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Longitudinal Body Composition Changes in Old Men and Women: Interrelationships With Worsening Disability

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Background. Few studies have evaluated prospectively age-related body composition changes and their relationships with worsening disability in the elderly population.

Methods. Ninety-seven women and 62 men aged 71.4 ± 2.2 and 71.6 ± 2.2 years, respectively, at baseline underwent dual-energy x-ray absorptiometry determinations at baseline and at 2- and 5.5-year follow-up intervals to measure total body and leg fat (FM) and total, appendicular, and leg fat-free mass (FFM). Height, weight, body mass index (BMI), and waist circumference (as well as reported disabilities using a four-level scale) were evaluated at baseline and at 2- and 5.5-year follow-up.

Results. In both sexes, total FM did not change significantly, while total, appendicular, and leg FFM significantly decreased over the study follow-up. In men and women losing weight, BMI, total and leg FM, and total, appendicular, and leg FFM significantly decreased. In weight-stable men and women, appendicular and leg FFM significantly decreased and BMI, waist circumference, and total FM significantly increased. Men lost significantly more total, appendicular, and leg FFM than did women, irrespective of whether they maintained or lost weight. Over the follow-up period, 43.3% of women and 43.5% of men declined in one or more levels of reported disability. We evaluated the effect of age, baseline BMI, FM, FFM, number of diseases, baseline 6-minute walking test, categories of weight change, total, appendicular, or leg FFM changes, total FM and waist changes on the probability of a decline in one or more levels of reported disability score over the follow-up period, taking into account sex. Patients losing appendicular and leg FFM were 2.15 and 2.53 times, respectively, more likely to report increased disability than were patients without FFM loss.

Conclusions. Reduction in appendicular or leg FFM was the main predictor of decline in one or more levels of reported disability in older men and women, and accounted for about a 2-fold increase in risk.

SEVERAL cross-sectional and a few longitudinal studies have shown age-dependent body composition changes with fat-free mass (FFM) decline and fat mass (FM) increase (1–9). These changes may play a critical role in influencing quality of life, physical status, and comorbidity in older people (10), as well as onset and progression of disability in the elderly population (11). Some but not all of the cross-sectional studies showed an association between low levels of FFM and physical disability (12–16).

However, only a few studies have evaluated prospectively age-related body composition changes and their relationships with the incidence of disability in the elderly population (17,18). Recently, Visser and colleagues (17) observed that men and women with low muscle strength and low thigh muscle mass evaluated by using computed tomography had an increased risk of developing mobility limitations. Janssen (18) showed severe sarcopenia to be a weak independent risk factor for the development of physical disability, suggesting that the effect of sarcopenia is considerably lower in longitudinal than in cross-sectional analyses.

The aim of this study was to prospectively evaluate, with a 5.5-year follow-up, age-related body composition changes in a sample of old men and women at the high end of the functional spectrum and to determine if changes in FM and total and appendicular FFM can be correlated with increased disability. As a strong relationship has been observed between leg FFM and lower physical performance (17), we also looked for a relationship between changes in leg FFM over the 5.5-year follow-up and a worsening of disability.

METHODS

Participants

Anthropometric measurements, body composition, and disability were evaluated at baseline and at 2- and 5.5-year follow-up in a cohort of community-dwelling elderly men and women. Participants were randomly selected from the list of 11 general practitioners in the city of Verona, Italy. Participants were eligible if they were able to walk at least 1/2 mile without difficulty and if they were free of cognitive impairment (Mini-Mental Status Examination score $>$ 24). None of the participants engaged in regular physical exercise more than once a week during the study. Exclusion criteria included renal insufficiency, disabling knee osteoarthritis, heart failure (New York Heart Association class 2 or higher), and serious lung disease. Individuals who had lost $>$ 5% of their body weight in the year preceding the study were also excluded. At baseline, 177 women and 97 men, between 68 and 78 years old, were eligible.

During the follow-up, 11 participants died; 17 participants could not visit the clinic due to the onset of illnesses such as cancer, cerebrovascular disease, immobility, or other serious chronic disease and 78 were lost to follow-up. We also excluded nine participants who showed improvements in physical function during the follow-up period. The present analyses were performed on 159 participants.

A comparison of the women excluded from the present analysis ($n = 80$) with those who were included shows that those excluded had more prevalent disability ($p < .01$), higher values on the Geriatric Depression Scale ($p < .05$), and more diseases ($p < .05$), whereas there were no significant differences in age, BMI, or any of the body composition variables. No significant differences were observed for any of the variables considered between men who were excluded ($n = 35$) and those included in the present analysis.

A total of 97 women and 62 men underwent all three dual-energy x-ray absorptiometry (DXA) determinations, at baseline and again after 2- and 5.5-year follow-up, and were thus included in the analysis. All of the participants gave their consent to participate in the study. The study was approved by the Ethical Committee of Verona University.

Anthropometry

With the participant barefoot and wearing light indoor clothing, body weight was measured to the nearest 0.1 kg (Salus scale; Milan, Italy), and height to the nearest 0.5 cm using a stadiometer (Salus stadiometer). BMI was calculated as body weight adjusted by stature (kg/m^2). Waist circumference was obtained with a measuring tape at the level of the narrowest part of the torso as viewed anteriorly.

DXA

Total body fat and appendicular, leg, and total FFM were determined using DXA. Baseline and 2-year evaluations were performed using a Hologic QDR 2000 fan beam densitometer (Waltham, MA) with software version 7.2. Due to technical reasons, the 5.5-year body composition evaluation was performed using a Hologic QDR 4500 fan beam densitometer with software version 8.21.

The characteristics and physical concepts of DXA measurements have been described elsewhere (19). All metal objects (jewelry, snaps, and belts) were removed. Measurements were taken with the participant positioned supine on the scanning table. Radiation exposure was < 8 millisieverts, and the mean measurement time was 6 minutes. Daily quality-assurance tests were performed according to the manufacturer's instructions. All scans were subsequently analyzed by a single trained investigator. The percentage of fat was calculated as FM (kg) measured by DXA divided by body weight (kg) measured by a scale.

With the use of specific landmarks provided by the software region toolbox, arms and legs were isolated on the skeletal x-ray planogram (anterior view). The arms were isolated by running a line through the humeral head, and the legs were isolated by drawing an angled line through the femoral neck. The fat and bone mineral-free portion of the extremities were assumed to represent appendicular skeletal muscle mass. Leg skeletal muscle mass and arm skeletal muscle mass represent the sum of both the right and left extremities. Appendicular skeletal muscle mass was calculated as the combined sum of leg and arm skeletal muscle mass (20).

DXA 4500 Calibration

Previous studies have shown that the Hologic QDR 4500 overestimates FFM compared with the Hologic QDR 2000 (21,22), thus a subsample of 13 participants were evaluated on the same day with both Hologic QDR 2000 and 4500 to obtain regression equations to adjust for differences in FFM and FM measurement. The following regression equations were obtained:

$$\text{Total FFM QDR 2000} = 0.975 \times \text{total FFM QDR 4500} - 1916.6$$
$$\text{Appendicular FFM QDR 2000} = 0.97 \times \text{Appendicular FFM QDR 4500} - 1736.3$$
$$\text{Leg FFM QDR 2000} = 0.999 \times \text{Leg FFM QDR 4500} - 1536.1$$
$$\text{Arm FFM QDR 2000} = 0.884 \times \text{Arm FFM QDR 4500} - 170.04$$
$$\text{FM QDR 2000} = 1.261 \times \text{FM QDR 4500} - 4045.0$$
$$\text{Leg FM QDR 2000} = 1.184 \times \text{Leg FM QDR 4500} - 95.4$$
$$\text{Arm FM QDR 2000} = 1.114 \times \text{Arm FM QDR 4500} + 97.6$$

Health Status

The presence of acute and chronic conditions was determined using standardized questionnaires already in use in the Italian Longitudinal Study on Aging (23). Participants underwent a careful clinical investigation at the beginning of the study, and again at the 2- and 5.5-year follow-up. Information regarding the onset of new diseases was obtained for each participant through their general practitioners. Chronic conditions assessed included cardiovascular disease, lung disease (emphysema, chronic bronchitis, and asthma), degenerative joint disease, and hypertension. Thirteen participants were diabetics, 12 participants showed Geriatric Depression Scale scores > 9. As a simple comorbidity index, the number of diseases in each participant was computed. Intentional and unintentional weight loss was evaluated using standardized questionnaires (23). A 6-minute walking test was performed to determine the distance walked by each participant at usual speed.

Reported Disability

Reported disability was defined according to Langlois and colleagues (24), based on the ability to carry out four of the six items from the Activities of Daily Living (ADL) scale (bathing, getting out of bed, dressing, and eating unaided) and walking across a small room, which were scored as easy, difficult, very difficult, or impossible, on three Rosow-Breslau physical function items (walking 800 meters, climbing stairs, doing heavy housework), again scored as easy, difficult, very difficult, or impossible, and on selected Instrumental Activities of Daily Living (IADL) (shopping, using the telephone, doing light housework, preparing meals). Four groups were identified:

Table 1. Anthropometric and Body Composition Variables at Baseline and After 2 Years and 66 Months of Follow-Up in Women

Variables $n = 97$	Basal Mean ± *SD*	2 Years Mean ± *SD*	5.5 Years Mean ± *SD*	*p* for Trend Linear	*p* for Trend Quadratic
Height, cm	155.14 ± 6.27	155.62 ± 5.99	155.34 ± 6.18	.21	.08
Weight, kg	64.15 ± 10.78	64.05 ± 11.17	64.63 ± 11.19	.17	.13
BMI, kg/m^2	26.52 ± 4.37	26.58 ± 4.58	26.84 ± 4.44	.07	.11
Waist, cm	82.42 ± 10.30	84.73 ± 10.46	85.08 ± 10.55	.001	.06
FM, kg*	26.19 ± 8.02	26.52 ± 8.57	26.72 ± 8.97	.063	.74
Leg FM, kg*	9.34 ± 2.87	9.38 ± 3.19	9.51 ± 3.12	.07	.70
Arm FM, kg*	3.45 ± 1.22	3.51 ± 1.31	3.62 ± 1.31	.001	.44
FFM, kg*	34.84 ± 4.05	34.61 ± 3.95	34.45 ± 4.44	.047	.87
Appendicular FFM, kg*	13.41 ± 1.92	13.23 ± 1.97	12.97 ± 2.07	.001	.51
Leg FFM, kg*	10.33 ± 1.52	10.08 ± 1.58	9.88 ± 1.67	.001	.66
Arm FFM, kg*	3.07 ± 0.51	3.14 ± 0.52	3.09 ± 0.51	.58	.007

Notes: *Evaluated by dual-energy x-ray absorptiometry (DXA).

SD = standard deviation; BMI = body mass index; FM = fat mass; FFM = fat-free mass; appendicular FFM = fat-free mass leg and arm.

1. Subjects without disability – if subjects reported ‘‘easy’’ for all the ADLs, ‘‘no difficulty’’ in the physical funcztions items, and ‘‘no difficulty’’ or ‘‘don’t do’’ for all IADLs
2. Subjects with mild disability – if participants reported difficult in one or more higher level of physical function items or IADLs but all other physical function tasks except walking 800 meters and ADLs were easy
3. Subjects with moderate disability – if participants reported that one or more physical function items was very difficult or impossible and/or could not walk 800 meters
4. Subjects with disability – if participants reported that one or more of the ADLs was difficult, very difficult, or impossible.

Changes in any reported disability score between baseline and subsequent assessment were divided into two categories: unchanged (defined by the same score over the follow-up period) or worsened (defined by the loss of one or more points in the scale over the follow-up period).

Statistical Analysis

Results are shown as means with standard deviations (*SD*). Preliminarily, the Kolmogorov–Smirnov test was performed on all the anthropometric variables (separately in men and in women) to assess evidence of non-normality in the data. None of the results of the tests were significant, so repeated-measures analyses of variance (ANOVA) were performed on the original variables. Because most of the interaction terms between gender and anthropometric and body composition changes were statistically significant, the results are reported stratified according to gender.

Differences in mean changes in body composition by weight change category over the 5.5-year period were tested by unpaired *t* test, whereas changes between baseline and 5.5-year follow-up were tested using paired *t* test. A comparison of changes between men and women was performed using an unpaired *t* test; to account for the effect of weight loss over the follow-up period, covariance analysis was also performed. A logistic regression analysis was used, considering any change in a reported disability score from baseline to subsequent assessment as the outcome (present vs absent). Among the independent variables, categories of change in anthropometric and body composition variables were considered. Each categorical variable was coded using two levels (stable/loser) with a cutoff at the 50th percentile of the corresponding change. When considering weight categories, a cutoff of 3% was used (i.e., participants were considered to be weight losers if they lost $> 3\%$ of body weight, and to be stable in all other cases). A significance level of 0.05 was used throughout the study. All statistical analyses were performed using SPSS (version 12.0 for Windows; SPSS, Chicago, IL) (25).

RESULTS

A total of 97 women and 62 men with baseline ages of 71.3 ± 2.2 and 71.6 ± 2.3 years, respectively, and baseline BMI values of 26.4 ± 4.4 and 27.1 ± 3.3 kg/m^2, respectively, were studied. Tables 1 and 2 show the main characteristics of the study population (mean ± *SD*) at baseline and after 2 and 5.5 years, respectively, in women and men. In women, no significant changes were observed in weight or BMI, but significant increases in waist circumference (p for trend $< .001$) were detected, whereas weight, waist circumference, and BMI did not change significantly in men. In both women and men, total FM did not change significantly, whereas total (respectively, p for trend $= .047$ and .001), appendicular (respectively, p for trend $< .001$ and .001) and leg FFM (respectively, p for trend $< .001$ and .001) decreased significantly.

The study population was then divided into two weight change categories: weight loss ($> 3\%$ loss) and stable. Absolute changes in the main anthropometric and body composition variables by weight change groups are shown in Table 3. A total of 25.8% of men and 24.7% of women lost weight during the follow-up period. In men and women who lost weight, BMI, total and leg FM, and total, appendicular, and leg FFM all significantly decreased. In weight-stable men and women, there was a significant decrease in appendicular and leg FFM and a significant increase in BMI, waist circumference, and total FM. Men lost significantly more total, appendicular, and leg FFM than did women, irrespective of whether they were weight stable or losing. After adjustment for body weight changes (data not shown in tables) the difference between weight-losing men and women remained statistically significant for changes in waist circumference ($p = .025$). Moreover, the

Table 2. Anthropometric and Body Composition Variables at Baseline and After 2 Years and 66 Months of Follow-Up in Men

Variables $n = 62$	Basal Mean ± *SD*	2 Years Mean ± *SD*	5.5 Years Mean ± *SD*	*p* for Trend Linear	*p* for Trend Quadratic
Height, cm	169.62 ± 8.21	169.90 ± 8.21	169.80 ± 8.13	.35	.25
Weight, kg	78.60 ± 11.02	78.72 ± 11.01	77.95 ± 10.78	.16	.27
BMI, kg/m^2	26.99 ± 3.28	27.27 ± 3.49	27.05 ± 3.32	.70	.08
Waist, cm	96.03 ± 8.79	97.59 ± 8.41	96.42 ± 8.87	.44	.001
FM, kg*	22.14 ± 6.45	22.62 ± 6.50	22.00 ± 6.96	.71	.06
Leg FM, kg*	6.14 ± 1.73	6.17 ± 1.79	6.20 ± 1.92	.56	.97
Arm FM, kg*	2.71 ± 0.76	2.71 ± 0.75	2.93 ± 1.04	.015	.09
FFM, kg*	52.36 ± 5.88	52.08 ± 5.52	50.43 ± 5.70	.001	.001
Appendicular FFM, kg*	21.39 ± 2.77	20.56 ± 3.47	20.09 ± 2.78	.001	.60
Leg FFM, kg*	15.86 ± 2.08	15.26 ± 1.87	14.73 ± 2.10	.001	.64
Arm FFM, kg*	5.53 ± 0.83	5.62 ± 0.78	5.35 ± 0.82	.02	.001

Notes: *Evaluated by dual-energy x-ray absorptiometry (DXA).

SD = standard deviation; BMI = body mass index; FM = fat mass; FFM = fat-free mass; appendicular FFM = fat-free mass leg and arm.

significant changes in total, appendicular, and leg FFM ($p = .18$), as well in FM ($p = .79$) were no longer significant.

Figure 1 shows the distribution of the reported disability scale during the follow-up period for women and men. The percentage of participants free from disability decreased from 68% to 40.2% at 2 years and to 36.1% at the 5.5-year follow-up in women and from 83.9% to 46.7% at 2 years and 44.3% at the 5.5-year follow-up in men. Over the 5.5-year follow-up period, 42 women (43.3%) and 27 men (43.5%) showed a decline in one or more levels of the reported disability scale (defined as a worsening in disability).

The effect of age, BMI, categories of weight change, baseline BMI, baseline FM and FFM, number of diseases, baseline walking test, categories of FFM changes (total, appendicular. or leg FFM), categories of total FM, and waist circumference changes on the probability of a reduced disability score over the study period was evaluated, taking into account sex. No significant interaction with gender was found. Sex-adjusted estimates of regression coefficients are displayed in Table 4. Only categories representing losses of appendicular and leg FFM were significant in this analysis.

As far as the number of diseases is concerned, a gender-related trend was observed (chi-square = 6.925, $p = .074$), showing an increasing probability of worsening disability score only for men with a higher number of diseases. (In women, the number of diseases appeared not to be associated with the response.) All the variables considered in the previous analysis were included in a multiple logistic regression model to evaluate their joint roles. Only the categories of loss of appendicular or leg FFM were significantly associated with a worsening in disability, whereas the other variables (displayed in Table 4), also with this multivariate analysis, were confirmed as not playing a significant role. When number of diseases (together with

Table 3. Absolute Changes in Body Composition by Weight-Change Group in Men and Women

	Loss > 3% ($N = 40$)	*p* Value (Baseline vs 5.5 y)	Weight Stability ($N = 119$)	*p* Value (Baseline vs 5.5 y)
Men				
n	16		46	
BMI*	−1.31 ± 1.07	< .001	0.59 ± 1.03	.01
Waist*	−4.25 ± 4.43	< .001	2.01 ± 2.27	< .001
Body weight*	−5.3 ± 2.28	< .001	0.95 ± 2.48	< .001
Total FM*	−3.94 ± 2.19	< .001	1.16 ± 2.43	.02
Leg FM*	−0.71 ± 0.76	.002	0.60 ± 2.08	.06
Total FFM*	−3.02 ± 1.79	< .001	−1.55 ± 2.09	< .001
Appendicular FFM*	−1.94 ± 1.27	< .001	−1.09 ± 1.38	< .001
Leg FFM	−1.58 ± 0.99	< .001	−0.97 ± 1.11	< .001
Women				
n	24		73	
BMI*	−0.83 ± 1.64	.02	0.89 ± 1.26	< .001
Waist*	−0.46 ± 3.07†	.47	3.10 ± 4.15	< .001
Body weight*	−3.42 ± 2.75†	< .001	1.76 ± 2.51	< .001
Total FM*	−2.38 ± 1.80†	< .001	1.49 ± 2.34	< .001
Leg FM*	−0.71 ± 0.76	< .001	0.61 ± 0.87	< .001
Total FFM*	−1.18 ± 1.73†	.003	−0.07 ± 1.89†	.74
Appendicular FFM*	−0.98 ± 0.92†	< .001	−0.27 ± 0.89†	.01
Leg FFM*	−0.95 ± 0.83†	< .001	−0.29 ± 0.78†	.002

Notes: *$p < .05$ weight losers vs weight stable; unpaired *t* test.

$^\dagger p < .05$ men vs women; unpaired *t* test.

BMI = body mass index; FM = fat mass; FFM = fat-free mass; appendicular FFM = fat-free mass leg and arm.

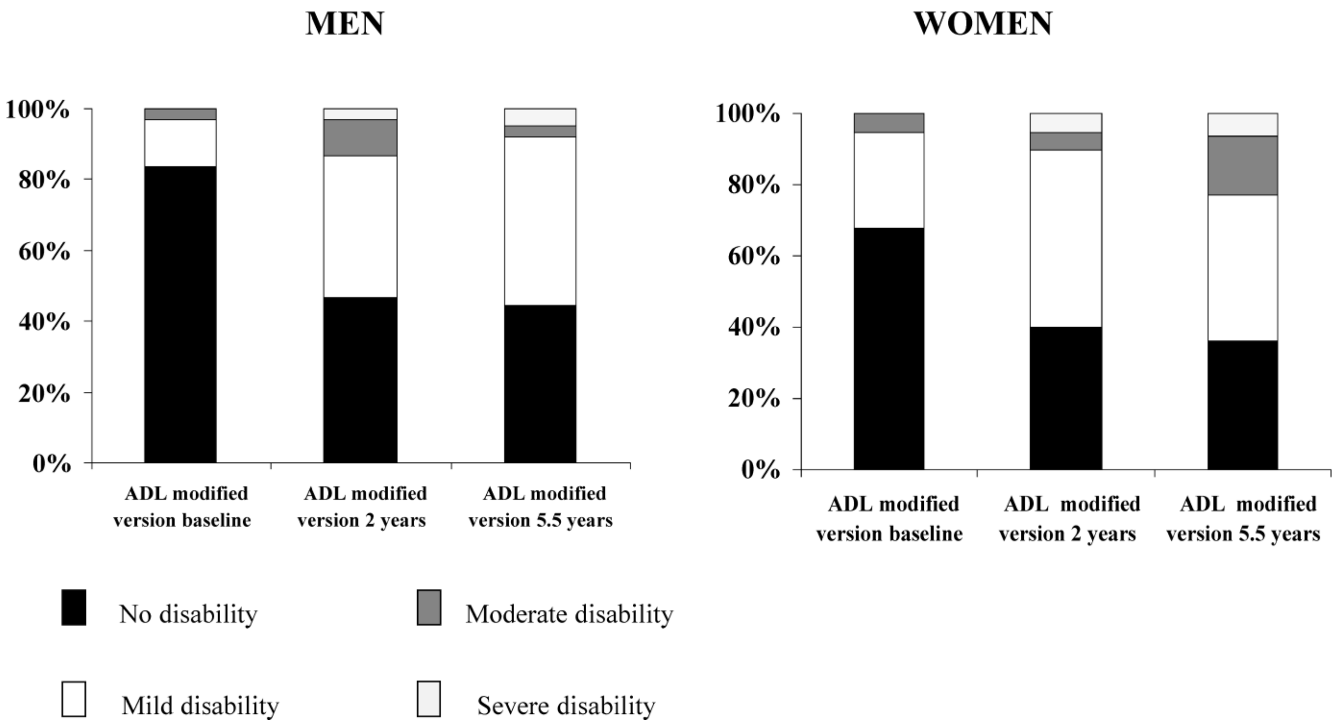

Figure 1. Distribution of reported disability scale during the follow-up period for men and women. ADL = activities of daily living.

the interaction with sex) were added to the model containing categories of loss of appendicular FFM, the interaction terms were marginally significant (chi-square = 7.456, $p = .059$), whereas the categories of loss of appendicular FFM confirmed a significant association. After having adjusted for sex and for the number of diseases (as well as the interaction between sex and the number of diseases), the odds of having a worsening in the disability score for patients who had lost appendicular FFM were 2.15 times higher than those of participants who had not (95% confidence interval, 1.10–4.20).

When we considered leg FFM instead of appendicular FFM in the logistic regression, the risk of a worsening in disability was 2.53 (95% confidence interval, 1.21–5.30) times higher in patients who had lost leg FFM than in those who had not.

DISCUSSION

Our 5.5-year longitudinal study in a sample of healthy elderly participants initially at the high end of the functional spectrum shows a significant decline in total, appendicular, and leg FFM in both genders independently of weight change, as well as a significant decline of participants free of any disability. More importantly, our findings show that the probability of having a worsening disability was significantly associated to the decline in FFM, and risk increased about 2-fold in the group of participants losing appendicular or leg FFM. Body composition changes across aging are influenced in men and women by body weight changes (4).

However, in our study sample, 75.3% of women and 74.2% of men were weight-stable over 5.5 years. Despite weight stability, in line with previous observations (5,26), we observed a significant decrease over time in appendicular and leg FFM in both men and women, suggesting that a decrease in FFM may be part of the physiological aging process.

In weight-stable participants, both men and women showed a significant increase in FM; this finding is in agreement with Hughes and colleagues (27), who, in a 9-year longitudinal study with a sample of 53 weight-stable men and 78 women aged 60 ± 8 years, observed that FM increased significantly in both men and women. We also observed a

Table 4. Sex-Adjusted Estimates Effects of Selected Variables on the Probability of Having a Worsening in the Disability Score (Logistic Regression Analysis)

Variables	Coefficient	*SE*	*z*	*p* Value
Weight categories	−0.54	0.48	−1.11	.27
Loss of total FFM categories	0.05	0.32	0.16	.89
Loss of Appendicular FFM categories	0.71	0.33	2.17	.03
Loss of Leg FFM categories	0.70	0.33	2.14	.03
Loss of total FM categories	0.07	0.32	0.22	.82
Changes in waist categories	−0.15	0.33	−0.46	.64
Appendicular FFM at baseline	0.01	0.07	0.09	.93
FM at baseline	0.02	0.02	0.95	.34
Age at baseline	−0.07	0.07	0.90	.37
ADLm at baseline	−0.54	0.38	−1.40	.16
Meters at six minutes walking test at baseline	−0.002	0.002	−0.86	.38
Height at baseline	−0.02	0.02	−0.88	.38
BMI at baseline	0.04	0.04	0.97	.33

Notes: Each effect was estimated after having entered sex and the considered variable in the model (only one variable at time).

SE = standard error; BMI = body mass index; FM = fat mass; FFM = fat-free mass; appendicular FFM = fat-free mass leg and arm; ADLm = activities of daily living, modified version.

significant waist circumference increase in both weight-stable men and women which, in line with previous observations, shows a redistribution of body fat with age (28,29).

In contrast, we observed that both FFM and FM significantly declined over time in weight-losing men and women. Furthermore, our results show that, in weight-stable individuals, the decrease in total, appendicular, and leg FFM is significantly higher in men than in women, suggesting a greater decline of FFM with age in men than in women. Even in weight-losing men the decrease in total, appendicular, and leg FFM was significantly higher than in women, but this difference was lost after adjustments for changes in body weight. These results seem to suggest that weight loss not only determines a decline in FM, but also modifies the gender effect on FFM decline over time.

During the follow-up period, the percentage of participants free from disability in our study sample decreased in both men and women; more importantly, 43.3% of women and 43.5% of men had a worsening disability. Age-dependent body composition changes have been assumed to be possible modifiable risk factors for disability.

A few longitudinal studies have evaluated the relationship between body composition and incident disability. However, to the best of our knowledge, our study is the first to evaluate the relationships between worsening disability and changes in muscle and FM over a 5.5-year follow-up. Previous studies, in fact, considered the relationships between baseline body composition, in terms of FFM or FM, and incident disability. Visser and colleagues (12) showed high values of body fat but not low values of FFM to be independent predictors of increased disability over 3 years in a group of older men and women.

Janssen (18), in an 8-year follow-up study, reported that the risk of developing disability was significantly higher in participants with severe sarcopenia than in those with normal muscle mass. He also pointed out that the relationship between sarcopenia and disability might be lower in longitudinal than in cross-sectional analyses. In our participants, a decline in appendicular and leg FFM was the main predictor of worsening disability; in particular, participants categorized as losing appendicular or leg FFM showed a 2-fold higher risk of having an increased disability. This finding supports the hypothesis that loss of muscle mass in the extremities is an important risk of physical disability in older ages and complements previous observations that show a significant association between lower extremity function and loss of muscle mass (30,31).

Our study failed to observe any relationship between changes in FM and waist circumference with worsening disability. In fact, changes in neither FM nor waist circumference were associated with higher risk for worsening disability over the follow-up period. This lack of association between FM and waist circumference changes with disability is in disagreement with previous cross-sectional observations (11,13), which showed a significant association between FM and body fat distribution with reported disability. It is possible to hypothesize that the role of FM gain in longitudinal analyses (especially for small gains as observed in our participants), may have less relevance to the worsening of physical disability than that observed in cross-sectional evaluations. Of course, other factors besides age-related body composition changes may have accounted for the increased risk for worsening disability in our participants. Recently it has been shown that the muscle strength of legs is a strong predictor of incident disability and that when muscle strength was taken into account, low muscle area as assessed by computed tomography was no longer associated with incident mobility disability (17). Thus our results should be confirmed by further studies that take into account both muscle mass and strength. It should, however, be considered that the age-related changes in muscle mass parallel muscle strength changes, even if the changes in mass are less noticeable (32).

Comorbidity may be another factor that increases the risk of developing disability; however, in our participants, the number of diseases, a poor surrogate marker of comorbidity, was associated with increased risk of a worsening disability in men only. It is possible to hypothesize that the use of a method to evaluate comorbidity able to take into account not only the number of diseases but also their degree of severity may have given us different results.

We failed to observe any relationship between weight change and worsening of disability; this finding is in partial agreement with Al Snih and colleagues (33), who reported that the association between weight change and lower extremities limitations is mediated by health conditions and muscle strength.

Study Limitation

Some limitations of our study should be recognized. First, we used a single method (DXA) to determine changes in body composition; the use of several independent methods to confirm our results would provide an added degree of confidence. More importantly, for technical reasons we needed to change from the DXA Hologic 2000 (used in the baseline and 2-year examinations) to the DXA Hologic 4500. An overestimation of FFM by the Hologic 4500 versus the 2000 has been previously shown (21,22). To correct this bias, we used a regression equation, performing two evaluations of body composition in 13 of our participants using the two different instruments, and adjusted values of body composition variables were used for the 5.5-year follow-up. The use of adjusted values, instead of measured values of body composition variables, could have induced an important bias. However, when we repeated our analyses after adjusting body composition variables obtained at the 5.5-year follow-up by using the calibration recently suggested by Schoeller and colleagues for Hologic QDR 4500, our results were unchanged (22).

It must also be noted that body composition changes observed between baseline and 2-year follow-up, as determined by the Hologic 2000, are consistent with those observed between 2-year follow-up and 5.5-year follow-up (obtained by the Hologic QDR 2000 and the Hologic QDR 4500, respectively) and that body composition changes observed in our participants over the 5.5-year follow-up are in line with those observed by others (9,32). Researchers might need to move from old to new generation DXA machines; thus the use of a regression equation should be acceptable as a way to correct inter-instrument variability.

In our study we did not assess incident disability but worsening disability, as we also included in the analyses participants moderately disabled at baseline. Nevertheless, when we repeated our analyses after excluding participants disabled at baseline, our results were still unchanged (data not shown in tables). Finally, our study population was small and limited to healthy old men and women initially well functioning and in good condition, as confirmed by the fact that the majority were weight stable during the study and thus cannot be considered representative of a normal aging population.

Conclusion

Our 5.5-year longitudinal study shows a significant decline in muscle mass in both genders independently of weight changes. More importantly, our findings show that the risk of having a worsening disability was significantly associated with the decline in appendicular and leg FFM, with an increased risk of about 2-fold in the group losing appendicular or leg FFM. Our findings linking FFM changes over time and worsening disability seem to show that the prevention of loss in FFM could be an important tool to reduce the risk of disability.

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