

Does lumbar paraspinal muscles improve after corrective fusion surgery in degenerative flat back?

Jung Hwan Lee, Sang-Ho Lee¹

ABSTRACT

Background: Degenerative flat back (DFB) is characterized by sagittal imbalance resulting from the loss of lumbar lordosis (LL). Extensive degeneration and weakness of lumbar paraspinal extensor muscle (PSE) are thought to be the main cause of DFB. This study is to evaluate correlation between preoperative PSE conditions and angular severity of DFB and to evaluate correlation between preoperative PSE conditions and degree of improvement of DFB obtained by corrective surgery.

Materials and Methods: Forty five patients with DFB who took magnetic resonance image (MRI) preoperatively and conducted simple radiography and three-dimensional gait analysis before and 6 months after corrective surgery were included. To determine the severity of PSE atrophy, the ratio between cross-sectional area of PSE and disc was calculated from L1–L2 to L4–L5 on MRI. To assess the degree of fat infiltration, the signal intensity of PSE was measured. Static parameters of spinopelvic segment were measured by simple radiography. Dynamic parameters of spinopelvic and lower limb joints were obtained by three-dimensional gait analysis.

Results: In static parameters, thoracic angle was correlated with atrophy and fat infiltration of upper PSE. Thoracic angle was less improved after surgery, as atrophy of upper PSE was more severe. In dynamic parameters, thoracic angle showed correlation with upper PSE conditions, whereas lumbar angle had correlation with middle to lower PSE conditions. While thoracic kyphosis was less improved after surgery, as atrophy of upper PSE was more severe, LL was less improved, as atrophy and fat infiltration of PSE from L1–L2 to L4–L5 were more severe.

Conclusions: Severity of atrophy or fat infiltration of PSE showed correlation with degree of angular deformity in patients with DFB and with less improvement after corrective surgery. Dynamic parameters showed more prominent correlation with PSE conditions than static parameters and also showed segmental specificity between PSE and angular deformity.

Key words: Degenerative flat back, fusion surgery, paraspinal muscle, three-dimensional motion analysis

MeSH terms: Spinal fusion, degenerative diseases, spinal contractures, muscle weakness, lumbar vertebrae

INTRODUCTION

Degenerative flat back (DFB) is frequent in Asian countries, which suggests that typical life style or working posture is associated with occurrence of DFB. They stand up or sit on the floor with waist flexion

and frequently work at home or farm with stooped posture, which contributes to decreased lumbar lordosis (LL) and weakness of paraspinal extensor muscles (PSEs). Decreased LL causes anterior displacement of the center of gravity, which leads to spinopelvic angular changes and causes various disabilities in daily life including gait difficulty.^{1,2} Although the exact pathophysiology of DFB has not yet been confirmed, extensive degeneration, and weakness of lumbar extensor muscles are thought to be the most important cause.^{3,4}

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The quantitative evaluations of lumbar extensor muscle have been developed using magnetic resonance image (MRI).^{4,6} The typical signs of muscle degeneration detected on MRI are muscle cross-sectional area (CSA) and fatty replacement of muscle, expressed as increased signal intensity (SI).^{6,7} Previous study using MRI histogram reported that DFB patients showed higher mean SI of back extensor muscles suggesting fat infiltration compared to normal control.⁵

Although radiographic examination can show characteristic sagittal deviation of spinopelvic alignment,⁸ it has the limitation only to reveal the static posture, and not to identify dynamic status such as ambulation. However, daily activities or functional aspects of patients are more related to dynamic status of spinopelvic segment than static posture. Treatment outcomes or patient satisfaction can be influenced more by dynamical parameters than by static parameters. Thus, it is assumed that assessment of dynamic parameters of DFB by three-dimensional motion analysis can provide clinically useful data about patients' functional status and treatment outcomes.⁹⁻¹² It can provide specific characteristics of spinopelvic and lower limb joints motion in patients with DFB and also reveal which improvement occurred following surgery in quantitative and objective way.

The purposes of this study were (1) to evaluate correlation between preoperative lumbar extensor muscle condition and angular severity of DFB and (2) to evaluate correlation between preoperative lumbar extensor muscle condition and degree of improvement of DFB obtained by corrective fusion surgery, in terms of static parameters by simple radiography and dynamic parameters by three-dimensional motion analysis.

MATERIALS AND METHODS

45 patients who underwent corrective fusion surgery for DFB between 2010 and 2012, (4 men and 41 women, mean age 69.9 ± 6.01 years) were included in this retrospective study. Lumbar MRI, whole spine X-ray, and three dimensional motion analysis were done before and 6 months after surgery in all the patients. The patients showed characteristic clinical features, including stooped posture while walking, inability to lift heavy objects, difficulty in climbing, and the need to use a support (such as an elbow) when standing in the kitchen. The patients who had history of previous lumbar surgery and prominent lower extremity pain or weakness affecting gait function were excluded from the study. The study was approved by the Institutional Review Board of our hospital. Fusion levels were as follows; T10-S1 in two patients, T11-S1 in four, L1-S1 in seven, L2-L5 in one, L2-S1 in 22, L2-S2 in two, and L3-S1 in seven.

Radiological evaluation (static parameters)

As for spinal sagittal parameters, thoracic kyphosis (TK), thoracolumbar junction (TLJ), and LL were measured in whole spine lateral view. The TK was measured from the T5 superior end plate to T12 inferior end plate. The TLJ was measured from the T10 superior end plate to L2 inferior end plate. The LL was measured from the T12 inferior end plate to S1 superior end plate by the Cobb method [Figure 1]. As for the pelvic parameters, pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT) were measured. The SS was the angle between the S1 superior end plate and a horizontal line. The PT was defined as the angle between a vertical line originating at the center of the bicoxofemoral axis and a line drawn between the same point and the middle of the superior end plate of S1. The PI was defined as the angle between the line perpendicular to the sacral plate and the line connecting the midpoint of the sacral plate to the bicoxofemoral axis [Figure 2].^{8,13}

Lumbar paraspinal extensor muscle measurement on magnetic resonance image

The conditions of lumbar PSEs were analyzed at the L1-L2, L2-L3, L3-L4, and L4-L5 levels. The L5-S1 level was not included because the axial cutting gantry was obstructed by



Figure 1: X-ray thoracolumbosacral spine lateral view showing spinal parameters such as thoracic kyphosis, thoracolumbar junction, and lumbar lordosis. (A) The thoracic kyphosis was measured from the T5 superior end plate to T12 inferior end plate. (B) The thoracolumbar junction was measured from the T10 superior end plate to L2 inferior end plate. (C) The lumbar lordosis was measured from the T12 inferior end plate to S1 superior end plate by the Cobb method

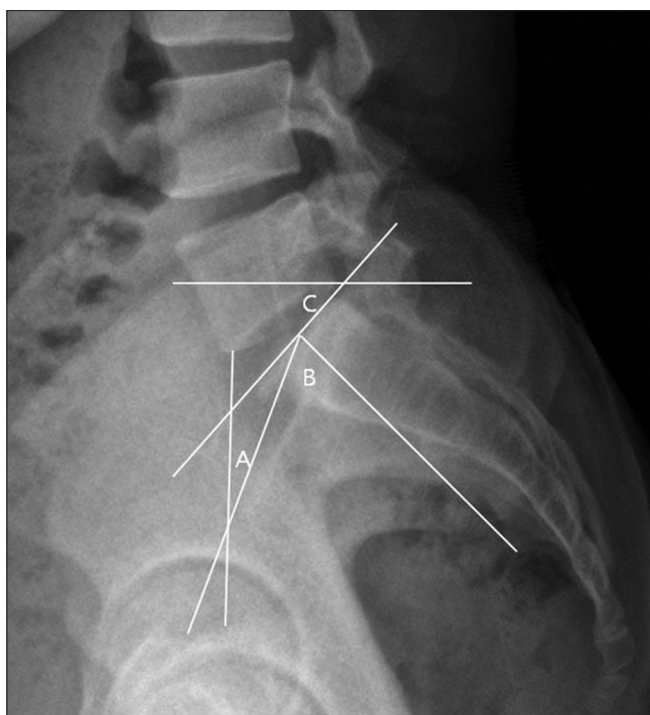


Figure 2: X-ray lumbosacral spine lateral view showing pelvic parameters including pelvic tilt, pelvic incidence, and sacral slope. (A) The pelvic tilt is defined as the angle between a vertical line originating at the center of the bicoxofemoral axis and a line drawn between the same point and the middle of the superior end plate of S1. (B) The pelvic incidence is defined as the angle between the line perpendicular to the sacral plate and the line connecting the midpoint of the sacral plate to the bicoxofemoral axis. (C) The sacral slope is the angle between the S1 superior end plate and a horizontal line

iliac crest and the muscular anatomy was quite different from the upper levels. The images were displayed and analyzed using PiView (Infinit, Seoul, Korea) digital image viewing software. The regions of interest (ROI) were outlined with a graphic cursor around the lumbar PSE including multifidi and erector spinae and on the intervertebral disc at each level.¹⁴

The degree of muscle atrophy was determined by measuring the CSA of the PSE compartment. In order to decrease the bias caused by differences in individual body size, the area of the PSE compartment was divided by intervertebral disc area of the same level (the ratio between the CSA of the PSE and the CSA of the intervertebral disc [PSE/disc CSA]) to represent the relative muscle compartment volume in each individual. The SI of the muscle within the ROI was additionally measured using a histogram, and the mean value of the SI in the patient's group was obtained [Figure 3].

Three-dimensional gait analysis (dynamic parameters)

Gait analysis was conducted using three-dimensional motion analyzer (Motion Analysis[®]; Motion Analysis Company, Santa Rosa, CA, USA). The instrument was calibrated prior to performing gait analysis on each subject. Markers of diameter 2.5 cm were attached bilaterally to the bony landmarks of the pelvis and lower extremities, including the L5-S1 intervertebral space, anterior superior iliac spine, anterior side of the midthigh, midpoint of the lateral knee, anterior side of the mid-tibia, lateral malleolus

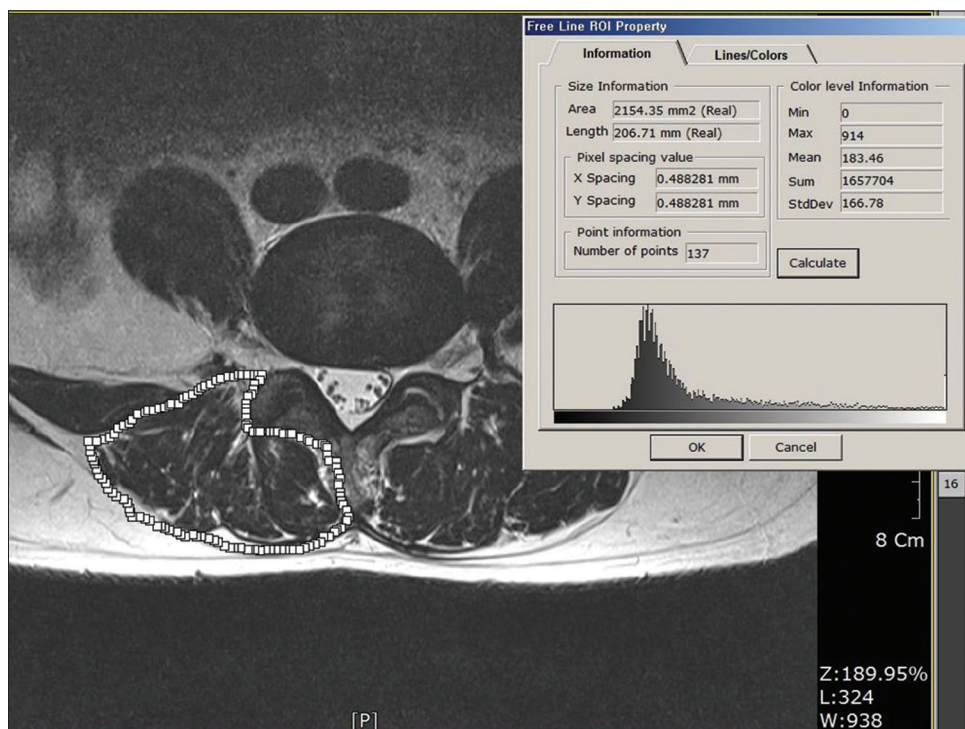


Figure 3: Mean value of the signal intensity was measured within paraspinal extensor muscle, using histogram of magnetic resonance image

of the fibula, dorsal side between the second and third metatarsal heads, and the calcaneal area on the same line as the metatarsal marker to assessing lower limb kinematics during ambulation. In addition, markers were attached to bony landmarks of the C7, T6, T12, L2, and L5 spinous processes for assessing kinematics of thoracic and lumbar vertebrae segments during ambulation [Figure 4]. The participants went through a 10 m walkway for dynamic test at a range of self-selected. The infrared camera determined the location of each marker during ambulation. The data were sent to SIMM (Software for Interactive Musculoskeletal Modeling) program® (Motionanalysis company, Santa Rosa, CA, USA) program and joint motions were calculated and analyzed. Maximal and minimal angle of posterior PT, hip, knee and ankle joints flexion angles in sagittal plane was measured during ambulation. In addition, maximal and minimal sagittal angle of thoracic vertebrae and lumbar vertebrae segment was obtained. Positive values of spinal columns and lower limbs meant kyphotic angle and flexion (ankle joint dorsiflexion).

All of these measurements were performed by single physician (JHL) who was expert in spine radiology and three-dimensional motion analysis.

Statistical analysis

Statistical analysis was performed using SPSS 12.0K (SPSS Inc., Chicago, IL, USA). A $P < 0.05$ was considered

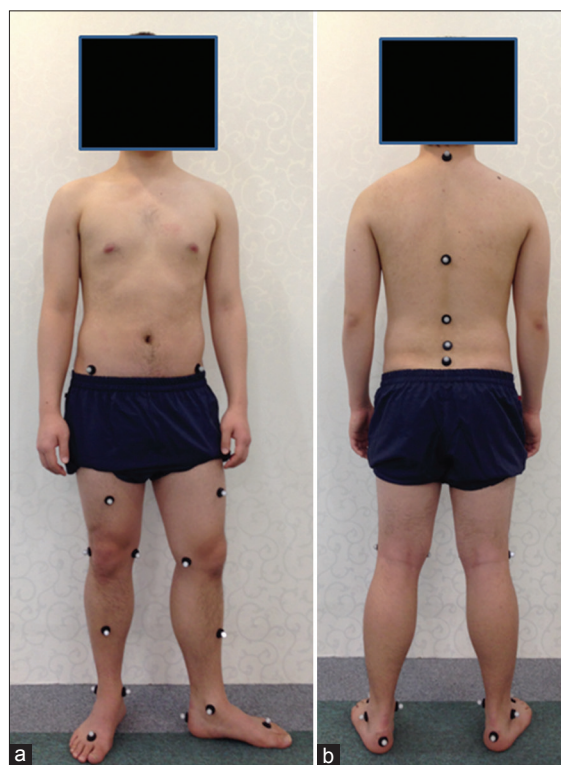


Figure 4: Clinical photographs (a and b) showing location of markers during three-dimensional motion analysis

statistically significant. The correlation between preoperative PSE measurements and static/dynamic parameters and the correlation between preoperative PSE measurements and degree of improvement of static/dynamic parameters obtained by corrective fusion surgery were determined using the Pearson correlation coefficient.

RESULTS

Correlation between paraspinal extensor muscle measurements and static parameters before surgery

TLJ was correlated significantly with L1–L2 PSE/disc CSA and L1–L2 SI. TK was correlated with L1–L2 SI, L3–L4 PSE/disc CSA, and L4–L5 SI [Table 1].

Correlation between paraspinal extensor muscle measurements and dynamic parameters before surgery

Maximal thoracic angle was correlated with L1–L2 PSE/disc CSA, L1–L2 SI, and L2–L3 PSE/disc CSA. Maximal lumbar angle was correlated with L3–L4 PSE/disc CSA and L4–L5 PSE/disc CSA. Minimal thoracic angle was correlated with L1–L2 PSE/disc CSA. Minimal lumbar angle was correlated with L2–L3 SI, L3–L4 PSE/disc CSA, and L3–L4 SI, and L4–L5 PSE/disc CSA [Table 2].

Maximal right hip and knee flexion angle were correlated with L4–L5 PSE/disc CSA. Minimal posterior PT angle was correlated with L2–L3 SI. Minimal right hip flexion angle was correlated with L3–L4 PSE/disc CSA and L4–L5 PSE/disc CSA. Minimal left ankle dorsiflexion angle was correlated with L1–L2, L2–L3, L3–L4, and L4–L5 SI.

Correlation between paraspinal extensor muscle measurement and improvement of static parameters obtained by surgery

The change (Δ) of TK was significantly correlated with L1–L2 and L2–L3 PSE/disc CSA [Table 3].

Correlation between paraspinal extensor muscle measurement and improvement of dynamic parameters obtained surgery

The Δ maximal thoracic angle showed significant correlation with L1–L2 and L2–L3 PSE/disc CSA. The Δ maximal lumbar angle showed significant correlation with L1–L2, L2–L3, L3–L4, and L4–L5 PSE/disc CSA. The Δ minimal thoracic angle showed significant correlation with L1–L2 and L2–L3 PSE/disc CSA. The Δ minimal lumbar angle showed significant correlation with L1–L2, L2–L3, L3–L4, and L4–L5 PSE/disc CSA [Table 4].

The Δ maximal pelvic posterior tilt was also correlated with L4–L5 PSE/disc CSA. The Δ maximal right and left hip

Table 1: Correlation between paraspinal extensor muscle measurement and static parameters

	L1-L2 PSE***/disc	L1-L2 SI†	L2-L3 PSE disc	L2-L3 SI	L3-L4 PSE/disc	L3-L4 SI	L4-L5 PSE/disc	L4-L5 SI
LL‡								
<i>r</i>	-0.171	0.074	-0.096	0.023	-0.069	0.009	-0.113	0.000
<i>P</i>	0.261	0.628	0.530	0.881	0.650	0.955	0.461	0.999
TLJ§								
<i>r</i>	-0.427	0.318	-0.382	0.224	-0.098	0.278	0.043	0.213
<i>P</i>	0.004*	0.035*	0.010*	0.144	0.527	0.068	0.782	0.165
TK								
<i>r</i>	0.177	-0.385	0.167	-0.152	0.326	-0.350	0.294	-0.304
<i>P</i>	0.250	0.010*	0.278	0.325	0.031*	0.020*	0.053	0.045*
PI**								
<i>r</i>	-0.053	0.060	-0.085	0.010	-0.027	0.035	-0.157	-0.081
<i>P</i>	0.731	0.693	0.577	0.949	0.859	0.819	0.302	0.598
PT††								
<i>r</i>	-0.069	0.168	-0.180	0.058	-0.134	0.052	-0.118	-0.121
<i>P</i>	0.654	0.270	0.237	0.706	0.380	0.736	0.439	0.427
SS‡‡								
<i>r</i>	0.040	-0.077	0.083	-0.052	0.087	-0.017	-0.066	0.007
<i>P</i>	0.792	0.616	0.588	0.732	0.570	0.912	0.667	0.962

P*<0.05. *PSE=Paraspinal extensor muscle, †SI=Signal intensity, ‡LL=Lumbar lordotic angle, §TLJ=Thoracolumbar junctional angle, ||TK=Thoracic kyphotic angle, **PI=Pelvic incidence, ††PT=Pelvic tilt, ‡‡SS=Sacral slope, *r*=correlation coefficient

Table 2: Correlation between paraspinal extensor muscle measurement and dynamic parameters

	L1-L2 PSE***/disc	L1-L2 SI†	L2-L3 PSE/disc	L2-L3 SI	L3-L4 PSE disc	L3-L4 SI	L4-L5 PSE disc	L4-L5 SI
Maximal thoracic angle								
<i>r</i>	0.384	-0.197	0.363	-0.022	0.186	-0.072	0.173	-0.088
<i>P</i>	0.010*	0.200*	0.015*	0.888	0.228	0.642	0.262	0.570
Maximal lumbar angle								
<i>r</i>	-0.241	0.096	-0.261	0.217	-0.345	0.238	-0.352	0.173
<i>P</i>	0.115	0.534	0.087	0.158	0.022*	0.119	0.019*	0.263
Maximal pelvic posterior tilt								
<i>r</i>	-0.13	0.19	-0.084	0.263	-0.11	0.248	-0.198	0.072
<i>P</i>	0.396	0.212	0.585	0.081	0.474	0.101	0.192	0.638
Minimal thoracic angle								
<i>r</i>	0.323	-0.174	0.211	-0.01	0.018	-0.126	0.092	-0.113
<i>P</i>	0.032*	0.259	0.169	0.947	0.906	0.415	0.551	0.465
Minimal lumbar angle								
<i>r</i>	-0.213	0.262	-0.261	0.355	-0.344	0.357	-0.359	0.274
<i>P</i>	0.164	0.085	0.087	0.018*	0.022*	0.018*	0.017*	0.072
Minimal pelvic posterior tilt								
<i>r</i>	-0.134	0.260	-0.085	0.326	-0.108	0.281	-0.203	-0.112
<i>P</i>	0.380	0.084	0.577	0.029*	0.481	0.061	0.181	0.462

P*<0.05. *PSE=Paraspinal extensor muscle, †SI=Signal intensity, *r*=Correlation coefficient

flexion angle was correlated with L2–L3, L3–L4, and L4–L5 PSE/disc CSA. The Δ minimal posterior PT was correlated with L2–L3 SI. The Δ minimal right ankle flexion angle was correlated with L1–L2 PSE/disc CSA.

DISCUSSION

The degeneration and weakness of PSE were thought to be important causes of DFB because the PSE played a role in maintaining spinal curvatures and their degeneration or atrophy resulted in a progressive kyphosis and sagittal imbalance.^{1,3,5} Degeneration of PSE was significantly

associated with facet arthropathy, which additionally contributed to progression of lumbar kyphosis.¹⁵ Facet arthropathy could elicit a reflex mechanism that inhibited muscle activity and further caused muscle atrophy.¹⁶ As well, kyphotic deformity, in turn, aggravated degeneration and weakness of PSE in more severe degree. Over lengthening of PSE caused by increased lumbar kyphotic angle lost the lever arm effects enough for appropriate contraction, which further aggravated muscle degeneration and atrophy.¹⁷ Low back pain caused by DFB could contribute to limited back movement and consequently, muscle atrophy. Vascular compression between the convexed lumbar

Table 3: Correlation between preoperative paraspinal extensor muscle measurement and improvement of static parameters obtained by surgery

	L1-L2 PSE***/disc	L1-L2 SI†	L2-L3 PSE/disc	L2-L3 SI	L3-L4 PSE/disc	L3-L4 SI	L4-L5 PSE/disc	L4-L5 SI
ΔLL^{\ddagger}								
<i>r</i>	0.023	-0.087	0.092	-0.048	0.055	-0.148	0.066	-0.148
<i>P</i>	0.882	0.571	0.549	0.753	0.718	0.333	0.669	0.333
$\Delta^{\S} TLJ$								
<i>r</i>	0.072	-0.099	0.038	-0.087	0.028	-0.165	0.044	-0.223
<i>P</i>	0.640	0.519	0.803	0.570	0.854	0.279	0.772	0.141
ΔTK^{\parallel}								
<i>r</i>	0.339	-0.059	0.344	-0.098	0.002	-0.149	0.063	-0.104
<i>P</i>	0.023*	0.701	0.021*	0.521	0.990	0.327	0.682	0.496
ΔPI^{**}								
<i>r</i>	0.109	-0.089	0.114	-0.060	0.021	-0.059	0.173	-0.010
<i>P</i>	0.478	0.560	0.458	0.693	0.891	0.702	0.256	0.948
$\Delta PT^{\dagger\dagger}$								
<i>r</i>	0.241	-0.064	0.219	-0.063	0.068	-0.074	0.036	-0.029
<i>P</i>	0.111	0.677	0.149	0.682	0.658	0.630	0.816	0.850
$\Delta SS^{\ddagger\ddagger}$								
<i>r</i>	-0.137	-0.017	0.111	-0.020	-0.079	-0.022	0.133	-0.024
<i>P</i>	0.368	0.911	0.468	0.897	0.608	0.887	0.382	0.875

P*<0.05. *PSE=Paraspinal extensor muscle, †SI=Signal intensity, ‡LL=Lumbar lordotic angle, †TLJ=Thoracolumbar junctional angle, †TK=Thoracic kyphotic angle, **PI=Pelvic incidence,

††PT=Pelvic tilt, ††SS=Sacral slope, *r*=Correlation coefficient

Table 4: Correlation between preoperative paraspinal extensor measurement and improvement of dynamic parameters obtained surgery

	L1-L2 PSE***/disc	L1-L2 SI†	L2-L3 PSE/disc	L2-L3 SI	L3-L4 PSE/disc	L3-L4 SI	L4-L5 PSE/disc	L4-L5 SI
Δ Maximal thoracic angle								
<i>r</i>	0.329	-0.171	0.335	-0.020	0.225	-0.027	0.246	-0.050
<i>P</i>	0.029*	0.266	0.026*	0.897	0.143	0.860	0.108	0.749
Δ Maximal lumbar angle								
<i>r</i>	0.342	-0.042	0.345	-0.117	0.423	-0.132	0.467	-0.068
<i>P</i>	0.023*	0.787	0.022*	0.450	0.004*	0.392	0.001*	0.663
Δ Maximal pelvic posterior tilt								
<i>r</i>	0.229	-0.188	0.211	-0.212	0.266	-0.264	0.376	-0.121
<i>P</i>	0.130	0.215	0.165	0.162	0.077	0.080	0.011*	0.427
Δ Minimal thoracic angle								
<i>r</i>	0.356	-0.050	0.369	0.089	0.227	-0.015	-0.247	-0.013
<i>P</i>	0.018*	0.747	0.014*	0.566	0.139	0.923	0.106	0.934
Δ Minimal lumbar angle								
<i>r</i>	0.327	-0.130	0.365	-0.256	0.425	-0.237	0.467	-0.164
<i>P</i>	0.030*	0.401	0.015*	0.093	0.004*	0.121	0.001*	0.288
Δ Minimal pelvic posterior tilt								
<i>r</i>	0.098	-0.281	0.004	-0.303	0.062	-0.285	0.163	-0.210
<i>P</i>	0.521	0.062	0.980	0.043*	0.685	0.057	0.286	0.167

P*<0.05. *PSE=Paraspinal extensor muscle, †SI=Signal intensity, *r*=Correlation coefficient

spine and the superficial fascia promoted atrophy of PSE by disturbing vascular supply.⁴ In spite of debates about causal relationship, extensor muscle degeneration and development of DFB were closely related with each other.

Histographic analysis using MRI has been reported to be an effective method to assess the degree of muscle degeneration. High SI in histography means severe degree of replacement of muscle by fat tissues, and this also suggests muscle degeneration or weakness as small CSA did.^{5,7} Several literatures demonstrated that the patients

with DFB had significantly smaller CSA and higher SI of the PSE compared with normal control or patients suffering from chronic low back pain without DFB.³⁻⁵

Current study demonstrated that PSE degeneration, expressed by reduced CSA and higher SI, was related to more kyphotic lumbar segment and more flat/lordotic thoracic segment as well as was also associated with less improvement after corrective surgery. In static parameters, as PSE condition was more severe, thoracic angle was more lordotic. It meant that more severe PSE condition lead

to more severe lumbar kyphosis (less LL), consequently resulted in flat/lordotic thoracic angle. After surgery, as upper PSE condition was more severe preoperatively, less improvement of TK was accomplished by corrective surgery.

In dynamic parameters, decreased thoracic kyphotic angle showed correlation with severity of upper PSE condition, whereas increased lumbar kyphotic angle had correlation with severity of middle to lower PSE condition. Similar results were found in terms of improvement after surgery. While improvement of TK after surgery was associated with upper PSE condition, improvement of LL was related to more extensive PSE condition, from L1–L2 to L4–L5 levels. Dynamic parameters showed more prominent correlation with preoperative PSE conditions than static parameters and also identify segmental specificity in the relationship between PSE condition and angular deformity. While upper PSE condition was related to angular change of thoracic segment, middle to lower PSE condition was related to angular change of lumbar segment.

This study showed that PSE conditions had more remarkable relationship with dynamic parameters than static parameters. Considering muscle activity influenced functional aspect, it was expected that PSE condition was more closely associated with dynamic parameters, which were relevant to functionality in daily activities. It has been reported that PSE condition was more relevant to patients with lower muscle strength, poorer functionality, or more severe pain. Among the patients with low back pain, those with smaller CSA of PSE revealed lower muscle strength.¹⁸ The patients with better functional performance among those diagnosed as lumbar stenosis exhibited a significantly larger CSA and a lower fat infiltration in PSE.¹⁵ In lumbar discectomy patients, patients with persistent pain showed significantly smaller CSA of multifidus and erector spinae than those with pain-free patients.¹⁹ Because functional impairments regarding daily activity were critical problems to patients' quality of life or satisfaction with treatment, assessment of dynamic parameters was more important. Three-dimensional motion analysis fulfilled more objective and quantitative evaluation of functional aspects than that of clinical assessments.

In lower limb dynamic parameters, even if no typical correlation was found, posterior PT angle, hip and knee flexion angle or ankle dorsiflexion angle was increased as PSE atrophy and fat infiltration was more severe. The less improvement of hip flexion angle was acquired after surgery, as PSE atrophy was more severe. It has been reported that DFB also leads to change of lower limb kinematics in addition to spinopelvic kinematics such as increased knee

flexion and ankle extension (dorsiflexion).²⁰ The change of low limb kinematics was assumed to be compensatory mechanism to prevent excessive anterior translation of body center related to stooped posture in DFB, including increased hip and knee flexion, ankle dorsiflexion, which further led to posterior PT.^{2,20,21} The poorer PSE conditions led to more severe lumbar kyphosis, which, further, caused the more prominent compensatory mechanism of lower limbs.

All of these surgeries were conducted by posterior approach, which could affect PSE conditions. However, it was assumed that because all of surgeries were conducted by posterior approach, all patients were in same conditions. Although all subjects underwent the corrective surgery by posterior approach, we could obtain the results that more severe preoperative PSE resulted in less improvement after corrective surgery and segmental specificity was found between PSE condition and angular deformity. In addition, fusion levels were variable and more wide excisions could produce more severe muscles atrophy. But most of patients underwent corrective surgery within lumbosacral area and even the corrective surgeries including thoracic area were conducted at lower levels of thoracic spine. The number of subjects undergoing surgeries of thoracic segments was relatively small, so that we could not stratify the results according to surgery level. However, we obtained the segmental specificity that thoracic angle showed correlation with preoperative upper PSE conditions, whereas lumbar angle had correlation with preoperative middle to lower PSE conditions, which was mainly found in dynamic parameters, not in static parameters. This suggested that surgical outcomes were influenced by preoperative PSE conditions rather than surgical level.

This study has several limitations. First, this study was retrospective study, so we recruited only the patients who conducted three-dimensional gait analysis before and 6 months after corrective surgeries. Second, we conducted motion analysis only in terms of ambulation. The tests about other daily activities regarding sit-to-stand movement, trunk flexion, or picking up object could provide more useful information related to patients' functional aspects. Third, motion analysis was done only in 6 months after surgery. Followup study such as 1 or 2 years could assess the change of patients' functional status in terms of long term surgical outcomes.

CONCLUSIONS

The severe atrophy or fat infiltration of PSE was related to severe angular deformity in patients with DFB and to less improvement after corrective surgery in terms of static

as well as dynamic parameters. Dynamic parameters were more prominently correlated with PSE conditions than static parameters and showed segmental specificity such that upper PSE condition was more correlated with thoracic curve and middle to lower PSE condition was more correlated with lumbar curve.

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Conflicts of interest

There are no conflicts of interest.

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