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# A Study on the Influence of Lumbar Lordosis and Intervertebral Disc Angle by Obesity

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**ABSTRACT**

Lumbar Lordosis Angle (LLA) is an index that can be used to evaluate the curvature of the lumbar vertebrae. It can measure the structural stability of the lumbar spine and the stability of each segment of the vertebral column at the intervertebral disc angle (IDA). Especially, our data shows it is found to be a strong positive correlation between obesity and the angle of lordosis for lumbar vertebrae. Also, the reason for the large IDA in the case of obesity seems to be the result of the weakening of anatomical structure as well as the gravity effect. And, the obesity interferes with normal sagittal balance and fails to maintain a straight posture with minimal energy. Therefore, the obesity can be an important factor in causing back pain by changing the lumbar lordosis.

Keyword: Lumbar vertebrae, Lordotic angle, Intervertebral angle, Mechanical load, Obesity

## Ⅰ. INTRODUCTION

People have optimal spinal curvature ranging from neck to pelvis in order to evenly distribute the load of body weight during walking or everyday life. Particularly, the lumbar spine takes the form of a normal physiological curve called a lordosis. The normal curvature distributes the weight evenly to minimize the load on the vertebral body. It increases the shock absorption function of the vertebrae and helps stability and equilibrium to each joint.[1] Maintaining a normal spinal curvature is important to absorb the shock to sudden forces.

The vertebral segments are anatomically located in the upper and lower vertebrae with the intervertebral disc at the center. It is composed of a triangular structure by an anterior structure, a facet joint, a ligament flavum, an interspinous ligament, and a supraspinatus ligament. The repetitive stimuli of instability lead to hypertrophy and Bony spur formation such as Joint capsule and yellow ligament of posterior joint restoring the vertebral segment, but causing stenosis of the spinal canal.[2]

Lumbar Lordosis Angle (LLA) is an index that can be used to evaluate the curvature of the lumbar spine. It can measure the structural stability of the lumbar spine and the stability of each segment of the vertebral column at the intervertebral disc angle (IDA) Scale.[3]

Recently, the Low back pain (LBP) is a major health problem affecting the adult population. The obesity is more likely to cause musculoskeletal disorders due to abnormal lordotic angles of the lumbar spine.

As the spinal disease patients increase, the demand

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for general radiography examination of the lumbar vertebrae is increasing, and as the digitization of the radiological equipment becomes generalized, it is used as the basic radiography examination of the patient.[4] The basic diagnostic methods of the Low back pain include physical examination and radiological examination. Especially, general radiography examination of the lumbar vertebrae using radiation is the most used as a basic examination for diagnosis of back pain. General radiography examination of the lumbar vertebrae is the most basic test for patients with various back pain and leg or pelvic sensation, inflammatory or degenerative diseases and deformities of other joints, tumors, trauma patients.[5]

In the case of the lordotic angle of lumbar vertebrae, a various values are presented according to the position to be measured. The normal range is 50° to 60° at standing posture[6], and G. Vaz et al.[7] reported a mean of 46.5°±11.1° in 100 healthy adults.

Usually, the general anteroposterior lumbar vertebrae examination is performed while the knee joint is flexed in order to stretch the physiological curvature in the recumbent position. The lateral examination is to bend the hip joint and the knee joint lightly to stabilize the posture in the recumbent position.[8] As for the posture at the general radioscopic lateral examination, Stagnara et al.[8] stated that there was no difference in the lordosis angle between the standing posture and the lateral recumbent posture. Whereas Anderson et al.[9] stated that there was difference by the contraction of the knee muscles due to the flexion of the knee. The lordotic angle of lumbar vertebrae is a representative index for evaluating the degree of bending of the lumbar vertebrae. However, the normal range is larger than that of the cervical spine or thoracic spine. And there is no measurement method that everyone is accredited. In order words, various methods can be used depending on the research. For example, Hansson et al.[10] measured the angle formed by the L1 and upper side of S1 and Fernand and Fox[11] used the method of using the upper side extension line of the S1 and upper side of L1.

This study was performed to measure the angle of the lordosis and the angle of the intervertebral disc with the lateral image of the lumbar vertebrae, which was examined in a lateral recumbent posture without weight load. Then, we investigated the angle of the intervertebral disc angle according to the angle of lordosis and would like to explain how obesity affects lordotic and intervertebral disc angle for lumbar vertebrae.

## Ⅱ. MATERIAL AND METHODS

This study is not related to IRB because it is patient data based on secondary statistics.

### 1. Research subjects

As a result of applying the moderate effect size 0.25, the power of 90%, and the significance level of 0.05 for the one - way ANOVA using the G * power 3.1 analysis, the number of samples satisfying the normal distribution was 166. We selected 170 patients who have the reading result of 'Negative' from the medical specialist of radiology among the patients who underwent the anteroposterior and lateral examination for lumbar vertebrae from January 1 to December 31, 2017.

### 2. Research method

#### 2.1 Lumbar lordosis angle (LLA) and Intervertebral disc angle (IDA)

In this study, the lordotic and intervertebral disc angle was measured in a lateral recumbent position. In order to observe the lordotic curve for the lumbar vertebrae, as shown Fig. 1 (a), (b), the crossing angle between the upper surface of L1 and the upper surface of S1 was measured[12] And the angle of the intersection of the line of the upper surface and the lower surface at disc of lumbar vertebrae was measured.[13] All measurements were averaged three times in order to reduce the error in the measurement.

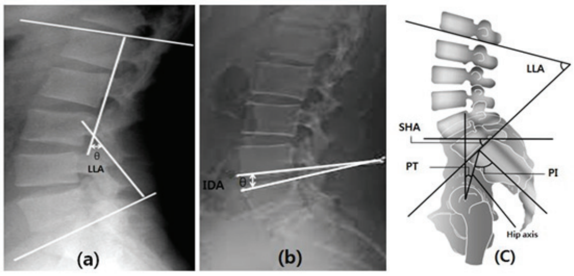


Fig. 1. (a), (b) Measurement of lumbar vertebral lordotic and intervertebral disc angle (c) Definition of the relationship between spinopelvic parameters. (PI: pelvic incidence; SHA: sacral horizontal angle; PT: pelvic tilt)

As shown in Fig. (c), the PI (pelvic incidence) reflects the morphology of the pelvis, which is constant for each person and is defined as the angle between a line perpendicular to the midpoint of the sacral end plate and the line to the center of the femoral heads. SHA (sacral horizontal angle) and PT (pelvic tilt) are variable depending on the version of the pelvis about the hip axis. SHA is the angle between the line along the S1 end plate and the HRL (horizontal reference line). PT is the angle between the line from the midpoint of the sacral plate to the center of the femoral heads and the VRL (vertical reference line).[14] The PI is the sum of SHA and PT (PI = SHA + PT), and the values of SHA and PT are larger than normal people when they are obese.[15]

### 3. Data analysis

Statistical analysis was performed using SPSS-PC 21.0 (Statistical Package for the Social Science, SPSS). LLA and BMI were used as independent variables and IDA for the lumbar vertebrae 3 to 4 (L3~L4), the lumbar vertebrae 4 to 5 (L4~L5) and the lumbar vertebrae 5 to sacrum 1 (L5~S1) were used as dependent variables, Independent T-test, one-way ANOVA, and Pearson correlation analysis were performed according to the results of the analysis. All data were considered to be statistically significant if the p-value was less than 0.05.

## Ⅲ. RESULT

### 1. Statistical analysis

First, we investigated the relationship among the lumbar lordosis angles (LLA), intervertebral disc angle (IDA) and Body Mass Index (BMI) for 170 patients.

The correlation of LLA and BMI showed a weak positive correlation with r = 0.244 (p<0.01) about 170 patients. Unlike BMI, in the case of correlation between the LLA and IDA for lumbar vertebrae, there was a positive correlation with statistically significant levels. Particularly, the correlation between LLA and IDA for L5 ~S1 was most powerful correlated with r = 0.469 (p<0.01).

Table 1. Correlation among Obesity, LLA and IDA angle

| Obesity | LLA | L3～L4 | L4～L5 |
|---|---|---|---|
| 1 | 0.444** | 0.051 | 0.194 |
| 0.444** | 1 | 0.264* | 0.417** |
| 0.051 | 0.264* | 1 | 0.637** |
| 0.194 | 0.417** | 0.637** | 1 |
| 0.029 | 0.318* | 0.448** | 0.750** |

*p<0.05, **p<0.01

We investigated the relationship between the LLA and obesity for 56 patients. Table 1 shows the results of correlation analysis among obesity, LLA and IDA for lumbar vertebrae. In the case of the relationship for 170 patients, it showed a weak positive correlation with r = 0.244 (p<0.01). However, in the relationship case of obesity and LLA, it showed a strong positive correlation with r = 0.444 (p<0.01), as shown in Table 1.

On the other hand, the correlation between obesity and IDA for L3~L4 was weakly positive with r = 0.051 (p>0.05), and IDA for L4~L5 was correlated with r = 0.194 (p>0.05), and IDA for L5~S1 was correlated with r = 0.029 (p>0.05). All was not statistically significant. This shows that obesity is considerably related to LLA more than each IDA. In the case of correlation between the LLA and IDA for lumbar vertebrae, there was a weak positive correlation with statistically significant levels. Like the result above, this shows that the LLA and the IDA are related to each other.

Particularly, the correlation between the LLA and IDA for L4~L5 was most powerful correlated with r = 0.417 ($p<0.01$). Perhaps we guess that this result will be related to instability for L4~L5 by the gravitation effect.

To determine the correlation between obesity and the IDA, we measured IDA according to BMI.

Table 2 shows the comparison of IDA according to BMI. We divided BMI as follow: normal 18.5~22.9, overweight 23~24.9, obesity >25. (weight(Kg) / height(cm)$^2$)

The IDA by Polly[12] was 9.3° for L3 ~ L4, 11° for L4 ~ L5 and 12° for L5 ~ S1. Also Vialle[16] presented 11° for L3 ~ L4, 13° for L4 ~ L5 and 15° for L5 ~ S1.

In this study, the mean IDA of normal people was 5.66° ± 3.57°, the mean of overweight people was 5.98° ± 3.18°, the mean of obese people was 6.42° ± 3.18° for L3 ~ L4. The normal people were 13.23° ± 4.90°, the overweight people were 14.66° ± 4.48° and the obese people were 16.83° ± 4.65° for L4 ~ L5. And the normal people was 29.13±5.50°, the overweight people were 34.46±4.04°, the obese people were 36.22±4.78 for L5 ~ S1. When comparing normal and obese people, IDA showed the largest difference of 7.09° for L5 ~ S1. The mean value of the Intervertebral disc angle was 5.98°±3.36° for L3 ~ L4, 14.73°±4.96° for L4 ~ L5 and 32.66°±5.91° for L5 ~ S1. We expected that obesity affects IDA because it was a big figure overall compared to other cases.

The previous researches reported that severe posterior spinal arthropathy syndrome if the IDA is more than 15° at L4 ~ L5.[3,7] Thus, obesity can cause lumbar instability such as lumbar degenerative disease, lumbar spinal stenosis, and spondylolisthesis, as shown in Table 2. Particularly, compared with the previous study, there was a big difference between L5 and S1. There are several variation factors in measuring vertebral curvature. The presence of curvature in the lateral recumbent position, the degree of knee flexion, the effect of day time, and other latent effects can lead to errors.[17]

Table3. Comparison of IDA angle according to LLA

| L-spine region | LLA Under 30° (n=77) | | LLA Over 30° (n=93) | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| L4~L5 | 13.10 | 4.98 | 16.09 | 4.53 |
| L5~S1 | 29.40 | 5.49 | 35.36 | 4.81 |

Average of LLA: 30.73 + 5.99

For confirming the effect of lordosis on the intervertebral disc angle, the LLA is divided into two classes at LLA of 30°, as shown in Table 3.

We could see that the lumbar lordosis affects the intervertebral disc angle from Table 3. At LLA of less than 30°, the average of IDA for L4~L5 was 13.10°±4.98° and the average for L4~L5 was 29.40°±5.49°. The average of IDA for L5~S1 was 16.30° more than L4~L5 below LLA of 30°. At LLA of more than 30°, the average of IDA for L4~L5 was 16.09°±4.53° and the average for L5~S1 was 35.36°±4.81°. The average of IDA for L5~S1 was 19.27° more than L4~L5 above LLA of 30°. The difference of IDA above LLA of 30° was 2.97° higher than the difference below LLA of 30°.

### 2. The effect of angle of lordosis and intervertebral disc angle by obesity

The obesity can change the biomechanical structure of lumbar vertebra body by the gravity load as well as weaken muscles around the lumbar vertebrae such as the psoas muscle. In addition, the changed body shape due to obesity can affect mechanical structure as well as a various musculo-skeletal disorders. For example, the intervertebral disc may be elongated or the space between discs may become wider or narrower and the lumbar lordosis easily occurs.

We biomechanically analyzed the effect of LLA, IVD by the obesity. The contribution of each anatomical structure to stability of the vertebrae was 39% in the spinal articulation, 29% in the intervertebral disc and the annulus fibrosus, 19% in the supraspinal ligament and the interspinal ligament and the ligamenta flava 13%.[18] Nolan and Sherk[19] report that the semispinalis cervicis and capitis muscles, the interspinous and supraspinous ligaments, which constitute the cervical spinous process ligament muscle complex, are important factors in maintaining cervical sagittal dynamic and static balance. Lee et al.[20] reported that cervical spine maintains cervical spine curvature by acting cervical spinous process ligament muscle complex from to maintain bio-mechanical load.

According to Norman[21], the most frequent cause of degenerative changes at L4 is the greater instability lumbar vertebra of L4 compared to the stability between each lumbar vertebra. In the case of obesity, the correlation between LLA and IDA at L4 ~L5 showed the most powerful correlation from Table 2. These facts can be expected to exert the greatest gravity force at L4.

We will explain the effect of obesity on LLA and IDA based on the description reported by Lee et al.[20] We consider that the peak of each lumbar vertebra is located at the center-left of each lumbar vertebra, as shown in Fig 2. And ignoring the complicated biomechanical mechanism, we considered only the gravity force exerted on lumbar vertebrae.

Fig. 2 schematically shows the effect of lordotic curvature and intervertebral disc by gravity load. To maintain sagittal dynamic, static balance of L4, $F_1$ muscle force such as transverse process, superior articular process generates the opposite force to Fsinθ. And the spinous process is related to the $F_2$ muscle force generates the opposite force to Fcosθ. The each lumbar vertebra may be pushed forward by Fsinθ or the each intervertebral disc may become wider by Fcosθ. $F_1$, $F_2$ muscle force can prevent the lumbar vertebra and intervertebral disk from protruding or widening.

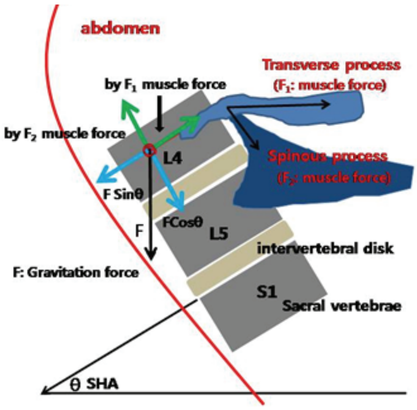


Fig. 2. Relation to lordotic and intervertebral disc angle by gravity load : The lateral side of the lumbar vertebra.

These results indicate that the IDA is influenced by obesity. As shown in Table 1, LLA and obesity are considerable relevance. As shown in Fig. 2, increasing the lordotic angle means increasing the SHA, which means a decrease of Fcosθ. The IDA between L5 and S1 make dominantly difference because the force balance between Fcosθ and F2 muscle force by L5 spinous process is broken. In other words, it means that the greatest force is transmitted to the L5 by gravity force. The reason for the large IDA in the case of obesity seems to be the result of the weakening of anatomical structure such as the psoas muscle as well as the gravity effect.

As mentioned earlier, we considered that the differences of LLA angles affected the disc angle due to the counteracting force of F2 muscle force by gravity effect. We expected that abdominal obesity could increase the angle of lordosis such as lumbar lordosis of pregnant women.

Table 2. Comparison of IDA angle according to BMI

| N=170 | | L3~L4 | | | L4~L5 | | | L5~S1 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | p-value | Mean | SD | p-value | Mean | SD | p-value |
| BMI | Normal (n=76) 18.5~22.9 | 5.66 | 3.57 | 0.441 | 13.23 | 4.90 | 0.000 | 29.13 | 5.50 | 0.000 |
| | Overweight(n=38) 23~24.9 | 5.98 | 3.18 | | 14.66 | 4.48 | | 34.46 | 4.04 | |
| | Obesity(n=56) >25 | 6.42 | 3.18 | | 16.83 | 4.65 | | 36.22 | 4.78 | |

## Ⅳ. DISCUSSION

Spinal disease is increasing due to aging population, aging, obesity, wrong living habits, and osteoporosis. Most of them are related the lumbar vertebrae. In addition, the number of patients suffering from lumbar vertebrae fractures due to falls and traffic accidents increases.

LLA is a representative index for evaluating the degree of curvature of the lumbar spine. It can evaluate the structural stability of lumbar region. IDA is a measure of the stability of each vertebrae body of the spine. Particularly, the changed body shape due to obesity can affect mechanical structure as well as various musculo-skeletal disorders. And the obesity increases your chances of causing lumbar instability. Because of this, it can be accompanied by spinal disease such as intervertebral herniation, lumbar spine dislocation, and anterior vertebral dislocation due to the mechanical action as shown in Fig. 2. We considered that the transverse process and spinous process muscle complex are important factors in maintaining vertebral body dynamic and static balance.

In this study, we tried to explain how obesity affects LLA and IDA for lumbar vertebrae. We explained roughly that the obesity could change the mechanical structure of the lumbar vertebral by the gravity load in the statistics. However, due to the lack of understanding of the complex biomechanical mechanisms of the lumbar spine, the exact pathologic ecology of spinal disease caused by obesity has not yet been identified. Also, the studies on spinal disease caused by obesity are insufficient. And the study of mechanical structural and musculoskeletal disorders by obesity is insufficient.

As a result of statistical analysis, we showed that the LLA and all patients had a weak positive correlation with $r = 0.244$ ($p < 0.01$). But in the case of LLA and obesity, they showed a strong positive correlation with $r=0.444$ ($p<0.01$). The LLA tended to increase statistically as the BMI increased. As Fig. 1 (c) shows, the LLA and SHA correlate with each other. This is because in the case of obesity, the SHA value has a larger value than normal, so it seems that the lumbar lordosis tends to increase with the change of spinal curvature by physiological load.[22,23]

The obese person can weaken muscles around the lumbar vertebral such the psoas muscle as well as $F_1$, $F_2$ muscle. This lead to the increase of $\theta$ by gravity force. This means the increase of $F\cos\theta$ while decreasing $F\sin\theta$. Because of this, the intervertebral disc may be elongated or the space between the discs may become wider. And the vertebral body may be gradually curved. Our result shows that LLA and IDA are influenced by the obesity from Table 1, 2.

The lumbar lordosis don't appear in the vertebrae of newborn babies, but due to the upright walking of humans, it is gradually affected by gravity. Obesity, in particular, causes physical and chemical changes, which can cause several complex neurological symptoms in the lower back and lower extremities.

If the lumbar lordosis that is abnormally bent toward the umbilicus by obesity, the spinal joint and the intervertebral disc can't withstand the gravity load, resulting in compression of the nerve root, muscle contraction, degenerative changes of the disc. Particularly, the most frequent cause of degenerative changes in L4 is the greater instability lumbar vertebra of L4 due to gravity load.

In the end, obesity is exposed to lumbar disc disease because of excessive pressure and belly fat. In order to prevent degenerative disease of the spine, it is important to lower the BMI.

## Ⅴ. CONCLUSION

Our data show the correlation between obesity and the angle of lordosis for lumbar vertebrae was found to be a strong positive correlation. The gravity load can affect the lordotic and intervertebral disc angle for lumbar vertebrae. In other words, the obesity can change the mechanical structure of the lumbar vertebral by the gravity load as well as weaken the muscles around the lumbar vertebrae. Also, the obesity interferes with normal sagittal balance and fails to maintain a straight posture with minimal energy, and lacks the ability to effectively distribute and absorb the load on the spine, making it impossible to maximize the efficiency of spinal muscle energy use. Therefore, the obesity can be an important factor in causing back pain by changing the lumbar lordosis.

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# 비만에 의한 허리뼈 전만과 추간판 각도의 영향에 관한 연구

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## 요 약

허리뼈 전만각(LLA)은 허리뼈의 곡률을 평가하는 데 사용할 수 있는 지표이다. 허리뼈의 구조적 안정성과 추간판 각도(IDA)에서 척추의 각 부분의 안정성을 측정할 수 있다. 특히, 본 연구 자료에 따르면 허리뼈에 대한 비만과 전만각 사이에는 강한 양의 상관관계가 있는 것으로 나타났다. 또한, 비만의 경우 IDA가 큰 이유는 해부학적 구조의 약화와 중력 효과의 결과인 것으로 보인다. 비만은 정상적인 시상면 균형을 방해하고 최소한의 에너지로 똑바른 자세를 유지하지 못한다. 따라서 비만은 허리뼈 전만증을 변화시켜 요통을 유발하는 중요한 요소가 될 수 있다.

중심단어: 허리뼈, 전만각, 추간판 각도, 기계적 하중, 비만

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