Cross-sectional area of posterior extensor muscles of the cervical spine in asymptomatic subjects: a 10-year longitudinal magnetic resonance imaging study

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Abstract There has been no prospective study on age-related changes of the extensor muscles of the cervical spine in healthy subjects. This study was conducted to elucidate any association between the changes in cross-sectional area of the extensor muscles of the cervical spine on MRIs and cervical disc degeneration or the development of clinical symptoms. Sixty-two subjects who underwent MR imaging by a 1.5-Tesla machine between 1993 and 1996 as asymptomatic volunteers in a previous study were recruited again 10 years later for this follow-up study. The mean interval between the studies was 11.0 ± 0.7 years. The cross-sectional areas of the multifidus, semispinalis cervicis, semispinalis capitis, and splenius capitis at C3–C4, C4–C5, and C5–C6 intervertebral levels were measured on T2-weighted axial images using Image J 1.42. The mean cross-sectional areas of the deep extensor muscles were $1,396.8 \pm 337.6 \text{ mm}^2$ at the C3–C4 level, $1,514.7 \pm 381.0 \text{ mm}^2$ at the C4–C5 level, and $1,542.8 \pm 373.5 \text{ mm}^2$ at the C5–C6 level in the previous investigation. The cross-sectional areas were

$1,498.7 \pm 374.4 \text{ mm}^2$ at the C3–C4 level, $1,569.9 \pm 390.9 \text{ mm}^2$ at the C4–C5 level, and $1,599.6 \pm 364.3 \text{ mm}^2$ at the 10-year follow-up. An increase in the cross-sectional area of the muscles was more frequently observed in subjects in their tens to thirties in the initial study, while a decrease was more frequently observed in those in their forties and older in the initial study. Disc degeneration was not correlated with a change in extensor muscle volume. Development of shoulder stiffness during follow-up was significantly negatively correlated with a change in the cross-sectional area of the deep extensor muscles.

Keywords Extensor muscle · Cervical spine · Longitudinal study · Magnetic resonance imaging (MRI) · Asymptomatic subjects

Background

The posterior extensor muscles of the cervical spine help stabilize the head, maintain the alignment of the cervical spine, and function in neck motion [13]. Dysfunction of these muscles may result in neck pain, cervical malalignment, and a reduced range of motion. Panjabi et al. [26] estimated that the neck musculature contributes about 80% to the mechanical stability of the cervical spine, and the osseoligamentous system contributes the remaining 20%.

As reported by Larsson [20], the total volume and strength of muscles tend to decrease with age. This may be true as well in the posterior extensor muscles of the cervical spine. Although several studies report age-related changes of the cervical spine [11, 12, 21, 22, 24], most of them have focused on aging of the intervertebral discs, but few report on age-related changes in the posterior extensor muscles of the cervical spine. Elliott et al. [8] measured the

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cross-sectional area of the cervical extensor musculature with a reliable MRI in an asymptomatic population. Their report primarily demonstrated the quantitative assessment of extensor muscles by using MRI data. However, that study included only females and used MRIs taken only at a single time point. As yet, there has been no prospective study on age-related changes of the extensor muscle of the cervical spine in healthy subjects although such a study would be helpful in correlating such changes with the development of clinical symptoms.

The present study was conducted to evaluate age-related changes in the volume of the posterior extensor muscles of the cervical spine using MRI data obtained at two time points and to elucidate any association between the cross-sectional area of the posterior extensor muscles and the development of clinical symptoms.

Subjects and methods

This study was conducted as a part of the 10-year prospective longitudinal study on age-related changes of the cervical spine in which 223 originally asymptomatic volunteers underwent MRI examination of the cervical spine twice between 1993 and 1996 for the first time and between 2004 and 2006 for the follow-up study [24]. Inclusion criteria for the present study were as follows: (1) subjects should undergo MRI in the same institution, (2) 1.5 Tesla superconducting MR machines should be used both in the initial and in the follow-up study, and (3) MR images should be clear enough to visualize the borders of the posterior extensor muscles of the cervical spine. Of the 223 asymptomatic volunteers, 161 subjects were excluded from the analysis, thereby providing the study population of 62 volunteers (Table 1). There were 24 males and 38 females, whose mean age was 37.3 ± 12.6 years at the time of the initial study. Age at the initial investigation was regarded as their individual age in this study. The mean time interval between the studies was 11.0 ± 0.7 years. This study was approved by the institutional review board, and informed consent was obtained from all participants. All subjects filled out questionnaires on symptoms related to the cervical spine and underwent physical examinations. Clinical symptoms observed at the second investigation were recorded. Stiff shoulder was defined as “myotonia, heaviness, and dull pain in the cervical to scapular regions,” according to the definition proposed by Takagishi et al. [25, 32]. The subjects were divided into subgroups according to the results of the questionnaires as smoking (subjects who had had a smoking habit during the prior 10-year period) or non-smoking; obese [body mass index (BMI) of 25 or more] or non-obese (BMI less than 25). The sagittal alignment of the cervical spine in the neutral

position on a lateral radiograph was classified as the lordosis or non-lordosis type, with the latter group including straight and sigmoid spines and kyphosis, according to the classification reported by Chiba et al. [4] (Fig. 1).

A 1.5-Tesla (T) superconducting imager was used for all subjects in the previous and the present imaging studies. The earlier imaging used a 1.5 T (Signa, General Electronic, WI, USA) superconducting imager and phased array coils, and a fast spin-echo technique with the following sequences: a T2-weighted sagittal image [repetition time (TR)/echo time (TE), 5000/102; echo train length, 16; thickness of slice, 5 mm; field of view (FOV), 24 cm; matrix size, 256×192 ; number of excitation (NEX), 4 times], and T2-weighted axial images (same as for the sagittal, except for the FOV, which was 16 cm). In the present investigation, all the images were taken by a fast spin-echo technique using a 1.5-T superconducting imager (Signa Excite HD 1.5 T, General Electronic, WI, USA) with the following sequences: T1-weighted sagittal images (TR/TE, 380/8.2; echo train length, 2), T2-weighted sagittal images (TR/TE, 5000/100; echo train length, 16; NEX, 3 times; thickness of slice, 4 mm; FOV, 24 cm; matrix size, 256×192 ; NEX, 3 times), and T2-weighted axial images (the same as for the sagittal images except for the following: TR/TE, 5000/102; thickness of slice, 5 mm; FOV, 16 cm). The axial images were positioned parallel to each intervertebral disc.

Fig. 1 Sagittal alignment of the cervical spine. A line (“A”) was drawn between the lower posterior corners of C2 and C7. Perpendicular lines were drawn from the lower posterior edge of the bodies of C3–C6 to this line, and their lengths were denoted as a1–a4. If every line a1–a4 was anterior to “A” and one was more than 2 mm, the curvature was defined as lordosis. If every line a1–a4 was less than 2 mm, the curvature was defined as straight. If a1–a4 was measurable both anterior and posterior to “A,” and one was more than 2 mm, the curvature was defined as sigmoid. If every line a1–a4 was posterior to “A” and one was more than 2 mm, the curvature was defined as kyphosis

Table 1 Profiles of 62 subjects

Mean age	37.3 ± 12.6 (19–65)
Age distribution (%)	
10–19	2 (3.2)
20–29	23 (37.1)
30–39	13 (21.0)
40–49	11 (17.7)
>50	13 (20.9)
Gender (%)	
Male	38 (61.3)
Female	24 (38.7)
Smoking (%)	
Smoking habit during the prior 10-year period	51 (82.3)
Others	11 (17.7)
BMI (%)	
<25	48 (77.4)
>25	14 (22.6)

The cross-sectional areas of the multifidus, semispinalis cervicis, semispinalis capitis, and splenius capitis at the C3–C4, C4–C5, and C5–C6 intervertebral levels were measured on T2-weighted axial images using Image J 1.42, a Java-based version of the public domain NIH Image software. Measurements at the other levels were not conducted because axial images had not been obtained for many of the subjects in the previous study. Measurements of the cross-sectional areas were conducted by one investigator (E.O.), who manually traced the defined region of interest within the fascial border of each muscle, bilaterally, on the T2-weighted images (Fig. 2). The measurement was repeated twice, and the results were averaged. To assess the intra- and interobserver error, 20 randomly chosen MR images were measured independently by the first investigator and again by a second investigator (D.I.).

Changes in the area of the muscles were defined as follows: increase, 10% larger in the cross-sectional area at the follow-up than in the previous investigation; decrease, 10% smaller; and unchanged, a change of 0–10%. Intervertebral disc degeneration was evaluated based on the following five MR findings: (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. The cervical intervertebral levels evaluated for disc degeneration included all levels from C2–C3 to C7–T1. To rate the MR findings, we used Matsumoto's classification [22], which was also used in the previous investigation, with a minor modification. The scoring system for the different MR findings is shown in Table 2.

Fig. 2 Posterior extensor muscles, visualized on an axial T2-weighted image at the C5–C6 level. The cross-sectional area of the *a* multifidus, *b* semispinalis cervicis, *c* semispinalis capitis, and *d* splenius capitis was measured using Image J 1.42 software, calibrated to the scale of the MR image

An increase of at least one grade in one or more intervertebral levels was regarded as the progression of degeneration.

Two experienced neuroradiologists, who were blinded to the identity of the subjects, independently read the MRI films 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 [24].

The statistical analysis was conducted using the Spearman's rank correlation coefficients test, Student's *t* test, and logistic regression analysis. Correlations between changes in the area of posterior extensor muscles and progression of intervertebral disc were evaluated by Spearman's rank correlation coefficients test. Student's *t* test was used to evaluate the association between the changes in cross-sectional area of posterior extensor muscles and the clinical symptoms of neck pain, stiff shoulders, and numbness in the upper extremities. The logistic regression analysis with the independent variables of age, gender, smoking, BMI, and cervical alignment was used to assess the association between increased cross-sectional area and lifetime habits. Intra-class correlation was used to assess the intra-observer and inter-observer error.

A *p* value less than 0.05 was considered statistically significant. All statistical analyses were performed using a statistical package, Dr. SPSS II for Windows (SPSS Japan Inc., Tokyo).

Results

The mean cross-sectional area of the multifidus was the smallest among the posterior extensor muscles at all

Table 2 Grading system for MR evaluation

1. Decrease in signal intensity of intervertebral disc
Grade 0: as bright as or slightly less bright than cerebrospinal fluid
Grade 1: Markedly darker than cerebrospinal fluid
Grade 2: no signal
2. Anterior compression of dura and spinal cord
Grade 0: no compression.
Grade 1: compression on dural sac only
Grade 2: compression on less than one-third of spinal cord
Grade 3: compression on more than one-third and less than two-thirds of spinal cord
Grade 4: compression on more than two-thirds of spinal cord
3. Posterior disc protrusion
Grade 0: no protrusion
Grade 1: disc material protruding beyond the posterior margin of the vertebral body without cord compression
Grade 2: beyond vertebral body with cord compression
4. Disc space narrowing
Grade 0: 100–75% of height of upper healthy disc
Grade 1: 75–50% of height of upper healthy disc
Grade 2: less than 50% of height of upper healthy disc
5. Foraminal stenosis
Grade 0: no stenosis
Grade 1: foraminal stenosis

intervertebral levels in both the previous and present studies, whereas the mean cross-sectional area of the semispinalis capitis and splenius capitis tended to be the largest at all intervertebral levels. The cross-sectional area of each posterior extensor muscle was largest at C5–C6. The mean cross-sectional areas of the posterior extensor muscles at the previous investigation were $1,396.8 \pm 337.6 \text{ mm}^2$ at the C3–C4 level, $1,514.7 \pm 381.0 \text{ mm}^2$ at C4–C5, and $1,542.8 \pm 373.5 \text{ mm}^2$ at C5–C6. At the 10-year follow-up, they were $1,498.7 \pm 374.4 \text{ mm}^2$ at the C3–C4 level, $1,569.9 \pm 390.9 \text{ mm}^2$ at C4–C5, and $1,599.6 \pm 364.3 \text{ mm}^2$ at C5–C6 (Table 3).

An increase in the total cross-sectional area of the extensor muscles was more frequently observed in subjects in their tens to thirties in the initial study, while a decrease was more frequently observed in those in their forties and older in the initial study (Fig. 3). The number of degenerated discs and total cross-sectional area of posterior extensor muscles were not significantly correlated with each other [Spearman rank correlation coefficients; -0.018 (N.S.)].

The development of stiff shoulders during the 10-year interval between the studies was significantly negatively correlated with an increase in the cross-sectional area of the semispinalis cervicis ($p = 0.026$). No significant correlation was observed between changes in the cross-sectional area of any muscles and neck pain or numbness in the upper limbs (Table 4).

Logistic regression analysis revealed that the increase in the cross-sectional areas of the posterior extensor muscles was significantly higher in males ($p = 0.047$), but there were no significant associations between changes in the cross-sectional areas and smoking, BMI, or cervical alignment (Table 5).

For intra-observer error, the estimated intra-class correlation was 0.900, and it was 0.844 for the inter-observer error. Therefore, the independent findings showed good agreement.

Discussion

In this longitudinal study, the cross-sectional area of the posterior extensor muscles of the cervical spine increased in individuals into their forties in the initial study and slowly decreased thereafter. This finding is consistent with an earlier study by Cohn [5] reporting that an age-related decrease in muscle volume starts in the fifth or sixth decade of life. Reductions in leg muscle cross-sectional area have also been observed to begin in early adulthood and to accelerate after age 50 [2].

Table 3 Cross-sectional area of the posterior extensor muscles

	Multifidus (mm^2)	Semispinalis cervicis (mm^2)	Semispinalis capitis (mm^2)	Splenius capitis (mm^2)	Total (mm^2)
Previous investigation					
C3–C4	208.5 ± 45.1	234.4 ± 50.5	479.7 ± 171.2	474.0 ± 144.8	$1,396.8 \pm 337.6$
C4–C5	257.9 ± 78.0	306.4 ± 61.6	480.4 ± 154.7	470.0 ± 158.1	$1,514.7 \pm 381.0$
C5–C6	259.3 ± 74.8	354.1 ± 89.1	431.7 ± 126.7	497.8 ± 148.8	$1,542.8 \pm 373.5$
10-year follow-up					
C3–C4	215.9 ± 55.6	234.3 ± 44.8	510.7 ± 193.5	537.8 ± 182.1	$1,498.7 \pm 374.4$
C4–C5	263.2 ± 81.1	311.5 ± 65.0	501.9 ± 152.9	493.3 ± 161.6	$1,569.9 \pm 390.9$
C5–C6	282.6 ± 79.9	358.5 ± 90.1	439.2 ± 122.6	519.2 ± 162.0	$1,599.6 \pm 364.3$

Fig. 3 Changes in the total cross-sectional area of the posterior extensor muscles by age group

The volume of the posterior extensor muscles was higher in males than in females. Frontera et al. [10], who estimated muscle mass from urinary creatinine excretion, reported that females have only 59–66% of the muscle mass of males. Janssen et al. [17] used whole-body MRI to assess the skeletal muscle in 468 males and females. They reported that males have significantly greater skeletal muscle mass than females and show a greater loss of skeletal muscle mass with aging. Thus, the higher volume of extensor muscles of the cervical spine in males than in females is likely to reflect gender-specific differences in total muscle volume.

In this study, a decrease in the cross-sectional area of posterior extensor muscles was significantly associated

Table 5 Relationship between changes in cross-sectional area and factors tested by logistic regression analyses

	<i>p</i> value	Odds ratio (95% CI)
Age	0.406	0.978 (0.928–1.030)
Gender (male)	0.047*	0.242 (0.060–0.984)
BMI	0.355	0.624 (0.229–1.696)
Smoking	0.204	3.263 (0.527–20.196)
Cervical alignment (lordosis)	0.465	0.617 (0.169–2.251)
Disc degeneration	0.737	0.963 (0.774–1.199)

An asterisk indicates statistical significance

95% CI 95% confidence interval

with the development of shoulder stiffness, which is considered to be related to dysfunction or spasm of the posterior extensor muscles of the cervical spine. The semispinalis cervicis is attached proximally to the spinous process of the C2–C5 vertebra and distally to the transverse process of the T1–T6 vertebra [29] and acts as the dynamic stabilizer of the cervical spine [23]. Recent studies revealed that preservation of the semispinalis cervicis attachment to C2 is important for reducing post-laminoplasty axial symptoms including neck and shoulder-girdle pain and maintaining sagittal alignment [15, 16, 33]. Thus, reduction in the muscle volume of semispinalis cervicis may be related to the development of shoulder stiffness although the underlying mechanism remains to be clarified by further studies.

There was no significant correlation between the number of degenerated discs and the total cross-sectional area of the posterior extensor muscles. Several studies [27, 28] have investigated the correlation between disc degeneration and muscles in the lumbar spine. Battié et al. [1] suggested that muscle strength has a greater impact on disc degeneration than any environmental factor.

The present study has several limitations. First, we measured muscle volumes only on T2-weighted axial

Table 4 Clinical symptoms and change in cross-sectional area of the cervical extensor muscles

	Neck pain			Stiff shoulder			Numbness in the upper limbs		
	No 55/62 (88.7%)	Yes 7/62 (11.3%)	<i>p</i> value	No 46/62 (74.2%)	Yes 16/62 (25.8%)	<i>p</i> value	No 57/62 (88.7%)	Yes 5/62 (11.3%)	<i>p</i> value
Multifidus	37.9 ± 111.1	21.7 ± 82.0	0.712	47.4 ± 117.8	3.5 ± 64.1	0.069	30.7 ± 102.0	96.2 ± 163.3	0.425
Semispinalis cervicis	10.9 ± 96.9	−1.9 ± 82.0	0.749	23.2 ± 104.2	−30.0 ± 68.3	0.026*	9.2 ± 88.1	12.8 ± 198.7	0.970
Semispinalis capitis	63.6 ± 246.2	30.7 ± 255.2	0.741	64.6 ± 261.1	46.2 ± 199.9	0.772	51.4 ± 235.7	156.0 ± 356.1	0.552
Splenius capitis	89.8 ± 231.3	255.9 ± 515.1	0.135	128.9 ± 308.5	49.9 ± 140.4	0.175	106.0 ± 281.2	137.8 ± 234.1	0.786

Parentheses indicate percentage

An asterisk indicates statistical significance

images because only T2-weighted pulse sequences were used for axial images in the protocol of the previous study. Previous reports have investigated the cervical musculature using T1-weighted [7–9, 15] or T2-weighted [3, 6, 28] images. However, it remains controversial which is better for the evaluation of cervical musculature. Second, in both studies, 1.5 T superconducting imagers were used, and the fast spin echo sequence was mainly used, but the types of MR imagers and softwares were not identical between the two studies, which might have resulted in some differences in the quality of images between the initial and second MRI. To minimize the impact of such differences in the image quality, large numbers of the subjects who underwent MRI using 0.5 Tesla imager in the initial study and whose MR images were poor in quality even by 1.5 T machines were excluded from this study. As a result, the estimated intra-class correlation between the two investigators, which was performed to assess reliability and reproducibility of measurements, showed good agreement. Third, the number of subjects included in this study was relatively small.

Nonetheless, this is the first longitudinal study on age-related changes in the posterior extensor muscles of the cervical spine in healthy individuals. Recently, more attention has been focused on the posterior extensor muscles of the cervical spine with regard to minimally invasive cervical spinal surgery [19, 29–31, 33, 34] and patients with cervical spinal trauma, such as whiplash injury [7, 9, 14, 18]. The age-related changes in the posterior extensor muscles described in this study can serve as a control for the assessment of changes in the posterior extensor muscles associated with various cervical spinal disorders and with non-surgical and surgical treatments for these disorders.

Conclusion

An increase in the cross-sectional area of the posterior extensor muscles was frequently observed in subjects in their tens to thirties in the initial study, while a decrease was observed in those in their forties and older in the initial study.

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