Acta Orthop. Belg., 2016, **82**, 467-473

ORIGINAL STUDY

Paraspinal muscle volume in patients with Scheuermann's Kyphosis

Radek KAISER, Eyal BEHRBALK, Petr WALDAUF, Petr REHOUSEK, Belen PEREZ, Hossein MEHDIAN

From The Center for Spinal Studies and Surgery, QMC, Nottingham University Hospitals NHS Trust, Nottingham, UK

To measure the cross-sectional area (CSA) of paraspinal muscles in Scheuermann's kyphosis patients.
Preoperative MRI images of 16 Scheuermann's kyphosis patients were analysed and compared to 16 patients with normal MRI images (control group). The CSAs were measured at L3-4 and L4-5.
Both groups showed similar demographics and patient characteristics. The multifidus muscles CSA were found to be significantly smaller at L3/4 level in Scheuermann's kyphosis patients (p = 0.022 on the left and p = 0.016 on the right side compared to control group). There was no significant change in multifidus CSA found at L4/5. The mean CSA of the extensor spinae muscles group were significantly smaller at all levels in Scheuermann's kyphosis patients : p = 0.001 bilaterally at L3/4 and p = 0.015 right side and p = 0.009 left side at L4/5 level.
This study shows that patients with Scheuermann's kyphosis deformity have significantly smaller CSA of lumbar multifidus and extensor spinae muscles.

Keywords : Scheuermann's kyphosis ; Paraspinal muscles ; Cross sectional area ; Psoas ; Multifidus ; Extensor Spinae.

INTRODUCTION

Scheuermann's kyphosis (SK) is the most common cause of thoracic and thoracolumbar structural kyphosis in adolescents (*23*). It develops slowly prior to puberty and accelerates in magnitude during the growth spurt (*22*). The diagnosis of SK is based on presence both thoracic hyperkyphosis greater than 60° and at least three consecutive vertebrae wedged 5° or more on lateral spine imaging according to Sørensen's criteria (*20*).

The prevalence of SK has been reported between 0.4-8% (*22*). Although several theories for the aetiology have been postulated, the exact cause of SK is still unknown (*23*). It has been reported that there is no correlation between the weight, height and BMI

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

■ Radek Kaiser[1,2], MD, PhD.
■ Eyal Behrbalk[2], MD.
■ Petr Waldauf[3], MD.
■ Petr Rehousek[2], MD.
■ Belen Perez[2], MD.
■ Hossein Mehdian[2], MD, MS (Orth), FRCS (Ed).

[1]*Department of Neurosurgery and Neurooncology, First Faculty of Medicine, Charles University and Military University Hospital Prague, Czech Republic.*
[2]*The Centre for Spinal Studies and Surgery, QMC, Nottingham University Hospitals NHS Trust, Nottingham, UK.*
[3]*Department of Anesthesiology and Critical Care Medicine, Third Faculty of Medicine, Charles University, Prague, Czech Republic.*

Correspondence : Radek Kaiser, MD, PhD Department of Neurosurgery and Neurooncology, First Faculty of Medicine, Charles University and Military University Hospital Prague,

and the magnitude of kyphotic curve in SK patients (*3*).

It has been stated that chronic spinal diseases (e.g. chronic back pain, degenerative kyphosis or scoliosis) are associated with atrophy of paraspinal muscles (*2,4,10,12,16,17*). MRI is considered the gold standard to assess muscle mass cross-sectional area (CSA) and density (*10*).

The aim of this study is to compare the CSA of the lumbar paraspinal muscles in SK patients with the normal population, as well as to analyse the possible relationship between the muscles CSA to the extent of thoracic kyphosis. To the best of our knowledge no previous study has documented SK patient's lumbar muscles CSA.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board. The study group consists of sixteen consecutive patients (twelve male and four female) operated on for SK between 2011 and 2013 with available whole spine sagittal MRI with axial lumbar cuts. MRI was performed to exclude neuroaxis pathologies or any compressive cord lesion prior to surgery (*9*). All patients had thoracic hyperkyphosis (mean T4–T12 Cobb angle 83.6 ± 6.1°) and at least three consecutive vertebral bodies with minimum 5° of wedging (*20*). Other than the SK deformity no other comorbidities were found. The indications for surgery in all patients were unacceptable cosmetic appearance and pain in thoracolumbar area without neurological impairment.

In the control group sixteen healthy patients with the same demographic and patient characteristics as our SKG were selected. These patients had no past history of axial or radicular pain or any chronic spinal condition. A whole spine MRI was performed for each patient. This was reported by an independent neuro-radiologist, orthopaedic and neurosurgeon spinal consultants to be without any spinal pathology.

A whole spine unsupported lateral X-rays were performed on both groups and were available for assessment.

The sagittal Cobb angle of the thoracic kyphosis (TK) was measured between the superior endplate of T4 and the inferior endplate of T12 vertebral body on standing radiograph. Similarly, the lumbar lordosis (LL) was measured between the superior endplate of L1 and the superior endplate of S1. For better visibility of the upper thoracic spine, the "Adjust contrast tool" was used in cases with poorer resolution. The radiographs were measured by 3 independent spinal surgeons who were blind to the subject status. The mean values were used for analysis.

Whole spine sagittal MRI was performed in all patients according to a standardised protocol on a whole-body system (1.5 T, Philips). The protocol consisted of T1-weighted sagittal spin-echo scans and T2-weighted sagittal gradient-echo scans. Both T1W and T2W axial scans were obtained in the lumbar region with a minimum three slices per disc level. All axial cuts were parallel to the disc space.

Locating the centre of L3-4 and L4-L5 intervertebral discs was performed using the PACS system internal measuring tool (GE medical system information technology centricity enterprise web). The split screen function was used to review the MRI images, one showing sagittal and the other axial cuts correlated to each other. An axial cut of the inferior endplate of L3 (for L3-4 level) and at the inferior endplate of L4 (for L4-5 level) were used to draw lines from anterior to posterior and from right to left borders of the vertebral body at their longest diameter. The crossing point of these lines determined the centre of the endplates on axial imaging. Finding of the disc centre on axial cuts and correlating it with the sagittal reconstructed images allowed us to measure the disc height at its midpoint ; a height that was divided to find the disc centre (*13*). The T2W axial cuts of the disc centre at L3-4 and L4-5 were saved as jpeg files for further analysis. The MRI images were assessed and measured three times by three spinal surgeons experienced in MRI imaging. They were blind to the subject status. All measurements of selected muscles were made on the saved jpeg files using the KLONK Image Measurement software (KLONK SmBa, Denmark). This method has been previously validated by several studies (Fig. 1) (*2,5,7,8,10-12,16*). We measured psoas major, multifidus and the combined bulk of the erector spinae (iliocostalis and longissimus muscles) on both sides. The erector spinae muscles were grouped together as their separate fascial boundaries were difficult to determine in some cases (*17*). For analysis, the mean values of CSA measurements were calculated.

The results were compared and analysed using the GEE (generalized estimating equation) analysis (for side differences) and Mann-Whitney U test. The intraclass correlation coefficient (ICC) were calculated to analyse the intra- and interobserver reliability. The statistical analysis was performed using Stata 13.1 software, Stata Corp. LP, Texas, USA. Significance was assumed at $p < 0.05$.

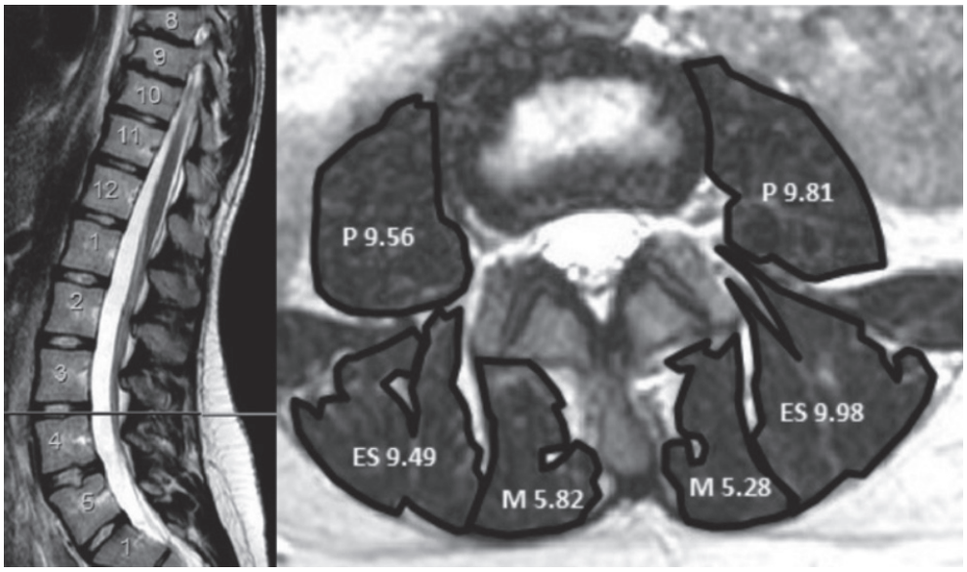

Fig. 1. — The figure shows sagittal view of lumbar spine and corresponding axial cut in L3/4 level in SK patient with CSA of psoas (P), multifidus (M) and erector spinae (ES) muscles obtained by using The KLONK Image Measurement software.

RESULTS

MRI images of 16 SK and 16 CG patients were reviewed. The SK and CG demographic data showed no significant differences (Table I – patients' characteristics). BMI was 23.06 ± 4.5 in the SKG and 22.72 ± 4.9 in our CG, $p > 0.05$. As expected, significant differences in the sagittal parameters between the groups was found ; SK patients had TK of 83.6 ± 6.1° and LL of 66.7 ± 10.4° were CG patients had TK of 34.6 ± 5.4° and LL of 32.5 ± 8.4° ($p < 0.001$).

The mean values of the CSA of psoas, multifidus and erector spinae muscles are summarized in Table 2. In SK patients the mean CSA of the multifidus muscles was significantly smaller on the left when compared to the right side at L3/4 level ($p = 0.02$). Similarly, in the CG patients the CSAs of psoas muscle at L3/4 level and erector spinae muscle at L4/5 level were smaller on the left side in compare to their right side ($p = 0.049$ and $p = 0.041$, respectively). Other side differences were not statistically significant ($p > 0.05$).

The mean CSA of psoas muscles at L3-4 and L4-5 showed no significant difference between both groups. The multifidus muscles were found to be smaller at L3/4 level in SKG patients ($p = 0.022$ on the left and $p = 0.016$ on the right side in compare to CG). The mean CSA of the extensor spinae muscles were also significantly smaller in SK patients compared to CG bilaterally at both levels ($p = 0.002$ and 0.003 at L3/4 – Fig. 2 and $p < 0.001$ at L4/5 – Fig. 3).

The intra- and interobserver ICC for all paraspinal muscles was ICC = 0.90 (95%CI = 0.87-0.93) and ICC = 0.83 (95%CI = 0.79-0.87), respectively.

DISCUSSION

Paraspinal and trunk muscles are considered as dynamic stabilizers of the spine-pelvis complex as well as providing motion to the different spinal segments. Erector spinae muscle complex has the longissimus muscle as its central component. Although it has capitis and cervical parts, its main functional mass arises from the posterior surface of the medial parts of the ribs and transverse processes of T1-L5. Iliocostalis and lumborum muscles constitute the most lateral parts of the lumbar and thoracic erector spinae complex (*21*). The innervation of multifidus bundle is uni-segmental and arises from the root exiting below the transverse spinal

Table I. — Patients' characteristics

	SKG	CG
Number of patients	16	16
Age (years±SD)	20.25 ± 6.3	22.81 ± 5.1#
Gender, n (%) Males Females	 12 (75%) 4 (25%)	 12 (75%) 4 (25%)
BMI (n ± SD)	23.06 ± 4.5	22.72 ± 4.9
Thoracic Kyphosis (Degrees ± SD)	83.6 ± 6.1°	34.6 ± 5.4°*
Lumbar Lordosis (Degrees ± SD)	66.7 ± 10.4°	32.5 ± 8.4°*

SKG : Scheuermann's Kyphosis Group ; CG : Control Group.
* $p < 0.001$, # $p = 0.07$.

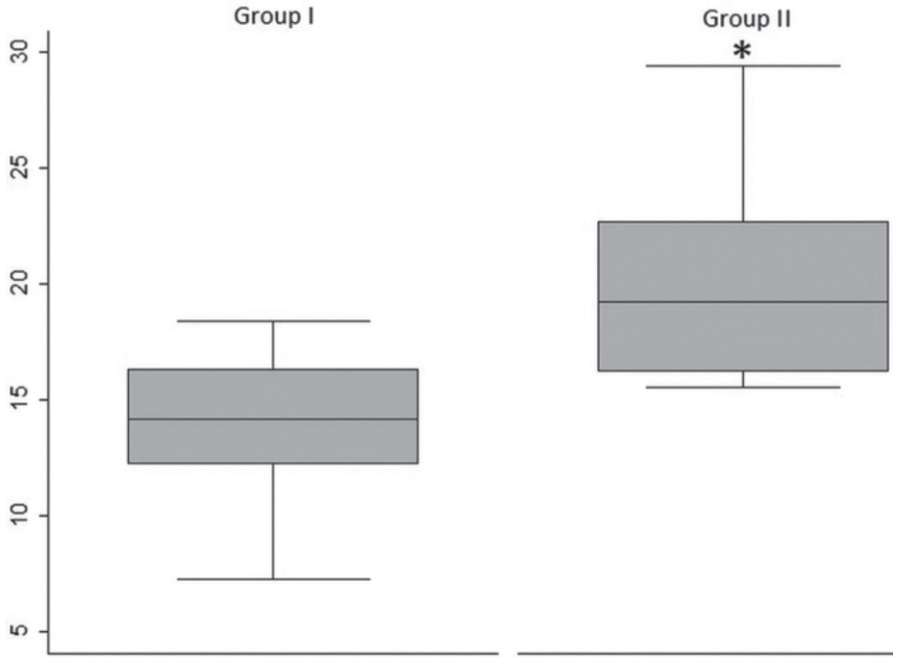

Fig. 2. — Box plot showing the CSA of erector spinae muscle in L3/4 level on the left side. Box plot shows the median value (horizontal line in box), and the interquartile range (25-75%) is represented by the box. Vertical axis – values of CSA in cm^2. Mann-Whitney U test, * $p < 0.05$.

process from which the fascicles. In contrast, innervation of the other paraspinal muscles is multi-segmental (*16*). Trunk muscles are classified into two groups : 1. Segmental spinal stabilizers - muscles directly attached to the lumbar vertebrae (lumbar multifidus, transversus abdominis and internal oblique muscles) and 2. General trunk stabilizers and large-torque producing muscles which are not attached to the lumbar vertebrae (erector spinae, rectus abdominis and external oblique muscles). Most of the extensor momentum of the trunk is generated from erector spinae muscle, rather than the multifidus muscle (*1,21*).

It has been suggested that disuse, muscle denervation or reflex inhibition could play a role in muscle atrophy in patients with chronic LBP. However,

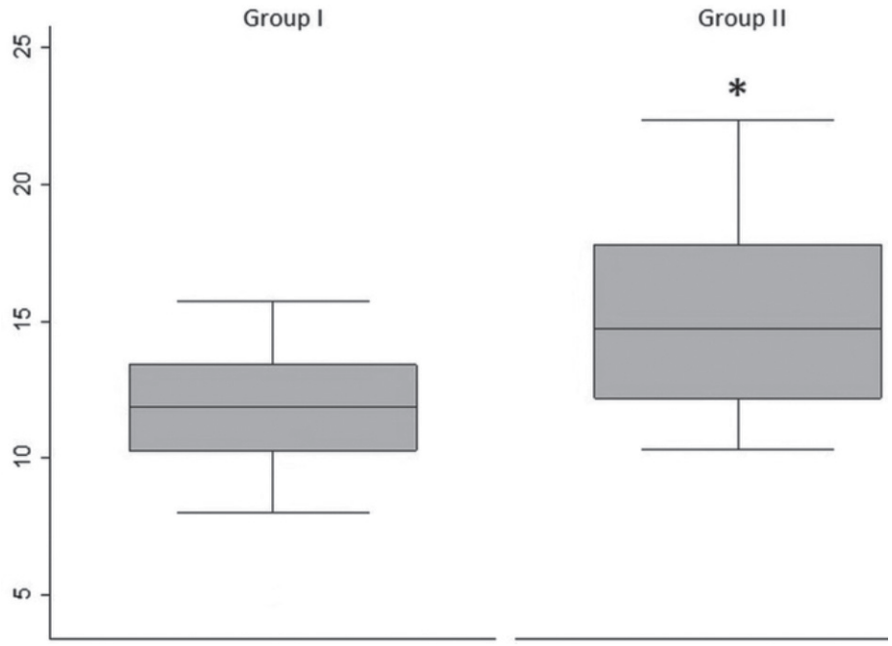

Fig. 3. — Box plot showing the CSA of erector spinae muscle in L4/5 level on the left side. Legend – see Fig. 1.

Table II. — The CSA of paraspinal muscles in cm^2± SD (standard deviation)

L3/4 level		SKG	CG	p-value	coefficient (95% CI)
Psoas	Left	13.68 ± 3.54	14.04 ± 4.38#	0.81	0.35 (-3.3; 2.6)
	Right	13.80 ± 3.58	14.27 ± 4.24	0.746	-0.47 (-3.4; 2.5)
Multifidus	Left	5.25 ± 1.60#	6.64 ± 1.53	0.022*	-1.38 (-2.6; -0.21)
	Right	5.44 ± 1.49	6.79 ± 1.43	0.016*	-1.4 (-2.4; -0.27)
Erector spinae	Left	13.84 ± 3.1	20.15 ± 4.38	< 0.001*	-6.3 (-9.1; -3.5)
	Right	13.72 ± 2.94	20.16 ± 4.34	< 0.001*	-6.4 (-9.2; -3.7)
L4/5 level					
Psoas	Left	14.33 ± 3.85	17.33 ± 4.44	0.057	-3 (6.1; 0.09)
	Right	14.50 ± 3.72	17.01 ± 4.49	0.106	-2.51 (-5.6; 0.56)
Multifidus	Left	6.80 ± 1.65	7.64 ± 1.38	0.14	-0.84 (-2; 0.29)
	Right	6.87 ± 1.58	7.20 ± 1.95	0.62	-0.33 (-1.6; 0.99)
Erector spinae	Left	11.27 ± 3.06	15.11 ± 3.44#	0.003*	-3.8 (-6.3; -1.41)
	Right	10.68 ± 3.87	15.29 ± 3.37	0.002*	-4.6 (-7.3; -1.9)

: statistically significant difference in CSA of specific muscle between left and right side (GEE test, $p < 0.05$).

* : statistically significant difference between the groups (Mann-Whitney U test, $p < 0.05$). Linear regression coefficient – mean difference in CSA between the groups (negative value means that median CSA in SKG is smaller).

it is still not clear whether muscle atrophy, asymmetry, or fatty infiltration results from LBP or represent a risk factor (*2*). Paraspinal muscle atrophy is a replacement of muscle fibres with fat and fibrous tissue, which might result in reduced functional contractility of muscle (*17*). Lee *et al* postulated that

the progression of acute LBP into chronic LBP is higher in patients with relatively smaller erector spinae muscle CSA to the total sum of lumbar muscles CSA (*12*). The explanation would be the lower ability of the lumbar erector spinae muscles to maintain the posture and balance since they are considered the main lumbar stabilizers (*21*). This is true especially during a sudden posture change or loading on the lumbar spine (*12*). In conclusion, it is noted that the multifdus and erector spinae muscle groups were smaller in patient with chronic LBP compared to healthy population (*2*).

The results showed that patients with SK have significantly smaller multifidus (in L3/4 level) and extensor spinae (in L3/4 and L4/5 levels) muscles than CG patients. The mean age of patients in control group was non-significantly higher ($p = 0.07$). However, this is unlikely to solely account for the difference observed between the examined groups muscle CSA. Although some significant side differences in particular sub-groups were found, these are not of high importance since the level of significance is not very convincible statistically ($p = 0.02$ for multifidus muscle in SKG and $p = 0.049$ for psoas and $p = 0.041$ for erector spinae muscle in CG). The differences may be explained by local asymmetry or the different obliquity of the MRI images.

When trying to understand the reduced volume of the extensor spinae in SK patients in compare to CG one can look at a study by Sinaki *et al* (*19*). They showed that in healthy postmenopausal women, strength of the spinal extensors is inversely associated with their thoracic kyphosis. O'Sullivan *et al* stated that sway-back posture, in which the C7 plumb line is behind the lumbar vertebral bodies rather than slightly in front, is associated with extended trunk. This causes a decrease in the recruitment of the lumbar erector spinae and an increase in the recruitment of the abdominal muscles to maintain sagittal balance (*14*). Pezolato *et al* found significant erector spinae muscle fat infiltration in lower lumbar area in individuals with sway-back posture (*15*). Same logic might explain the extensor spinae muscle weakness in the SKG. The reduced volume of spinal extensors may be explained by lumbar hyperlordosis which is often presented in SK patients (*23*). The hyperlordosis is most certainly compensatory one since the surgical correction of thoracic hyperkyphosis gives its predictable spontaneous decrease (*6*). Therefore it can be hypothesize that this compensatory hyperlordosis curve shift the axial loading forces posteriorly therefore necessitating less extensor muscle power to keep SK patients erect.

Ristolainen *et al* stated that untreated patients with SK have higher risk for back pain, reported lower quality of life and reported poorer general health than controls. However, these facts do not correlate with the degree of kyphosis (*18*). It may be postulated that the higher risk for back pain in these patients may be due to multifidus and erector spinae muscles atrophy as previously discussed.

The limitations of this study were : 1. Small cohort ; it could not be asserted whether the side differences in particular muscles were true findings. However, given that surgical correction of SK is a complex and uncommon procedure we believe that these limitations are inevitable. 2. No clinical data collection ; further study is needed to assess back pain in SK patients and correlate this with extensor muscles atrophy.

CONCLUSION

Although the exact pathophysiology of Scheuermann's kyphosis is still unknown, these results show that it is associated with reduced volume of extensor spinae muscle. This fact might be explained by SK patients' compensatory lumbar hyperlordosis. Increased back pain in SK patients might be a result of their decreased extensor muscle CSA.

REFERENCES

1. **Bergmark A.** Stability of the lumbar spine. A study in mechanical engineering. *Acta Orthop Scand Suppl* 1989 ; 230 : 1-54.
2. **Fortin M, Macedo LG.** Multifidus and paraspinal muscle group cross-sectional areas of patients with low back pain and control patients : a systematic review with a focus on blinding. *Phys Ther* 2013 ; 93 : 873-888.
3. **Fotiadis E, Kenanidis E, Samoladas E, Christodoulou A, Akritopoulos P, Akritopoulou K.** Scheuermann's

disease : focus on weight and height role. *Eur Spine J* 2008 ; 17 : 673-678.

4. **Hyun SJ, Bae CW, Lee SH, Rhim SC.** Fatty Degeneration of Paraspinal Muscle in Patients With the Degenerative Lumbar Kyphosis : A New Evaluation Method of Quantitative Digital Analysis Using MRI and CT Scan. *J Spinal Disord Tech* 2013.
5. **Hyun SJ, Kim YB, Kim YS, Park SW, Nam TK, Hong HJ *et al.*** Postoperative changes in paraspinal muscle volume : comparison between paramedian interfascial and midline approaches for lumbar fusion. *J Korean Med Sci* 2007 ; 22 : 646-651,
6. **Jansen RC, van Rhijn LW, van Ooij A.** Predictable correction of the unfused lumbar lordosis after thoracic correction and fusion in Scheuermann kyphosis. *Spine (Phila Pa 1976)* 2006 ; 31 : 1227-1231.
7. **Kader DF, Wardlaw D, Smith FW.** Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. *Clin Radiol* 2000 ; 55 : 145-149.
8. **Kang CH, Shin MJ, Kim SM, Lee SH, Lee CS.** MRI of paraspinal muscles in lumbar degenerative kyphosis patients and control patients with chronic low back pain. *Clin Radiol* 2007 ; 62 : 479-486.
9. **Kapetanos GA, Hantzidis PT, Anagnostidis KS, Kirkos JM.** Thoracic cord compression caused by disk herniation in Scheuermann's disease : a case report and review of the literature. *Eur Spine J* 2006 ; 15 Suppl 5 : 553-558.
10. **Kim H, Lee CK, Yeom JS, Lee JH, Cho JH, Shin SI *et al.*** Asymmetry of the cross-sectional area of paravertebral and psoas muscle in patients with degenerative scoliosis. *Eur Spine J* 2013 ; 22 : 1332-1338.
11. **Kim JY, Chae SU, Kim GD, Cha MS.** Changes of paraspinal muscles in postmenopausal osteoporotic spinal compression fractures : magnetic resonance imaging study. *J Bone Metab* 2013 ; 20 : 75-81.
12. **Lee HI, Song J, Lee HS, Kang JY, Kim M, Ryu JS.** Association between Cross-sectional Areas of Lumbar Muscles on Magnetic Resonance Imaging and Chronicity of Low Back Pain. *Ann Rehabil Med* 2011 ; 35 : 852-859.
13. **Lidar Z, Behrbalk E, Regev GJ, Salame K, Keynan O, Schweiger C *et al.*** Intervertebral disc height changes after weight reduction in morbidly obese patients and its effect on quality of life and radicular and low back pain. *Spine* 2012 ; 37 : 1947-1952.
14. **O'Sullivan PB, Grahamslaw KM, Kendell M, Lapenskie SC, Moller NE, Richards KV.** The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. *Spine (Phila Pa 1976)* 2002 ; 27 : 1238-1244.
15. **Pezolato A, de Vasconcelos EE, Defino HL, Nogueira-Barbosa MH.** Fat infiltration in the lumbar multifidus and erector spinae muscles in subjects with sway-back posture. *Eur Spine J* 2012 ; 21 : 2158-2164.
16. **Ploumis A, Michailidis N, Christodoulou P, Kalaitzoglou I, Gouvas G, Beris A.** Ipsilateral atrophy of paraspinal and psoas muscle in unilateral back pain patients with monosegmental degenerative disc disease. *Br J Radiol* 2011 ; 84 : 709-713.
17. **Ranson CA, Burnett AF, Kerslake R, Batt ME, O'Sullivan PB.** An investigation into the use of MR imaging to determine the functional cross sectional area of lumbar paraspinal muscles. *Eur Spine J* 2006 ; 15 : 764-773.
18. **Ristolainen L, Kettunen JA, Heliovaara M, Kujala UM, Heinonen A, Schlenzka D**. Untreated Scheuermann's disease : a 37-year follow-up study. Eur Spine J 2012 ; 21 : 819-824.
19. **Sinaki M, Itoi E, Rogers JW, Bergstralh EJ, Wahner HW.** Correlation of back extensor strength with thoracic kyphosis and lumbar lordosis in estrogen-deficient women. *Am J Phys Med Rehabil* 1996 ; 75 : 370-374.
20. **Sørensen K.** Scheuermann's juvenile kyphosis : clinical appearances, radiography, aetiology, and prognosis. *Copenhagen* : Munksgaard, 1964
21. **Standring S, Gray H.** Gray's anatomy : the anatomical basis of clinical practice, ed 40th. Edinburgh : Churchill Livingstone/Elsevier, 2008
22. **Tribus CB.** Scheuermann's kyphosis in adolescents and adults : diagnosis and management. *J Am Acad Orthop Surg* 1998 ; 6 : 36-43.
23. **Wenger DR, Frick SL.** Scheuermann kyphosis. *Spine (Phila Pa 1976)* 1999 ; 24 : 2630-2639.