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Original Article

Physical performance of elderly adults in association with thigh tissue composition: a cross-sectional study

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Abstract. [Purpose] Literature has revealed age-related changes in body regional tissues in the form of reduced muscle size and increased adipose tissue. There is also a decline in the performance of physical function with aging. The aim of this study is to examine the partial and part correlations between physical performance and thigh tissue composition among elderly adults. [Subjects and Methods] Twenty-two elderly participants enrolled in this cross-sectional study. Mid-thigh CT images were used to determine the cross-sectional area of the muscular and adipose tissues. Principal component score of physical function was calculated from 5 performance based physical function tests using principal component analysis. Partial and part correlation statistics were used to explore the association between physical performance and tissue composition. [Results] There were significant, moderate negative partial and part associations between the principal component score and cross-sectional area of thigh muscles, quadriceps muscle and quadriceps normal density muscle. Significant, moderate positive partial and part correlations were found between intramuscular adipose tissue and the principal component score. [Conclusion] Elderly adults' performance of physical function is associated with regional tissue composition.

Key words: Adipose tissue, Muscles, Principal component analysis

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INTRODUCTION

Our bodies are composed of different kinds of tissues. The largest tissue in the body is the muscular tissue which can be divided, according to fat content in the muscle, into normal- and low-density muscle tissues. The normal density muscle tissue is the fat-free or lean muscle tissue. Furthermore, there is an adipose tissue which is classified into subcutaneous and intramuscular adipose tissues.

Primary sarcopenia is an age-related process[1)]. It is associated with loss of muscle size and strength[2)]. The decline in the number of muscle fibers[3)] along with atrophy[4)] of remaining muscle fibers could explain the reduced size of the muscles with aging. Furthermore, aging is associated with increased fat content in the muscles[5)]. Consequently, tissue composition changes with advancing age[6)].

Performance of physical function also declines with aging[7)], and even reporting physical disabilities increases with advancing age[8)]. The relationship between tissue composition and physical performance has been investigated previously in several reports. However, there are inconsistent results regarding the association of different tissue composition and physical performance. Visser et al.[6)] found that smaller mid-thigh muscle area and reduced muscle attenuation are associated with poor physical function. Marcus et al.[9)] examined the contribution of mid-thigh tissue composition in the mobility function in the elderly. The authors reported that intramuscular adipose tissue (IMAT) was the only thigh tissue contributing significantly in all functional mobility regression models.

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The aim of this study is to explore the association of the thigh tissue composition and physical performance in the elderly population. We hypothesized that greater thigh muscle cross-sectional area (CSA) and smaller thigh IMAT CSA will be associated with better scores on physical performance after controlling for body height and weight.

SUBJECTS AND METHODS

Participants in this study were healthy, between 65–80 years old and could walk independently without the use of assistive devices. The exclusion criteria included uncontrolled hypertension, a history of cardiovascular disease, a history of neurological disease, a history of chronic or significant respiratory disease, inflammatory arthritis, muscle disease, or current participation in a regular strengthening exercise program.

Participants were recruited between 2008 and 2011 through different methods including television advertisement, newspaper announcement and research centers registry lists.

The Institutional Review Board (IRB) of the University of Pittsburgh approved all study procedures (approval No. PRO07110007-10) and all subjects signed an informed consent form before participating in the study.

This study had a cross-sectional design and aimed to explore partial and part correlations between physical performance and the composition of the thigh region among healthy elderly population after controlling for body weight and height.

Axial CT images were obtained to quantify the CSA of the tissues composing the mid-thigh region. The femoral midpoint is the most selected location for CT images of the thigh region in the literature. Subjects were imaged in the supine position with the legs extended flat on the table. An anterior posterior scout image of the entire femur was used to determine the femoral midpoint. The femoral length was measured from the most lateral part of the greater trochanter to the most lateral part of the lateral femoral condyle. A single, 10 mm thick axial image slice was obtained at the femoral midpoint. Scanning parameters of the image are 120 kVp and 200–250 mA. Adipose and muscular tissues' CSA were calculated from the CT images using commercially available software (Slice-O-Matic, Tomovision, Montreal, Canada). Areas of the tissues were measured electronically by selecting regions of interest defined by attenuation values: −190 to −30 Hounsfield Units (HU) for adipose tissue, 0 to 100 HU for the total muscle, and 35 to 100 HU for normal density muscle (NDM)[10, 11]. Subcutaneous adipose tissue (SAT) was distinguished from IMAT by manually tracing fascia covering the thigh muscles. Quadriceps muscles were distinguished from the Hamstrings by manual tracing. The coefficient of variation for test retest reliability of the mid-thigh attenuation was 0.51%[12].

Physical performance was assessed using 5 tests: the timed stair climb test, the timed ramp up test, the timed up and go test, the 4-meter walking time test and 5 times chair rise test. For all those tests, participants were given 1 practice trial, followed by 2 test trials. One-minute rest was given between trials. The trial with the shorter time was used in the analysis. Tests were administered without specific order.

For the timed stair climb test, the participants were instructed to climb a flight of stairs consisting of 11 steps with a step height of 17 cm, as fast as possible. The time to climb the flight of stairs was recorded by using automated digital timing system (SPARQ). One cone of the system was placed at the bottom and the other one was place at the top of the stairs.

For the timed ramp up test, the participants were instructed to walk up as fast as possible a ramp with a 3.66 m length and a 0.32 m rise. The automated digital timing system (SPARQ) was used to record the time to walk up the length of the ramp. One cone was placed at the beginning and other one at top of the ramp.

For the timed up and go test, the participants sat on a standard height chair with armrests. On the command "go" they stood up and walked 3 meters (to a mark on the floor), turned around, walked back to the chair and sat down. A stopwatch was used to measure the time from the command "go" to the time when the subject sat down[13].

For the 4-meter walking time test, the participants were asked to walk 4 meters at their regular speed. The automated digital timing system (SPARQ) was used to record the time to complete the 4 meters. The cones of the system were placed 4 meters apart. Participants were instructed to stand 1.5 meters before the first cone to avoid the acceleration phase of walking. Additionally, participants were instructed to continue walking after crossing the second cone to avoid deceleration of walking.

For the 5 times chair rise test, the participants were asked to stand up straight and sit down as fast as possible 5 times without pausing in between. Subjects kept their arms crossed on their chests while performing the test. Stopwatch was used to record the time from the command "go" while participants were seated till they came back to sitting position after completing 5 stand ups.

Statistical analysis: Prior to examining the partial and part correlations between physical performance and CSA of the thigh tissue composition, principal component analysis was used to combine scores of the physical performance tests into a single principal component score for physical function.

The principal component analysis was utilized for data reduction. Since all tests used in this study are performance-based tests, and their units of measurement are in seconds, it was believed that using a principal component analysis would provide one measure that represents physical function. The components whose eigenvalues are greater than 1 was used as a rule to determine the number of principal components to be retained from the analysis.

All subjects were able to complete all physical performance tests with the exception of one who was unable to complete only the 5 times chair rise test. Therefore, the principal component score of physical function for that subject was not computed.

As expected, the results of the principal component analysis in this study revealed 1 component whose eigenvalue greater than 1. Because all tests used in this study are performance-based tests, they should load on a single dimension representing physical function. Consequently, the decision was appropriate to combine the 5 performance tests into 1 principal component score. This score was computed as described by Fitzgerald et al.[14)] by transforming each subject's time on each of the 5 performance tests to Z score. Then, Z score for each variable was multiplied by the principal component coefficient for the corresponding variable, afterward the transformed variables were summed across subjects to calculate a principal component score for each subject. Since the principal component score is composed of timed variables, a smaller score illustrates faster performance; accordingly, better physical functional status.

Partial and part correlation coefficients were calculated to determine the relationship between the principal component score and the whole thigh muscles, quadriceps muscle, quadriceps NDM, thigh IMAT and SAT cross-sectional areas after controlling for subjects' weight and height.

RESULTS

Twenty-two subjects participated in this study (59.1% females). The mean age of this sample was 71.6 years. The mean weight and height of the participants were 78.6 kg and 1.7 m respectively. Subjects' demographic information and baseline measurements of the examination variables are presented in Table 1.

Partial, part and zero-order correlations were run to determine the relationship between thigh region tissue composition and the principal component score of physical function. The results of the correlation coefficients are presented in Table 2. There were significant, moderate negative partial and part associations between the principal component score and CSA of thigh muscles, quadriceps muscle and quadriceps NDM after controlling for weight and height. Significant, moderate positive partial and part correlations were found between IMAT and the principal component score. However, there were non-significant, moderate positive partial and part correlation between SAT and the principal component score. Furthermore, there were non-significant, weak zero-order correlations between principal component score and CSA of all tissues composing the thigh region.

Table 1. Demographic variables and the outcome variables examined

	Mean (n)	Standard Deviation
Age (years)	71.6 (22)	4.6
Weight (kg)	78.6 (22)	15.2
Height (m)	1.7 (22)	0.1
Thigh muscle CSA† (cm^2)	105.5 (22)	27.3
Quadriceps muscle CSA† (cm^2)	49.0 (22)	12.3
Quadriceps NDM‡ CSA† (cm^2)	41.9 (22)	13.2
IMAD§ CSA† (cm^2)	8.5 (22)	5.1
SAT¶ CSA† (cm^2)	92.0 (22)	57.4
Chair raise (s)	13.3 (21)	5.1
Timed stair climb test (s)	5.4 (22)	2.7
Timed ramp up test (s)	2.3 (22)	0.4
Timed up and go test (s)	7.5 (22)	1.8
4-meter walking time (s)	3.2 (22)	0.7

†: CSA: Cross Sectional Area, ‡: NDM: Normal Density Muscle, §: IMAD: Intra-Muscular Adipose Tissue, ¶: SAT: Subcutaneous Adipose Tissue.

Table 2. Partial, part and zero-order correlation coefficients between principle component score of physical function and thigh tissue composition

Thigh tissue composition CSA†	Partial r	Part r	p value*	Zero-order r	p value**
Thigh muscle	−0.51	−0.50	0.027	−0.21	0.36
Quadriceps muscle	−0.47	−0.47	0.041	−0.21	0.37
Quadriceps NDM‡	−0.50	−0.49	0.030	−0.28	0.23
IMAD§	0.49	0.48	0.034	0.28	0.22
SAT¶	0.37	0.37	0.114	0.15	0.51

†: CSA: Cross Sectional Area, ‡: NDM: Normal Density Muscle, §: IMAD: Intra-Muscular Adipose Tissue, ¶: SAT: Subcutaneous Adipose Tissue, *p value for partial and part correlations, **p value for zero-order correlations.

DISCUSSION

This cross-sectional study of the thigh region tissue composition and physical performance among elderly adults indicates that, after controlling for subjects' height and weight, larger CSA of the thigh muscles, quadriceps muscle and quadriceps NDM were significantly associated with a smaller principal component score of physical function. Also, increase in the CSA of the IMAT was significantly associated with increase in the principal component score of physical function.

One of the strengths of this study is the use of the partial and part correlations. They allowed us to explore the relationship between the principal component score of physical function and thigh tissue composition while controlling for subjects' height and weight. The partial correlation examines the relationship between dependent and independent variables while the effects of other co-variables were taken out from both correlating variables. Therefore, the effect of height and weight were taken out from both the physical function score and thigh tissue composition in the partial correlation procedure. Furthermore, in the part correlation, the effects of co-variables were taken out from the independent variable only. Therefore, in the part correlation the effects of height and weight were controlled for from the thigh tissue composition variables.

While examining the zero-order correlations between physical function score and thigh tissue composition that are presented in Table 2, we see that there were weak insignificant associations between dependent and independent variables. However, partial and part correlations showed moderate significant correlations between physical function score and thigh tissue composition while controlling for height and weight. This suggests that height and weight had great influence in controlling for the relationship between physical function score and thigh tissue composition.

In the partial correlation, the variabilities of the muscular tissue variables in the thigh region (comprising of all thigh muscles or quadriceps muscle or more specifically the quadriceps NDM) were able to explain significantly 22–26% of the variability in the principal component score of physical function that is not associated with height and weight. Moreover, the variability of the IMAT explains significantly 24% of the variability of the principal component score of physical function that is not associated with height and weight.

In part correlation, the variabilities of muscular tissues and IMAT explain significantly 22–25% and 23% respectively of the variability in the principal component score of physical function given that the height and weight are included. The similarity of the explained variability in the dependent variable by the independent variables in both the partial and part correlations suggests that the height and weight had greater influence on the independent variables than the dependent variables.

The results of this study suggest that better physical functional status is associated with larger CSA of the muscular compartment and smaller CSA of the IMAT compartment of the thigh region. Our results agree with previous reports. Marcus et al.[9] reported the correlations between thigh muscle and IMAT CSA and 4 performance tests: 6-minute walk, stair ascend, stair descend and timed up and go tests. Zero order correlations revealed moderate significant association between thigh muscle and IMAT CSA and the performance tests. The direction of the correlation suggests that increased thigh muscle CSA and decreased thigh IMAT CSA are associated with good scores on the performance tests. Furthermore, Marcus et al. reported part correlations between performance tests and thigh tissue composition throughout 4 different regression models[9]. Thigh IMAT CSA was contributing significantly in each regression model and its part correlation with each performance test is 0.23, 0.39, 0.37, and 0.28 for 6-minute walk, stair ascend, stair descend and timed up and got tests respectively. However, thigh muscle CSA was contributing significantly in the 6-minute walk test only and its part correlation was −0.3. The part correlations between the principal component score of physical function and thigh tissues' CSA found in our study were stronger than those reported by Marcus et al[9].

Buford et al.[15] also examined the association between femoral tissue composition and physical function in the elderly. Physical function was assessed by the SPPB test and gait speed. Buford et al.[15] found that femoral muscle mass was the only tissue compartment associated significantly and positively with both physical function tests. In contrast to our results and the result by Marcus et al.[9], Buford et al.[15] did not find association between femoral IMAT and physical function.

Another strong element of this study is the use of principal component analysis. It allowed us to reduce the number of variables in the study. The principal component analysis was done on the physical performance variables which are the dependent variables in this study. Therefore, it gave us a statistical advantage of not repeating the analysis for each dependent variable. Accordingly, the probability of inflating type I error was reduced.

Lastly, there are some limitations in this study that need to be addressed. First, the cross-sectional design of the study did not allow us to state causative conclusions. Future studies should focus on the effect of increasing thigh muscular tissue and decreasing thigh IMAT CSA on improving physical performance. Second, sample size was relatively small. Larger sample would allow us to have wide spectrum of scores on all variables. Consequently, a larger sample would help us in exploring the true relationship between variables using more sophisticated statistical analyses.

In conclusion, elderly adults' performance of physical function is moderately associated with regional tissue composition. Larger muscular tissue CSA and smaller intramuscular adipose tissue CSA within the thigh region demonstrate better scores on physical function of the elderly.

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