J. Phys. Ther. Sci.
24: 271–274, 2012

# Kinematic Analysis of Lumbar Spine Depending on Three McKenzie's Extension Exercises in Prone

Gak Hwang Bo, PT, PhD[1)], So Hyun Park, PT, PhD[2)]

[1)] *Department of Physical Therapy, College of Rehabilitation Science, Daegu University*
[2)] *Department of Physical Therapy, Kyungsung University: 314-79 Daeyeon-Dong, Nam-Gu, Busan 608-736 South Korea.*
*TEL: +82 10-2244-1436, FAX: +82 51-663-4870, E-mail: ptpsh812@gmail.com*

**Abstract.** [Purpose] This study was conducted to compare three McKenzie's extension exercises in the prone position using kinematic analysis with fluoroscopy. [Subjects and Methods] Twelve healthy females without a history of low back pain participated. Lumbosacral lordorsis, intervertebral body angle, anterior heights of intervertebral disc and intervertebral body displacement were measured in three exercises: prone lying, prone lying on elbows, prone press-up. [Results] Prone press-up had a significantly higher value of lumbosacral lordosis than prone lying on elbows and prone lying ($p<0.05$). The intervertebral body angle and anterior height of the intervertebral disc at L3/4 were significantly higher in prone lying on elbows and prone press-up than in prone lying ($p<0.05$). There were significant differences among all exercises at L4/5 in the anterior height of the intervertebral disc($p<0.05$), and a significantly higher value in prone press-up than in prone lying or prone lying on elbows at L5/S1 ($p<0.05$). However, there was no significant difference in intervertebral body displacement ($p>0.05$). [Conclusion] These findings suggest that prone lying on the elbows might be effective at treating disc bulging at the cephalic level and that prone press-ups are effective for treatment of relatively caudal lumbar disc pathology. Our study provides normative reference values for treating low back pain during McKenzie's exercise.
**Key words:** McKenzie method, Fluoroscopy, Lumbar kinematics

*(This article was submitted Sep. 29, 2011, and was accepted Nov. 9, 2011)*

## INTRODUCTION

The McKenzie method is widely used in management of non-specific spinal pain[1–3)], and is effective for pain relief, physical performance, such as increasing range of motion (ROM), and reduction of related fear[1,4)]. The exercises of the McKenzie method are intended to promptly reduce patients' symptoms and can easily be learned, so they can be used as a direct patient self-management tool whenever the patient experiences symptoms, and to prevent low back pain from recurring once patients are fully recovered[5)].

In the McKenzie method[6)], the exercise program consists of six exercises: four extension exercises and two flexion exercises. Extension exercises are clinically preferred over flexion and are performed in the prone and standing position. Three serial extension exercises in prone lying are especially used in the treatment of acute spinal pain: prone lying, prone lying on the elbows, and prone press-ups. McKenzie reported these are the most useful and effective first-aid procedures.

The recovery mechanism of spinal pain induced by the McKenzie exercise is not clear. When performing lumbar extension, the vertebral body is posteriorly rotated, combined with small posterior translation in the saggital plane. Inferior articular processes and the spinous process are moved downward[7)]. These spinal movements change lumbar intervertebral disc morphology, and the nuclear pulposus may be migrated anteriorly[8, 9)]. Thus the nucleus would be moved away from the innervated annular wall, which may move the symptoms from a distal position to a more proximal one. This symptom is called centralization and is associated with a good prognosis and increased ROM[10)].

A few experiments have reported a change of segmental motion during lumbar extension but those studies were commonly conducted on cadavers[11, 12)]. An *in vivo* study of the kinematics of simple lumbar extension in standing and sitting was conducted but it was not related to therapeutic exercise[13, 14)], and the kinematics of the lumbar spine during passive extension were not analyzed. Therefore, the purpose of this study was to compare lumbar kinematics using fluoroscopy among three McKenzie's extension exercises in the prone position.

## SUBJECTS AND METHODS

### *Subjects*

Twelve healthy subjects without neurological or musculoskeletal disease (12 females, mean age: 21.4±0.5 years) participated in this experiment. The exclusion criteria included previous spinal problems, current medical treatment for spinal pain, and pregnancy.

The principal objective of this study and the radiologic

**Table 1** . Results of lumbar spine kinematics, depending on McKenzie's exercise of prone lying, prone lying on elbows and prone press-up

| | | Exercise1 | Exercise2 | Exercise3 |
|---|---|---|---|---|
| Lumbosacral lordorsis (degree) | *,+,# | 39.95 (9.29) | 47.91 (8.91) | 54.11(6.39) |
| Intervertebral body angle (degree) | L3/4*,+ | 8.39 (4.03) | 12.05 (3.95) | 13.33(2.94) |
| | L4/5*,+,# | 13.20 (3.85) | 16.84 (3.56) | 18.55(3.93) |
| Intervertebral body displacement (norm) | L3/4 | -0.11 (0.04) | -0.13 (0.02) | -0.09(0.12) |
| | L4/5 | -0.13 (0.03) | -0.14 (0.04) | -0.10(0.12) |
| | L5/S1 | -0.13 (0.05) | -0.13 (0.04) | -0.06(0.16) |
| Anterior heights of intervertebral disc (norm) | L3/4*,+ | 0.33(0.04) | 0.37(0.04) | 0.38(0.05) |
| | L4/5*,+,# | 0.39(0.04) | 0.43(0.05) | 0.45(0.04) |
| | L5/S1+,# | 0.44(0.07) | 0.46(0.07) | 0.50(0.06) |

*significant differences level at $p<0.05$ between exercise 1 and 2, + exercise 1 and 3, # exercise 2 and 3

risks were explained to the subjects and their written informed consent was obtained before the start of the study. This protocol was conducted in accordance with the ethical standards of the Declaration of Helsinki.

*Procedure*

One physical therapist taught subjects the exact movements to be performed. The subjects lay in a prone, relaxed position. The exercise is divided into three: prone lying, prone lying on the elbows, prone press-up[6]. The first is "prone lying", in which subjects lie face down and relax completely. The second is "prone lying on the elbows", in which subjects place their elbows under their shoulders so that they lean on their forearms and then relax completely. The third is "prone press-up", in which subjects straighten their elbows under their shoulders in the press-up position. Subjects practiced each position three times in preparation. After practices, an x-ray tube was pointed at their lumbar spine, from L3 to superior end plate of sacrum in the saggital plane, and a radiograph was taken in each exercise using fluoroscopy (ARCADIS Orbic, Siemens, USA). Images were sent to the picture archiving communication system (PACS) and the digitized images were analyzed using LabVIEW software (National Instruments, USA).

For kinematic analysis, the lumbosacral lordorsis, intervertebral body angle, anterior heights of intervertebral disc and intervertebral body displacement were analyzed following the description of a previous study [13, 14]. Lumbosacral lordorsis was defined as the angle between the midplane lines of L3 and the superior end plate of the sacrum. The intervertebral body angle was defined as the angle between adjacent midplane lines. The angle was given a positive value when the wedge opened ventrally. The anterior height of the intervertebral disc was the sum of the perpendicular distance of the anterior-inferior corner of the cranial vertebra and of the perpendicular distance of the anterior-superior corner of the caudal vertebra from the bisectrix.

The intervertebral body displacement was defined as the distance between the perpendicular projections of the vertebral body center points to the bisectrix. When the center point of the cranial vertebra was positioned anterior to the caudal vertebra, it was expressed as a positive value. To account for variations in magnification and stature, anterior heights of intervertebral disc and intervertebral body displacement were divided by the mean depth (mean of the superior endplate and inferior endplate) of the cranial vertebra.

Prior to measurement of the spine, 10 radiographs of the lumbar spine were evaluated to determine inter-observer reliability. The ICC value was 0.99 (95%CI: 0.96–0.99).

Comparisons among the three exercises regarding lumbosacral lordorsis, intervertebral body angle, anterior heights of intervertebral disc and intervertebral body displacement were analyzed using repeated measures one-factor analysis. PASW 18.0 for Windows was used for all analyses, and statistical significance was accepted for p-values of $<0.05$.

## RESULTS

Twelve subjects were enrolled, all of whom were females. They had a mean age of 21.4±0.5 years, a mean weight of 51.13±3.87 kg and a mean height of 162.40±4.61 cm. Increases in the lumbar extension angles, generally increased the values of lumbosacral lordosis, intervertebral body angles and anterior heights of intervertebral discs. Prone press-up had a significantly higher value of lumbosacral lordosis than those of prone lying on elbows and prone lying ($p<0.05$). The intervertebral body angle was significantly higher in prone lying on elbows and prone press-up than in prone lying at the L3/4 level ($p<0.05$), and there were significant differences among all the exercises at the L4/5 level ($p<0.05$). The anterior height of the intervertebral discs were significantly higher in prone lying on the elbows and prone press-up than in prone lying at the L3/4 level ($p<0.05$). There were significant differences in anterior intervetebral disc height among all exercises at the L4/5 level ($p<0.05$), and a significantly higher value in prone press-up than in prone lying or prone lying on the elbows at the L5/S1 level ($p<0.05$). However, there were no significant differences among the exercises in intervertebral body displacement ($p>0.05$) (Table 1).

## DISCUSSION

In the literature, the McKenzie exercise has been shown to be effective for pain relief and increase of ROM[3, 15]; however, there has been no research into the biomechanical changes induced by McKenzie's extension exercises at the lumbar spine. In this study, we observed the kinematic changes of lumbosacral lordorsis, intervertebral body angle and anterior heights of intervertebral discs as the axis of motion moved caudally with increasing lumbar extension.

Lumbosacral lordorsis increased according to increased lumbar extension. Masharawi et al. [16] reported that the vertebra body and disc morphology affected lordorsis, and Aspden[17] suggested that lumbosacral lordorsis acts positively on lumbar biomechanical stability. However, there is controversy as to how lumbosacral lordorsis affects low back pain. Some report lumbosacral lordorsis is significantly reduced in low back pain patients[18, 19], while others report greater lordorsis[20].

Commonly, the overall spine motion occurs through segment motion. The axis of extension movement of the lumbar spine is not constant and varies in location depending on the position of the joint and posture[7]. In this study, intervertebral body angles were increased with increasing lumbar extension. We assume that the movement of the axis of lumbar extension moves caudally with increasing lumbar extension in the prone position.

Disc height is changed with spinal motion as well as compression of the disc[21]. In this study, anterior disc heights at the L3-4 and L4-5 levels, relatively cephalic segments, significantly increased in prone lying on elbows compare to prone lying. Anterior disc heights at the L4-5 and L5-S1 levels, relatively caudal segments, significantly increased in prone press-up compare to prone lying on elbows. Lumbar extension tends to reduce stress in the anterior annulus and nucleus, but increase it in the posterior annulus. At this time, the hydrophilic property of the disc redistributes the pressure under compression. In situations of annulus fibrosus injury or tear, the nucleus pulposus could migrate into a lower resistance area[8]. Therefore, the extension exercises of the McKenzie method would be helpful for patients with posterior disc bulging by migrating the nucleus pulposus anteriorly.

Displacement concurrently occurs in lumbar extension[7]. It has been suggested that 2 millimeters of anterior sagittal displacement is normal for intervertebral joints of the lumbar spine[22], with 2.8 millimeters representing the upper limit of normal[23]. Li et al.[24] reported that the average displacements at the L2-3, L3-4 and L4-5 levels were between 0.7 and 1.5 mm during active flexion-extension in asymptomatic elderly as measured by a dual fluoroscopy system. Displacement was not significantly changed during each McKenzie's exercise in this study because healthy subjects were employed.

This study has some limitations: a small sample size; healthy young women subjects who did not represent the kinematics in a pathological situation; and limited analysis of the lower lumbar spine from L3 to the sacrum due to limited field of view available.

To our knowledge, this is the first study to conduct the kinematic analysis of the lumbar spinal segment during McKenzie's exercises. Our results suggest prone lying on the elbows is sufficient for treatment of disc bulging at L3-4 and L4-5, and prone press-up is effective for treatment of relatively caudal lumbar disc pathologies at L4-5, L5 to S1. Our study provides normative reference values for physical therapists, physicians and researchers treating low back pain, but further studies will be required to establish the relationship between pain relief and kinematic change during McKenzie's exercise.

## ACKNOWLEDGEMENT

This Research was supported by the Daegu University Research Grant, 2010.

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