was associated with physical performance only among women but in a counterintuitive manner; greater lean mass predicted poorer performance. Similarly, fat free muscle index was negatively associated with later physical performance. Lean mass residual not associated with physical performance. However, lean mass to BMI ratio had a positive association with later physical performance (β=0.31, $p<0.001$ in men; β=0.30, $p<0.001$ in women).

The relationships between fat and lean mass and their joint relationship with the Senior Fitness Test sum score are illustrated in Figure 1. These scatterplots show that for a given fat mass level, the predicted physical performance varies only little across the range of lean mass. However, for a given lean mass level, the predicted physical performance varies greatly across the range of fat mass.

Correlations between the confounders and measures of body composition (Table S1), between the confounders and Senior Fitness Test sum score (Table S2), and between the measures of body composition and Senior Fitness Test subscores (Table S3) are given as Electronic Supplementary Material.

4. Discussion

The results of this study showed that measures of adiposity, namely waist circumference, fat mass, and percent body fat were most strongly associated with physical performance ten years later. Measures of lean mass, in turn, were associated with later physical performance in a counterintuitive manner; greater lean mass was associated with poorer physical performance.

The results suggest that lean mass alone is not a good predictor of later physical performance among older people. This is in line with previous cross-sectional studies, in which measures of lean mass without adjustment for fat mass, i.e. appendicular lean mass adjusted for height (9,11,12) or total lean mass (9,22), were either negatively or not at all associated with physical performance. Further, Delmonico and colleagues found that when defined using appendicular lean mass per height squared method, sarcopenia did not predict later physical performance among men and women aged 70-79 years (13). However, a cross-sectional study utilizing NHANES data reported that lower lean mass was associated with a greater risk of physical disability among persons 60 years and older (7). In the present study, absolute lean mass in women and fat-free mass index in both sexes were inversely associated with physical performance i.e. higher lean mass was associated with poorer physical performance. These findings stem from fat mass confounding lean mass; individuals with high fat mass tend to also have higher lean mass than those with low fat mass. Therefore, it is challenging to use lean mass as a predictor of physical performance without accounting for the influence of fat mass.

We also used a variable – lean mass residual – that removed the variance in lean mass explained by fat mass and height. Unexpectedly, also lean mass residual was a poor predictor of physical performance. A recent study reported that greater lean mass residual was associated with a lower risk of incident disability but only among women (23). In another study, both men and women defined as sarcopenic using the residual method had poorer physical performance after 5 years and a greater decline in lower limb physical performance than non-sarcopenic individuals (13). Lean mass to BMI ratio is another variable, in which lean mass is proportioned to adiposity. Lean mass to BMI ratio appeared to be a good predictor of physical performance in the present study. This is in agreement with a large cross-sectional study, which suggested that low lean mass to BMI ratio was associated with slow walking speed among both men and women, whereas – counterintuitively – low appendicular lean mass without adjustment for BMI was associated with higher walking speed (14).

Measures of adiposity were better predictors of later physical performance than measures of lean mass. The dominance of fat mass over lean mass was also supported by the regression of physical performance on lean and fat mass as illustrated in the Figure 1. A previous longitudinal study found greater percent body fat to predict greater decline in walking endurance, within an age range comparable to that in our study, after a follow-up of up to four years (24). However, among older participants, 70-79 years, no associations were found. Cross-sectional studies have also shown inverse associations between percent body fat and physical performance (22,25).

Even simple measures, waist circumference and BMI, may also be useful when predicting later physical performance. Greater waist circumference and BMI predicted later physical performance as strongly as fat mass, and percentage body fat in men and women. In agreement with our results, Jerome and colleagues reported that BMI was negatively associated with a change in walking endurance (24). However, as standardized coefficients were not reported, comparison of variance explained between BMI and percentage fat mass was not possible. Greater waist circumference was associated with slow walking speed in a longitudinal (26) and a cross-sectional (25) study. However, not all studies have found anthropometric measures useful in predicting future physical performance. Waist-to-hip ratio has been reported not to be associated with walking speed 3 years later (27) or with change in walking speed or chair stands time in a 10-year follow-up (28).

There are several potential explanations for the results. Fat mass serves as extra mechanical load while moving, which may directly slow performance in chair rise test and walking test. Adiposity has also been found to reduce physical activity (29,30). Hence, individuals with high adiposity in the baseline may have been less physically active during the follow-up leading to poorer physical performance. Fat mass may also affect physical performance through some other mechanism, such as inflammation, atherosclerosis, and insulin resistance. Excess adipose tissue induces systemic low-grade inflammation (31). Inflammation, measured as high levels of interleukin-6, C-reactive protein, and interleukin-1 receptor antagonist, has been found to be associated with poor physical performance and muscle strength in older persons (32–34). Excess adiposity may also lead to atherosclerosis (35), which may impair physical performance through reduced cardiovascular function. Finally, obesity increases insulin resistance (36). which, in turn, has been found to be associated with slower walking speed, lower endurance (37,38) and muscle force per unit of muscle mass (39).

The strengths of the present study include longitudinal design with a 10-year follow-up. Body composition assessment – instead of relying solely on BMI – allowed us to study fat and lean mass separately. Physical performance was based on a battery of tests developed for older adults and the tests measured physical performance across a wide range of functioning.

This study has also some limitations. Although our design was longitudinal, we had no information on the participants' physical performance at the baseline and hence, we were not able to assess the change in physical performance. Bioelectrical impedance analysis was used to determine body composition but use of dual-energy x-ray absorptiometry would have ensured better validity. As typical in study samples with older adults, there was a loss of participants in the follow-up. Those who participated in the follow-up had better functioning at baseline than those who did not participate in the follow-up and hence, these results may be applicable only to older adults with relatively good functional status. Our participants were Caucasian and the results may not be generalizable to other populations.

4.1. Conclusion

The results suggest that body composition measures that reflect adiposity predict physical performance better than measures that reflect lean mass. The results of this study can be used when appraising usefulness of body composition indicators for definition of sarcopenia and sarcopenic obesity. More longitudinal studies comparing predictive ability of different body composition measures are needed.

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6. Conflicts of interest statement

The authors state that they have no conflicts of interest.

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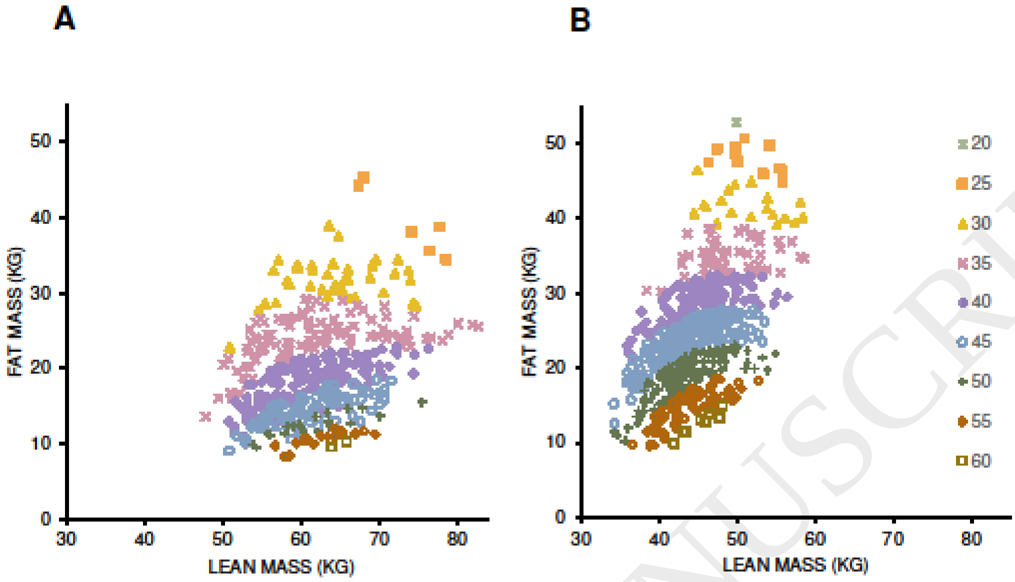
8. Figure legends

Figure 1. Lean mass – fat mass scatter plots for men (A) and women (B). Predicted Senior Fitness Test (SFT) score has been obtained by regressing SFT score on lean and fat mass. Predicted SFT score categories are displayed with different symbols.


A
B
FAT MASS (KG)
LEAN MASS (KG)
0
10
20
30
40
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40
50
60
70
80
20
25
30
35
40
45
50
55
60