Changes in Cross-sectional Areas of Posterior Extensor Muscles in Thoracic Spine: A 10-year Longitudinal MRI Study

Hitoshi Umezawa

Department of Orthopedic Surgery, Keio University School of Medicine

Kenshi Daimon

Department of Orthopedic Surgery, Keio University School of Medicine

Hirokazu Fujiwara

Department of Diagnostic Radiology, Keio University School of Medicine,

Yuji Nishiwaki

Department of Environmental and Occupational Health, School of Medicine, Toho University

Takehiro Michikawa

Department of Environmental and Occupational Health, School of Medicine, Toho University

Eijiro Okada

Department of Orthopedic Surgery, Keio University School of Medicine

Kenya Nojiri

Department of Orthopedic Surgery, Isehara Kyodo Hospital

Masahiko Watanabe

Department of Orthopedic Surgery, Tokai University School of Medicine

Hiroyuki Katoh

Department of Orthopedic Surgery, Tokai University School of Medicine

Kentaro Shimizu

Department of Orthopedic Surgery, Spine Center, Sanokosei General Hospital

Hiroko Ishihama

Department of Orthopedic Surgery, Spine Center, Sanokosei General Hospital

Nobuyuki Fujita

Fujita Health University Orthopedic Surgery

Takashi Tsuji

National Hospital Organization Tokyo Medical Center

Masaya Nakamura

Department of Orthopedic Surgery, Keio University School of Medicine

Morio Matsumoto

Department of Orthopedic Surgery, Keio University School of Medicine

Kota Watanabe (✉ watakota@gmail.com)

Research Article

Keywords: Extensor muscle, Thoracic vertebrae, Longitudinal study, Magnetic resonance imaging, Adult, Aged, Aging, Follow-up studies, Humans, Muscle degeneration, Diagnostic imaging, Pathology, Middle Aged, Asymptomatic subjects

Posted Date: September 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-877012/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Abstract

This study aimed to examine changes in the cross-sectional areas (CSAs) of posterior extensor muscles in the thoracic spine over 10 years and identify related factors. The subjects of this study were 85 volunteers (mean age: 44.8 ± 11.5) and the average follow-up period was about 10 years. The CSAs of the transversospinalis muscles, erector spinae muscles, and total CSAs of the extensor muscles from T1/2 to T11/12 were measured on MRI. The extent of muscle fat infiltration was assessed by the signal intensity (luminance) of the extensor muscles' total cross section compared to a section of pure muscle. Associations of age, sex, body mass index, lifestyle, back pain, neck pain, neck stiffness, and intervertebral disc degeneration with the 10-year CSAs changes and muscle fat infiltration were examined by Poisson regression analysis. The mean CSAs of all index muscles increased significantly. Exercise habit was associated with increased CSAs of the erector spinae muscles and the total area of the extensor muscles. The cross-section mean luminance increased significantly from baseline, indicating a significant increase of fat infiltration in the posterior extensor muscles. Progression of disc degeneration was negatively associated with the increase of fat infiltration in the total extensor muscles.

Introduction

The posterior extensor muscles of the thoracic spine help maintain sagittal alignment and facilitate spinal motion, including dorsiflexion and rotation of the thoracic spine.^{1,2} Dysfunction or atrophy of these muscles can result in malalignment of the thoracic spine and a reduced range of motion, significantly affecting activities of daily living.^{3,4} Sasaki⁵ conducted a cross-sectional study that measured the cross-sectional area (CSAs) of thoracic paraspinal muscles in asymptomatic populations using axial T2-weighted magnetic resonance imaging (MRI). The CSAs of the erector spinae, multifidus, and psoas muscles were found to be generally larger in males than in females and decreased with age. Fat infiltration of the posterior extensor muscles is generally higher in females than in males and has been reported to be associated with disuse, altered leptin signaling, sex steroid deficiency, and exposure to glucocorticoids.^{6,7} Although several studies have reported age-related changes in the posterior extensor muscles of the cervical and lumbar spines,^{8–14} longitudinal changes in the thoracic spine of healthy subjects have not been reported. The present study aimed to evaluate the 10-year longitudinal changes in the CSAs of the thoracic posterior extensor muscles by MRI and to investigate whether these changes were related to clinical symptoms and lifestyle habits.

Methods

Ethical statement

This study was approved by the ethics committee of Keio University School of Medicine (approval number 20150050), and written informed consent was obtained from all participants. Experiments were conducted in accordance with the Ministry of Education, Culture, Sports, Science and Technology of Japan, and Ministry of Health, Labor and Welfare of Japan guidelines.

Subjects

The present study, which examines the 10-year longitudinal changes of the thoracic paravertebral muscles, was conducted as part of a 20-year longitudinal MRI study of the cervical spine.⁸⁻¹² (Fig. 1). Whole-spine MRI images were obtained from a total of 223 asymptomatic subjects during the period from 2005 to 2007 in the initial study. For this study, we contacted the original subjects by mail and requested their participation in a 10-year follow-up study taking place between 2015 and 2017. Among the 223 original subjects, 103 agreed to participate in the present study (follow-up rate of 46.2%), and MRI as well as physical examinations were conducted at eight of the original 11 participating institutions. The omission of required imaging sequences or the lack of image quality that allowed for clear visualization of the borders of the posterior extensor muscle led to the exclusion of 16 cases, leaving 85 cases as the subjects of this study (final follow-up rate of 38.1%) (Fig. 1).

There were 50 male and 35 female subjects, with a mean age of 44.8 ± 11.5 years at the initial study conducted 10 years ago (distribution shown in Table 1) and a mean interval of 9.9 ± 0.8 years between the MRI studies. All subjects filled questionnaires related to clinical symptoms and lifestyle habits and underwent physical examinations by spine surgeons.

MRI Examination

In the initial study, MRI were acquired using a 1.5-Tesla (T) (SIGNA Excite HD 1.5 T, General Electronic, WI, USA) superconducting MRI scanner, using the imaging protocol detailed in our earlier report.⁹ In the present study, at one principal institution, where about half of the subjects in this study underwent MRI, the MR images were taken by a fast spin-echo technique using a 1.5 T superconducting scanner and phased array coils (Excelart Vantage, TOSHIBA) with the following sequence: a T2-weighted axial images (TR/ TE, 3600/120; ETL, 23; 4-mm slice thickness; FOV 16 cm; matrix size, 256×192 ; number of excitations NEX, 2). At the other institutions, basically the same protocol was used as at the principal institution, i.e., a fast spin-echo sequence was employed. T2-weighted axial images parallel to each vertebral discs were analyzed in this study.

Measurements of Paraspinal Muscle Cross-sectional Area

The CSAs of the transversospinalis muscles (rotatores, multifidus, semispinalis), erector spinae muscles (spinalis, longissimus, iliocostalis), and total extensor muscles at each thoracic intervertebral level were measured on T2-weighted axial images after scale calibration. Using Image J 1.52a, a Java-based version of the public domain NIH software, the fascial border of each muscle was manually traced (Fig. 2), yielding the area of the muscle cross section. Each measurement was taken twice, and the values were averaged.

The measurements for each thoracic intervertebral level from T1/2 to T11/12 were compared between the initial and 10-year follow-up MRI studies. The change in muscle CSAs was calculated as follows:

CSAs change (%) = (CSAs at follow-up – CSAs at initial study) / CSAs at initial study x 100.

Evaluation of Fat Infiltration of the Muscle

The degree of fat infiltration was evaluated by the luminance of the cross section of each extensor muscle group at each thoracic intervertebral level, using the luminance of pure muscle tissue as reference. Since the luminance of fat tissue is higher than muscle, increased fat infiltration of muscle will be reflected as increased luminance. Fat infiltration rate was calculated as follows:

Fat infiltration rate (%) = luminance in CSAs of whole muscle / luminance in pure muscle luminance x 100.^{15,16}

The changes in the fat infiltration rate were compared between the initial and follow-up study.

Evaluation of Intervertebral Disc Degeneration

Degeneration of the intervertebral disc was evaluated based on the following five findings on MRI: (1) decrease in the signal intensity of the intervertebral discs, (2) anterior compression of the dura and the spinal cord, (3) posterior disc protrusion, (4) disc-space narrowing, and (5) foraminal stenosis. MR findings were scored with several modifications in the Matsumoto classification⁸ in Okada's study⁹. The scoring system for the different MR findings is shown in Supplement 1. An increase of at least 1 grade in any intervertebral level was considered to be the progress of degeneration.

Two experienced neuroradiologists blinded to the subjects independently read the MRI images and graded the intervertebral discs. The final results used the findings of one of the two neuroradiologists. The interobserver reliability was good to excellent, as reported previously.¹¹

Statistical Analysis

Student's *t*-tests were used to compare the mean CSAs of the study muscles in the initial study with those in the 10-year follow-up study. A Poisson regression analysis was applied to evaluate the associations of age, sex, medical history, lifestyle, and disc degeneration with the changes in posterior extensor muscle CSAs and luminance.

A *P*-value of < 0.05 was considered to be indicative of statistical significance. All statistical analyses were performed using Dr. SPSS for Windows (SPSS Japan Inc., Tokyo, Japan) and Stata15 for Windows (Stata Corporation, College Station, TX, USA).

For the interobserver error assessment, 20 randomly chosen MR images were measured independently by the first investigator (H.U.) and second investigator (H.I.). For the intraobserver error assessment, 20 images were randomly selected, and the images were measured two times with an interval of 3 months. The values measured by the first investigator (H.U.) were used for this study.

Results

Changes in Cross-Sectional Area Over 10 Years

The mean CSAs of the transversospinalis muscles, erector spinae muscles, and combined extensor muscles significantly increased over 10 years, from $557 \pm 105 \text{ mm}^2$ to $609 \pm 119 \text{ mm}^2$, from $873 \pm 225 \text{ mm}^2$ to $934 \pm 234 \text{ mm}^2$, and from $1430 \pm 321 \text{ mm}^2$ to $1543 \pm 342 \text{ mm}^2$, respectively. The CSAs of each muscle group separately or combined significantly increased over 10 years at all intervertebral levels from T1/2 to T11/12 (Figs. 3).

Regarding the intraobserver error, the estimated intraclass correlation was 0.90, and the interobserver error was 0.87. Therefore, there was good agreement between these independent findings.

Factors Associated with Changes in the Cross-Sectional Areas of the Muscles

Univariate analysis showed that exercise performed at least once a week was significantly associated with the changes in the CSAs of the erector spinae muscles and combined extensor muscles. Age, sex, smoking, alcohol, obesity, and progression of disc degeneration were not significantly associated with CSAs changes (Table 2). The clinical symptoms (low back pain, neck pain, stiff shoulder), smoking, drinking, obesity, or progression of disc degeneration were not significantly associated with CSAs changes (Table 2). After adjusting for age and sex, we found that age and exercise habits were significantly associated with increased CSAs of the erector spinae muscles and combined extensor muscles. The relative risks (RRs) of age over 40 years old for increased CSAs was 0.8 (95% CI: 0.7-1.0) in combined extensor muscles, and exercise habits for the increase in CSAs were 1.4 (95% CI: 1.1–1.7) for the erector spinae muscles, and 1.3 (95% CI: 1.1–1.5) for the combined extensor muscles (Table 3).

Factors Associated with Changes in Fat Infiltration of Total muscles over 10 Years

The mean luminance of the posterior extensor muscles significantly increased from 121% in the initial study to 154% in the follow-up study. Univariate analysis revealed that the progression of disc degeneration was significantly associated with the changes in luminance over 10 years with an RR of 0.5 (95% CI: 0.3–0.96). (Table 4). The multivariable model that included factors such as age, sex, and exercise habit revealed that progression of disc degeneration was negatively associated with increased luminance, with an RR of 0.5 (95% CI: 0.3–0.97) (Table 5).

Discussion

Changes in the Cross-Sectional Areas of the Posterior Extensor Muscles over 10 Years

In this 10-year longitudinal study, the CSAs of the posterior extensor muscles of the thoracic spine, including the transversospinalis muscles and erector spinae muscles, both separately and combined, significantly increased over 10 years at all intervertebral levels. Regarding the cervical spine, Okada reported that the CSAs of posterior extensor muscles in the cervical spine increased in patients in their

teens up to 40 years old, but began to decrease after that.⁹ Kennis conducted a 9.5-year longitudinal study using dual-energy X-ray absorptiometry and reported that whole-body muscle mass in middle-aged (35–39 years) men significantly increased.¹⁷ In a study measuring skeletal muscle mass in 433 volunteers, Kyle reported that appendicular skeletal muscle mass peaked between the ages of 35 and 59 years in men, suggesting that age-associated muscle atrophy starts in the fifth or sixth decades.¹⁸ In the present study, the average age of the participants was 45 years, with 73% of participants under the age of 50 in the initial study, and the proportion of males was 59% (Table 1). The participants' background was one of the factors explaining the overall increase in the mean CSAs found in the study.

Factors Associated with the Changes in the Cross-Sectional Areas of Muscles

Age of over 40 years old was a significant factor associated with the decrease in the CSAs of the posterior extensor muscles. As mentioned previously, Okada et al. reported that the cross-sectional area of the posterior extensor of the cervical spine increased in their tens to thirties and decreased in the forties and older.⁹ And Cohn reported that an age-related decrease in muscle volume starts in the fifth or sixth decade of life.¹⁹

In addition to age, exercising at least once a week at the time of follow up was also a significant factor associated with the increase in the CSAs of the posterior extensor muscles. Several studies have reported increased muscle mass with exercise.^{20–25} Franchi measured the CSAs of femur muscles in healthy subjects using MRI and reported a significant increase with exercise.²¹ In a study of exercise and low back pain, Ko reported that exercise significantly increased the muscle strength of the posterior extensor muscles of the lower back.²⁰ Nutrition has also been reported to affect muscle mass,^{22–25} but the present study did not collect information about nutrition status.

Factors Associated with Changes in Fat Infiltration of Total muscles over 10 Years

In the present study, we compared the luminance of a muscle's cross section to the luminance of pure muscle to evaluate fat infiltration. The method used was previously reported by Fischer and Mengirardi, who evaluated the fat infiltration of muscle with magnetic resonance spectroscopy (MRS)^{15,16} by comparing the luminance of the entire muscle to a section of muscle without fatty degeneration. By analyzing the spectroscopy graphs, this method enables separate quantification of muscle intracellular and extracellular fat. In this study, the progression of disc degeneration was negatively associated with the increase of fat infiltration in the muscles, with a relative risk of 0.5, making it unlikely that disc degeneration promotes fat infiltration in the thoracic extensor muscles.

Study Limitations

There are several limitations in this study that should be considered when interpreting our results. First, we measured muscle volumes only on T2-weighted axial images because axial images were acquired only with a T2-weighted pulse sequence in the initial trial protocol. Previous reports have investigated

muscle structure by using T1-weighted^{26–29} or T2-weighted^{30–32} images, and the superiority of either sequence in illustrating the muscle structure has remained controversial. Second, in this study, 1.5-T superconducting imagers and a fast spin-echo sequence were used. However, the types of MR imagers and software were not identical between the two testing periods, which might have resulted in some differences in the quality of images between the initial and follow-up MRI. However, the estimated intraclass correlation between the two investigators that was performed to assess the reliability and reproducibility of the measurements, showed good agreement. Third, the number of subjects included in this study was relatively small, and there was bias in the sex and age distribution of the population.

Nonetheless, we are not aware of any longitudinal studies evaluating the changes in the posterior extensor muscles of the thoracic spine in healthy individuals. More attention has been focused on the thoracic extensor muscles in patients after spinal fusion³³ or thoracic spine trauma.¹¹ The age-related changes in posterior extensor muscles described in this study can serve as a reference for changes in thoracic extensor muscles in association with various thoracic spinal disorders or with non-surgical and surgical treatments for these disorders.

Conclusion

The thoracic posterior extensor muscles of the subjects in this study showed an increase in CSAs over 10 years. Exercise habit influenced the change in CSAs of the erector spinae muscles and the combined extensor muscles. In addition, fat infiltration into the thoracic posterior extensor muscles increased significantly over 10 years. The results of this study could be useful information for understanding the effect of age on the posterior extensor muscles in the thoracic spine.

Declarations

Author contributions

H.U., M.M., K.W. conceived the study. H.U., K.D., E.O., K.N., M.W., H.K., K.S., H.I., N.F., T.T., M.N. performed data collection. H.U., H.F., rated the images. H.U., Y.N., T.M. analyzed the results. All authors reviewed the manuscript.

References

1. Bogduk, N. & Macintosh, J. E. The applied anatomy of the thoracolumbar fascia. *Spine*. 9, 164-170 (1984).
2. Willard, F. H., Vleeming, A., Schuenke, M. D., Danneels, L. & Schleip, R. The thoracolumbar fascia: anatomy, function and clinical considerations. *J. Anat.* 221, 507-536 (2012).
3. Kasukawa, Y. *et al.* Age-related changes in muscle strength and spinal kyphosis angles in an elderly Japanese population. *Clin. Interv. Aging*. 12, 413-420 (2017).

4. Hu, Z. *et al.* 2020 Young investigator award winner: Age- and sex-related normative value of whole-body sagittal alignment based on 584 asymptomatic Chinese adult population from age 20 to 89. *Spine*. 45, 79-87 (2020).
5. Sasaki, T. *et al.* MRI defined paraspinal muscle morphology in Japanese population: The Wakayama Spine Study. *PLOS. ONE*. 12, e0187765; 10.1371/journal.pone.0187765 (2017).
6. Hamrick, M.W., McGee-Lawrence, M. E. & Frechette, D. M. Fatty Infiltration of Skeletal Muscle: Mechanisms and Comparisons with Bone Marrow Adiposity. *Front Endocrinol*. 7, 69; 10.3389/fendo.2016.00069 (2016).
7. Urrutia, J. *et al.* Lumbar paraspinal muscle fat infiltration is independently associated with sex, age, and inter-vertebral disc degeneration in symptomatic patients. *Skeletal Radiol*. 47, 955-961 (2018).
8. Matsumoto, M. *et al.* MRI of cervical intervertebral discs in asymptomatic subjects. *J. Bone Joint Surg. Br*. 80, 19-24 (1998).
9. Okada, E. *et al.* Cross-sectional area of posterior extensor muscles of the cervical spine in asymptomatic subjects: A 10-year longitudinal magnetic resonance imaging study. *Eur. Spine J*. 20, 1567-1573 (2011).
10. Daimon, K. *et al.* A 20-year prospective longitudinal MRI study of degeneration of the cervical spine in a volunteer cohort assessed using MRI: Follow-up of a cross-sectional study. *J. Bone Joint Surg. Am*. 100, 843-849 (2018).
11. Ichihara, D. *et al.* Longitudinal magnetic resonance imaging study on whiplash injury patients: Minimum 10-year follow-up. *J. Orthop. Sci*. 14, 602-610 (2009).
12. Gore, D. R. Roentgenographic findings in the cervical spine in asymptomatic persons: A ten-year follow-up. *Spine*. 26, 2463-2466 (2001).
13. Gore, D. R., Sepic, S. B. & Gardner, G. M. Roentgenographic findings of the cervical spine in asymptomatic people. *Spine*. 11, 521-524 (1986).
14. Lehto, I. J. *et al.* Age-related MRI changes at 0.1 T in cervical discs in asymptomatic subjects. *Neuroradiology*. 36, 49-53 (1994).
15. Fischer, M. A. *et al.* Quantification of muscle fat in patients with low back pain: comparison of multi-echo MR imaging with single-voxel MR spectroscopy. *Radiology*. 266, 555-563 (2013).
16. Mengiardi, B. *et al.* Fat content of lumbar paraspinal muscles in patients with chronic low back pain and asymptomatic volunteers: quantification with MR spectroscopy. *Radiology*. 240, 786-792 (2006).
17. Kennis, E. *et al.* Longitudinal impact of aging on muscle quality in middle-aged men. *Age*. 36, 9689; 10.1007/s11357-014-9689-1 (2014).
18. Kyle, U. G. *et al.* Age-related differences in fat-free mass, skeletal muscle, body cell mass and fat mass between 18 and 94 years. *Eur. J. Clin. Nutr*. 55, 663-672 (2001).
19. Cohn, S. H. *et al.* Compartmental body composition based on total-body nitrogen, potassium, and calcium. *Am. J. Physiol*. 239, 524-530 (1980).

20. Ko, K. J., Ha, G. C., Yook, Y. S. & Kang, S. J. Effects of 12-week lumbar stabilization exercise and sling exercise on lumbosacral region angle, lumbar muscle strength, and pain scale of patients with chronic low back pain. *J. Phys. Ther. Sci.* 30, 18-22 (2018).
21. Franchi, M. V. *et al.* Muscle thickness correlates to muscle cross-sectional area in the assessment of strength training-induced hypertrophy. *Scand. J. Med. Sci. Sports.* 28, 846-853 (2018).
22. Ebeling, P. R., Cicuttini, F., Scott, D. & Jones, G. Promoting mobility and healthy aging in men: A narrative review. *Osteoporos. Int.* 30, 1911-1922 (2019).
23. Mithal, A. *et al.* Impact of nutrition on muscle mass, strength, and performance in older adults. *Osteoporos. Int.* 24, 1555-1566 (2013).
24. Beaudart, C. *et al.* Effects of protein, essential amino acids, B-hydroxy B-methylbutyrate, creatine, dehydroepiandrosterone and fatty acid supplementation on muscle mass, muscle strength and physical performance in older people aged 60 years and over. A systematic review of the literature. *J. Nutr. Health Aging.* 22, 117-130 (2018).
25. Denison, H. J., Cooper, C., Sayer, A. A. & Robinson, S. M. Prevention and optimal management of sarcopenia: a review of combined exercise and nutrition interventions to improve muscle outcomes in older people. *Clin. Interv. Aging.* 10, 859-869 (2015).
26. Elliott, J. *et al.* Fatty infiltration in the cervical extensor muscles in persistent whiplash-associated disorders: A magnetic resonance imaging analysis. *Spine.* 31, E847-855 (2006).
27. Elliott, J. M., Jull, G. A., Noteboom, J. T., Durbridge, G. L. & Gibbon, W. W. Magnetic resonance imaging study of cross-sectional area of the cervical extensor musculature in an asymptomatic cohort. *Clin. Anat.* 20, 35-40 (2007).
28. Elliott, J. M., Jull, G. A., Noteboom, J. T. & Gibbon, W. W. MRI study of the cross-sectional area for the cervical extensor musculature in patient whiplash associated disorders (WAD). *Man. Ther.* 13, 258-265 (2008).
29. Iizuka, H. *et al.* Extensor musculature of the cervical spine after laminoplasty: morphologic evaluation by coronal view of the magnetic resonance image. *Spine.* 26, 2220-2226 (2001).
30. Parkkola, R., Rytokoski, U. & Kormano, M. Magnetic resonance imaging of the discs and trunk muscles in patients with chronic low back pain and healthy control subjects. *Spine.* 18, 830-836 (1993).
31. Cagnie, B., D'Hooge, R., Achten, E., Cambier, D. & Danneels, L. A magnetic resonance imaging investigation into the function of the deep cervical flexors during the performance of craniocervical flexion. *J. Manipulative Physiol. Ther.* 33, 286-291 (2010).
32. Conley, M. S., Meyer, R. A., Bloomberg, J. J., Feedback, D. L. & Dudley, G. A. Noninvasive analysis of human neck muscle function. *Spine.* 20, 2505-2512 (1995).
33. Matsumoto, M. *et al.* Changes in the cross-sectional area of deep posterior extensor muscles of the cervical spine after anterior decompression and fusion: 10-year follow-up study using MRI. *Eur. Spine J.* 21, 304-308 (2012).

Tables

Table 1
Profiles of 85 subjects.

Mean age (years)	44.8 ± 11.5
Age distribution (%)	Number (%)
≤ 20–29	6 (7.1)
30–39	28 (32.9)
40–49	28 (32.9)
50–59	11 (13.0)
≥ 60	12 (14.1)
Sex (%)	
Male	50 (58.9)
Female	35 (41.1)
Body mass index (%)	
<25	65 (76.5)
≥25	20 (23.5)

Table 2

Relationship between changes in the rate of increased CSAs and factors tested by univariate analyses.

	Transversospinalis muscles		Erector spinae muscles		Total muscles	
	Relative Risk (95% CI)	<i>P</i> - value	Relative Risk (95% CI)	<i>P</i> - value	Relative Risk (95% CI)	<i>P</i> - value
Age (years)	0.9 (0.8–1.1)	.23	0.8 (0.7–1.0)	.10	0.8 (0.7–1.0)	.06
Sex	1.2 (1.0–1.4)	.051	1.2 (0.9–1.4)	.23	1.1 (0.9–1.3)	.49
Exercise habit	1.1 (0.9–1.3)	.30	1.3 (1.1–1.7)	< 0.01*	1.2 (1.0–1.5)	.02*
Body mass index (kg/m ²)	1.1 (1.0–1.3)	.08	0.9 (0.7–1.2)	.48	1.0 (0.8–1.2)	.76
Disc degeneration	1.0 (0.8–1.2)	.88	0.9 (0.7–1.2)	.56	0.9 (0.8–1.1)	.42
Smoking	0.9 (0.7–1.3)	.71	0.9 (0.6–1.4)	.77	1.0 (0.7–1.3)	.96
Alcohol	0.9 (0.8–1.1)	.43	1.2 (0.9–1.5)	.26	1.0 (0.8–1.2)	.76
Clinical symptoms						
Low back pain	1.0 (0.9–1.2)	.60	0.9 (0.7–1.1)	.32	0.9 (0.8–1.2)	.58
Neck pain	1.1 (1.0–1.3)	.15	1.1 (0.8–1.4)	.48	1.1 (0.9–1.3)	.42
Stiff shoulder	1.1 (0.9–1.3)	.30	1.0 (0.8–1.3)	.83	1.1 (0.9–1.4)	.24
An asterisk indicates statistical significance						
95% CI/95%: confidence interval						

Table 3

Relationship between changes in the rate of increased CSAs and factors tested by Poisson analyses.

	Transversospinalis muscles		Erector spinae muscles		Total muscles	
	Relative Risk (95% CI)	<i>P</i> -value	Relative Risk (95% CI)	<i>P</i> -value	Relative Risk (95% CI)	<i>P</i> -value
Age (years)	0.9 (0.8–1.1)	.21	0.8 (0.6–1.0)	0.07	0.8 (0.7–1.0)	.048*
Sex	1.2 (1.0–1.4)	.04*	1.2 (0.9–1.5)	0.14	1.1 (0.9–1.3)	.36
Exercise habit	1.1 (0.1–1.2)	.23	1.4 (1.1–1.7)	< 0.01*	1.3 (1.1–1.5)	.01*
An asterisk indicates statistical significance						
95% CI/95%: confidence interval						

Table 4

Relationship between changes in the luminance of increased CSAs and factors tested by univariate analyses.

	Relative Risk (95% CI)	<i>P</i>-value
Age (years)	1.2 (0.6–2.1)	.65
Sex	1.0 (0.5–1.7)	.87
Body mass index (kg/m ²)	0.8 (0.4–1.7)	.59
Exercise habit	1.0 (0.5–1.8)	.89
Smoking	1.0 (0.4–2.4)	.94
Alcohol	0.9 (0.5–1.6)	.67
Disc degeneration	0.5 (0.3–0.96)	.04*
Clinical symptoms		
Low back pain	1.0 (0.6–1.8)	1
Neck pain	0.8 (0.4–1.8)	.59
Stiff shoulder	1.0 (0.6–1.8)	.96
An asterisk indicates statistical significance		
95% CI/95%: confidence interval		

Table 5
Relationship between changes in the luminance of increased CSAs and factors tested by Poisson regression analyses.

	Relative Risk (95% CI)	P value
Age (years)	1.1 (0.6–2.0)	.72
Sex	1.0 (0.6–1.8)	1.0
Exercise habit	1.0 (0.5–1.7)	.9
Disc degeneration	0.5 (0.3–0.97)	.04*
An asterisk indicates statistical significance		
95% CI/95%: confidence interval		

Figures

Figure 1

Study design. This study evaluated the 10-year longitudinal changes of the paravertebral muscles in the thoracic spine and was conducted as part of a 20-year longitudinal study of the cervical spine.

Figure 2

Posterior extensor muscles visualized on an axial T2-weighted image. The cross-sectional area of the transversospinalis muscles (a, rotatores; b, multifidus; c, semispinalis), erector spinae muscles (d, spinalis; e, longissimus; f, iliocostalis) were measured by using the calibrated scale on the MR images.

Figure 3

The cross-sectional areas of the total posterior extensor muscles at each intervertebral disc level. The cross-sectional areas of the total posterior extensor muscles significantly increased over 10 years at all levels from T1/2 to T11/12.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryFile1.pdf](#)