

Risk Factors for Decrease in The Cross-Sectional Area of the Paraspinal Muscle in 1,849 Individuals: A 10-Year Longitudinal Study

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Abstract

We investigated longitudinal losses of paraspinal muscle area in healthy individuals in a 10-year longitudinal retrospective observational study. Data from 1,849 individuals (1,690 men, 159 women) screened using computed tomography were examined. Logistic regression was performed to determine risk factors associated with paraspinal muscle area decreases; the area was significantly decreased at 10 years compared with the area at baseline regardless of age or sex, starting at 30 years of age. In regression analysis, only aging (≥ 50 s [odds ratio [OR], 1.72; 95% confidence interval [CI], 1.05–2.84; $p=0.03$] and ≥ 60 s [OR, 2.67; 95% CI, 1.55–4.60; $p<0.001$]) was a risk factor for psoas major area decreases. Age ≥ 60 years (OR, 2.05; 95% CI, 1.24–3.39; $p=0.005$), body mass index ≥ 25 kg/m² (OR, 1.32; 95% CI, 1.01–1.73; $p=0.04$), and visceral fat ≥ 100 cm² (OR, 1.61; 95% CI, 1.20–2.15; $p=0.001$) were risk factors for erector muscle area decreases; physical activity ≥ 900 kcal/week (OR, 0.68; 95% CI, 0.50–0.94; $p=0.02$) reduced erector muscle area loss in males. Our study demonstrated that walking >45 minutes daily could reduce paraspinal muscle loss, which in turn can decrease the risk of falls and low-back pain and might eventually help prevent sarcopenia.

Introduction

Sarcopenia is characterized by the progressive loss of skeletal muscle mass and strength and presents a risk for adverse outcomes, including physical disability, poor quality of life (QOL), and death ^{1,2}. This condition increases the risk of falls in older individuals, often resulting in fractures in areas such as the femoral neck ^{3–5}. These fractures negatively affect QOL and increase the number of bedridden patients and medical costs ^{6,7}. Tinetti *et al.* ⁸ described that walking disability and the risk of falls would be caused by the decrease of paraspinal muscle strength. Additionally, there are a few articles describing the association between paraspinal cross-sectional areas and low back pain ^{9,10}. Thus, preventing the decrease of paraspinal muscle strength is important for reducing adverse events, especially in countries with rapidly aging populations.

Current research shows an association between skeletal muscle area and specific characteristics. Landi *et al.* found that cerebrovascular disease and osteoarthritis were specific risk factors of sarcopenia in older patients ¹¹. Raval *et al.* determined that higher body mass index (BMI) in individuals with peripheral artery disease was associated with more adverse changes in calf muscle characteristics in a 2-year longitudinal study ¹².

Few longitudinal studies in healthy populations have reported paraspinal muscle changes, despite losses being associated with falls and back pain ^{13,14}. Therefore, this study aimed to longitudinally compare the paraspinal muscle area in healthy individuals and determine risk factors associated with given changes. We hypothesized that risk factors, such as obesity and lack of exercise, would cause paraspinal muscle area loss, starting in individuals in their 40s.

Results

Individuals

Of 9,749 individuals, 3,931 were excluded based on preliminary criteria. Specifically, 2010 subjects underwent computed tomography (CT) screenings twice from 2004 to 2006, and the second set of data was excluded. In 1,867 individuals, cross-sectional CT did not include the area between the L4 upper edge and L4/5 disc. Individuals with a history of lumbar surgery were excluded ($n = 54$). Individuals who did not undergo a CT screening of visceral fat at 10 years and those with a CT scan that did not measure the area between the L4 upper edge and L4/5 disc 10 years after their initial screening ($n = 3,908$ and $n = 61$, respectively) were excluded. In total, 1,849 individuals (1,690 male, 159 female) met the inclusion criteria. The recruitment and application of the exclusion criteria are described in a flow chart (Fig. 1)

Baseline demographic variables

Demographic data according to age groups are summarized in Table 1. No significant differences in BMI were found between age groups for both sexes, while body fat and subcutaneous fat in male subjects decreased with age. Conversely, despite no change in BMI, visceral fat area increased until the subjects were in their 50s for both sexes, most notably in male subjects in their 30s and 40s. Physical activity in male subjects increased with age.

Baseline muscle, fat area composition, and fat rate of muscles

Baseline paraspinal muscle composition for each age group is presented in Table 1. Areas of both the psoas major and the erector muscles in male subjects decreased with age. Although no significant differences were found in the fat area of the psoas major among age groups, erector muscle fat area increased with age in both sexes.

Table 1
Summary demographic and health characteristics of the individuals at baseline

	Male (n = 1,690)					Female (n = 159)					
	30s (n = 135)	40s (n = 424)	50s (n = 855)	60s (n = 276)	F	P-value	40s (n = 27)	50s (n = 101)	60s (n = 31)	F	P-value
BMI (kg/m ²)	24.4 ± 3.4 (17.9–35.8)	24.6 ± 3.2 (17.1–36.1)	23.9 ± 2.6 (16.7–33.4)	23.7 ± 2.3 (17.6–31.7)	1.60	0.188	23.0 ± 3.5 (16.5–32.4)	23.3 ± 3.0 (18.3–33.0)	22.2 ± 2.0 (19.2–28.0)	1.93	0.149
Body fat (%)	23.4 ± 4.7 (12.1–37.2)	23.1 ± 4.9 (0–39.2)	21.9 ± 4.1 (10.0–38.6)	21.2 ± 4.2 (10.0–32.2)	14.97	< 0.001	28.4 ± 5.8 (17.5–39.1)	29.1 ± 5.5 (16.2–44.5)	27.6 ± 4.2 (19.7–35.2)	1.44	0.240
Visceral fat (cm ²)	108.3 ± 54.0 (10.8–244.0)	127.9 ± 52.0 (9.6–302.1)	131.8 ± 54.2 (2.9–317.7)	128.2 ± 53.6 (0–279.0)	7.55	< 0.001	62.6 ± 36.9 (13.8–151.0)	87.9 ± 49.2 (0–227.0)	81.9 ± 34.3 (20.0–140.0)	3.20	0.044
Subcutaneous fat (cm ²)	146.6 ± 76.5 (15.2–417.0)	143.3 ± 61.5 (11.0–402.8)	124.9 ± 45.6 (7.0–272.1)	113.8 ± 40.5 (18.5–260.0)	25.17	< 0.001	155.6 ± 72.1 (61.7–317.0)	183.1 ± 73.3 (33.0–381.0)	162.4 ± 48.8 (61.0–278.0)	2.65	0.074
Physical activity (kcal/week)	501.8 ± 393.6 (0–1950.0)	606.8 ± 514.4 (0–4620.0)	760.2 ± 1,025.9 (0–14375.0)	960.5 ± 1,220.0 (0–9562.5)	11.27	< 0.001	610.4 ± 962.7 (0–4800.0)	537.6 ± 975.2 (0–4890.0)	697.6 ± 958.4 (0–3750.0)	0.49	0.612
Smoker (%)	85 (63.0)	243 (57.3)	387 (45.3)	85 (30.8)	-	-	4 (14.3)	3 (2.9)	1 (2.9)	-	-
Drinker (%)	103 (76.3)	338 (79.7)	665 (77.8)	202 (73.2)	-	-	10 (35.7)	21 (20.6)	4 (11.4)	-	-
Area of psoas major (cm ²)	29.2 ± 4.7 (14.7–44.0)	28.7 ± 5.1 (15.2–45.8)	25.7 ± 4.7 (9.3–43.1)	24.2 ± 4.3 (12.5–39.7)	74.85	< 0.001	17.3 ± 3.5 (10.0–26.8)	14.7 ± 3.3 (7.4–23.7)	14.0 ± 2.5 (8.0–18.6)	8.10	< 0.001
Fat area of psoas major (cm ²)	0.8 ± 0.6 (0.1–3.1)	1.0 ± 0.6 (0–3.1)	0.9 ± 0.6 (0–4.8)	1.0 ± 0.7 (0–3.3)	1.99	0.114	0.7 ± 0.6 (0.2–2.4)	0.8 ± 0.6 (0–3.1)	0.7 ± 0.6 (0.1–2.5)	0.55	0.580
Area of erector muscle (cm ²)	50.2 ± 7.7 (33.2–78.0)	48.0 ± 7.2 (29.5–71.9)	46.1 ± 6.6 (18.4–69.8)	44.8 ± 6.5 (28.4–63.7)	26.15	< 0.001	38.1 ± 5.6 (28.6–52.8)	35.6 ± 4.8 (23.4–47.6)	35.0 ± 5.1 (21.2–44.8)	2.59	0.078
Fat area of erector muscle (cm ²)	1.7 ± 1.3 (0.1–10.2)	1.9 ± 1.3 (0.1–11.3)	2.2 ± 1.5 (0–11.4)	2.7 ± 1.9 (0–11.2)	20.12	< 0.001	2.5 ± 1.4 (0.4–5.6)	3.6 ± 2.2 (0.2–9.2)	3.8 ± 2.5 (0.7–13.2)	3.40	0.036

Data are expressed as mean ± standard deviation (range) except smoker and drinker. BMI, body mass index.

Male (n = 1,690)						Female (n = 159)					
Fat rate of psoas major area (%)	2.9 ± 1.9 (0.2– 9.8)	3.3 ± 2.1 (0.1– 11.6)	3.7 ± 2.4 (0–26.6)	4.2 ± 2.8 (0– 12.7)	11.55	< 0.001	4.3 ± 3.0 (1.1– 12.5)	5.6 ± 4.0 (0.2– 24.2)	5.4 ± 5.0 (0.9– 24.9)	1.28	0.282
Fat rate of erector muscle area (%)	3.3 ± 2.6 (0.2– 18.2)	3.9 ± 2.7 (0.2– 21.7)	4.8 ± 3.5 (0.1– 25.3)	6.0 ± 4.6 (0.1– 26.5)	28.49	< 0.001	6.7 ± 3.9 (1.1– 15.9)	10.4 ± 6.8 (0.6– 29.6)	11.4 ± 9.1 (0.7– 13.2)	3.78	0.025
Data are expressed as mean ± standard deviation (range) except smoker and drinker. BMI, body mass index.											

Changes in the muscle area between baseline and 10 years

The 10-year changes in the paraspinal muscle area by age group and sex are shown in Figs. 2a and 2b. The paraspinal muscle area at the 10-year follow-up was significantly smaller than the baseline regardless of age or sex. For individuals in the 30–39-year age group, significant loss already existed in the psoas major and erector muscle areas. The rate of both the psoas major and erector muscle area loss was 4–6% per decade for male subjects aged 30–59 years and approximately 8% for male subjects in their 60s. The rate of erector muscle area loss was approximately 6% for female subjects in their 40s and approximately 10% per decade for female subjects in their 50s and 60s. In contrast, the highest reduction of the psoas muscle area was in female subjects aged 40–49 years. Although male subjects in their 50s and 60s had larger psoas major area reduction rates than female subjects of the same age, female subjects in their 50s and 60s had the largest erector muscle area loss (Fig. 2c).

Multivariate analysis

The mean loss in the highest quartile of the psoas major area was $-20.0 \pm 6.2\%$ (range; -45.1% to -13.1%) ($n = 423$), and erector muscle loss was $-19.6 \pm 9.7\%$ (range; -67.1% to -11.2%) ($n = 423$). The mean loss in the lower three quartiles of the psoas major area was $-2.3 \pm 7.1\%$ (range; -13.0% – 21.1%) ($n = 1,267$), and erector muscle loss was $0.1 \pm 7.1\%$ (range; -11.2% – 20.9%) ($n = 1,267$). The results of a multivariate analysis evaluating risk factors of both the psoas major and the erector muscle area loss are presented in Table 2. Only aging (≥ 50 s [odds ratio [OR], 1.72; 95% confidence interval [CI], 1.05–2.84; $p = 0.03$] and ≥ 60 s [OR, 2.67; 95% CI, 1.55–4.60; $p < 0.001$]) was a risk factor for decreases in the psoas major area. Age ≥ 60 (OR, 2.05; 95% CI, 1.24–3.39; $p = 0.005$), BMI ≥ 25 kg/m² (OR, 1.32; 95% CI, 1.01–1.73; $p = 0.04$), and visceral fat ≥ 100 cm² (OR, 1.61; 95% CI, 1.20–2.15; $p = 0.001$) were risk factors for decreases in the erector muscle area, while physical activity ≥ 900 kcal/week (OR, 0.68; 95% CI, 0.50–0.94; $P = 0.02$) reduced erector muscle area loss in male subjects.

Table 2
Multivariate analysis for predicting changes in the psoas major and erector muscle area

Risk factors			Score assigned	Psoas major			Erector muscle		
				OR	95% CI	P-value	OR	95% CI	P-value
All generations	Age 30s		0	Reference	-	-	Reference	-	-
	40s		1	1.52	0.90–2.56	0.12	0.76	0.46–1.24	0.27
	50s		2	1.72	1.05–2.84	0.03	1.26	0.80–1.98	0.33
	60s		3	2.67	1.55–4.60	< 0.001	2.05	1.24–3.39	0.005
	Alcohol	-	0	Reference	-	-	Reference	-	-
		+	1	0.91	0.70–1.19	0.49	0.95	0.72–1.24	0.69
	smoking	-	0	Reference	-	-	Reference	-	-
		+	1	1.01	0.81–1.27	0.92	0.84	0.67–1.06	0.15
	BMI (kg/m ²)	< 25.0	0	Reference	-	-	Reference	-	-
		≥ 25.0	1	1.21	0.92–1.58	0.17	1.32	1.01–1.73	0.04
	Body fat (%)	< 25.0	0	Reference	-	-	Reference	-	-
		≥ 25.0	1	0.87	0.64–1.17	0.34	1.05	0.78–1.40	0.75
	Visceral fat (cm ²)	< 100.0	0	Reference	-	-	Reference	-	-
		≥ 100.0	1	1.24	0.94–1.63	0.13	1.61	1.20–2.15	0.001
	Physical activity (kcal/week)	< 275.0	0	Reference	-	-	Reference	-	-
		< 510.0	1	1.19	0.87–1.65	0.28	0.90	0.66–1.24	0.53
		< 900.0	2	1.06	0.78–1.46	0.70	0.81	0.59–1.10	0.17
		< 900.0	3	1.19	0.86–1.63	0.29	0.68	0.50–0.94	0.02
		≥ 900.0							

Discussion

We longitudinally investigated changes in the paraspinal muscle area of healthy individuals and determined the risk factors for paraspinal muscle loss according to age group and sex. Both the psoas and erector muscle areas significantly decreased after a 10-year period for all age groups and sexes in individuals starting in their 30s. The rate of paraspinal muscle area loss increased gradually with age except for psoas muscle area loss in female subjects. A regression analysis revealed that only age ≥ 50 years was a risk factor for decreases in the psoas major area. Age ≥ 60 years, BMI ≥ 25 kg/m², and visceral fat ≥ 100 cm² were risk factors for decreases in the erector muscle area, while physical activity ≥ 900 kcal/week reduced erector muscle area loss in male subjects.

Age-related muscle change in paraspinal muscle or skeletal muscle has been examined in cross-sectional studies. Sasaki *et al.* measured the paraspinal muscle area of 796 Japanese participants (mean age = 63.5 years, categorized as < 50, 50–59, 60–69, 70–79, and \geq 80 years old) in a cross-sectional study and revealed that muscle area significantly decreased in individuals in their 50s compared to those aged < 50 years¹⁵. Another cross-sectional study examined the influence of age and whole-body skeletal muscle mass in 468 participants (age range, 18–88 years) using magnetic resonance imaging and found that skeletal muscle mass gradually increased until individuals were in their 30s and started to decrease around ages of 45–50 years¹⁶. However, the present longitudinal study firstly provides evidence of a noticeable decrease in muscle area occurring in individuals in their 30s since it included healthy individuals from multiple age groups to calculate muscle area loss.

Although previous longitudinal studies have reported significant changes in the cross-sectional muscle area, most investigated the lower extremity muscle area and included older individuals. In a study of 1,880 older adults, Goodpaster *et al.* reported an annual reduction of approximately 1% in the lean leg area¹⁷. Delmonico *et al.* reported changes in the mid-thigh muscle area in individuals in their 70s over a 5-year period and found a 3–5% decrease¹⁸. The rate of muscle area loss per year in the present study was lower than in previous studies, and this is likely due to study differences in the measured muscle and age groups targeted. In the longitudinal study for paraspinal muscle, Mäki *et al.* longitudinally investigated 298 participants (mean age, 21.2 years; range, 19–22) with follow-up scans conducted at a mean age of 30.6 years and found that the paraspinal muscle area, except for the area of the psoas major, increased in the young adult population (20–30 years of age)¹⁹. Therefore, our results add to the aforementioned evidence that the paraspinal muscle area, except for the area of the psoas major, increases in individuals from their 20s to 30s, and the paraspinal muscle included in both psoas major and erector muscle area decreases after that.

Our research indicated that alcohol and smoking were not leading risk factors for a decrease in paraspinal muscle area. A previous study found that skeletal muscle autophagy increased with alcohol consumption²⁰. However, another study on alcohol consumption effects reported no sarcopenia correlation²¹. Our results support this as we found no association of alcohol consumption with the paraspinal muscle area.

Previous studies have reported an association between physical activity and muscle strength in older people^{22,23}. In a 5-year longitudinal analysis, Rantanen *et al.* demonstrated that maintaining activity levels prevents muscle strength decline with age²⁴. Our study confirms these trends and adds evidence to the amount of physical activity required. Hao *et al.* reported an association between the skeletal muscle mass index (SMMI) and physical activity for 640 adolescents in short-term outcomes and suggested that SMMI was positively associated with physical activity²⁵. However, there is limited knowledge regarding the association between skeletal muscle mass changes and the amount of physical activity for individuals aged 30–60. Our study indicates that exercise burning 900 kcal/week, including daily movement such as commuting on foot, attenuates erector muscle area loss in male subjects. This translates to walking at 4.0 km/h for 300 min/week for individuals weighing 60 kg. Based on our findings, we recommend that male subjects walk more than 45 min daily.

The longitudinal study design and large sample size of healthy individuals are two strengths of the present study. Moreover, a multivariate analysis with variables from comprehensive health data allowed for robust analysis. However, this study has some limitations. First, participants were not randomly selected from the general Japanese population since screenings were conducted for employees of corporations in Hitachi city. Additionally, there is a possibility that the visceral fat site as measured by CT revealed differences between baseline and 10-year follow-up values as CT imaging was done at the umbilicus level; however, we accounted for this by excluding individuals whose CT scans were not between the L4 upper edge and L4/5 disc area. Finally, this study did not assess the inter- and intra-observer reliability of muscle area measurements.

In conclusion, the paraspinal muscle area significantly decreased over a 10-year period for all age groups, starting in the 30s. Aging was a risk factor for decreases in the psoas major area. Additionally, aging, obesity, and visceral obesity were risk factors for decreases in the erector muscle area. However, physical activity \geq 900 kcal/week reduced erector muscle area loss in male subjects. This indicates that walking for > 45 minutes daily could reduce paraspinal muscle loss, which in turn can decrease the risk of falls and low back pain and might eventually help prevent sarcopenia.

Methods

Study Participants

This study was approved by the Ethics Committee of Medical Research of the University of Occupational and Environmental Health Institutional Review Board in accordance with the Declaration of Helsinki 2013. Informed consent was obtained from all participants, and all experiments were performed according to relevant guidelines and regulations.

Individuals who underwent a low-dose CT screening of the abdominal visceral fat area during annual health check-ups from April 2004 to March 2006 at the Hitachi Health Care Center were recruited for this study. For individuals screened twice within the period, the first set of data was used. Measurement of the visceral fat area with a CT scanner was performed as described previously^{26–28}. Single-slice imaging was done at the umbilicus level in the supine position using a Redix Turbo CT scanner (Hitachi Medico, Tokyo, Japan). Imaging conditions were set at 120 kV, 50 mA, with a 5-mm slice thickness. Individuals whose cross-sectional CT images did not include the area between the lumbar (L4) upper edge and the L4/5 disc, as well as those with history of lumbar surgery, were excluded. Individuals who did not undergo CT screening 10 years after their initial screening and whose CT images did not include the area between the L4 upper edge and L4/5 disc at the 10-year screening were excluded.

Examinations

Self-administered demographic and health questionnaire

Individuals completed a self-administered questionnaire with lifestyle-related questions including occupation, work posture, smoking habits, alcohol consumption, family history, medical history, physical activity, and health-related QOL. For this study, data on the frequency and current or past use of cigarettes and alcohol consumption were collected. Those who never or occasionally drank alcohol were considered non-drinkers, and those who never smoked or smoked in the past were considered non-smokers.

Physical activity

Physical activity was calculated according to previous reports²⁹. Information on physical activity was obtained from the questionnaire. When preferred activities were not listed, activities of similar exertion levels were selected. Of the 20 types of exercise listed, “other” was not used. Metabolic equivalents (METs) of each activity based on physical activity guidelines were assigned (if the MET value was not on the list, a related value was used)³⁰. Of the 19 exercises, 13 (work and commuting, walking, swimming, golf practice, golf, baseball, softball, cycling, table tennis, badminton, strength training, light jogging [approximately 6 min/km], jogging, soccer, tennis, aerobics, and jump rope) were active activities (> 6 METs), and weekly and hourly METs were calculated. Walking time for commuting was self-reported. Calories burned during commuting were calculated by multiplying the daily walking time by five (assuming two days off a week). Total physical activity was calculated from the calories burned for regular exercise during leisure plus those for commuting.

Anthropometric measurements

Anthropometric measurements were performed. BMI was calculated by dividing weight (kg) by the square of height (m²). The percentage of body fat was measured using a bioelectrical impedance analysis where fat mass was divided by total mass and multiplied by 100. Measurements with a CT scanner of visceral fat and the subcutaneous fat area at the umbilicus level were performed as described previously^{26–28}.

Paraspinal muscle area

Paraspinal muscle area was assessed by a retrospective examination of CT scans utilizing the musclePointer software (HITACHI Ltd., Tokyo, Japan). CT images were divided by the threshold value of -400 Hounsfield units (HU) into two cross-sectional areas: air and other tissue. The skin area was removed, and the areas of other tissues left in CT images were divided by the threshold value of -50 HU into two cross-sectional areas: fat and bone muscle. Software automatically scanned each paraspinal muscle (bilateral psoas major and erector). The erector muscle contains the longissimus thoracis, iliocostalis lumborum, and multifidus. Results were manually adjusted and compared with the original image. Each area was calculated, and data were entered into an Excel spreadsheet (Fig. 3).

Statistical Analysis

For descriptive variables, individuals were grouped by age in 10-year increments and by sex. Demographic and clinical characteristics are summarized as means ± standard deviations. Muscle areas between baseline and a 10-year follow-up were compared using a

paired t-test. A one-way analysis of variance compared baseline demographic variables, muscle, and fat area composition according to age group for each sex. Given the small female sample size, a logistic regression analysis was performed only for male subjects. Four groups were created according to quartiles of muscle area loss. The group with the lower three quartiles (bottom 75%) was designated as the referent group. Covariates were dichotomized with reference groups of non-drinkers, non-smokers, BMI < 25 kg/m², body fat < 25%, and visceral fat < 100 cm², except for physical activity, which was split into quartiles. Associations between muscle area loss and potential risk factors were assessed via a multivariable logistic regression analysis, with muscle area loss dichotomized into the highest quartile of muscle area lost (top 25%) versus the lower three quartiles (bottom 75%). OR and 95% 95% CIs were calculated using the referent group. All statistical analyses were performed using STATA/IC 14 (StataCorp, College Station, TX, USA). The level of significance was set at a probability of < 0.05.

Declarations

Data availability statement

The data are not available for public access because of patient privacy concerns, but are available from the corresponding author on reasonable request.

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Author contributions: E.N and Y.M approved the submitted version. E.N, Y.M and A.S contributed to the conception or design of the work. E.N, Y.M, M.T, T.N, M.T, M.K, T.K, K.N, K.S, S.U, and T.H contributed to the acquisition, analysis and interpretation of data. E.N and Y.M have drafted the work and substantively revised it.

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Figures

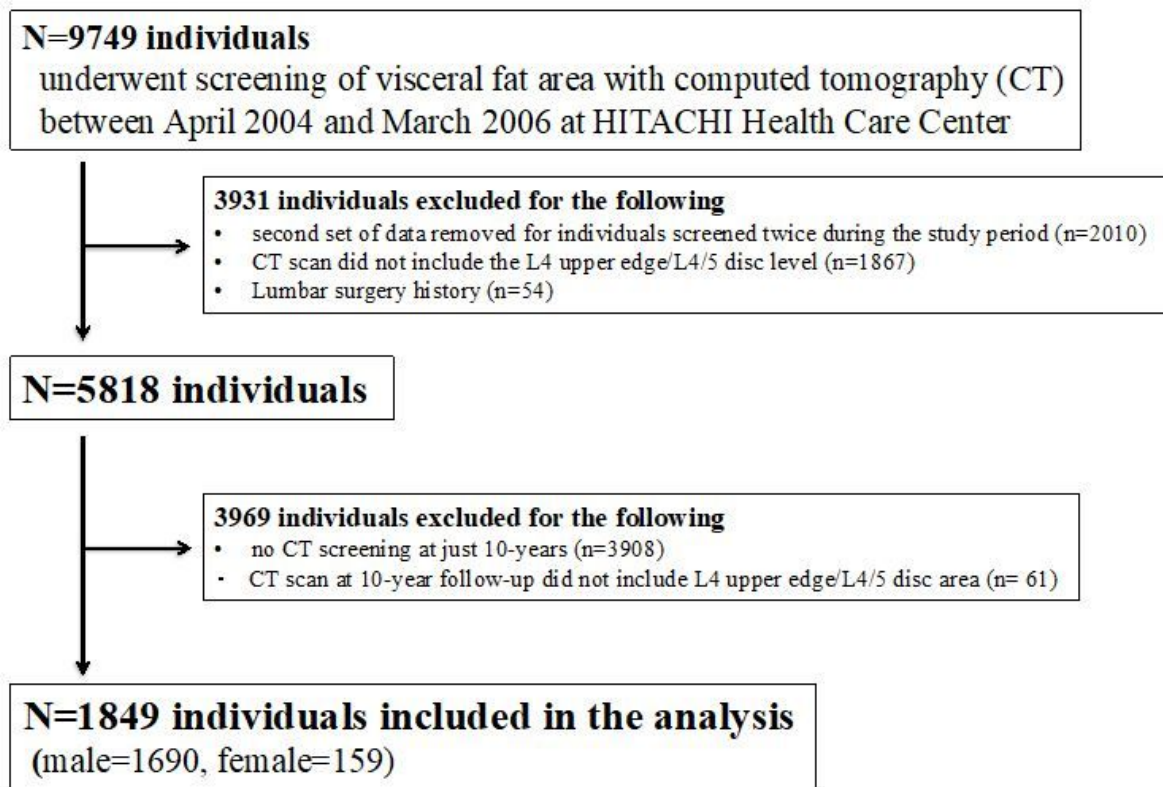


Figure 1

Study flow diagram

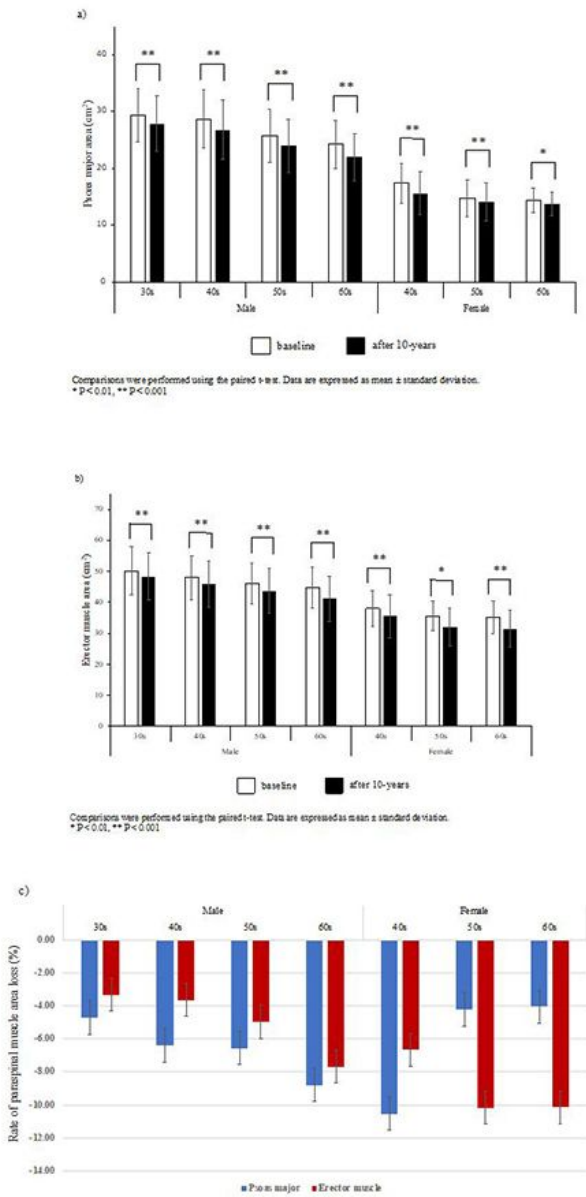


Figure 2

Differences in paraspinal muscle areas over a 10-year period a) Differences in the psoas major muscle area over 10 years. b) Differences in the erector muscle area over 10 years. c) Rate of paraspinal muscle area loss over 10 years.

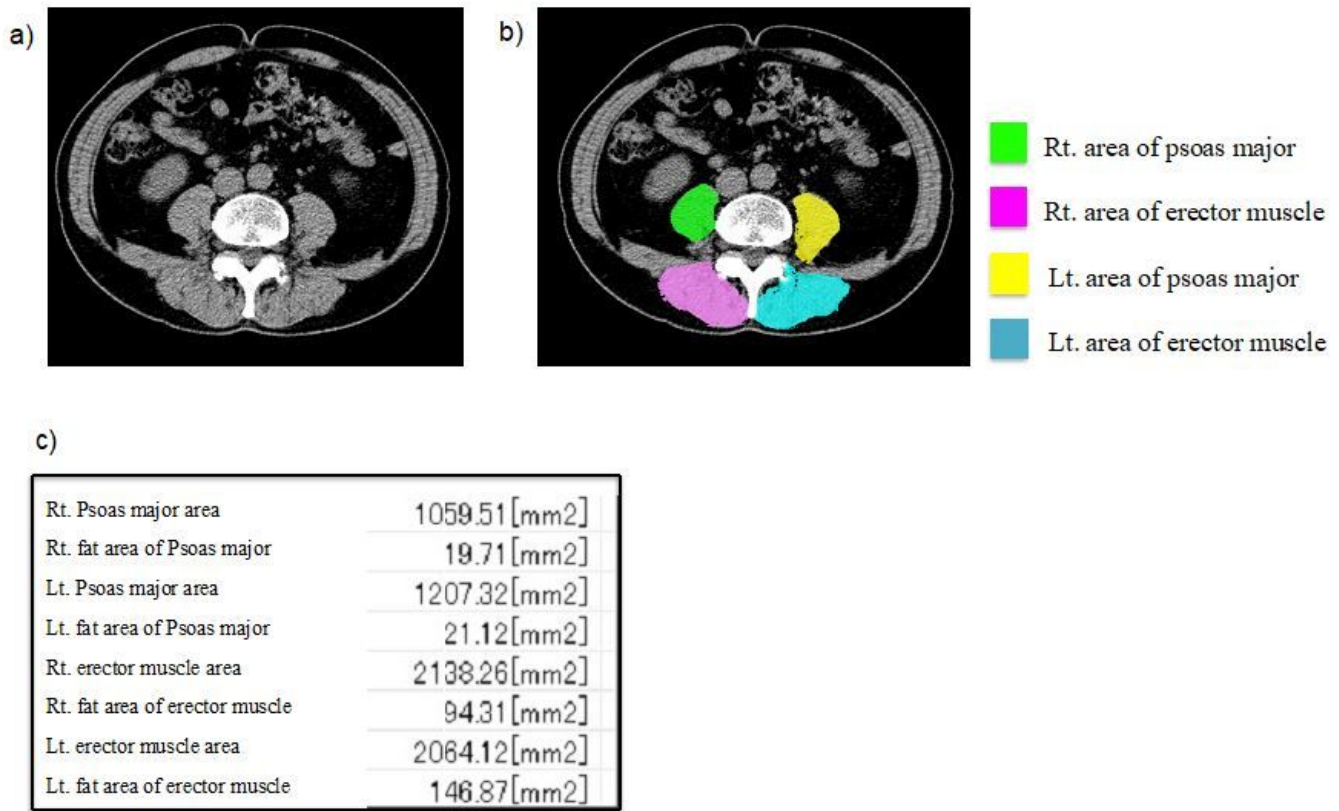


Figure 3

Representative view with musclePointer software a) An original image of the visceral fat at the level of the umbilicus as observed using computed tomography. b) Software calculated the area of each muscle automatically, and researchers manually made fine adjustments. c) Analysis results with each area calculated automatically.