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Changes in Psoas Major and Quadriceps Cross Sectional Area in Elderly People after 12 Weeks of Exercise

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The purpose of this study was to investigate whether 12-weeks of movement training would increase the psoas major cross-sectional area (CSA) in senior men and women. Fifty eight men and women aged 65 to 80 years old (69.6±3.7, 30 male, 28 female) were divided into a control (n=19) and exercise group (n=39). Subjects were assessed before and after the training program for stature, body mass, and magnetic resonance imaging of the psoas major and the quadriceps muscle. The experimental group performed exercises using machines designed to improve the movement of the hip at a frequency of twice every week, with a total of 23 trainings in 12-weeks. Magnetic resonance images of both thighs and the abdomen and psoas major were obtained, aimed at 50% of the length of the greater trochanter and the lower edge of the femur and between the fourth (L4) and fifth (L5) lumbars. A 9.4% increase in the psoas major CSA in the training group was observed. In the male and female breakdown, a 11.5% and 8.4% change was observed in males and females, respectively. In the quadriceps, there was no significant statistical improvement in either males or females. Furthermore, in the control group, there was no significant change seen in either the psoas major or the quadriceps. As a result of conducting training that enables upkeep of posture and smooth linkage of the lumbar spine, the pelvis and thighbone, the psoas major CSA of older adults were improved in a short period of time. For this reason, the possibility of improving the psoas CSA, which decreases remarkably with increased age, by improving the linkage of the body trunk is also suggested.

Key words : Training, aging, muscle, movement

Introduction

Walking ability is commonly given as a determinant of QoL in elderly people, and in recent years attention has been directed to the strong relationship between walking ability and the mass of the psoas major muscles [17]. The psoas major is a muscle that originates from the lumbar spine and inserts on the lesser trochanter of the femur. It contributes to movement of the lower back, pelvis, and hip. Its functions are thought to include flexion of the hip joint, flexion of the lower back, and maintenance of the posture of the lower back and hips. The importance of the psoas major in walking ability is thought to be as a route for transmission of energy produced in the major muscle groups of the legs to the arms [22], in its significant activity for the maintenance of a standing posture [3], and in contributing to stability in the femur, pelvis, and lumbar spine when the leg contacts the ground during walking [24].

Many studies have shown the decrease in muscle accompanying age. Nelson et al. reported that after the age of 50 years muscle mass decreased by 454 g per year [21], Evans and Roseburg demonstrated that in adults from their 30s to 40s who do not perform regular muscle training, muscle mass decreases 227 g per year [6], and Larsson et al. reported that fast muscle fiber decreased to 50% by the age of 80 years old in men who worked in offices [18]. In studies using MRI or ultrasound that looked at changes in muscles with age in individuals, changes were reported in the quadriceps femoris muscle [29] and in extensors and flexors of the elbows and knees [16]. It has been reported that the psoas major decreases with age at a higher rate than the quadriceps fem-

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oris muscle, and that this decrease is considerable from an early age [17,28]. However, there have been many fewer studies on the psoas major than on the limbs.

It is easy to infer that many physical movement functions, including walking ability, are decreased in the elderly. To improve physical movement in the elderly, therefore, we look forward to development of exercises to increase the mass of the psoas major and the accumulation of evidence for their effectiveness. However, studies on the effect of continuous exercise on the psoas major include that of Parkkola, who conducted a study in which young people trained for 18 weeks [24]. Almost all other reports are about the effects on development and competition, including in athletes during puberty [25], wrestlers [15], soccer players [11], and track and field athletes [12]. No studies have examined changes in the psoas major in elderly people.

Using electromyograms and engineering models, Andersson investigated exercise for the improvement of the psoas major and reported that the psoas major plays important roles in supporting the lumbar spine and maintaining movement such as walking at speeds of 2 m per second or more [2]. For this purpose, exercises such as leg raises and hip flexion, which are flexion movements of the hip joint through coordination of the lumbar spine, pelvis, and femur, are thought to be effective [24]. However, because of the decreased range of movement of the hips in elderly people [19], the locally applied load, the major role of the psoas major in maintaining a standing posture [2], and that the role of the psoas major is transmitting energy from the legs to the arms [12], it may be that normal resistance training is not effective as exercise of the trunk to increase the mass of the psoas major in elderly people. Based on findings that the psoas major is closely related to the upright posture during walking movement [2], that the range of hip movement decreases with age in the elderly [19], and that there is little rotation in the hip in the walking movement of elderly, we hypothesized that hip movement exercise in the standing posture may increase the size of the psoas major in elderly people.

In this study, using a sprint training machine and a positional-axle bicycle ergometer developed by Kobayashi [14] as exercise machines for hip movement, we had elderly subjects aged 60 years or older perform hip exercise in the standing posture for 12 weeks to investigate whether continuous exercise increases the size of the psoas major in elderly people.

Materials and Methods

Subjects

The subjects of this study were 58 people (30 men, 28 women) aged 65-80 yr (69.6±3.7 yr) who had no orthopedic diseases, were under no movement restrictions by a doctor, and did no special exercise beyond normal activities of daily living. The subjects were randomly divided into a group that participated in a class that exercised using the machines (20 men, 19 women), and a control group that did not participate in the class (9 men, 10 women). Each of the groups was further divided by sex to investigate sex differences. After obtaining written and verbal informed consent, a doctor determined subjects' fitness to participate. Participants completed a questionnaire on health history and underwent a general medical checkup including measurement of blood pressure. Eligible participants who agreed were enrolled. This research was approved by the Shizuoka Prefecture General Health Center Ethical Review Board.

Study protocol

After the exercise group underwent pre-intervention measurements, they exercised twice a week for 23 sessions. Post-intervention measurements were taken at session 24. The control group underwent measurements with the same timing. At each session of the exercise program, the subjects' physical condition was first checked, followed by 10 minutes of warming up. They then exercises for about 15 minutes each on a sprint training machine and positional-axle bicycle ergometer developed by Professor Emeritus Kando Kobayashi of Tokyo University [14].

Sprint training machine

The feet are fixed to pedals, and move forward and backward in a repeated continuous reciprocal movement at a fixed speed. When the pedal has moved to the rear in the reciprocal movement, users pull it up and move it forward (Fig. 1). In performing this movement, subjects repeatedly rotate the pelvis, rotate the hips, flex and extend the hips, and flex and extend the lumbar spine while moving slowly.

Positional-axle bicycle ergometer

The positional-axle bicycle ergometer is very similar to a regular bicycle ergometer, but unlike a regular bicycle ergometer the pedals move independently. The pedal axles move backward, and so the movement is not a circular

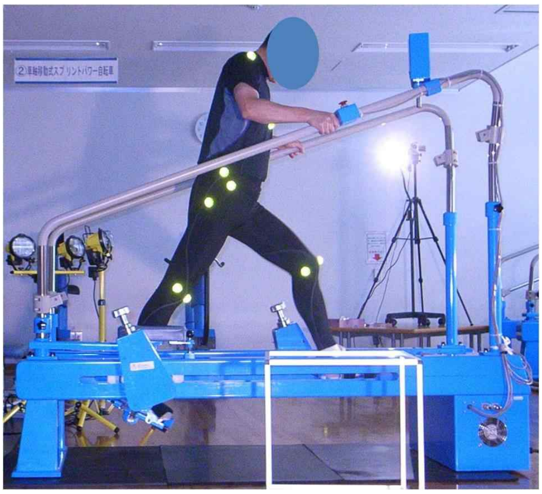

Fig. 1. Sprint training machine.

movement, as seen with normal bicycle ergometers, but elliptical (Fig. 2). The elliptical rather than circular movement of the pedals on this machine makes it easier to perform rotation of the pelvis, rotation and flexion of the hips, and flexion and extension of the lumbar spine.

Measurement of cross-sectional area of psoas major

Magnetic resonance images of both thighs and the abdomen were obtained using a 1.5-T MR scanner (1.5-T MR scanner Signa Horizon, Siemens-Asahi Medical Technologies, Tokyo, Japan) with a body coil to determine the cross-sectional area (CSA) of quadriceps femoris muscle and psoas major muscle of both sides. The subjects were scanned while lying supine with the knee and hip joints extended and arms

Fig. 2. Positional-axle bicycle ergometer.

relaxed by their sides. Longitudinal images of the thigh were obtained to identify the greater and lower edges of the femur (Hoshikawa et al. 2006). Three transverse T1-weighted images of 8 mm slice thickness (TR 500, TE 22, matrix 384×256, FOV 400) were obtained, aimed at 50% of the length of the greater trochanter and the lower edge of the femur with a 5 mm gap. The closest slice was selected to determine the CSA of the quadriceps femoris (Fig. 3). To measure the CSA of the psoas major, longitudinal scans were done to identify the position of the lumbar vertebrae, and then a transverse T1-weighted image of 8mm slice thickness (TR 500, TE 22, matrix 384×256, FOV 400) was obtained, aimed between the fourth (L4) and fifth (L5) lumbar vertebrae as described by Peltonen et al. [25] (Fig. 3).

The images were stored in JPEG format on a Windows-based PC using image analysis software (Image, National Institutes of Health) and traced using a tablet pad (PTZ-630, Wacom, Japan). The borderlines of the psoas major and quadriceps were traced by a person knowledgeable in anatomy and with experience of MRI image tracing. The sum of the left and right values of both psoas major and quadriceps was used. Intraobserver difference in the calculation of the muscle CSA was tested by repeating the CSA determinations 10 times in a pilot study with three subjects in this study. The coefficient of variation for every CSA determination was less than 1%.

Statistics

The subjects were measured twice, before and after the intervention. The effect of exercise in increasing the CSA of the psoas major was judged by comparing the amount of change after the intervention in the exercise and control groups. Measurement values are expressed as mean±standard deviation. An analysis of variance by repeated measures

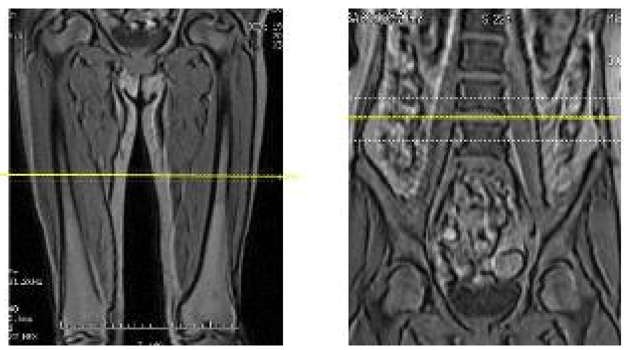

Fig. 3. Determined CSA of quadriceps femoris muscle and psoas major.

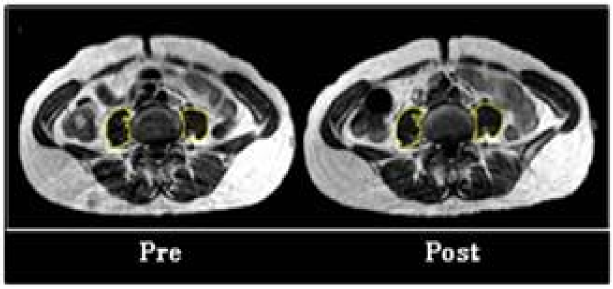

Fig. 4. Changes in muscle CSA of the psoas major after training.

was conducted for within group changes in the CSA of the psoas major before and after exercise, and post-hoc tests were conducted for those in which differences were seen. The amount of change in the CSA of the psoas major was obtained by dividing the post-intervention value plus the change in the post-intervention value by the pre-intervention value. Post-hoc tests were conducted when an analysis of variance was conducted in the amount of change, and differences were seen. Pearson's correlation coefficient was used to obtain the correlation between age and CSA of the psoas major. All statistical analyses were done using Excel Statistics 2008 (SSRI), with $p<0.05$ taken to be the level of significance.

Results

Differences between groups in measurements before the start of exercise

The physical characteristics of each group before the start of exercise are shown in Table 1. No significant differences were seen between the exercise and control groups in age, height, or weight in the results of measurements before the start of exercise. Significant differences were seen in height and weight between men and women in the exercise group and men and women in the control group. The CSAs of the psoas major and quadriceps femoris in each group before the start of exercise are shown in Table 2. The results of measurements before the start of exercise showed no significant differences between the CSAs of the psoas major or quadriceps femoris in the exercise and control groups. Gender differences were seen, however, with significant differences between the CSAs of the psoas major and quadriceps femoris of men and women in both the exercise and control groups.

Relationship between age and cross-sectional area of muscle in measurements before the start of exercise

No significant difference was seen between age and CSA of the psoas major or quadriceps femoris in either the exercise or control group before the start of exercise. In addition, no gender differences were seen in the correlation trend between age and CSA of muscle.

Changes after exercise in the class

In the exercise group, the CSA of the psoas major increased from 19.7±0.5 cm^2 before exercise to 21.4±0.6 cm^2 after exercise. All subjects showed an increase, ranging 1 -

Table 1. Age, height and body mass of the participants

	N	Age (yr)	Height (cm)	Weight (kg)
Training men	20	70.2±4.6	162.1±3.9	61.1±6.3
Training women	19	68.9±3.0	153.7±6.6	55.8±10.0
Training all	39	69.5±3.9	158.0±6.8	58.6±8.6
Control men	10	70.6±4.4	165.2±3.7	66.4±7.6
Control women	9	68.8±1.9	152.8±5.1	54.5±6.0
Control all	19	69.7±3.5	159.3±7.7	60.8±9.0

Table 2. Changes in psoas major and quadriceps CSA

	Psoas major (cm^2±SD)			Quadriceps (cm^2±SD)		
	Pre	Post		Pre	Post	
Training male	23.9±3.8	25.8±3.9	*	117.4±13.0	121.0±15.5	N.S.
Training female	15.0±2.4	16.7±2.4	*	85.1±12.7	87.2±11.9	N.S.
Training all	19.7±5.5	21.4±5.6	*	101.6±20.7	103.4±21.8	N.S.
Control male	24.2±3.5	23.5±3.8	N.S.	120.4±17.1	120.8±18.7	N.S.
Control female	15.6±3.0	15.7±3.5	N.S.	85.9± 9.0	84.0±8.2	N.S.
Control all	20.2±5.4	19.9±5.3	N.S.	104.3±22.3	105.0±23.9	N.S.

*$p<0.05$

33%, with a mean of 9.4%. No significant difference was seen between the sexes in the amount of change, which was 11.5% in men and 8.4% in women. In the control group, no significant difference was seen before and after exercise in the CSA of the psoas major. No significant difference was seen in either group in the CSA of the quadriceps femoris before and after exercise. In the exercise group, a weakly significant correlation of 0.332 in men and 0.302 and women was seen between age and the increase rate after exercise of the CSA of the psoas muscle.

Discussion

Kuno et al. [17] showed a strong correlation between the CSA of the psoas major and walking speed in elderly people, Takahashi et al. [28] showed that is difficult to maintain the activities of daily living with general exercises alone, and Andersson et al. [2] showed that the psoas major contributes greatly to maintaining posture and walking movements. These studies indicate the great importance of increasing the mass of the psoas major in order to improve the physical movements of older adults. In addition, with regard to decreasing muscle mass with age, Kuno et al. [17], Takahashi et al. [28] indicated that the CSA of the psoas major shows a larger decrease with age than the muscles of the limbs, and Kuno et al. [17] reported that compared with people in their 20s, the psoas major decreases 18.2% in men and 21.2% in women in their 40s, 31.8% in men and 34.9% in women in their 50s, 38.0% in men and 37.9% in women in their early 60s, 40.6% in men and 36.6% in women in their late 60s, 47.7% in men and 41.1% in women in their early 70s, and 51.6% in men and 51.4% in women in their late 70s. Takahashi et al. [28] also reported that the mass of the quadriceps femoris is maintained until age 40, and even in the 60s does not show a rapid deterioration, whereas the mass of the psoas major decreases from the 20s and declines rapidly from the 70s. This also indicates the need to strengthen the psoas major through training because of the large decrease that occurs with age.

In the measurements before exercise in this study, no significant differences were seen between the exercise and control groups in age, height, weight, CSA of the psoas major, or CSA of the quadriceps femoris. The CSA of the psoas major in subjects was significantly greater in men, at 24.0±3.7 cm^2, than in women, at 15.2±2.5 cm^2. Similarly, the CSA of the quadriceps femoris was significantly greater in men, at 118.3±10.1 cm^2, than in women, at 85.3±11.7 cm^2. The mean age of the subjects in this study was 70.3±1.5 years for men and 68.9±0.7 years for women. In a report by Kubo et al. [16], the CSA of the psoas major was 16.1 cm^2 and 11.1 cm^2 for men in their 70s and women in their 60s, respectively, and so the muscle mass of the subjects in the present study was greater. The decrease in muscle mass with age is not due to age alone but is also greatly affected by living habits [17], and so it may be assumed that the participants in the present study got more exercise in their daily lives than the subjects that previous study.

With regard to differences in muscle mass between the sexes, Abe et al. [1] found that the proportion of muscle mass of women to that of men was 63% in the arms, 50% in the trunk, and 75% in legs. In the present study the quadriceps femoris was 72%, close to the data for legs according to Abe et al. [1]. In contrast, the psoas major of women was 63% that of men, different than the disparity in muscle mass between men and women in the trunk area according to Abe et al. [1]. This is thought to be because the psoas major is located further toward the legs than the trunk, and functions more as a muscle of the legs , so that it shows values closer to those of the leg muscles. As a result, a tendency for a significant increase in the CSA of the psoas major was seen after exercise twice a week for 23 sessions in elderly people 60 years of age or older. There was no difference between the sexes in the rate of increase, and the effect of age on the rate of increase was low.

Reports on increases in the CSA of the psoas major are very few compared with those for the limbs. The effect of resistance training for limbs is widely known, and consistent results on increases in muscle mass have been seen. There are also reports that show resistance training in older adults can increase muscle strength just as it does in young people. Ozaki et al. [23] reported increases of 3.5% in the CSA of muscles of the thigh after exercising 4 times a week for 10 weeks, and Frontera et al. [8] reported an increase of 11.4% in the CSA of the quadriceps femoris muscle after isokinetic knee extension exercises 36 times over 12 weeks. In a large-scale study examining the effects of muscle and endurance training in young and middle-aged and elderly people, it was reported from an experiment with 1,132 males and females who performed muscle training for 25 minutes that the increase in lean mass was the same in the elderly group of people aged in their 60s to 80s as that in the middle-aged and young group. With regard to increased muscle strength in women, Campbell et al. [4] reported increased muscle strength as a result of training for three months in women (54-71 years) who were mainly sedentary in their daily lives. Fiatarone et al. [7] showed increased muscle mass of 14.5% in a study of men and women 86 to 96 years of age, and reported that there was no gender difference. The finding in the present study that the CSA of the psoas major increased in elderly people without regard to age or sex would also seem to be very valuable.

Although studies showing increases in the CSA of the psoas major from training are few, Parkkola et al. [24] reported an increase of 22% after training for 18 weeks in university students. In that study flexion and extension exercises of the trunk placed a load on the muscle of about 60% of its maximum strength, and the increase in muscle mass was measured. Since hip flexion is a major action of the psoas major muscles [2], the results of this study are readily accepted. Considering this, our results support the possibility that the psoas major muscles can be increased in size in older adults if an appropriate load is applied.

However, because of the decreased range of trunk motion in elderly people [19], it would probably be difficult to have them perform flexion movement with the high-intensity of the young subjects in the study of Parkkola et al. [24]. The psoas major is also reported to have functions other than flexion of the hip joint, including extension and rotation of the hip, flexion of the lumbar spine, and support of the lumbar spine. In addition, from a study on the action of the psoas major during activities of daily living, it was reported that it supports the pelvis and lumbar spine during walking, and supports a standing posture [2]. Psoas major activity is also reported to be higher in a standing than in a sitting posture [2]. In the exercise machine used in this study, the feet are fixed in pedals in a standing posture, and the pedals automatically move forward and backward to coordinate and move the lumbar spine, pelvis, and femur. The movement also rotates the pelvis, rotates the hip joint, flexes and extends the hips, and flexes and extends the lumbar spine. These motions promote muscle activity of the psoas major, as mentioned above, and so are thought to produce increases in the psoas major muscle mass regardless of age and sex.

The present study showed that exercise that flexes and extends the hip joint and moves the pelvis in the standing position can increase the CSA of the psoas major in elderly people. This is conjectured to be because it activated the functions around the hips that are thought to deteriorate with age. In the future we will investigate how exercise around the pelvis affects daily living functions of elderly people, which may contribute to elucidating improvements in physical functions of elderly people.

Conclusion

As a result of training aimed at upkeep of posture and smooth linkage of the lumbar spine, the pelvis and the thighbone, the psoas major CSA of senior citizens improved over a short period time. This suggests the possibility of improving the psoas CSA, which markedly decreases with ageing, by improving the linkage of the body trunk. There is a need to research how the body trunk linkage changes with this kind of training. From research into how the body trunk linkage changes with ageing, the importance of a training program to control the deterioration of body strength of senior citizens may be suggested. The improvement over a short time in body trunk muscle CSA in which muscle hypertrophy is considered to more readily occur than in other muscles was achieved by conducting a training program which focused on the linkage of the body trunk and the extremities.

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초록 : 고령자를 대상으로 12주간 운동이 대요근 및 대퇴부 근횡단면적에 미치는 영향

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본 연구는 남녀 노인을 대상으로 12주간의 트레이닝을 실시한 후, 대요근과 대퇴부 근육의 근 횡단면적의 변화를 검토하였다. 연구 대상자는 65세에서 80세까지의 노인 58명(남성 30명, 여성 28명)이었으며, 대조군 19명과 운동군 39명으로 나누어 실시하였다. 측정항목은 신장, 체중, 체질량, 대요근과 대퇴부의 근 횡단면적을 측정하였다. 근육의 평가는 자기공명영상법(MRI)을 사용하여 실험 전, 후 실시하였다. 운동군은 대요근과 대퇴부 근육을 증가시키기 위하여 특별히 고안된 기계를 사용하여 평균 주 2일, 12주 동안 23번의 트레이닝을 실시하였다. 대요근의 측정부위는 L4와 L5의 중간부위를 분석하고, 대퇴부는 대퇴골과 무릎까지 길이를 나누어 50%부위에서 분석하였다. 트레이닝 후, 운동군의 대요근 근횡단면적은 9.4% 증가하였다(남성 11.5%, 여성 8.4%). 그러나 대퇴부 근 횡단면적은 남녀 모두 운동 후 증가경향은 나타나지 않았다. 또한 같은 기간 대조군의 근 횡단면적에서도 유의한 변화는 나타나지 않았다. 대요근은 자세 유지와 허리, 골반 및 대퇴부의 연결에 중요한 역할을 담당하기 때문에, 특히 노인의 이동활동에 중요하다고 사료된다. 본 연구에서는 새로이 개발된 트레이닝 기계를 사용하여 단기간 트레이닝 후, 대요근 근 횡단면적의 증가를 확인하였으며, 이것은 노인들의 근력 및 이동능력의 향상 가능성이 시사되었다.