Journal of Gerontology: MEDICAL SCIENCES
1998, Vol. 53A, No.3, M214–M221

Body Fat and Skeletal Muscle Mass in Relation to Physical Disability in Very Old Men and Women of the Framingham Heart Study

M. Visser,[1] T. B. Harris,[1] J. Langlois,[1] M. T. Hannan,[2] R. Roubenoff,[3]
D. T. Felson,[4] P. W. F. Wilson,[5] and D. P. Kiel[2]

[1]National Institute on Aging, Epidemiology, Demography, and Biometry Program, Bethesda, Maryland.
[2]Harvard Medical School Division on Aging, and Hebrew Rehabilitation Center for Aged, Research and Training Institute, Boston.
[3]Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University School of Medicine, Boston.
[4]Boston University Arthritis Center, Boston University School of Medicine.
[5]National Heart, Lung, and Blood Institute, The Framingham Heart Study, Framingham, Massachusetts.

Background. Low muscle mass has been assumed to be associated with disability, but no studies confirming this association have been published. High body weight and high body mass index, both rough indicators of body fatness, have been shown to increase the risk for disability; however, the specific role of body fatness has not been studied.

Methods. The relations of skeletal muscle mass and percent body fat with self-reported physical disability were studied in 753 men and women aged 72 to 95 years. Cross-sectional data from biennial examination 22 (1992–1993) of the Framingham Heart Study were used. Body composition was assessed by dual-energy x-ray absorptiometry. Disability was scored as any versus none on a 9-item questionnaire.

Results. Total body and lower extremity muscle mass were not associated with disability in either men or women. However, a strong positive association between percent body fat and disability was observed. The odds ratio for disability in those in the highest tertile of body fatness was 2.69 (95% confidence interval 1.45–5.00) for women and 3.08 (1.22–7.81) for men compared to those in the lowest tertile. The increased risk could not be explained by age, education, physical activity, smoking, alcohol use, estrogen use (women only), muscle mass, and health status. Analyses restricting disability to mobility items gave similar results.

Conclusions. In contrast to current assumptions, low skeletal muscle mass was not associated with self-reported physical disability. Persons with a high percent body fat had high levels of disability. Because it cannot be ruled out that persons with low skeletal muscle mass dropped out earlier in the study, prospective studies are needed to further assess the relationship between body composition and physical disability.

TO increase the years free of disability in old age, it is important to understand the factors associated with impaired physical function. Body weight and body mass index (BMI) have been reported to play an important role in physical disability in older men and women. Cross-sectional studies have shown that persons with heavier body weight and higher BMI were more disabled than those of medium body weight and BMI (1–6). In addition, a high BMI has been shown to be predictive of disability risk at 2 to 14 years follow-up (7–10). Reports of the association between low BMI and disability are contradictory (3,4). In one study this association was stronger among persons with chronic conditions than among healthy persons (3).

A limitation of these studies is the use of body weight and BMI, which does not take into account the composition of the body and is only a rough indicator of body fatness. The relationship between the two major individual components of body composition—muscle mass and fat—and functional disability has not been well studied. The age-related loss of muscle mass (11,12), or sarcopenia, has been assumed to contribute to disability in old age (13). Several cross-sectional studies have reported an inverse association between muscle strength and disability (14,15). This relationship has been confirmed in intervention studies showing that increased muscle strength after resistance training, even in very old persons (16), was associated with improvement in physical function (17,18). Because greater muscle strength is related to greater muscle mass (16,19–21), an inverse association between muscle mass and disability has been hypothesized but not examined directly. No studies have specifically investigated the relation between muscle mass and disability.

Similarly, no studies have directly examined the association between body fat and disability. Body fat may be associated with disability through its positive relationship with chronic disease (22–24). High body fatness may also be a marker for physical inactivity, which has been shown to increase the risk of disability (25). A direct influence of body fatness on disability is also possible, because excessive fat places a greater burden on the body and limits movement. The relative increase in body fatness with aging (11,12) may increase older individuals' risk of physical disability. Increased knowledge of the role of body composition in physical disability may contribute to the prevention of disability in old age by defining optimal body composition for elderly persons.

To our knowledge, this study is the first to investigate the relationship of total and regional body composition, determined by dual-energy x-ray absorptiometry (DXA), with self-reported physical disability status. This cross-sectional study of Framingham Heart Study cohort participants is unique in that it includes information on the individual components of body composition, muscle and fat, as well as disability in a large cohort of very old men and women. We tested the hypothesis that a low skeletal muscle mass and/or a high body fatness in very old men and women is associated with physical disability.

Table 1. Percentage of Women and Men, Aged 72 to 95 Years, With Self-reported Disability* on Physical Function Items

	Women (N = 478)		Men (N = 275)	
Function Items	*n*	%	*n*	%
1. Stooping, crouching, kneeling†	101	21.1	24	8.7
2. Standing long period (15 min)†	49	10.3	19	6.9
3. Walking 0.5 mile†	50	10.5	15	5.5
4. Reaching arms above shoulder	15	3.1	6	2.2
5. Handling small objects	25	5.2	8	2.9
6. Lifting 10 pounds from floor	36	7.5	3	1.1
7. Pulling large object	73	15.3	12	4.4
8. Getting into/out of car	14	2.9	4	1.5
9. Putting socks/stockings on	16	3.3	1	0.4

*Report of "a lot of difficulty," "unable to do," or "don't do on doctor's orders" at examination 22.

†Item used also to calculate mobility-related disability.

Methods

Subjects

Subjects are participants of the Framingham Heart Study. The original cohort of 5,209 men and women aged 30–62 years was recruited in 1948–1951 for an examination of cardiovascular disease and has been biennially examined since 1948 (26). In 1992–1993, approximately 1,161 participants of the original cohort were still alive and 932 attended the 22nd clinic examination. A total of 789 men and women agreed to a whole body DXA scan. Data for the 753 participants (478 women and 275 men) who also had complete data on self-reported physical disability status were included in the statistical analyses. The Boston University institutional review board approved the study protocol.

Using data of both examination 20 and examination 22, anthropometric measures of subjects who had a DXA scan at examination 22 were compared with those who had no scan. Within each sex, no statistically significant differences were observed for body weight, BMI, triceps skinfold, subscapula skinfold, and abdomen skinfold thickness, suggesting no apparent differences in body composition between subjects who had a DXA scan and those who did not.

Procedures

Self-reported physical disability status, self-rated health, and measurements of grip strength and anthropometry were obtained at the examination 22 clinic visit. A whole body DXA scan for the assessment of skeletal muscle mass and percent body fat was made during an additional clinic visit within 2–3 weeks of the index visit. Information on potential confounders was obtained from the baseline examination and examinations 20 and 22.

Physical disability status.—The subjects were asked the nine physical function questions listed in Table 1. The items have been used in the Framingham Heart Study (27) and are adapted from the Rosow and Breslau (28) and Nagi (29) scales. Evaluation of the reliability of the measures used here by repeated testing after 3 weeks showed agreement of 89% for measures of mobility and 80–92% for the Nagi items (30).

Overall disability scores were created using all nine function items, including both upper body and lower body disability. First, a categorical score was created. Persons who reported having "no difficulty," "little difficulty," or "some difficulty" in performing the item scored 0 for that item; persons who reported "a lot of difficulty," "unable to do," or "don't do on doctor's orders" received a score of 1. Persons with a score of 0 for all nine items (no physical disability) were contrasted with those with a score of 1 for one or more items. Secondly, an ordinal score was created accounting for level of difficulty. Persons who reported having "no difficulty" in performing an item scored 0 for that item, "little difficulty" scored 1, "some difficulty" scored 2, etc. The ordinal score was created by summing up all nine items.

Because muscle mass might be particularly important for lower extremity disability, we also created mobility-related disability scores based on function items 1–3 only. Both a categorical score and an ordinal score were created.

Body composition.—Body composition was assessed by dual-energy x-ray absorptiometry using a LUNAR DPX-L whole body scanner (Lunar Radiation Corp, Madison, WI) in the fast mode at 150 mA. The DXA scans were made in the afternoon with the subjects wearing a gown. Body composition was calculated using version 1.3 of the manufacturer's software. The amount of total body tissue from the scan was positively correlated with body weight measured on a calibrated scale during the first clinic visit (r = .99, p = .0001 for women and r = .96, p = .0001 for men). DXA partitions the body into two fractions, bone ash and soft tissue. The ratio of soft tissue attenuation (R value) is used to divide the soft tissue into fat and fat-free components. The bone-free and fat-free component of the body was assumed to represent total body skeletal muscle mass. Skeletal muscle mass in the legs (sum of both leg regions on the DXA scan) was assessed similarly (31). Percent body fat was calculated as fat tissue divided by total body tissue. Reproducibility was tested in 19 subjects who had two whole body DXA scans performed on the same day after repositioning. The intraclass correlation coefficients were as follows: .99 for whole body fat mass, .99 for bone-free lean mass, and .99 for leg bone-free lean mass.

Within each sex, subjects were categorized by tertile of total body skeletal muscle mass (or by tertile of leg skeletal muscle mass), and by tertile of percent body fat. Consistent with our hypothesis for body composition and disability, those in the highest tertile of skeletal muscle mass, or those in the lowest tertile of percent body fat were considered as the reference group. The cutoff points for the tertiles of total body skeletal muscle mass were: <35.2 kg, 35.2–39.1 kg, >39.1 kg for women, and <51.2 kg, 51.2–56.9 kg and >56.9 kg for men; for leg skeletal muscle mass: <11.3 kg, 11.3–12.6 kg, >12.6 kg for women, and <16.8 kg, 16.8–18.9 kg, and >18.9 kg for men; for percent body fat: <37.2%, 37.2–43.7%, >43.7% for women, and <27.2%, 27.2–32.0%, and >32.0% for men. Absolute skeletal muscle mass was used because this measure has been reported to be associated with muscle strength (19–21). Percent body fat was used because it adjusts the amount of fat for body size. A fat mass of 20 kg will be a greater burden for a body of 50 kg than for a body of 80 kg. In addition, fat mass was strongly associated with skeletal muscle mass ($r = .38$, $p = .0001$ for men; $r = .50$, $p = .0001$ for women), while percent body fat was more independent of skeletal muscle mass ($r = .08$, $p = .19$ for men and $r = .18$, $p = .0001$ for women).

Grip strength.—Grip strength was used as an additional indicator of muscle mass with those in the highest tertile of strength as the reference group. Grip strength was measured on the dominant hand using a Jamar isometric dynamometer. The maximum strength (kg) out of three attempts was used. Maximum grip strength was available for 336 women (70.3%) and 205 men (74.5%).

Fat distribution.—The waist circumference and the ratio of waist and hip circumference were used as indicators of fat distribution. Waist circumference was measured at the level of the umbilicus, and hip circumference was measured at the level of the maximal protrusion of the gluteal muscles.

Potential Confounders

Physical activity.—At examination 20, subjects were asked for the number of hours per day that they slept and performed sedentary, slight, moderate, and heavy activities. A physical activity index was calculated by multiplying the hours for each of the five activities by the intensity score for each activity and summing the values across activities (32).

Health status.—Self-rated health at examination 22 was reported as excellent, good, fair, or poor. A measure of comorbidity was created using information obtained at examination 20. Previous or current presence of a variety of chronic conditions was determined using the medical interview, previous clinic data, and medical records. The chronic conditions assessed included: diabetes mellitus, lung disease (emphysema, chronic bronchitis, asthma, other), joint disease (gout, degenerative joint disease, rheumatoid arthritis), cancer, and hypertension. The presence of some conditions was also determined by information on medication use, as follows: coronary heart disease (cardiac glycosides, nitroglycerine, longer-acting nitrates, calcium channel blockers, beta blockers, loop diuretics), diabetes mellitus (insulin, oral hypoglycemics), arthritis (daily use of nonsteroidal anti-inflammatory agents), and lung disease (bronchodilator aerosols). The sum of the number of self-reported conditions (which ranged from 0 to 6) was used in the analyses.

Other potential confounders.—Based on self-report at examination 22, participants were categorized as former/never or current cigarette smokers. Current smokers were defined as persons regularly smoking cigarettes in the past year. Reported number of alcoholic drinks per week at examination 22 was used to categorize subjects as non-drinkers or drinkers. Women were divided into estrogen user or nonuser groups based on the self-reported information on current estrogen replacement therapy at examination 22. Education level was defined as the number of years of completed education as obtained at the baseline examination. Recent weight loss was calculated as the absolute change in weight between examination 20 and examination 22.

Statistical Analyses

All analyses were conducted separately for men and women using SAS software (SAS Institute, Inc., Cary, NC). Reported correlations are Pearson's product-moment correlations. The Mantel-Haenzel chi-square statistic was used to test the association of health status, smoking, use of alcohol, estrogen use (women only), and physical disability score with tertile of skeletal muscle mass and tertile of percent body fat. Analysis of variance was used to test the association of tertile of skeletal muscle mass and tertile of percent body fat with selected continuous variables. Multiple logistic regression analysis was used to assess the association of the categorical disability scores with tertile of skeletal muscle mass (total body and legs) after adjustment for age, education, physical activity, health status, smoking, alcohol use, estrogen use (women only), and body height. This analysis was repeated including percent body fat as an additional covariate. Similar analyses were done using tertile of maximum grip strength as the main independent variable. Multiple logistic regression analysis was also used to assess the association between the categorical disability scores and tertile of percent body fat, after adjustment for age, education, physical activity, health status, smoking, alcohol use, and estrogen use (women only). This analysis was repeated including total body skeletal muscle mass as an additional covariate. Similar analyses were done using tertile of waist circumference, or tertile of the ratio of waist and hip circumference as the main independent variable. All analyses were repeated including weight change as an additional covariate. The associations between body composition and the ordinal disability scores were evaluated using analysis of variance. Because persons missing values for specific covariates were omitted from that analysis only, the number of subjects differed slightly for each analysis.

Results

The physical disability status of the study sample for specific function items is shown in Table 1. Among women, 172 (36.0%) and among men, 54 (19.6%) reported disability for one or more items. Mobility-related disability was present in 129 women (27.0%) and 41 men (14.9%).

Men and women in the lowest tertile of total body skeletal muscle mass were older, had a lower body weight, BMI and percent body fat, were shorter, had a greater weight loss in the previous four years, and had a lower grip strength compared with those in the highest tertile (Table 2). Men in the lowest tertile of total body skeletal muscle mass were less active, tended to smoke more ($p = .06$), and drank less alcohol, while women in the lowest tertile had fewer chronic diseases. Men and women in the highest tertile of percent body fat had a higher body weight and BMI, smoked less, and had gained more weight in the previous four years compared with those in the lowest tertile. Women in the highest tertile of percent body fat had a higher total body skeletal muscle mass and had more chronic illnesses.

Physical disability status by level of total body skeletal muscle mass is shown in Figure 1. No association was observed between the prevalence of physical disability and total body skeletal muscle mass ($p > 0.4$), nor was an association observed for leg skeletal muscle mass (not shown). After multivariable adjustment, women and men in the lowest tertile of total body skeletal muscle mass or leg skeletal muscle mass were not more likely to be disabled than those in the highest tertile of skeletal muscle mass (Tables 3 and 4). Per one standard deviation increase in skeletal muscle mass, no decrease in odds ratio (OR) was observed. Adding percent body fat as a covariate slightly increased the OR for physical disability in the lowest tertile of skeletal muscle mass (OR 0.73 for women and 1.33 for men); however, the association was still not significant (data not shown). Similar results were observed for mobility-related disability. Using analysis of variance, no association was observed between total body skeletal muscle mass or leg muscle mass and the ordinal disability scores accounting for reported level of difficulty (results not shown).

Maximum grip strength was positively correlated with total body skeletal muscle mass in both men ($r = .50$, $p = .0001$) and women ($r = .46$, $p = .0001$). The strongest association was observed with arm skeletal muscle mass ($r = .53$, $p = .0001$ for men and $r = .50$, $p = .0001$ for women). These associations remained significant after adjustment for

Table 2. Description of Women and Men by Tertile of Total Body Skeletal Muscle Mass and Percent Body Fat

	Women			Men		
	Low	Mid	High	Low	Mid	High
Tertile of Muscle Mass						
Age (y)	79.2 ± 0.3	78.1 ± 0.3	77.8 ± 0.3**	79.4 ± 0.4	78.1 ± 0.4	76.3 ± 0.4***
Body weight (kg)	54.8 ± 0.7	64.0 ± 0.7	74.2 ± 0.7***	68.1 ± 1.0	77.6 ± 1.0	90.5 ± 1.0***
Weight change past 4 years (kg)	–0.8 ± 0.4	–1.0 ± 0.4	0.2 ± 0.4 *	–2.0 ± 0.6	–1.5 ± 0.6	0.7 ± 0.6 **
Height (m)	1.51 ± 0.00	1.56 ± 0.00	1.60 ± 0.00***	1.65 ± 0.01	1.70 ± 0.01	1.75 ± 0.01***
Body mass index (kg/m²)	24.0 ± 0.4	26.4 ± 0.3	29.2 ± 0.3***	25.0 ± 0.4	27.0 ± 0.4	29.6 ± 0.4***
Body fat (%)	37.8 ± 0.6	39.9 ± 0.6	41.6 ± 0.6***	28.7 ± 0.7	28.9 ± 0.7	31.0 ± 0.7*
Total body skeletal muscle mass (kg)	32.8 ± 0.2	37.1 ± 0.2	42.1 ± 0.2 ***	47.6 ± 0.3	54.2 ± 0.3	60.5 ± 0.3***
Maximum grip strength (kg)	17.3 ± 0.4	19.2 ± 0.4	21.7 ± 0.4***	27.7 ± 0.7	32.1 ± 0.7	35.2 ± 0.7***
Years education (y)†	5.5 ± 0.2	5.6 ± 0.2	5.9 ± 0.2	5.3 ± 0.2	5.0 ± 0.2	5.3 ± 0.2
Physical activity index‡	34.0 ± 0.4	33.7 ± 0.4	33.8 ± 0.4	32.8 ± 0.6	33.5 ± 0.6	36.2 ± 0.6***
Smoking (%)	7.6	13.5	4.4	8.0	3.3	4.4
Alcohol use (%)	58.6	55.8	59.9	53.4	69.2	71.4*
Estrogen use (%)	6.4	9.2	6.4	—	—	—
No chronic illness (%)‡	19.9	18.9	15.2*	20.2	16.1	20.5
Self-rated health "excellent" (%)	25.8	28.1	23.4	28.6	31.1	32.6
Tertile of percent body fat						
Age (y)	78.5 ± 0.3	78.6 ± 0.3	77.9 ± 0.3	78.6 ± 0.4	77.6 ± 0.4	77.6 ± 0.4
Body weight (kg)	54.0 ± 0.7	64.3 ± 0.7	74.9 ± 0.7***	69.6 ± 1.1	77.8 ± 1.1	88.8 ± 1.1***
Weight change past 4 years (kg)	–1.8 ± 0.3	–0.5 ± 0.4	0.8 ± 0.4***	–2.5 ± 0.6	–0.0 ± 0.6	–0.1 ± 0.6**
Height (m)	1.56 ± 0.01	1.56 ± 0.01	1.55 ± 0.01	1.70 ± 0.01	1.70 ± 0.01	1.70 ± 0.01
Body mass index (kg/m²)	22.3 ± 0.3	26.3 ± 0.3	31.1 ± 0.3***	24.1 ± 0.3	26.9 ± 0.3	30.6 ± 0.3***
Body fat (%)	30.6 ± 0.3	40.6 ± 0.3	48.0 ± 0.3***	22.3 ± 0.3	29.6 ± 0.3	36.6 ± 0.3***
Total body skeletal muscle mass (kg)	36.3 ± 0.3	37.6 ± 0.3	38.1 ± 0.3***	53.9 ± 0.6	53.8 ± 0.6	54.8 ± 0.6
Maximum grip strength (kg)	19.4 ± 0.4	19.5 ± 0.4	19.2 ± 0.4	31.3 ± 0.8	32.3 ± 0.8	31.9 ± 0.8
Years of education (y)†	5.9 ± 0.2	5.6 ± 0.2	5.5 ± 0.2	5.1 ± 0.2	5.5 ± 0.2	5.0 ± 0.2
Physical activity index‡	34.2 ± 0.4	33.7 ± 0.4	33.5 ± 0.4	34.3 ± 0.6	34.6 ± 0.6	33.6 ± 0.7
Smoking (%)	12.8	7.6	5.1*	9.9	3.3	2.3*
Alcohol use (%)	55.5	55.7	63.1	64.8	63.7	65.9
Estrogen use (%)	8.5	7.0	6.5	—	—	—
No chronic illness (%)‡	22.5	20.9	10.5**	23.5	17.3	16.1
Self-rated health "excellent" (%)	34.6	25.8	17.0	29.7	35.2	27.5

*$p < .05$, **$p < .01$, ***$p < .001$ differences by tertile by analysis of variance or X^2.

†Based on examination 1.

‡Based on examination 20.

age and height. The odds ratios for physical disability for subjects in the lowest tertile of maximum grip strength compared to the subjects in the highest tertile, after adjustment for potential confounders, were .90 (95% confidence interval [CI] 0.48–1.69) for women and 1.76 (95% CI 0.69–4.47) for men. These results were not significant and were of similar direction and magnitude to those for skeletal muscle mass.

The prevalence of physical disability and mobility-related disability in both men and women was positively associated with percent body fat ($p < .05$, Figure 2). After adjustment for potential confounders, women and men in the highest tertile of body fatness were 2.69 and 3.08 times, respectively, more likely to be disabled than those in the lowest tertile (Table 5). Per one standard deviation increase in body fatness (8% for women and 7% for men), the odds ratio was 1.61 (95% CI 1.24–2.08) for women and 1.60 (95% CI 1.10–2.33) for men. The increase in odds ratio for each standard deviation increase in body fatness was similar for men and women. Similar results were obtained for mobility-related disability. The odds ratios did not change after including total body muscle mass in the model. To avoid possible mathematical errors inherent to the expression of body fat as a ratio of body mass, the analysis was repeated using absolute fat mass. The analysis showed similar results. Women in the highest tertile of fat mass were 2.61 times more likely (95% CI 1.40–4.86) to be disabled than those in the lowest tertile. For men this value was 4.55 (95% CI 1.64–12.60). Values for mobility-related disability were 3.26

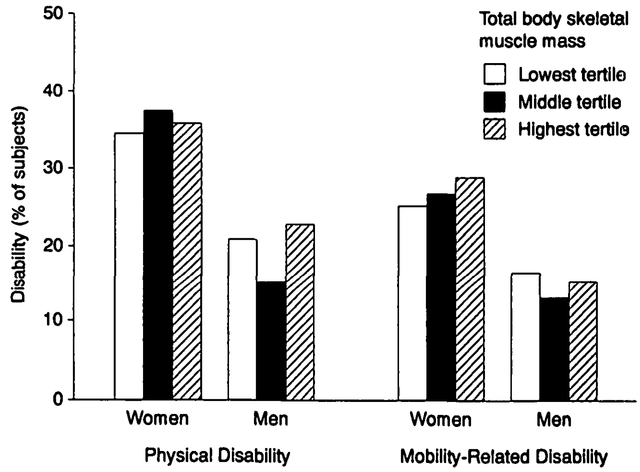

Figure 1. The prevalence of self-reported overall disability and mobility-related disability in women and men, aged 72 to 95 years, by level of total body skeletal muscle mass.

Table 3. Crude and Adjusted Odds Ratios for Overall Disability and Mobility-Related Disability Among Women and Men, Aged 72 to 95 Years, According to Tertile of Total Body Skeletal Muscle Mass

	Overall Disability				Mobility Disability			
	Women		Men		Women		Men	
	OR	(95% CI)*	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Crude								
Low	0.95	(0.60–1.50)	0.89	(0.44–1.80)	0.83	(0.50–1.36)	1.10	(0.50–2.43)
Medium	1.07	(0.68–1.69)	0.61	(0.29–1.28)	0.90	(0.55–1.47)	0.84	(0.36–1.92)
High	1.0		1.0		1.0		1.0	
Adjusted†								
Low	0.55	(0.27–1.13)	1.06	(0.35–3.18)	0.39	(0.18–0.85)	1.61	(0.47–5.52)
Medium	0.80	(0.42–1.50)	0.53	(0.20–1.41)	0.55	(0.28–1.11)	0.80	(0.27–2.43)
High	1.0		1.0		1.0		1.0	

*Odds ratio (OR) with 95% confidence interval (CI). The tertile with highest muscle mass was used as reference group.
†Adjusted for age, education, self-rated health, chronic illness, physical activity, smoking, alcohol use, estrogen use (women only), and body height.

Table 4. Crude and Adjusted Odds Ratios for Overall Disability and Mobility-Related Disability Among Women and Men, Aged 72 to 95 Years, According to Tertile of Leg Skeletal Muscle Mass

	Overall Disability				Mobility Disability			
	Women		Men		Women		Men	
	OR	(95% CI)*	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Crude								
Low	1.00	(0.63–1.59)	1.16	(0.57–2.37)	0.91	(0.55–1.49)	1.42	(0.63–3.20)
Medium	1.20	(0.76–1.89)	0.87	(0.41–1.82)	0.99	(0.61–1.62)	1.10	(0.47–2.55)
High	1.0		1.0		1.0		1.0	
Adjusted†								
Low	0.70	(0.35–1.41)	1.42	(0.50–4.05)	0.53	(0.25–1.14)	2.01	(0.62–6.53)
Medium	0.95	(0.51–1.77)	0.84	(0.32–2.15)	0.64	(0.32–1.26)	1.09	(0.37–3.17)
High	1.0		1.0		1.0		1.0	

*Odds ratio (OR) with 95% confidence interval (CI). The tertile with highest muscle mass was used as reference group.
†Adjusted for age, education, self-rated health, chronic illness, physical activity, smoking, alcohol use, estrogen use (women only), and body height.

(95% CI 1.63–6.52) and 5.38 (95% CI 1.69–17.20) for women and men, respectively. Analyses of variance using the ordinal disability scores accounting for reported level of difficulty also showed a positive association with percent body fat (results not shown).

The distribution of body fat (measured by waist circumference and the ratio of waist and hip circumference) was not associated with disability (not shown).

Including weight change during the past four years as a covariate did not alter the conclusions.

Discussion

Body composition changes with age are characterized by an increase in body fatness and a reduction in lean mass and muscle mass (11,12). Loss of muscle mass, known as sarcopenia, has been hypothesized to play an important role in the decline of physical function with aging (13). The present cross-sectional study is, to our knowledge, the first to investigate the relationship of total body and regional body composition to disability at very old age. The findings support our hypothesis for body fatness but not for muscle mass. The results suggest that a high percent body fat, not low skeletal muscle mass, is associated with physical disability in both men and women.

This study confirms the findings of previous investigations reporting a higher disability risk for subjects with high BMI and high body weight (1–10) and extends the findings to show that body fatness is likely to account for the increased risk.

Several mechanisms may underlie the observed association between percent body fat and physical disability. Persons with a high percent body fat may be disabled because of chronic disease (33,34) associated with overweight in old age, including diabetes mellitus (22), osteoarthritis (23), and heart disease (24). Overweight persons may also become disabled as a result of physical inactivity (25). Conversely, older persons may experience an increase in body fat after becoming disabled, e.g., as a result of decreased physical activity caused by the disability. In the present study, however, the relationship between body fatness and disability remained significant after adjustment for chronic disease, self-rated health, and physical activity. Our results suggest a direct influence of body fatness on risk of disability through an increased physical burden on the body, limiting movement and increasing strain on joints and muscles. Because the present study is cross-sectional, a causal relationship can only be inferred. Longitudinal studies are necessary to clarify the mechanism by which body fatness is related to physical disability.

Weight gain in old age is likely to be the result largely of gains in fat (11), and overweight in old age is associated with an increased risk of disease (22–24). The results of these studies and the present study suggest that weight gain with aging should be avoided. It should be acknowledged, however, that results from studies investigating the relationship between body weight or BMI and mortality are contradictory and that it has been suggested that modest weight gain in old age reduces mortality risk (35,36). It may be that heavier older persons cope better with the metabolic stress of disease and thus are less likely to die

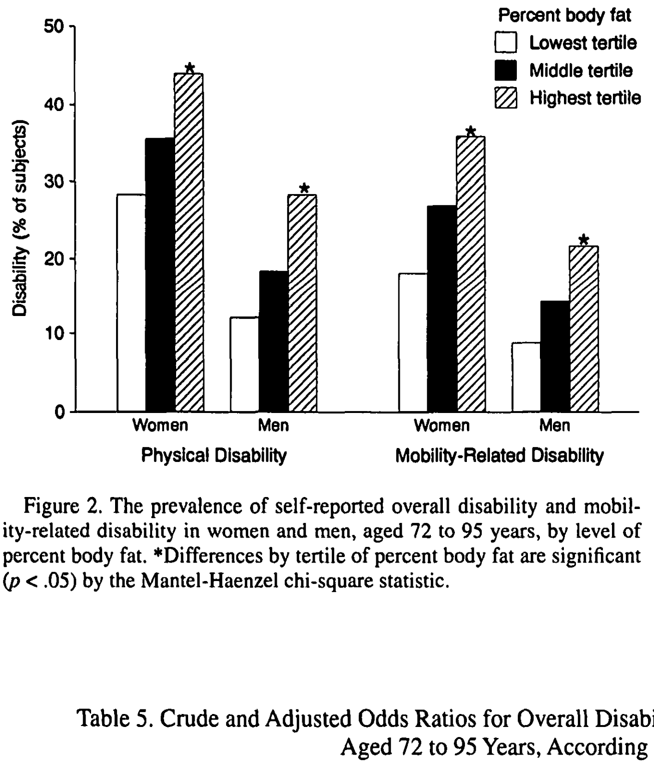

Figure 2. The prevalence of self-reported overall disability and mobility-related disability in women and men, aged 72 to 95 years, by level of percent body fat. *Differences by tertile of percent body fat are significant ($p < .05$) by the Mantel-Haenzel chi-square statistic.

Table 5. Crude and Adjusted Odds Ratios for Overall Disability and Mobility-Related Disability Among Women and Men, Aged 72 to 95 Years, According to Tertile of Percent Total Body Fat

	Overall Disability				Mobility Disability			
	Women		Men		Women		Men	
	OR	(95% CI)*	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Crude								
Low	1.0		1.0		1.0		1.0	
Medium	1.40	(0.87–2.25)	1.65	(0.73–3.75)	1.65	(0.97–2.81)	1.71	(0.67–4.34)
High	1.99	(1.25–3.18)	2.87	(1.32–6.23)	2.51	(1.49–4.20)	2.88	(1.20–6.94)
Adjusted†								
Low	1.0		1.0		1.0		1.0	
Medium	1.67	(0.90–3.07)	2.01	(0.77–5.25)	2.17	(1.07–4.37)	1.88	(0.64–5.51)
High	2.69	(1.45–5.00)	3.08	(1.22–7.81)	4.07	(2.00–8.28)	3.04	(1.09–8.50)

*Odds ratio (OR) with 95% confidence interval (CI). The tertile with lowest percent body fat was used as reference group.

†Adjusted for age, education, self-rated health, chronic illness, physical activity, estrogen use (women only), alcohol use, and smoking.

from the disease; a possible consequence of this survival, however, may be more years afflicted by disability.

In this study no association was observed between skeletal muscle mass and disability. Although muscle mass and muscle strength are strongly associated (16,19–21), strength may better reflect physical disability and may be influenced by factors other than muscle mass, such as disease, muscle use, and muscle morphology (37). However, no association between grip strength, the only strength measure available in this study, and disability was observed, confirming the findings of a previous study (15). We recognize, however, that grip strength may not be the most appropriate measure of strength for this analysis, and further research in this area using leg strength measures would be appropriate.

It is possible that a recent decline in muscle mass may be a more important determinant of physical disability than the absolute quantity of muscle mass. Increases in muscle mass after training have been shown to be related to increased functional performance (16–18). Similarly, decreases in muscle mass may be related to a loss of function. Longitudinal studies are necessary to investigate the effect of sarcopenia on self-reported disability and physical performance.

The nonsignificant findings for skeletal muscle mass may be explained by the fact that low weight subjects, who are more likely to be frail and to have a low skeletal muscle mass, were underrepresented in the study. Only a small percentage of subjects in the present study sample were extremely underweight (2.6% of the women and 1.1% of the men had a BMI<19 kg/m^2), and it may be that long-term Framingham participants with low muscle mass were more likely to drop out, potentially biasing this study. A higher mortality risk has been reported in older men and women with low muscle mass (38). To address this possible bias, we compared those who returned for examination 22 with those who dropped out of the study after examination 20 (4 years earlier) and found comparable body weight, BMI, and skinfold thicknesses. In addition, comparable weight change was observed between examination 18 and 20 and between examination 19 and 20. However, those who dropped out were older and more disabled. Among women they were less physically active and had more chronic conditions. These analyses suggest that disabled and sick persons were more likely to drop out; however, the data do not indicate that they were leaner or recently lost more weight compared to those who returned for examination 22. However, since we cannot rule out the possibility that frail elderly subjects with low skeletal muscle mass died or dropped out of the study before examination 20, the generalizibility of our findings is limited to healthier older people.

Potential problems related to the measurement of fat mass and muscle mass may have influenced our findings. Muscle mass was assessed by DXA, a method which has been well validated in younger populations (31,39,40). Although DXA validation studies in old age are limited, good agreement between DXA and bioelectrical impedance measurements has been observed (41). In the study it was assumed that the fat-free and bone-free tissue represents skeletal muscle mass (31). This assumption is probably more valid in the arms and legs, as total body estimates include various organs. In the present study the use of total body skeletal muscle mass or leg skeletal muscle mass gave similar, statistically nonsignificant, results. A third issue is that the validity of DXA measurements in obese subjects has been questioned, as tissue thickness may influence estimates of percent body fat (42) and bone minerals (43). In addition, obese persons may exceed the scanner study window, causing an underestimation, especially of soft tissue. Excluding the very obese subjects with a BMI of 35 kg/m^2 and higher (6 men and 14 women) from the statistical analyses did not markedly change the odds ratios.

The use of self-reported physical disability as the outcome may be a limitation of the study. Although self-reported disability predicts mortality (44) and nursing home admission (45), and correlates highly with scores on performance tests (46,47), performance measures may be more indicative of actual physical functioning. Misclassification using self-reported data may be especially true among overweight persons, who may overestimate physical disability because (a) they perform the tasks less often, or (b) tasks appear too strenuous for them, despite the presence of sufficient muscle mass and muscle strength to perform the tasks. In fact, men and women in our study in the highest tertile of percent body fat had the highest muscle mass and a comparable grip strength to those with a lower percent body fat. Use of timed performance tests in future studies might clarify these associations.

Finally, the information on two confounders was assessed at examination 20. Data on physical activity score were not collected at examination 22, and the information from examination 20 used in this analysis was the most recent available. Because in the Framingham Heart Study the chronic disease measure is based on a careful disease adjudication process for each condition, information on chronic disease for examination 22 was not yet available. However, the strong association between body fatness and disability observed in the present study is not likely to be explained by incomplete adjustment for these two confounders.

To our knowledge the present study is the first to show that body composition is strongly associated with physical disability in very old age. High percent body fat was associated with an increased estimated risk of physical disability, including mobility disability. In contrast to current assumptions, muscle mass was not associated with disability. Prospective studies, including both self-reported disability and physical performance tests, would extend these findings. The information could help in identifying persons who will benefit from intervention programs that may reduce the risk for disability, such as training programs to increase muscle mass or weight loss programs to decrease body fatness.

Acknowledgment

Address correspondence to Dr. M. Visser, Visiting Fellow, NIA/Epidemiology, Demography, and Biometry Program, Gateway Building, Room 3C309, 7201 Wisconsin Avenue MSC 9205, Bethesda, MD 20892-0205. E-mail: VisserM@gw.nia.nih.gov

References

1. Pinsky JL, Branch LG, Jette AM, et al. Framingham Disability Study: relationship of disability to cardiovascular risk factors among persons free of diagnosed cardiovascular disease. *Am J Epidemiol.* 1985;122:644–656.
2. Keil JE, Gazes PC, Sutherland SE, Rust PF, Branch LG, Tyroler HA.

Predictors of physical disability in elderly Blacks and Whites of the Charleston Heart Study. *J Clin Epidemiol.* 1989;42:521–529.
3. Verbrugge LM, Gates DM, Ike RW. Risk factors for disability among U.S. adults with arthritis. *J Clin Epidemiol.* 1991;44:167–182.
4. Galanos AN, Pieper CF, Cornoni-Huntley JC, Bales CW, Fillenbaum GG. Nutrition and function: is there a relationship between body mass index and the functional capabilities of community-dwelling elderly? *J Am Geriatr Soc.* 1994;42:368–373.
5. Nelson HD, Nevitt MC, Scott JC, Stone KL, Cummings SR. Smoking, alcohol, and neuromuscular and physical function of older women. *JAMA.* 1994;272:1825–1831.
6. Ensrud KE, Nevitt MC, Yunis C, et al. Correlates of impaired function in older women. *J Am Geriatr Soc.* 1994;42:481–489.
7. Launer LJ, Harris T, Rumpel C, Madans J. Body mass index, weight change, and risk of mobility disability in middle-aged and older women. *JAMA.* 1994;271:1093–1098.
8. Harris T, Kovar MG, Suzman R, Kleinman JC, Feldman JJ. Longitudinal study of physical ability in the oldest-old. *Am J Public Health.* 1989;79:698–702.
9. LaCroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in late life II: smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol.* 1993;137:858–869.
10. Seeman TE, Charpentier PA, Berkman LF, et al. Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur Studies of Successful Aging. *J Gerontol Med Sci.* 1994;49:M97–M108.
11. Borkan GA, Norris AH. Fat redistribution and the changing body dimensions of the adult male. *Hum Biol.* 1977;49:495–514.
12. Flynn MA, Nolph GB, Baker AS, Martin WM, Krause G. Total body potassium in aging humans: a longitudinal study. *Am J Clin Nutr.* 1989;50:713–717.
13. Evans WJ. What is sarcopenia? *J Gerontol.* 1995;50A (special issue, Sarcopenia):5–8.
14. Hyatt RH, Whitelaw MN, Bhat A, Scott S, Maxwell JD. Association of muscle strength with functional status of elderly people. *Age Ageing.* 1990;19:330–336.
15. Avlund K, Schroll M, Davidsen M, Lovborg B, Rantanen T. Maximal isometric muscle strength and functional ability in daily activities among 75–year-old men and women. *Scand J Med Sci Sports.* 1994;4:32–40.
16. Fiatarone MA, O'Neill EF, Ryan ND, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med.* 1994;330:1769–1775.
17. Brown M, Holloszy JO. Effects of walking, jogging and cycling on strength, flexibility, speed and balance in 60- to 72-year olds. *Aging Clin Exp Res.* 1993;5:427–434.
18. Ades PA, Ballor DL, Ashikaga T, Utton JL, Nair KS. Weight training improves walking endurance in healthy elderly persons. *Ann Intern Med.* 1996;124:568–572.
19. Freilich RJ, Kirsner RLG, Byrne E. Isometric strength and thickness relationships in human quadriceps muscle. *Neuromusc Disord.* 1995;5:415–422.
20. Reed RL, Pearlmutter L, Yochum K, Meredith KE, Mooradian AD. The relationship between muscle mass and muscle strength in the elderly. *J Am Geriatr Soc.* 1991;39:555–561.
21. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *J Appl Physiol.* 1991;71:644–650.
22. Kaye SA, Folsom AR, Sprafka JM, Prineas RJ, Wallace RB. Increased incidence of diabetes mellitus in relation to abdominal adiposity in older women. *J Clin Epidemiol.* 1991;44:329–334.
23. Felson DT, Zhang Y, Anthony JM, Naimark A, Anderson JJ. Weight loss reduced the risk for symptomatic knee osteoarthritis in women. *Ann Intern Med.* 1992;116:535–539.
24. Harris TB, Ballard-Barbasch R, Madans J, Makuc DM, Feldman JJ. Overweight, weight loss, and risk of coronary heart disease in older women. *Am J Epidemiol.* 1993;137:1318–1327.
25. Simonsick EM, Lafferty ME, Phillips CL, et al. Risk due to inactivity in physically capable older adults. *Am J Public Health.* 1993;83:1443–1450.
26. Dawber TR, Meadors GF, Moore FE. Epidemiological approaches to heart disease: the Framingham Study. *Am J Public Health.* 1951;41:279–286.
27. Jette AM, Branch LG. The Framingham Disability Study: II. Physical disability among the aging. *Am J Public Health.* 1981;71:1211–1216.
28. Rosow I, Breslau H. A Guttman health scale for the aged. *J Gerontol.* 1966;21:556–559.
29. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q.* 1976;54:439–468.
30. Smith LA, Branch LG, Scherr PA, et al. Short-term variability of measures of physical function in older people. *J Am Geriatr Soc.* 1990;38:993–998.
31. Heymsfield SB, Smith R, Aulet M, et al. Appendicular skeletal muscle mass: measurement by dual-energy absorptiometry. *Am J Clin Nutr.* 1990;52:214–218.
32. Kannel WB, Sorlie PD. Some health benefits of physical activity: The Framingham study. *Arch Intern Med.* 1979;139:857–861.
33. Guccione AA, Felson DT, Anderson JJ, et al. The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. *Am J Public Health.* 1994;84:351–358.
34. Boult C, Kane RL, Louis TA, Boult L, McCaffrey D. Chronic conditions that lead to functional limitations in the elderly. *J Gerontol Med Sci.* 1994;49:M28–M36.
35. Cornoni-Huntley JC, Harris TB, Everett DF, et al. An overview of body weight of older persons, including the impact on mortality. *J Clin Epidemiol.* 1991;44:743–753.
36. Andres R, Muller DC, Sorkin JD. Long-term effects of change in body weight on all-cause mortality. *Ann Intern Med.* 1993;119:737–743.
37. Larsson LG, Grimby G, Karlsson J. Muscle strength and speed of movement in relation to age and muscle morphology. *J Appl Physiol.* 1979;46:451–456.
38. Steen B, Isaksson B, Svanborg A. Body composition at 70 and 75 years of age: a longitudinal population study. *J Clin Exp Gerontol.* 1979;1:185–200.
39. Fuller NJ, Laskey MA, Elia M. Assessment of the composition of major body regions by dual-energy X-ray absorptiometry (DEXA), with special reference to limb muscle mass. *Clin Physiol.* 1992;12:253–266.
40. Wang Z, Visser M, Ma R, et al. Skeletal muscle mass: evaluation of neutron activation and dual-energy x-ray absorptiometry methods. *J Appl Physiol.* 1996;80:824–831.
41. Svendsen OL, Haarbo J, Heitmann BL, Gotfredsen A, Christiansen C. Measurement of body fat in elderly subjects by dual-energy x-ray absorptiometry, bioelectrical impedance, and anthropometry. *Am J Clin Nutr.* 1991;53:1117–1123.
42. Haarbo J, Gotfredsen A, Hassager C, Christiansen C. Validation of body composition by dual energy x-ray absorptiometry (DEXA). *Clin Physiol.* 1991;11:331–341.
43. Johnson J, Dawson-Hughes B. Precision and stability of dual-energy x-ray absorptiometry measurements. *Calcif Tissue Int.* 1991;49:174–178.
44. Corti MC, Guralnik JM, Salive ME, Sorkin JD. Serum albumin and physical disability as predictors of mortality in older persons. *JAMA.* 1994;272:1036–1042.
45. Salive ME, Collins KS, Foley DJ, George LK. Predictors of nursing home admission in a biracial population. *Am J Public Health.* 1993;83:1765–1767.
46. Reuben DB, Siu AL, Kimpau S. The predictive validity of self-report and performance-based measures of function and health. *J Gerontol Med Sci.* 1992;47:M106–M110.
47. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol Med Sci.* 1994;49:M85–M94.

Received February 13, 1997
Accepted October 6, 1997