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Research Article

Body Composition Remodeling and Incident Mobility Limitations in African Ancestry Men

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Abstract

Background: Mobility limitations are common, with higher prevalence in African Americans compared with whites, and are associated with disability, institutionalization, and death. Aging is associated with losses of lean mass and a shift to central adiposity, which are more pronounced in African Americans. We aimed to examine the association of body composition remodeling with incident mobility limitations in older men of African ancestry.

Methods: Seven-year changes in body composition were measured using peripheral quantitative computed tomography (pQCT) of the calf and whole-body dual x-ray absorptiometry (DXA) in 505 African ancestry men aged ≥60 years and free of self-reported mobility limitations at baseline. Self-reported incident mobility limitations were assessed at 7-year follow-up. Odds of developing mobility limitations associated with baseline and change in body composition were quantified using separate logistic regression models.

Results: Seventy-five men (14.9%) developed incident mobility limitations over 6.2 ± 0.6 years. Baseline body composition was not associated with incident mobility limitations. After adjustment for covariates, gaining total and intermuscular fat were associated with incident mobility limitations (odds ratio [OR]: 1.60; 95% confidence interval [CI]: 1.21–2.13; OR: 1.51; 95% CI: 1.18–1.94). Changes in DXA lean mass were not related to mobility limitations; however, maintaining pQCT calf muscle area was protective against mobility limitations (OR: 0.65; 95% CI: 0.48–0.87).

Conclusions: Increases in body fat, and particularly intermuscular fat, and decreases in calf skeletal muscle area were associated with a higher risk of developing mobility limitations. Our findings emphasize the importance of body composition remodeling in the development of mobility limitations among African ancestry men.

Keywords: Muscle, Fat, Computed tomography, DXA and Tobago

Mobility disability and limitations are common among older adults (1) and associated with lower quality of life (2), increased risk for disability (3), institutionalization (4), and mortality (5,6). In the United States, the prevalence and incidence of mobility disability and limitations are higher in African-Americans compared with whites (7–9). However, little is known about the risk factors for and burden of mobility limitations in older adults of African ancestry outside the United States, where large demographic changes are expected to increase the burden of chronic disease and disability among older adults over the next 50 years (10).

Aging is associated with a gradual loss of lean mass and a shift to more central adiposity (11,12), with greater losses of lean mass in blacks compared with whites (13,14). In cross-sectional studies of older adults, the strength of the association between lean mass and mobility varies considerably (1,9,15–19). Longitudinal studies are

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needed to address these relationships as one measure does not capture complex body composition changes with aging. Furthermore, previous studies relied on dual energy x-ray absorptiometry (DXA) or bioelectrical impedance, which, as opposed to computed tomography (CT), are not direct measures of skeletal muscle mass and are influenced by hydration status (20). Thus, longitudinal studies employing more direct measures of skeletal muscle mass are needed to assess the association between body composition remodeling and incident mobility limitations.

Higher levels of fat mass have been related to mobility limitations in older adults (8). However, associations between fat mass changes and mobility limitations have not been specifically examined. Furthermore, specific fat depots, such as intermuscular adipose tissue (IMAT), are particularly related to adverse health effects such as inflammation (21), poorer muscle power (22) and physical function (23), declining gait speed (24), and mobility limitations (25). IMAT is also higher in African Americans compared with whites in some studies and increases with age independent of overall weight change (26). However, little is known about the impact of age-associated changes in intermuscular fat depots on mobility limitations, especially in African ancestry individuals outside the United States.

The goals of the current analyses were to quantify the incidence and risk of mobility limitations associated with both baseline and body composition changes over an average of 6 years in a population cohort of African ancestry men aged 60 years and older from the Caribbean Island of Tobago. Tobago has a successful, universal health care system, and life expectancy is similar to U.S. Black American men. Although, differences between the Caribbean and American lifestyles do exist (eg, universal health care, higher sun exposure, and fish consumption among Caribbeans), muscle and fat profiles are very similar. For example, compared with Caucasian men, both African American and Afro-Caribbean men have lower muscle quality but higher total and appendicular lean mass, as well as lower total body and visceral fat but greater skeletal muscle fat infiltration (27–30). We hypothesized that this cohort of Caribbean men would have lower incidence of mobility limitations than observed in African Americans due to dietary and lifestyle differences. We also hypothesized that the relationship between body composition and incident mobility limitations will be similar in Afro-Caribbean compared with African American Men. Specifically, losing muscle and gaining intermuscular fat measured by peripheral quantitative computed tomography (pQCT) would be associated with higher odds of incident mobility limitations. Finally, we hypothesized that losing lean mass, especially appendicular lean mass, and gaining fat mass as measured by DXA would be associated with higher odds of developing mobility limitations, but these associations would not be as strong as pQCT measures.

Methods

Study Population

Three thousand three hundred men aged 40 years and older on the Caribbean island of Tobago were recruited between 1998 and 2003 for a population-based prostate-specific antigen screening study (13). To be eligible, men had to be ambulatory, noninstitutionalized, and not terminally ill. Ancestry informative genetic markers have confirmed a low admixture (6% non-African) in this population (14). Written informed consent was obtained from all study participants using forms approved by the Institutional Review Boards of the University of Pittsburgh and the Tobago Division of Health and Social Services.

In 2004–2007 (baseline for the current analysis), body composition was assessed for the first time by both pQCT and DXA (Hologic QDR 4500W; Hologic Inc., Bedford, MA) in 2,152 men (70% of survivors)(31). Importantly, there were no differences in age, height, weight, and body mass index between men who completed pQCT scans and those that did not (32). From 2010 to 2013, follow-up scans were conducted in 1,515 men (82% of survivors) (31). The present analysis is restricted to the 505 men aged 60+ years who were free of mobility limitations in 2004 and who had completed baseline and follow-up body composition data.

pQCT and DXA Measured Body Composition

A pQCT scan at the tibia was obtained using the Stratec XCT-2000 scanner (Orthometrix, Inc., White Plains, NY,) as described (28,31,32), to measure cross-sectional areas (CSAs) of total muscle, total adipose tissue, subcutaneous adipose tissue, and IMAT in cm^2. Images were analyzed by a single investigator (C.L.G.) using the Stratec analysis software version 5.5D (Orthometrix, Inc.).

Whole-body DXA measurements were made using a QDR 4500W densitometer (Hologic Inc.). Scans were analyzed for total and trunk fat mass as well as total and appendicular lean mass using QDR software version 8.26a. Baseline and change in body composition were the primary independent variables in all analyses.

Mobility Limitations

At baseline and the 6-year follow-up visit, men were asked (a) "Do you have ANY difficulty walking 2 or 3 blocks outside on level ground?" and (b) "Do you have ANY difficulty climbing up 10 steps without resting?." "Yes, No, or Do not do.". If "Yes," they were asked how much difficulty they had: "Some," "Much," or "Unable to do" and if "this was because of a health or physical problem?." If "do not do," they were also asked "if this was because of a health or physical problem." We categorized those reporting any difficulty or not performing either of these tasks because of a health or physical problem as having mobility limitations. Men with prevalent mobility limitation were excluded from analyses, and incident mobility limitations were used as the primary outcome variable for subsequent analysis.

Other Measures

Height was measured using a wall-mounted stadiometer. Weight was measured without shoes on a balance beam scale. Information on lifestyle habits, demographic information, medical conditions, and medication use was assessed using interviewer-administered questionnaires. Hypertension was defined as having systolic blood pressure ≥140 mmHg or use of antihypertensive medications. Diabetes was defined as self-reported treatment or fasting blood glucose ≥126 mmol/L. Cardiovascular disease was defined as self-reported history of heart attack, stroke, or congestive heart failure. Smoking was recorded as never or ever smoked. Alcohol consumption was divided into >1 drink/day versus ≤1 drink/day. Self-reported walking was recorded, and the questions were phrased to assess walking for exercise or leisure.

Statistical Analyses

Means and standard deviations or frequencies and percentages were calculated for baseline characteristics. Comparisons between men with and without incident mobility limitations were made using *t* tests, nonparametric, and chi-squared tests as appropriate. Unadjusted changes in body composition were compared between men with and without incident mobility limitations using paired *t*- or nonparametric tests.

The likelihood of developing mobility limitations associated with body composition change was assessed using separate multivariable

logistic regression models for each body composition measure. Odds ratios were expressed per standard deviation change in body composition measure. Potential covariates included age, education, marital status, drinks/week, smoking, body mass index, height, self-reported cardiovascular disease, arthritis/gout, diabetes, hypertension, and walking habits. Covariates were entered into the models if they were different between men with and without mobility limitation at the $p < .15$ level and were retained in the final model if significant at the $p < .20$ level. Models that included change in body composition measures as the primary independent variables were additionally adjusted for baseline body composition. Finally, to determine whether associations with body composition remodeling were driven by total weight change, we examined models adjusted for change in total body weight, we built models additionally adjusted for change in total body weight. All analyses were performed using SAS v.9.4 (Cary, NC).

Results

Seventy-five men (14.9%) developed incident mobility limitations over 6.2 ± 0.6 years. Men with incident mobility limitations were older, heavier, and had a higher prevalence of hypertension, diabetes, and arthritis at baseline (all $p < .05$, Table 1). Men with incident mobility limitations also had higher baseline fat and intermuscular CSAs, as well as lower muscle density, higher total fat, and trunk fat mass (all $p < .05$, Table 1).

There was considerable variation in overall weight change with both groups losing weight on average. The mobility limitations group lost almost twice as much weight, but the difference did not reach statistical significance ($p = .21$, Table 2). Men with incident mobility limitations experienced greater increases in total and intermuscular fat CSAs and decreases in skeletal muscle CSA and density (all $p < .05$, Table 2). Men who developed incident mobility limitations also lost significantly more total and appendicular lean mass ($p < .05$) but experienced similar changes in total and trunk fat mass.

In multivariable logistic regression models, no baseline body composition measures were associated with incident mobility limitations (Table 3). Change in total body weight was also not related to incident mobility limitations. However, gaining or maintaining total fat and IMAT CSAs from pQCT (models do not differentiate between gaining or not losing) were related to a higher likelihood of developing incident mobility limitations. Gaining total and trunk fat mass were also related to a higher risk of developing incident mobility limitations. Change in subcutaneous fat CSA was not related to incident mobility limitations. Gaining total skeletal muscle CSA and density were associated with 53.8% and 44.9% lower risk of incident mobility limitations per standard deviation of change (odds ratio [OR]: 0.65; 95% confidence interval [CI]: 0.48–0.87; OR: 0.69; 95% CI: 0.51–0.92), respectively. However, change in DXA total and appendicular lean mass was not related to incident mobility limitations.

Associations between changes in DXA body composition measures and incident mobility limitation became stronger after adjustment for total weight change (Table 3). These results reflect that gaining more fat or losing more lean than expected given a total weight change are particularly predictive of incident mobility limitations.

Discussion

In this cohort of older community-dwelling African ancestry men, for every 4.0 kg increase in DXA total fat mass, the likelihood of developing incident mobility limitations increased by 60% over an average of 6 years. Trunk fat mass increase was also related

Table 1. Baseline Characteristics of African Ancestry Men Who Did and Did Not Develop Mobility Limitation Over 6 y

	Mobility Intact, $n = 430$ (85.1%)	Incident Mobility Limitations,* $n = 75$ (14.9%)	p Value
Age	66.3 (5.1)†	70.9 (6.5)	<.01
Ever married, yes	401 (93.3)	72 (96.0)	.61
Ever smoker, yes	135 (31.4)	25 (33.3)	.79
Drinks, >1 per day	24 (5.6)	2 (2.7)	.40
High school or higher education, yes	93 (21.6)	11 (14.7)	.22
Body weight, kg	81.2 (13.3)	86.4 (15.1)	.01
BMI	26.7 (3.9)	29.5 (6.1)	<.01
Walk past month, yes	315 (73.3)	51 (68.0)	.40
Hypertension, yes	256 (59.5)	60 (80.0)	<.01
Cardiovascular disease, yes	16 (3.7)	6 (8.0)	.12
Diabetes, yes	90 (21.4)	28 (38.9)	<.01
Arthritis or gout, yes	69 (16.1)	25 (33.3)	<.01
pQCT			
Total fat, cm^2	17.2 (7.9)	20.5 (8.7)	<.01
subQ fat, cm^2	12.7 (6.1)	14.2 (7.3)	.11
IMAT, cm^2	2.9 (2.6)	4.6 (4.2)	<.01
Muscle CSA, cm^2	72.3 (11.6)	71.3 (12.1)	.42
Muscle density, HU	72.4 (3.7)	70.4 (5.4)	.01
DXA			
Total fat, kg	17.2 (6.4)	20.7 (7.8)	<.01
Trunk fat, kg	8.6 (3.5)	10.4 (3.8)	<.01
Total lean, kg	59.0 (7.5)	60.5 (8.4)	.11
Appendicular lean, kg	27.7 (4.2)	27.9 (5.4)	.69

Note: BMI = Body mass index; CSA = Cross-sectional area; DXA = Dual x-ray absorptiometry; IMAT = Intermuscular adipose tissue; pQCT = Peripheral computed tomography.

*Incident mobility limitations: any difficulty walking two to three blocks or climbing up 10 steps due to a health/physical problem.

†Data are expressed as mean (*SD*) or frequency (%).

Table 2. Change in Body Composition among African Ancestry Men Who Did and Did Not Develop a Mobility Limitation Over 6 y

	Mobility Intact, n = 430 (85.1%)		Incident Mobility Limitations,* n = 75 (14.9%)		
pQCT	Absolute Δ	Percent Δ	Absolute Δ	Percent Δ	p Value
Total fat, cm²	1.4 (4.5)†	9.4 (29.5)	3.8 (7.7)	21.8 (42.9)	.02
subQ fat, cm²	0.9 (3.8)	13.2 (54.8)	2.6 (8.8)	40.9 (163.1)	.12
IMAT, cm²	0.5 (2.7)	62.4 (161.9)	1.6 (4.3)	101.9 (250.5)	.04
Muscle CSA, cm²	−1.5 (7.1)	−2.1 (10.0)	−5.9 (7.9)	−8.4 (11.4)	<.01
Muscle density, HU	−2.6 (3.3)	−3.5 (4.6)	−4.3 (4.6)	−6.3 (6.9)	.01
Weight, kg	−0.9 (5.9)	−0.8 (7.3)	−1.6 (7.3)	−2.4 (10.5)	.21
DXA					
Total fat, kg	2.4 (3.8)	16.5 (26.3)	3.7 (4.8)	20.3 (30.2)	.03
Trunk fat, kg	1.4 (2.1)	19.7 (31.1)	1.9 (2.6)	21.2 (33.7)	.09
Total lean, kg	−3.7 (2.8)	−6.3 (4.6)	−5.1 (3.4)	−8.4 (5.6)	<.01
Appendicular lean, kg	−1.8 (1.5)	−6.5 (5.3)	−2.5 (1.9)	−8.9 (6.8)	.01

Note: CSA = Cross-sectional area; DXA = Dual x-ray absorptiometry; IMAT = Intermuscular adipose tissue; pQCT = Peripheral computed tomography.
*Incident mobility limitations: any difficulty walking two to three blocks or climbing up 10 steps due to a health/physical problem.
†Data are expressed as mean (*SD*).

Table 3. Association Between Baseline and Change in Body Composition with Incident Mobility Limitations in African Ancestry Men

	Model 1*		Adjusted for Total Weight Change
Parameter	Odds Ratio (95% CI) Associated w/baseline	Odds Ratio (95% CI) Associated w/change	Odds Ratio (95% CI) Associated w/change
pQCT total fat	1.04 (0.73–1.48)†	1.42 (1.10–1.81)	1.48 (1.10–1.98)
pQCT subQ fat	0.95 (0.67–1.34)	1.24 (0.98–1.58)	1.22 (0.94–1.58)
pQCT IMAT	1.09 (0.84–1.42)	1.51 (1.18–1.94)‡	1.50 (1.16–1.94)‡
pQCT total muscle	0.79 (0.56–1.12)	0.65 (0.48–0.87)‡	0.61 (0.46–0.83)‡
pQCT muscle density	0.82 (0.58–1.14)	0.69 (0.51–0.92)‡	0.70 (0.52–0.94)‡
Total weight	0.80 (0.43–1.50)	1.19 (0.90–1.57)	—
DXA total fat	0.88 (0.52–1.49)†	1.60 (1.21–2.13)‡	2.02 (1.29–3.15)‡
DXA trunk fat	0.94 (0.59–1.50)	1.47 (1.11–1.94)‡	1.70 (1.10–2.65)‡
DXA total lean	0.97 (0.65–1.44)	0.85 (0.64–1.13)	0.63 (0.43–0.91)‡
DXA appendicular lean	0.85 (0.5–1.24)	0.81 (0.61–1.07)	0.56 (0.39–0.81)‡

Note: CI = Confidence interval; DXA = Dual x-ray absorptiometry; IMAT = Intermuscular adipose tissue; pQCT = Peripheral computed tomography.
*Models adjusted for age, BMI, height, cardiovascular disease, diabetes, arthritis/gout, hypertension, and walking. Change models are adjusted for baseline body composition.
†OR are per *SD* with and decrease as the referent.
‡Denotes significant associations at the $p < .05$ level.

to increased risk of developing mobility limitations; however, this association was not as strong as total fat mass change. No baseline measures of body fat, from either DXA or pQCT, were related to developing incident mobility limitations, suggesting that serial measures of body composition are necessary to assess risk of mobility limitations associated with adiposity. These findings are similar to those observed in other studies where only men in the highest quintile of body fat had higher odds of functional and mobility limitations (8,33,34). In Health ABC, fat mass change explained a large proportion of the risk of mobility limitations associated with weight loss (35), which corroborates our observations that greater increases in fat mass are associated with increased risk of incident mobility limitations. However, also in Health ABC, fat mass change from DXA was not related to gait-speed decline (24). These differences could be due to the different outcomes (gait speed vs self-reported mobility limitations) and the gait-speed analyses pooled men and women. To our knowledge, these are the longitudinal studies that have examined the association between body composition changes and incidence of mobility limitation.

Total and appendicular lean mass change were not related to incident mobility limitations; however, decreasing calf muscle area measured with pQCT was associated with mobility limitations. This is consistent with findings from Health ABC where thigh muscle area loss measured using CT but not lean mass loss from DXA was associated with gait-speed decline (24) and mortality risk (36). This suggests that more direct measures of skeletal muscle, such as CT or MRI, may be needed to assess the health risks associated with muscle loss. Baseline measures of lean mass and skeletal muscle density were not related to mobility limitations. Cross-sectional studies of body composition have not consistently predicted mobility and functional limitations (18). For example, lean mass measured using bioelectrical impedance was not related to mobility limitations in NHANES (8), The Cardiovascular Health Study (34), and The British Regional Heart Study (33). In contrast, Visser et al. showed that thigh muscle area measured using CT was related to mobility disability in the Health Aging and Body Composition Study (9). Furthermore, when indexed to height or body size, measures of lean mass using bioelectrical impedance were not associated with mobility limitations

in NHANES after adjustment for key covariates (37). Differences between our findings and those of Visser et al. may be due to Health ABC participants being more than 10 years older on average than our cohort, and CT scans of the thigh, as opposed to the calf, were obtained. However, both the calf and thigh muscles are important for ambulation, with the thigh being the primary knee extensor and calf providing "push-off" power for each step. Our findings paired with the inconsistencies in the present literature suggest that in order to identify those at risk of mobility limitations attributable to body composition alterations, serial measures over time rather than at one point in time may be required.

Importantly, associations between changes in both DXA and pQCT measures with mobility limitations were stronger when adjusting for overall weight change. Thus, men who gained more fat or lost more lean mass than expected for a given body weight change had a higher likelihood of developing mobility limitations. Another key finding of the current analysis was that IMAT area was much more strongly related to developing mobility limitations than subcutaneous fat area. Likewise, decreasing skeletal muscle density was strongly associated with developing mobility limitations. Muscle density is a surrogate for intramyocellular fat (38) or fat deposits within muscle cells or fibers; thus, increasing intramyocellular lipids may impair skeletal muscle metabolism and/or contractile function and ultimately lead to the development of mobility limitations. Our findings add to the growing body of literature linking intermuscular and intramyocellular adipose tissue to adverse health outcomes in older adults such as declining gait speed, mobility limitations, and poor physical performance (24,25).

Fifteen percent of the African ancestry men aged 60 years and older in our cohort developed incident mobility limitations after an average of 6 years. These rates are lower than those observed in previous studies such as Health ABC where 40% of men developed mobility disability over 8 years (35) and in the Minority Aging Research Study, where 48.5% of blacks developed IADL limitations over an average of 4.9 years (39). In the Ibadan Study of Aging, of the 1,887 Nigerian men and women aged 65 years and older that were disability free, 24.2% developed ADL disability after 5 years (40). Differences in mobility incidence rates between these studies may be due to the younger age of our participants. Alternatively, men in the current study may be less susceptible to mobility disability due lifestyle, environment (eg, high sunshine exposure) socioeconomic status, cultural differences, access to medical care (eg, universal health system in the Caribbean region), genetic admixture, and/or dietary factors (in particular, higher fish intake among the African Caribbeans) that warrant further investigation in a cross-cultural study.

As expected, body composition changes over 6 years were quite variable in the current cohort. Men lost weight on average and had a tendency to gain body fat and lose lean mass. Total lean mass decreased by 1.1% per year, which is very similar to the 1.2% decrease in leg lean mass observed in black men in the Health Aging and Body Composition Study (13). Calf IMAT increased by 10% per year in all men, which is similar to the 9.7% per year increase in thigh IMAT seen in Health ABC (26). Men in the current study lost about half as much (0.5%/y) muscle area compared with men in Health ABC study (1.0%/y); however, Health ABC measured muscle area of the thigh (as opposed to the calf), and there may be regional differences in rates of skeletal muscle loss with aging. To our knowledge, no studies have examined differences in thigh compared with calf muscle loss with age; however, both have been shown to decrease with age and are important for ambulation.

The present study has several potential limitations. First, body composition was only measured at two time points; thus, we may have missed possible body composition changes over the short term. Second, only men were included; thus, results may not be generalizable to women. Third, the primary outcome was self-reported mobility limitations as opposed to an objective performance measure; however, self-reported functional capacity is highly correlated with performance tests, and our mobility questions are widely used in the field. The current study also has several notable strengths. First, our study adds important information about the incidence and risk factors for mobility limitation in a rapidly growing but under-studied segment of the population. Second, we measured body composition with DXA and CT, which are valid and widely used measures of body composition. Third, there was a relatively long period of follow-up, which allowed us to examine the concurrent association between body composition remodeling and incident mobility limitations.

In conclusion, greater increases in overall body fat, and particularly intermuscular fat, were associated with incident mobility limitations among older African ancestry men. The maintenance of calf skeletal muscle area with aging was associated with a lower risk of developing mobility limitations. Furthermore, no baseline measures of body fat or lean mass were associated with mobility limitations, emphasizing the importance of capturing body composition remodeling. Finally, all associations were stronger in the context of overall weight change. Thus, our findings suggest that identifying older African ancestry men who are gaining or losing a disproportionate amount of fat and/or lean mass for a given change in body weight may be particularly useful for identifying those at high risk of developing mobility limitations.

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Conflict of Interest

None reported.

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