

Different changes of quantity due to aging in the psoas major and quadriceps femoris muscles in women

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Abstract

Bone fractures cause disabilities that leave the elderly bedridden and strengthening the muscles of the lower limbs, especially the quadriceps femoris, is the main kinematical method of preventing falls. Recently, however, it has become clear that the psoas major is critical for walking ability. We examined changes due to aging in the size of the psoas major compared with changes in the quadriceps femoris. Bone fractures are more frequent in women than in men; our participants (n=210) were therefore exclusively women ranging in age from 20 to 79 and divided into 6 age groups (n=35 each) in 10-year increments. Cross-sectional areas of the two muscles were measured by an MR scanner for a comparative estimation of muscle size. The psoas major showed the greatest quantity in subjects in their 20s, after which it declined steadily until the 60s and dramatically in the 70s, while the area of the quadriceps femoris was preserved until the 40s and showed no dramatic later decline. Exercise beyond regular daily activities is recommended to prevent the psoas major from decreasing in volume. We also recommend the development of a method of maintaining its muscle volume which would target women younger than 40 and older than 60.

Keywords: Psoas Major, Quadriceps Femoris, Muscle Quantity, Cross-section, Aging

Introduction

Disabilities in elderly people caused by falling have recently become a social problem in Japan. According to an investigation conducted by the Japanese Ministry of Labor and Welfare¹, bone fracture accounts for 43% of these disabilities. Falling has been identified as the most frequent cause of disabilities that leave the elderly bedridden, and the number of bone fractures caused by falling is approximately 2.5 times greater in women than in men¹. The prevention of falling is hence an important health subject for the quality of life of older women.

Elderly people fall for a number of reasons, including cerebral apoplexy, Parkinson's disease, rheumatism, and

general movement in daily life, with general movement accounting for the greatest number of falls². Falling occurs during ordinary movement such as walking, transferring from a sitting or lying position to a standing position or vice versa, going up and down the stairs, getting over low steps, bending down to pick up an object from the floor, and stretching out a hand. Since falling is a phenomenon that can happen to any elderly person, a specific plan to prevent falls before they happen has been urgently sought.

Hence, it is necessary to examine factors in addition to aging that contribute to falling in healthy elderly people. There are 8 factors that have been identified in our country as internal factors that are affected by aging: sense, sight, nerves, muscle skeletal system, balance function, the influence of medicines on the nervous system and sleeping patterns³. The muscles in the musculoskeletal system, which change remarkably with aging^{4,5}, were our particular focus in the present research. Anti-gravity muscles, especially the quadriceps femoris among the muscles of the lower limbs, have been identified as muscles related to falling^{6,7}. In recent years, the relationship between falling and the psoas major muscle has attracted attention because it has been reported that this muscle plays an important role in the ability of old-

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Age class	n	Age*	Height** (cm)	Weight** (kg)	Psoas major** (mm ²)	Psoas major** (adjusted)# (mm ²)	Quadriceps femoris** (mm ²)	Quadriceps femoris** (adjusted)# (mm ²)
20-29	35	20.6±1.6 (20-29)	160.7±5.1 ^a (152-172)	56.1±8.4 ^a (42-86)	991.0±158.4 ^a (660.7-1354.5)	914.5±137.6 ^a (520.1-1171.4)	4096.7±663.6 ^a (2983.6-5619.3)	3792.2±604.2 ^{a,b} (2559.4-5019.3)
30-39	35	35.9±2.5 (30-39)	160.7±6.0 ^a (148-172)	54.5±6.6 ^{a,b} (41-75)	931.5±122.8 ^{a,b} (663.4-1303.3)	852.8±145.6 ^{a,b} (418.1-1124.3)	3966.1±680.2 ^a (3054.9-5916.3)	3659.9±573.0 ^{a,b} (2755.6-5118.1)
40-49	35	45.2±3.1 (40-49)	157.8±4.0 ^b (150-164)	55.4±7.5 ^a (43-80)	892.7±173.1 ^{b,c} (496.2-1268.3)	854.9±183.0 ^{a,b} (490.3-1202.6)	4018.6±645.9 ^a (2776.5-5126.4)	3886.1±655.7 ^a (2633.8-5102.8)
50-59	35	54.3±2.5 (50-59)	155.2±4.6 ^c (145-165)	54.1±6.4 ^{a,b} (40-67)	825.2±158.9 ^{c,d} (433.3-1350.9)	831.7±158.2 ^{b,c} (479.0-1285.2)	3608.0±379.9 ^b (2652.9-4369.5)	3633.9±416.2 ^{a,b} (2623.6-4359.5)
60-69	35	65.9±2.9 (60-69)	150.6±5.5 ^d (139-162)	53.8±7.5 ^{a,b} (44-75)	757.1±151.3 ^d (474.0-1140.8)	831.5±172.2 ^{b,c} (487.0-1209.7)	3287.5±567.6 ^c (2058.8-4718.5)	3583.9±565.3 ^b (2322.5-5171.7)
70-79	35	73.5±2.7 (70-79)	148.5±5.0 ^d (135-158)	51.4±8.1 ^b (37-74)	624.5±132.4 ^e (309.8-928.1)	730.1±111.7 ^d (452.0-946.9)	2962.2±464.1 ^d (2346.3-4160.3)	3383.0±522.1 ^c (2595.3-4762.5)

* Upper: mean ± standard deviation; lower: range.

** Values with letter superscripts are significantly different ($p < 0.05$).

Individual CSAs were adjusted as follows. Adjusted individual CSA = individual CSA - b (height - mean height of all individuals), where b is the slope in the regression of CSA on height.

Table 1. Physical characteristics of the subjects* and the average cross-sectional areas*(CSAs) of the psoas major and quadriceps femoris muscles by age class.

erly people to walk⁸. Kuno et al.⁹ reported that the training of the psoas major muscle and its neighbor muscles influenced the walking ability of the elderly. It has been suggested that falls among the elderly may be related to atrophy of this muscle¹⁰, which is the pelvic muscle connecting the lumbar vertebra and the thigh bone. In spite of this recent research concerning the psoas major muscle⁸⁻¹⁰, its fundamental characteristics and the differences in characteristics between this muscle and the quadriceps femoris muscle have not yet been fully described.

The present study focuses on the psoas major as one aspect of the research on the prevention of falls in elderly people. Since women have a greater risk than men of suffering bone fracture due to falling, we aimed our study at comparing changes that occur with aging in the quantity of the quadriceps femoris muscle with that of the psoas major muscle in an entirely female sample.

Subjects and methods

Subjects

The subjects were limited to women for the reasons mentioned above. Women from ages 20 to 79 who lived in two neighboring cities in the same prefecture were invited to participate in this study. The participants in the 20s were university students and half of them did light physical exercises from once to three times per week. Those in the 30s were composed of housewives and workers and half of them played ball games, for instance volleyball, from once to three times per week. Most of the participants in the 60s and 70s

consisted of farmers' wives and they were involved in weeding and other similar farming activities from three to five times a week.

The research project was explained in detail to interested applicants, and informed consent was obtained. Each participant was assigned to the appropriate age group; there were 6 groups organized in 10-year increments. We continued to accept subjects until each age group consisted of 35 subjects, giving a total number of 210 subjects. This study was approved by the Ethical Committee of Niigata University.

Measurement methods

Cross-sectional areas (CSAs) of both the psoas major and quadriceps femoris muscles were measured to estimate muscle size. The psoas major was measured at the top end of the crest of the ilium; the position of the crest of the ilium was confirmed by palpation. The quadriceps femoris was measured at the 30% proximal point between the top of the right greater trochanter and the lateral joint space of the right knee joint between the femur and the tibia. Measurement points were selected after trials to obtain the most precise circumference of the muscles, with reference to the work of Kin et al.⁸ and Kuno et al.¹⁰.

The CSAs of both muscles were measured using magnetic resonance images (MRI; Hitachi Medico, Tokyo, Japan).

The circumferences of the muscles were traced and the CSAs were calculated. The value of each CSA was standardized by the mean-height which was most correlated with the CSAs.

Adjustment of CSAs

Individual CSAs were adjusted using the following equation. Adjusted individual CSA = individual CSA - b (height - mean height of all individuals), where b is the slope in the regression of the CSA on height.

Statistical analyses

Each age group from the 30s to the 70s was compared with the 20s group in order to examine changes due to aging in the average CSAs of the psoas major and the quadriceps femoris. Next, we compared the average ratio of the muscle cross-section of each age group over the age of 30 with that of the 20s group between the psoas major and quadriceps femoris.

The t-test after the F-test for equality of variances was used as a statistical test in both cases. Statistical significance was set at 5%.

Results

Characteristics of the subjects and the CSAs of muscle

The physical characteristics of the subjects are shown in Table 1. A significant difference in mean height was recognized between the 20s group and each age group over the age of 40. Additionally, a significant difference in weight was recognized between the 20s group and the 70s group. The CSAs of the psoas major and quadriceps femoris were found to be correlated with mean-height: ($r=0.538$, $p<0.001$ and $r=0.579$, $p<0.001$, respectively) and weight ($r=0.439$, $p<0.001$ and $r=0.533$, $p<0.001$, respectively). The averages of the CSAs and the standardized cross-sectional areas by the height of both muscles are shown by age group in Table 1.

The CSAs of the psoas major and quadriceps femoris muscles of the leg did not differ between right and left legs in any age group.

Changes in the CSAs of the muscles due to aging

The changes in the CSAs of the psoas major adjusted by mean height for each age group is shown in Table 1; these data were used to estimate changes in muscle volume due to aging. The mean height-adjusted average was highest in the 20s group (914.5 mm^2) and began to decrease in the 50s group (831.7 mm^2 , $p=0.022$). A significant difference was also detected between the 20s and the 50s ($p<0.05$) and between the 20s and the 60s (831.5 mm^2 , $p<0.05$). The minimum value was observed in the 70s (730.1 mm^2 , $p<0.001$). In addition, a significant difference was observed between the 60s and the 70s ($p<0.01$).

The changes in the CSAs of the quadriceps femoris adjusted by mean height for each age group are shown in Table 1. The average was highest in the 20s group (3792.2 mm^2) and remained unchanged until the 60s group (3583.9 mm^2 , $p=0.141$). A significant difference was found for the first

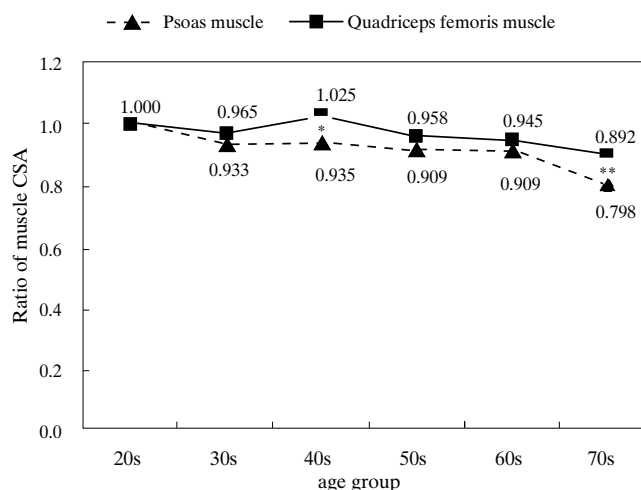


Figure 1. Ratios of mean height-adjusted cross-sectional areas (CSAs) of older groups compared with those of the 20s age group. * $p<0.05$; ** $p<0.01$.

time between the 20s and 70s groups (3383.0 mm^2 , $p=0.0034$); significant differences were also observed between the 20s and 60s groups (3583.9 mm^2) and between the 20s and 70s groups (3383.0 mm^2 , $p<0.01$), and between the 60s and 70s groups ($p<0.05$).

Comparison of the muscle cross-section ratios of each age group with that of the 20's group

The average ratios of the CSAs of both the psoas major and quadriceps femoris muscles for each age group compared with those of the 20's group are shown in Figure 1. A significant difference in the ratios between the psoas major and quadriceps femoris was detected with the 40s group (0.935 vs. 1.025, respectively; $p=0.048$, $p<0.05$) with the 70s group (0.798 vs. 0.892, respectively; $p=0.004$, $p<0.01$).

Discussion

In the present study, we focused primarily on the psoas major muscle, whose atrophy is closely related to falling while walking in the elderly. The psoas major has three predominant functions: raising the thigh high and extending the stride while walking; maintaining the pelvis in an upright position and pulling the lumbar spine from the side of the abdomen to facilitate walking posture; and supporting the head, making a natural S-shaped curve in the backbone¹⁰. These functions are necessary for the human being to move by bipedal locomotion.

Though the functions of the psoas major muscle are important, research on this muscle is sparse. One report dealt with the psoas major as a part of the iliopsoas¹¹. The main focus of research on walking and falling has been the

quantity of the quadriceps femoris muscle. The present study put a focus on the psoas major and the CSAs of the muscle were compared with those of the quadriceps femoris muscle.

In the present study, we measured the CSAs of the psoas major and quadriceps femoris muscles using MRI. MRI has been gaining attention as a method of taking measurements inside the body with the advantages of not using radiation as in X-ray photography and computed tomography (CT) scanning and of being capable of measuring the cross-section of a muscle more precisely than ultrasonic devices¹²⁻¹⁷.

Kin et al.⁸ and Kuno et al.⁹ reported that the cross-sections of the psoas major muscle decrease significantly in the 50s in both men and women ($p < 0.05$). In the current research, CSAs of the psoas major muscle were found to decrease with aging, and a statistically significant difference was first observed between the 20s and 40s groups. We suggest that the start of the decline in the cross-section of the psoas major muscle starts earlier than previously believed. Furthermore, we found that the decrease in the cross-section of the psoas major was greatest between the 60s and the 70s, a finding that strongly suggests a connection with falling in the elderly.

In another study, Sato et al.¹⁸ measured the crossing areas of the extensor and flexor muscles in the thighs of men and women aged from their 20s to their 60s using a supersonic cross-cutting image photography system for the body and extremities. They reported that a significant difference was observed in the extensor muscles in the thighs between women in the 60s age group and those in the age groups of the 20s and 30s. In the present study, the CSAs of the quadriceps femoris remained unchanged until the 40s and declined significantly in the 50s. Although our measuring methods were not identical for both muscles, we found that the decline in the CSAs areas of the quadriceps femoris started later in age than the decline in the psoas major. The remarkable decline after the 60s observed for the psoas major muscle was not seen in the case of the quadriceps femoris.

The difference in the decline of CSAs due to aging between the psoas major and quadriceps femoris became clearer through comparison of the muscle cross-section ratios of each older age group with the 20s group between the two muscles. Compared to the decline in the cross-sections of quadriceps femoris muscles, the decline of psoas major muscles was greater in the 40s and 70s age groups, with a balance of the ratios for the two muscles of 9.4% in the 70s group. This balance was almost identical to that reported by Kuno et al. (approximately 10%)⁹.

The psoas major is an inner muscle of the body and the quadriceps femoris is a surface muscle. It is generally possible to recognize the decline of the latter, but rarely that of the former. Thus, it is critical to develop a method of maintaining the psoas major. The differences in the characteristics of the decline of the two muscles suggest that countermeasures specific to each generation should be developed. One should be initiated before the age of 50 and another should be continued through the 60s and 70s in order to

maintain the volume of the inner muscle and eventually to prevent falls. Ishizu et al.¹⁹ reported that the mean muscle strength of the psoas major for the exercise group (mean age 65.2 years old, $n=12$) CSAs elevated from 10.5 ± 1.5 to 12.1 ± 2.6 (cm^2 , $p < 0.05$) while that of the control group (mean age 68.0 years old, $n=16$) dropped from 10.3 ± 2.0 to 9.5 ± 2.0 (cm^2 , $p < 0.05$). This study suggested the importance of training of the psoas major for the elderly.

All subjects in the present study were women who shared the same cultural and social backgrounds. However, there was a big difference in physique among the age groups. Although there were no significant differences in weight between each age group except in the case of the 70s group, the most remarkable difference was observed in height, which correlated with the cross-sections of muscles. The primary reason for this large difference in height among the age groups is the study design, which was cross-sectional (that is, all age groups were investigated at the same particular point of time) rather than prospective (in which groups would be followed for a long period of time). The value of the CSAs was hence adjusted by mean height to standardize the obtained values in order to compensate for differences in physique.

In conclusion, the present research clarified a marked difference in the pattern of decline due to aging in CSAs comparing the psoas major and quadriceps femoris muscles. The decline of the psoas major was found to start after the 20s, and continues to decrease until the 70s. The decline from the 60's through the 70s was most remarkable. On the other hand, the quadriceps femoris was maintained until the 60s. Methods of maintaining the psoas major that are specific to each generation should be developed.

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