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# Trunk Muscle Composition as a Predictor of Reduced Functional Capacity in the Health, Aging and Body Composition Study: The Moderating Role of Back Pain

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**Background.** Cross-sectionally, lower trunk muscle attenuation (higher fat infiltration) has been associated with poorer physical function in older adults. We hypothesize that lower trunk muscle attenuation will be associated with lower functional capacity 3 years later and that back pain status will moderate this relationship.

**Methods.** The study sample consisted of a biracial cohort of well functioning men (739) and women (788) aged 70–79 years from the Pittsburgh site of the Health, Aging and Body Composition (Health ABC) study. Computed tomography was used to measure trunk muscle area and attenuation of the lumbar paraspinal, lateral abdominal, and rectus abdominus muscles at baseline. The Health ABC Physical Performance Battery (usual and narrow walk, chair stands, and standing balance) was used to measure functional capacity at the first and fourth annual clinic visits.

**Results.** Regardless of back pain status, average trunk muscle attenuation (but not muscle area) was positively associated with overall physical performance, particularly balance ( $p < .01$ ), in a fully adjusted model. The association between trunk attenuation and functional capacity was significantly stronger in participants with at least moderate back pain in the year prior to baseline ( $p < .05$  for interaction; attenuation  $\times$  back pain). Participants with moderate to extreme back pain had a greater decline in function over time ( $p < .05$ ).

**Conclusions.** Older adults with poorer trunk muscle composition (higher fat infiltration) exhibit reduced functional capacity, especially balance, 3 years later. Improving trunk muscle composition may be an important yet overlooked approach to maintain function and potentially reduce balance impairments, particularly in persons with a history of back pain.

THE abdominal and lumbar paraspinal muscles provide necessary levels of trunk stability for optimal performance of typical activities of daily living (1,2). Cross-sectionally, lower levels of trunk muscle attenuation (higher fat infiltration), not trunk muscle mass, have been associated with diminished functional capacity in healthy older adults (3). The majority of evidence for the association of muscle composition with physical function has focused on thigh muscle area and/or attenuation and function both cross-sectionally and longitudinally (4–8), but recent cross-sectional work has demonstrated that trunk muscle attenuation explains a greater proportion of variance in lower extremity physical function than does thigh attenuation, highlighting the importance of trunk muscles (3). The role of trunk muscle composition in the decline of functional capacity over time has yet to be addressed.

In the back pain literature, poor trunk muscle function has been implicated as both a cause and consequence of pain (9). Back pain is the most frequently reported musculoskeletal problem in people older than 75 years (10,11). In fact, 17.3% of all physician visits for back pain involve individuals older than 65 years (10,12,13). Evidence regarding the detrimental impact of back pain on perceived and observed physical function has only recently begun to emerge

(3,14–16). Even less is known about the interaction between trunk muscle composition and back pain severity in relation to functional capacity. To maintain functional capacity, it is important to investigate the role that trunk muscle composition may play in functional changes over time and how back pain may affect this relationship.

This study examines longitudinal associations between trunk muscle composition, back pain, and physical function in a biracial cohort of men and women aged 70–79 years participating in the Health, Aging and Body Composition (Health ABC) study. We hypothesize that lower trunk muscle attenuation will be associated with reduced functional capacity 3 years later and that this relationship will be stronger in persons with a history of back pain. Given the activity limitations associated with back pain, we postulate that the presence of moderate to extreme back pain at baseline, independent of muscle composition, will be associated with greater functional decline over 3 years.

## METHODS

### Participants

The Health ABC study population consists of 3075 well functioning black (42%) and white, men (48%) and women.

Potential participants were identified from a random sample of white Medicare beneficiaries and all age-eligible community-dwelling black residents in designated ZIP code areas surrounding Pittsburgh, Pennsylvania, and Memphis, Tennessee. For the present study, only participants from the Pittsburgh site were included because computed tomography (CT) scans of the paraspinal muscles were done only at this site. The sample for the present analysis consists of 1527 black (44%) and white, men (48%) and women. Eligibility criteria included: age of 70–79 years during the recruitment period of March 1997 through July 1998; no self-reported difficulty in walking one quarter mile, walking up 10 steps, or performing basic activities of daily living; no known life-threatening cancers; and no plans to move out of the area in the next 3 years.

Of the 1527 participants, 86 died during the 3-year follow-up period and 218 did not attend the year 4 clinic visit. An additional 29 participants were missing performance test data and were thus excluded, leaving a total of 1194 participants (78% of the original Pittsburgh cohort) available for longitudinal analysis.

At baseline, the 333 excluded participants were slightly older (74.0 vs 73.6 years,  $p < .05$ ), less physically active (74.57 vs 88.08 kcal/kg/week,  $p < .01$ ), more likely to be black (55.6% vs 40.5%,  $p < .001$ ), and had lower Health ABC performance scores (1.99 vs 2.26,  $p < .001$ ) than the remaining cohort. No differences were found for total body fat, body mass index, trunk muscle area or attenuation, sex, or back pain severity ( $p > .05$  for each).

#### *Muscle Mass and Attenuation*

Axial CT scans at the L4–L5 disk space were acquired at the Pittsburgh site (GE9800 Advantage; General Electric, Milwaukee, WI) based on a lateral abdominal scout. A cross-sectional scan of 10 mm thickness was obtained at the L4–L5 disc space (140 kVp, 300–360 mA). Muscle area and muscle attenuation of the abdominal and paraspinal muscles were calculated from the axial CT images using proprietary developmental software (RSI Systems, Boulder, CO) with automated determination of the image and pixel sizing.

Muscle area was calculated by multiplying the number of pixels of nonbone, nonadipose tissue within the fascial plane by the pixel area. Muscle attenuation was calculated by averaging CT number (pixel intensity) values of the regions outlined on the images. CT numbers were defined on a Hounsfield Unit (HU) scale where 0 equals HU of water and –1000 equals HU of air. Higher levels of HU are associated with lower levels of fat infiltration. This measure of fat infiltration has been previously validated in muscle biopsy studies (17). Reproducibility of muscle area and attenuation values, assessed by reanalysis of a 5% convenience sample, demonstrated a coefficient of variation <5%.

Intermuscular adipose tissue was distinguished from subcutaneous adipose tissue by manually drawing a line along the deep fascial plane surrounding abdominal muscles. Muscle and adipose tissue areas were identified based on a bimodal image histogram resulting from the distribution of CT numbers in muscle and adipose tissue. Peaks are readily separable, and the area of fat in the image was determined by area under the fat peak of the histogram.

After the adipose tissue was separated from the muscle, individual muscle groups were identified. Muscles were well outlined by adipose tissue. In instances where separations were not clear, fat–muscle borders were outlined manually with internal controls in place to assure that no bone density pixels were included with muscle area.

#### *Physical Function*

The Health ABC Physical Performance Battery (PPB), used to assess physical function at year 1 and year 4 visits, consists of four lower extremity performance tests, including time to complete five chair stands, timed standing balance (semi-tandem, full-tandem, and single-leg stands), timed usual pace 6 m walk, and timed narrow 6 m walk. Ratio scores ranging from 0 to 1 were calculated for each battery component, where 1 represents the maximal performance observed for healthy older adults. Participants unable to complete a test were assigned a score of 0 for that test. Ratio scores from the four tests are added together for a continuous scale ranging from 0 to 4. Higher scores represent higher levels of physical function. Specific operational definitions and scoring procedures for the Health ABC PPB have been described in detail previously (18).

#### *Back Pain Status*

Back pain was categorized from responses to the following questions: “In the past 12 months, have you had any pain in your back? If yes, would you rate the pain as mild, moderate, severe, or extreme?” Based on previous work, moderate pain severity was used as the break point (14,15,19). Therefore, back pain status was categorized as presence or absence of moderate to extreme back pain during the 12 months prior to baseline.

#### *Covariates*

Baseline covariates included age, race, sex, height, total body fat, thigh muscle area or attenuation, physical activity, and prevalent disease status. Standing height was measured to the nearest millimeter using a wall-mounted stadiometer. Total body fat was included because high levels are associated with greater muscle mass (20,21), higher fat infiltration in muscles (22), and poorer physical performance (20,21). Total body fat was measured using fan beam DXA (Hologic QDR4500A, software version 8.21; Waltham, MA). Because smaller midthigh muscle area and higher fat infiltration in the thigh are associated with poorer physical performance, thigh muscle area and attenuation were included as covariates; measurement of thigh composition has been previously described (4). Physical activity over the past 7 days was ascertained using an interviewer-administered questionnaire. A metabolic equivalent was assigned to each activity/intensity combination and used to calculate kilocalories per week per kilogram of body weight spent on that activity (23). Disease status was based on physician-diagnosed diseases, clinic data, and medication use. The following diseases were included: heart disease, lung disease, stroke, arthritis, hip fracture, osteoporosis, and diabetes mellitus.

Table 1. Baseline Characteristics According to Back Pain Severity Level at Year 1

Characteristics	No/Mild LBP (N = 1105)	Moderate/Extreme LBP (N = 410)
Age, y, mean (SD)	73.72 (2.88)	73.60 (2.82)
Race, % black	43.80	43.90
Sex, % female	47.60	62.20*
Body mass index, kg/m <sup>2</sup> , mean (SD)	27.32 (4.58)	28.86 (5.36)*
Total body fat, kg, mean (SD)	25.40 (8.59)	28.24 (9.71)*
Average trunk muscle area, cm <sup>2</sup> (SD)	12.05 (3.05)	11.82 (3.12)
Average trunk muscle attenuation, HU (SD)	20.80 (10.41)	17.43 (10.59)*
Health ABC score, mean (SD)	2.25 (.54)	2.06 (.57)*

Notes: \**p* < .0001. Missing data on back pain status for 12 participants. LBP = low back pain; SD = standard deviation; HU = Hounsfield Units; Health ABC = Health, Aging and Body Composition Study.

Data Analysis

All analyses were performed using SAS software, version 8.2 (SAS Institute, Inc., Cary, NC). Muscle area and attenuation values for paraspinal muscles, rectus abdominus, and lateral abdominals were averaged to create composite trunk area and attenuation values. Separate multiple linear regression analyses were used to examine associations of trunk muscle area and attenuation with performance-based physical function. To examine associations, independent of other factors, both analyses were adjusted for all covariates as well as for back pain and baseline Health ABC PPB score. In a separate step, the appropriate interaction term (trunk muscle attenuation × back pain or trunk muscle area × back pain) was entered into the model to test for a significant moderator effect (24). Because this term was significant (*p* < .05), adjusted multiple linear regression analyses stratified by back pain status were conducted to examine how the association of trunk muscle attenuation and physical function varied by back pain. Independent *t* tests were used to compare physical function at year 4 and change in function over 3 years according to back pain status at year 1. All means were adjusted for age, race, sex, height, total body fat, physical activity, prevalent disease status, and trunk muscle composition.

RESULTS

Baseline characteristics for the sample are displayed in Table 1. Participants with higher back pain severity were more likely to be women, have higher body mass index, higher total body fat, and lower trunk muscle attenuation levels as well as poorer physical performance.

Table 2 demonstrates the absence of a longitudinal association between trunk muscle area and lower extremity function, although greater thigh muscle area was associated with better physical function. There was not a significant interaction effect between trunk area and back pain status (*p* > .05).

In contrast, Table 3 shows a significant positive association between trunk muscle attenuation and function

Table 2. Longitudinal Association Between Baseline Trunk Muscle Area and Physical Function at the Year 4 Annual Clinic Visit

Variable	Parameter Estimate	Standard Error	Partial <i>R</i> <sup>2</sup>
Intercept	2.505	.573	
Trunk muscle area	-.014	.006	.001
Thigh muscle area	.004 <sup>†</sup>	.001	.045
Back pain severity	-.090*	.029	.003
Year 1 Health ABC score	.678 <sup>†</sup>	.028	.441
Covariates			.033
Model <i>R</i> <sup>2</sup> = .523 <sup>†</sup>			

Notes: Dependent variable = Year 4 Health, Aging and Body Composition Study (Health ABC) Physical Performance Battery score (0–4).

\**p* < .001.

<sup>†</sup>*p* < .0001.

3 years later. The model explains nearly 52% of variance in physical function score with trunk muscle attenuation contributing approximately 12% to the explained variance. Trunk muscle attenuation was not only a significant predictor of composite function score, but also individual standing balance (*p* < .01) and narrow walk (test of dynamic balance) (*p* < .01) components.

There was a significant interaction between trunk muscle attenuation and back pain status in predicting physical function 3 years later (*p* < .05). As seen in Figure 1 and Table 4, the positive association between trunk attenuation and function is stronger in the group with higher back pain severity. Trunk muscle attenuation explains nearly twice the amount of variance in function in the high back pain severity group (17.8% vs 8.7%).

Figure 2 shows that the group reporting moderate to extreme pain at baseline had significantly poorer function at baseline and 3 years later. This group also experienced a significantly greater decline in performance scores over time (*p* < .05). The mean change in Health ABC PPB score for those with no to mild back pain was .18 (95% confidence interval [CI], .15–.21) compared to .26 (95% CI, .22–.31) for those with moderate to extreme back pain. Change in Health ABC PPB score among those persons with moderate to extreme back pain appears to be largely driven by decline in standing balance score. There was a significantly larger reduction in balance score among the high severity group (.11 [95% CI, .08–.13]) as compared with the low severity group (.05 [95% CI, .03–.07]) (*p* < .001).

Table 3. Longitudinal Association Between Baseline Trunk Muscle Attenuation and Physical Function at the Year 4 Annual Clinic Visit

Variable	Parameter Estimate	Standard Error	Partial <i>R</i> <sup>2</sup>
Intercept	2.585	.590	
Trunk muscle attenuation	.006*	.002	.123
Thigh muscle attenuation	-.002	.003	.024
Back pain severity	-.088*	.029	.003
Year 1 Health ABC score	.694 <sup>†</sup>	.029	.346
Covariates			.026
Model <i>R</i> <sup>2</sup> = .519 <sup>†</sup>			

Notes: Dependent variable = Year 4 Health, Aging and Body Composition Study (Health ABC) Physical Performance Battery score (0–4).

\**p* < .01.

<sup>†</sup>*p* < .0001.

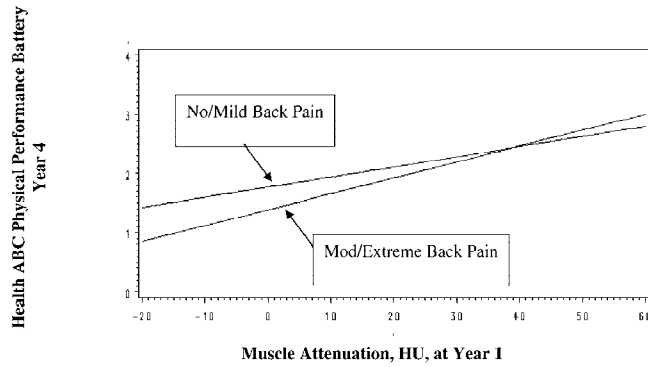


Figure 1. Interaction between trunk muscle attenuation and back pain status in prediction of physical function 3 years later,  $p < .05$ .

DISCUSSION

As hypothesized from our cross-sectional work, older adults who exhibit evidence of poor trunk muscle composition (higher levels of fat infiltration) appear to have a greater risk of reduced mobility-related function over time, which is more pronounced in those persons with a history of at least moderate back pain severity. Importantly, the association between lower levels of trunk muscle attenuation and lower functional capacity is completely independent of thigh muscle composition. This finding has important implications for rehabilitation efforts to improve mobility-related function in older adults because current efforts have largely focused on lower extremity muscles. It is noteworthy that the most substantial associations between muscle composition and function concerned tests that tap both static and dynamic balance (Table 4). Because poor balance has been consistently linked with mobility deficits and falls among

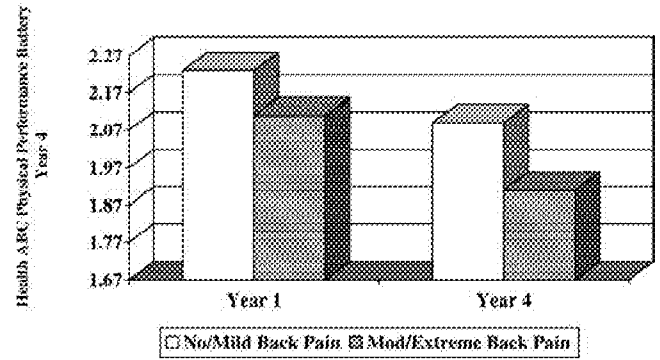


Figure 2. Change in functional capacity over 3 years according to back pain status. Significant between-group (back pain status) differences in Health, Aging and Body Composition (ABC) Physical Performance Battery score ( $p < .0001$ ) at baseline and year 4. Significant within-group differences from baseline to year 4 for both back pain groups ( $p < .0001$ ).

older adults (25,26), efforts to improve and maintain mobility status should include attention to trunk muscle integrity.

The relationship between trunk attenuation and function exists whether or not a recent history of back pain is reported, but low attenuation values predict greater functional deficits for participants with reports of at least moderate back pain. We suspect that decreased physical activity following an episode of back pain may explain the accelerated decline in function. In testing this possibility, we found that although persons with moderate to extreme back pain reported similar engagement in brisk walking (the most common form of exercise in this cohort) as persons with no to mild back pain at baseline (45.2 min/wk vs 42 min/wk,  $p = .81$ ), this group reported much lower levels of participation by the year 2 visit (15.4 min/wk vs 29.6 min/wk,  $p = .02$ ).

Based on the current rehabilitation literature related to back pain, which stresses strengthening of paraspinal and lateral abdominal muscles while limiting rectus abdominus activity in the treatment of back pain (27–30), we examined associations between individual trunk muscle groups and function. Back pain had a moderating effect in the case of the paraspinal and lateral abdominal muscles ( $p < .05$  and  $p < .01$ , respectively, for interaction terms), but not with rectus abdominus ( $p > .05$ ). Paraspinal muscle attenuation explained more variance in function among those persons with moderate to extreme back pain as compared to those with no to mild pain (13%,  $p < .05$  vs 6%,  $p < .05$ ); the same was true of lateral abdominal muscle attenuation (16%,  $p < .05$  vs nonsignificant  $R^2$ ). In the presence of greater back pain severity, addressing trunk muscle composition, particularly the paraspinals and lateral abdominals, may be an important way to improve functional status and delay functional decline.

Although we were unable to determine chronicity of back pain prior to study entry or over the 3-year follow-up, it is noteworthy that a single report of moderate to extreme back pain in the year prior to baseline is clearly associated with greater decline in function over 3 years. This finding argues strongly for both identifying cases of back pain and pursuing effective, active treatments for back pain, such as trunk-strengthening exercises, because the typical response

Table 4. Longitudinal Association Between Baseline Trunk Muscle Attenuation and Physical Function at the Year 4 Annual Clinic Visit Stratified by Back Pain Status

Variable	Parameter Estimate	Standard Error	Partial $R^2$
No pain to mild back pain			
Intercept	2.500	.667	
Trunk muscle attenuation	.005*	.002	.087
Thigh muscle attenuation	-.001	.004	.025
Year 1 Health ABC score	.668 <sup>‡</sup>	.033	.343
Covariates			.029
Model $R^2 = .484^{\ddagger}$			
Moderate to extreme back pain			
Intercept	2.312	1.040	
Trunk muscle attenuation	.011 <sup>†</sup>	.004	.178
Thigh muscle attenuation	-.006	.006	.023
Year 1 Health ABC score	.748 <sup>‡</sup>	.058	.334
Covariates			.002
Model $R^2 = .537^{\ddagger}$			

Notes: For no pain to mild back pain, dependent variable = Year 4 Health, Aging and Body Composition (Health ABC) Physical Performance Battery score (0–4); for moderate to extreme back pain, dependent variable = Year 4 Health ABC physical performance score (0–4).

\* $p = .043$ .

<sup>†</sup> $p = .011$ .

<sup>‡</sup> $p < .0001$ .

to an episode of back pain is likely to be activity reduction, which has potentially serious consequences for overall functional capacity.

A primary advantage of this longitudinal study is the use of a large population-based sample with rarely available in vivo CT measurements of muscle area and attenuation as well as validated and reliable measures of physical function. The prospective nature of this study allows us to highlight possible intervention points on the pathway to disability by identifying factors such as muscle attenuation and back pain that predict functional decline. A major study limitation is the lack of major disability in the cohort, which restricts the generalizability of findings to healthy persons between the ages of 70–79 years.

### Conclusion

The association between lower trunk muscle attenuation (higher fat infiltration) and reduced functional capacity 3 years later in older adults, particularly those with more severe back pain, highlights the need to consider the trunk muscles in assessing and treating mobility difficulties. The strong association with balance indicators suggests that poor trunk muscle integrity may contribute to other common functional problems in elderly persons, including fall risk. Future analyses should focus on the role of trunk muscle composition in falls among healthy older persons.

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