A Comparison of Lumbar Lordotic Curves between Herniated Nucleus Pulposus Patients and Normal Subject Using a Flexible Curve Ruler

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Purpose: We attempt to assess the differences in the degree of lumbar lordosis in patients with lower back pain caused by the herniation of the nucleus pulposus and in normal people (divided into male and female groups).

Methods: This study was conducted with 14 patients (7 males, 7 females) diagnosed with, and being treated for, lumbar herniated nucleus pulposus and 14 normal people (7 males, 7 females). In order to examine the degree of lumbar lordosis in these subjects, hip flexor lengthening tests were conducted and the lumbar curves were measured in three postures (supine, sitting, and prone) and the results were compared.

Results: The measured values of the curves for the standing and prone postures showed statistically significant differences between the normal group and the patient group, between the normal male group and the male patient group, and between the normal female group and the female patient group (p<0.05).

Conclusion: The measurement method that uses flexible curve rulers in the standing or prone postures can be usefully utilized in assessing the lumbar lordosis of patients with lumbar herniation of the nucleus pulposus.

Keywords: Lumbar Hemiated nucleus pulposus, Lumbar lordosis, Flexible curve rulers

1. Introduction

The frequency of occurrence of lower back pain is increasing as society is further industrialized.1 Lower back pain is a common affliction that appears in 60~80% of adults and is known to restrict daily activities.2 The causes of lower back pain include reduced physical activities, reduced psoas muscle strength, poor posture, the use of immoderate force, and excessive tension,3 as well as spinal injuries, such as fractures and dislocations, and structural causes, such as scoliosis, spondylolisthesis, stenosis, and the herniation of the nucleus pulposus.4

In most cases, the herniation of the nucleus pulposus occurs on the posterolateral or posterior side of the spinal cord or spinal nerve roots.4 Four types of herniation of the nucleus pulposus have been presented, based on the degree of severity.5 Nuclear protrusions, which are the most minor type of herniation, may compress the posterior fibers of the annulus fibrosus and the posterior ligament, causing local low back pain.4 A general mechanism of the herniation of the nucleus pulposus is the accumulation of minor injuries, caused by repeated work performed with the lumbar part excessively flexed.6 Lumbar part extension is the reverse of flexion and it increases natural lumbar lordosis. Lumbar hyperextension tends to cause anterior movements of the annulus fibrosus, thereby reducing intradiscal pressure. For this reason, the pain of nuclear protrusion or prolapse patients, which is related to the compression of the spine or nerve roots, is relieved.6

The degrees of lumbar lordosis and reduced lumbar
motility are considered important as clinical characteristics of patients who suffer from lower back pain caused by the herniation of the nucleus pulposus. Clinicians mainly assess the posture of patients with spinal dysfunction when the patients are standing comfortably. Many researchers have presented that, if a patient was standing in a posture of excessive lumbar lordosis, the patient’s erector muscle and hip flexor should contract to support his/her body, while his/her abdominal muscle should be weakened and drooping. These assessments of postures were based on visual inspections. Visual inspections do not reliably provide quantitative information on lumbar lordosis. Surface measuring methods that can quantify lumbar lordosis include a pantograph, a De Brunner Kyphometer, an inclinometer, Metrecom, and flexible curves.

Bergenudd et al. reported that the degree of lumbar lordosis measured using pantographs in standing postures were higher in women than in men, and Youdas et al. reported that the degree of lumbar lordosis measured using flexible curve rulers was higher in women than in men. Norton et al. reported that the degree of lumbar lordosis measured using Metrecom was higher in women than in men. Through these three studies, it can be seen that the degree of lumbar lordosis in standing postures was higher in women than in men. In a study conducted on 90 subjects (45 males, 45 females), Youdas et al. reported that the age of the patient and the degree of lumbar lordosis in standing postures were not highly associated (r=0.11, 0.42). Youdas et al. also reported that BMIs and the degree of lumbar lordosis in standing posture were not highly associated (r=0.07, 0.10).

Many studies on the degree of lumbar lordosis for lower back pain patients have been reported, although different results have been reported by individual researchers. Christie et al. reported that the degree of lumbar lordosis increased more in the lower back pain patient groups and in the chronic lower back pain patient groups than in the non-lower back pain groups. However, Youdas et al. reported that there was no significant difference in the degree of lumbar lordosis between low back pain groups and non-lower back pain groups. Park et al. reported that the degree of lumbar lordosis decreased in lower back pain patient groups compared to normal people. As such, different results were drawn according to the researcher and the study method. Although studies on the relationship between lower back pain and lumbar lordosis have drawn different results, the studies conducted in Korea that compare the degree of lumbar lordosis in patients with lower back pain caused by the herniation of the nucleus pulposus and normal people are insufficient. Therefore, we attempt to assess the differences in the degree of lumbar lordosis in patients with lower back pain caused by the herniation of the nucleus pulposus and in normal people (divided into male and female groups).

II. Materials and Methods

1. Subjects
This study was conducted with 14 patients (7 males, 7 females), who had been diagnosed with lumbar herniated nucleus pulposus (LHNP) and were being treated, and 14 normal people (7 males, 7 females). The selection criteria

<table>
<thead>
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<th>Variables</th>
<th>HNP (n=14)</th>
<th>Normal (n=14)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Range</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>40.0±11.5</td>
<td>23~25</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.2±7.6</td>
<td>153.6~74.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.2±6.2</td>
<td>53.8~74.2</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.8±2.8</td>
<td>18.5~28.7</td>
</tr>
<tr>
<td>VAS (cm)</td>
<td>3.5±1.6</td>
<td>2~7</td>
</tr>
<tr>
<td>ODI (%)</td>
<td>27.9±11.1</td>
<td>14~15</td>
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</table>

HNP: herniated nucleus pulposus, BMI: body mass index, VAS: visual analogue scale (range 0~10), ODI: Oswestry back pain disability questionnaire (range 0~100).

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for patients with LHNP required that the patients had been diagnosed with a protrusion, from among the types of LHNP, based on findings from magnetic resonance imaging (MRI), had no experience with orthopedic surgery, and could sufficiently assume the experimental postures in this study. The selection criteria for the normal subjects required that they had not experienced any orthopedic or neurological disorder in their lumbar part, had not experienced lower back pain for the last six months, and had no history of surgery on lumbar–part joints. All the subjects sufficiently understood the purpose and method of this study and voluntarily agreed before they participated in the experiment. The general characteristics of the subjects are as follows (Table 1).

2. Methods
1) Measurement tools and assessment
(1) Visual analog scale (VAS)
The VAS was used for measurement of pain. Participants rated their level of neck pain at rest on a VAS: a 10 cm sliding scale anchored by the descriptors “no pain” and “worst pain imaginable.”

(2) Body mass index (BMI)
BMI is defined as the ratio of weight (kg) to the square of height (m). For the BMI of the subjects, a score of 20 to 25 was defined as normal weight, a score less than 20 was classified as underweight, and a score of 25 to 30 was classified as overweight. A score over 30 indicated obesity.

(3) Oswestry back pain disability questionnaire (ODQ)
This tool was used to assess dysfunction in daily life resulting from lower back pain. Restrictions on functional daily activities were divided into ten sections and the subjects were encouraged to voluntarily answer the related questions. Each section was divided into six sub-levels, represented by scores ranging from 0 points to 5 points. 0 points indicates that there was no restriction on functional activities, while 5 points indicates that there was a high degree of restriction. The maximum score for the six sub-levels of the ten sections was 50 points, and the degree of dysfunction for each subject was summed up as a score and integrated as a percentage (%).

Higher scores indicated higher degrees of dysfunction.

2) Length of hip flexor muscle
Kendall et al. reported that as the degree of lumbar lordosis increased, the passive tension of the hip flexor increased, and thus the lengthening of the hip flexor decreased. The subject should lie supine, with his/her hip joint and knees completely straightened and arms crossed on his/her chest. The right leg should be measured first for all subjects. A hand of tester 2 should completely bend the left knee of the subject and slowly and passively bend the subject’s hip joint to move the knee toward the chest of the subject, another hand of tester 2 should push the right knee toward the table in order to full extension. Tester 1 should palpate the spinous processes of the L3–4 of the subject to place the end of the tester’s finger between the L4–5 of the subject and the table. After having the subject bend his/her hip joint only until he/she can maintain his/her L3–4 level against the table, tester 1 should use a 360° universal goniometer (UG) to measure the right trunk–thigh angle of the subject, while the axis of UG is positioned at the subject’s greater trochanter, placing the fixed arm parallel to the longitudinal axis of the trunk of the subject and the table and placing the moving arm on the longitudinal axis of the right thigh of the subject. The left leg should be measured using the same method. Intraclass coefficient (ICC) estimates the reliability of a single measurement made by the tester. The indirect measurement of length of the right and left one-joint hip flexor estimates the ICC of 0.60, 0.54 respectively.

3) Lumbar curve
(1) Standing
The subject should stand in a comfortable posture in bare feet, facing forward. Tester 1 should attach adhesive points to the spinous processes of the T12, L4, and S2 of the subject and place a flexible curve ruler along the spinal curvature of the subject to form the same shape. Tester 2 should record the locations where the adhesive points cross the flexible curve ruler. After moving the flexible curve ruler to a piece of paper, without changing the shape, tester 1 should hold the flexible curve ruler while tester 2 draws a line along its
convex contour. The location of the points corresponding to the spinous processes of the T12, L4, and S2 should also be marked on the contour line on the paper.

(2) Sitting
The method for measuring the peak lumbar flexion range of motion is used to indirectly measure the length of the muscle in the lower lumbar part of the subject. The subject should perch on the edge of a chair. The subject should spread his/her legs to the width of his/her shoulders, hang his/her hands to the sides of his/her feet, and bend his/her waist forward maximally, so that his/her head is placed between his/her knees. Then, tester 1 should palpate the spinous processes of the subject’s T12, L4, and S2 to attach adhesive points on the spinous processes; the subject should maintain this posture for 15 seconds at the end range of the posture, so that the soft tissues of the lower lumbar part are relaxed and become soft. After recovering the initial posture, the subject should be encouraged to bend his/her waist forward maximally once again. Tester 1 should place a flexible curve ruler along the spinal curvature of the subject, so that it forms the same shape.

(3) Prone
By passively extending the lumbar spine, using the same method as McKenzie’s prone press-up method, the length of the abdominal muscle can be indirectly estimated. The subject should take a prone posture on a table and tester 1 should palpate the spinous processes of the T12, L4, and S2 to attach adhesive points. Tester 2 should instruct the subject to straighten his/her shoulders and elbows and then press the table with his/her palms to extend his/her lumbar spine. At this time, tester 2 should hold the subject’s iliac crest with his thumbs and place the distal tips of the remaining fingers between the anterior superior iliac spine (ASIS) of the subject and the table. This is to find the point where the subject’s ASIS begins to separate from the distal tips of the fingers of tester 2 (when the subject is extending his/her lumbar spine), as this is the end point of the lumbar movement. The subject should maintain the maximum passive extension of the lumbar spine for 15 minutes and then repeat this three times. On the fourth time, tester 1 should place a flexible curve ruler along the spinal curvature of the subject, so that it takes the same shape.

4) Procedure
As study subjects, patients who had been diagnosed with a protrusion, from among the types of LHNPs, based on MRI findings, were classified into a hemiated nucleus pulposus (HNP) group and 14 normal subjects were selected (7 males, 7 females) per group. The HNP patient group completed one highly reliable questionnaires (ODQ). All the subjects changed into clothes suitable for measurement before the hip flexor length tests were conducted. Beginning with their right legs, their lumbar curves were measured in three postures.

Figure 1. Posture of lumbar lordosis in standing and two methods for calculating lumbar curves. (A) Measurement size of lumbar lordosis (standing). (B) To calculate lumbar curves, tangents and trigonometry were used. (range 21°–49°, mean 43°) \[ \theta = 4 \times \arctan(2H/L) \]. (C) Index of lumbar lordosis = l/K \times 100 \( l \) = width of lumbar lordosis \( K \) = length of the lumbar spine.
(standing, sitting, and prone).

The curves were quantified using two measurement methods: the angles of lumbar lordosis and the indexes of lumbar lordosis. The angles of lumbar lordosis are measured by connecting point T12 and point S2 on the contour line with a straight line (L) and then measuring the straight line in millimeters. Then, a line vertically connects this line with point L4 (H); it is measured in millimeters. This length is the height of the curve. The angle of lordosis (θ) is obtained from the following equation: \( A: \theta=4 \times \arctan(2H/L) \)\(^{27} \) (Figure 1A).

The indexes of lumbar lordosis indirectly measure the degree of lumbar lordosis: the indexes of lumbar lordosis are calculated using a modified De Brunner kyphometer measuring method. The horizontal distance (D) between the straight line (K) that connects point T12 with point S2 and the point that is farthest from this straight line should be obtained. The indexes of lumbar lordosis are obtained from the following equation: \( B: \text{index of lumbar lordosis}=D/K \times 100^{30} \) (Figure 1B).

3. Statistical analysis

The data from this study were statistically processed using the SPSS ver. 18.0 program for Windows (SPSS Inc., Chicago, IL, USA). For normality test of fewer subjects (14 patients per group), the Shapiro-Wilk normality test was conducted. Independent sample t-tests were conducted to examine the differences in the lengths of hip flexors and the degree of lumbar lordosis in the HNP patient group (7 males, 7 females) and the normal subjects (7 males, 7 females), and the significance level for all statistical tests was determined as \( \alpha = 0.05 \).

### Table 2. A comparison of lumbar lordosis in HNP and normal subjects

<table>
<thead>
<tr>
<th>Variables</th>
<th>HNP (n=14)</th>
<th>Normal (n=14)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle (°)</td>
<td>Standing: 22.36±8.68*</td>
<td>40.33±8.59</td>
<td>5.51</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Sitting: 21.38±9.53</td>
<td>26.32±6.06</td>
<td>1.64</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Prone: 28.57±9.37</td>
<td>44.41±14.61</td>
<td>3.41</td>
<td>0.01</td>
</tr>
<tr>
<td>Index</td>
<td>Standing: 5.31±2.35</td>
<td>9.74±2.10</td>
<td>5.26</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Sitting: 5.90±2.71</td>
<td>6.42±10.28</td>
<td>0.65</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>Prone: 7.33±2.68</td>
<td>11.62±2.98</td>
<td>4.01</td>
<td>0.00</td>
</tr>
</tbody>
</table>

HNP: herniated nucleus pulposus.

*Values are number or mean±standard deviation. \(^{1}p<0.05\).

### III. Results

1. Subjects

As study subjects, the LHNP patient group average age, height, weight, and BMI were 40 (11.5) years old, 168.2 (7.6) cm, 64.2 (6.3) kg and 22.8 (2.8) kg/m\(^2\) respectively. In addition, the LHNP patient group average VAS and ODI were 3.5 (1.6) cm and 27.9 (11.1) % respectively. The normal group average age, height, weight, and BMI were 29.6 (4.5) years old, 168.9 (7.8) cm, 64.2 (14.8) kg and 22.1 (3.4) kg/m\(^2\) respectively.

2. Measurement of the hip flexor length

This measurement method is frequently used to indirectly measure the length of the hip flexor. The larger is the angle of lumbar lordosis, shorter the length of the hip flexor, and thus the smaller the trunk-thigh angle. However, in this study, the measured values of the lengthening of the hip flexor were shown to be smaller in the LHNP patient group (right side: 176.85°, left side: 177.07°) than in the normal group (right side: 177.14°, left side: 178.29°). The length of the hip flexor was compared between the HNP patient group and the normal group through independent sample t-tests, and the results showed no statistically significant differences between the two groups, except for the left trunk-thigh angles (p<0.05).

3. Measurement of the lumbar curves of the subjects

1) Measurement of the lumbar curves of the HNP and normal groups

The lumbar curves of the HNP patient group and the normal
group were measured in three postures (standing, sitting, and prone) and were compared with independent sample t-tests; in the results, both the angles and indexes showed statistically significant differences for the curves in the standing and prone postures (p<0.05) (Table 2).

2) Measurement of the lumbar curves of the male HNP and normal groups

The lumbar curves of the male HNP patient group and the normal male group were measured in three postures (standing, sitting, and prone) and were compared using independent sample t-tests; in the results, both the angles and indexes showed statistically significant differences for the curves in the standing and prone postures (p<0.05) (Table 3).

3) Measurement of the lumbar curves of the female HNP and normal groups

The lumbar curves of the female HNP patient group and the normal female group were measured in three postures (standing, sitting, and prone) and were compared using independent sample t-tests; in the results, both the angles and indexes showed statistically significant differences for the curves in the standing and prone postures (p<0.05) (Table 4).

IV. Discussion

This study was conducted with 14 patients (7 males, 7 females) diagnosed with, and being treated for, LHNPP and 14 normal people (7 males, 7 females). In order to examine the degree of lumbar lordosis in these subjects, hip flexor lengthening tests were conducted and the lumbar curves were measured in three postures (supine, sitting, and prone) and the results were compared.

Flexible curves were used to measure the degree of lumbar lordosis. Hart and Rose\(^9\) reported that the ICC of the results of measurement for the lumbar curves of 89 subjects obtained in standing postures, and when the subjects maximally bent their waists forward, was 0.97 the validity of this figure was obtained by comparing the results with the images of lumbar curves taken in radiographs. Link et al.\(^9\) reported the

| Table 3. A comparison of lumbar lordosis in HNP and normal male |
|----------------------|-----------------|----------|----------|
|                      | HNP (n=7)       | Normal (n=7) | t        | p        |
| Angle (°)            | Standng        | 20.04±9.58*  | 38.89±10.50 | 3.50     | 0.00*    |
|                      | Sitting         | 25.33±10.27 | 26.80±4.90  | 0.34     | 0.74     |
|                      | Prone           | 26.96±10.27 | 40.33±10.34 | 2.42     | 0.03*    |
| Index                | Standing        | 4.57±2.49   | 8.92±2.43   | 3.31     | 0.01*    |
|                      | Sitting         | 7.39±2.38   | 6.90±6.1    | -0.52    | 0.61     |
|                      | Prone           | 7.05±2.81   | 11.07±1.40  | 3.39     | 0.01*    |

HNP: herniated nucleus pulposus.
*Values are number or mean±standard deviation. *p<0.05.

| Table 4. A comparison of lumbar lordosis in HNP and normal female |
|----------------------|-----------------|----------|----------|
|                      | HNP (n=7)       | Normal (n=7) | t        | p        |
| Angle (°)            | Standing        | 24.68±7.69*  | 41.78±6.67 | 4.93     | 0.00*    |
|                      | Sitting         | 17.43±7.43  | 25.83±7.43 | 0.11     | 0.92     |
|                      | Prone           | 30.18±8.86  | 48.48±17.79| 2.78     | 0.02*    |
| Index                | Standing        | 6.05±2.12   | 10.56±1.43 | 5.53     | 0.00*    |
|                      | Sitting         | 4.41±2.26   | 5.93±1.62  | -1.33    | 0.21     |
|                      | Prone           | 7.61±2.72   | 12.16±4.08 | 2.73     | 0.02*    |

HNP: herniated nucleus pulposus.
*Values are number or mean±standard deviation. *p<0.05.
degree of lumbar lordosis for 61 men measured in a standing posture using flexible curves, and the result was $34.3 \pm 9.9^\circ$ on average. Nourbaksh and Arab reported the degree of lumbar lordosis for 150 men measured using flexible curves, and the result was $35 \pm 13^\circ$ on average.

Youdas et al. reported the degree of lumbar lordosis for 90 people (45 male; 45 female) using flexible curves, and the result was $37.5 \pm 11^\circ$ on average for the men and $52.7 \pm 15.3^\circ$ on average for the women. Although these measured values are a little different from the values obtained in this study – $38.89 \pm 10.50^\circ$ on average among the normal men and $41.78 \pm 1.43^\circ$ on average among the normal women — the fact that the degree of lumbar lordosis for the women was larger than for the men was the same in both studies. Youdas et al. also measured the degree of lumbar lordosis in the prone posture and reported that the values were $50.1 \pm 9.2^\circ$ on average for the normal men, $42.7 \pm 8.8^\circ$ on average for the chronic lumbar back pain (CLBP) men, $56.5 \pm 10.4^\circ$ on average for the normal women, and $56 \pm 12^\circ$ on average for the CLBP women. The measured values in this study were shown to be $40.33 \pm 10.34^\circ$ on average among normal men, $26.96 \pm 10.27^\circ$ on average among LHN patients, $48.48 \pm 17.79^\circ$ on average among normal women, and $30.18 \pm 8.86^\circ$ on average among LHN patients. The reason why the differences in the measured values between the two groups are larger than in previous studies is likely because, in the case of LHN patients, the pain is severe when the lumbar spine is extended, and the range of extending motion is limited due to the weakened lumbar extensors. The measured values of lumbar curves in the sitting posture did not show statistically significant differences between the LHN patients and the normal group. This is because LHN patients had less severe pain during lumbar flexion and their range of flexion was not as limited, compared to lumbar extension, because of their flattened lumbar curves.

Link et al. reported that they measured the associations between the degree of lumbar lordosis and the lengthening of the hip flexor in two postures (standing and sitting) in 61 men, using flexible curves, and the results showed statistically significant associations ($r=0.25$, $p=0.05$). Kendall et al. reported that as the degree of lumbar lordosis increased, the passive tension of the hip flexor increased, and thus the lengthening of the hip flexor decreased. However, in this study, the measured values of the lengthening of the hip flexor were shown to be smaller in the LHN patient group (right side=176.86$, left side=177.07$) than in the normal group (right side=177.14$, left side=178.29$). This is likely because the end points of measurement, determined when the hip joint was passively bent, might have been inaccurate.

The limitations of this study are as follows: First, the number of compared subjects was small. There were difficulties in selecting patients diagnosed with a protrusion from among the LHN patients. Second, the ages of the LHN patients and the ages of the normal subjects could not be equalized. However, some researchers reported that age and lumbar curve were not highly associated.

This study was intended to compare the degree of lumbar lordosis in the lumbar herniation of nucleus pulposus patients and normal people, divided into male and female groups. The lumbar curves of the LHN patients and the normal subjects were measured in three postures using flexible curve rulers: in the results, the measured values of the curves for the standing and prone postures showed statistically significant differences between the normal group and the patient group, between the normal male group and the male patient group, and between the normal female group and the female patient group ($p<0.05$).

The above results show that patients with lumbar herniation of the nucleus pulposus had a decreased degree of lumbar lordosis in the standing posture, as compared to normal subjects. Therefore, the measurement method that uses flexible curve rulers in the standing or prone postures can be usefully utilized in assessing the lumbar lordosis of patients with lumbar herniation of the nucleus pulposus.

**Author Contributions**

Research design: Jung YM, Choi JD

Acquisition of data: Jung YM

Analysis and interpretation of data: Jung YM, Choi JD

Drafting of the manuscript: Jung YM

Research supervision: Choi JD
References