Estimation of Radius of Curvature of Lumbar Spine Using Bending Sensor for Low Back Pain Prevention

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Abstract. Estimation of the disk load in order to prevent low back pain is useful. However, the conventional methods of measuring disc load are invasive and their use is limited due to measurement environments. This study proposes a new method of estimating the lumbar disc load to measure curvature of the lumbar portion and to estimate the lumbar disc load safely using a bending sensor. The radius curvature can be measured relatively easily and without damaging the body by using this method. The bending sensors are attached along vertebra end of five vertebras and the curvature of the lumbar portion is estimated by reading the change in output voltage. The lumbar disk load with static posture was estimated by proposed method. The result shows the same tendency as the previous method. The proposed method has a possibility of developing a new system using the biofeedback based on the lumbar disc load.

Keywords: Bending sensor, Herniated disk, Wearable sensing system, Radius of curvature

1 Introduction

In recent years, people suffering from low back pain increase by changes in labor environment and living environment. But the obvious way for preventing low back pain is not yet introduced. So it is useful to develop of wearable sensor system for preventing low back pain. Although there are various causes in low back pain, this study targets a herniated disk. Herniated disk works as cushioning material that exists between the vertebrae of the lumbar. Pain and numbness come out when excessive force is applied to herniated disk. Therefore we can make use for treatment, rehabilitation and prevention if it is possible to measure the load on the disk.

Useful method of measuring the load on the disk has been reported up to the present time. One of them is a method of inserting a direct pressure sensor into the disk by Nachemson an orthopedist in Sweden. This method is a highly accurate, and measurement can be done in various positions but it has a risk of damaging the body, sometimes putting a patient into surgical operation. The other previous research[1-2] suggests that there is a way to measure the intervertebral disc load by using a non-linear three-dimensional finite element model of the vertebrae disk based on the CTs and to estimate the joint moments and muscle tone by adapting the inverse kinematics. But it is difficult to measure the mechanical properties of the dynamic characteristics because it is a partial model links. To measure with high precision and the procedure of measurement is complicated because there are various factors to be considered. The present study group focuses on the vertebral edge which exists near skin surface of the back. Since lumbar system is curved due to the attitude change[3], a bending sensor is attached along the five vertebral edge portions that constitute the lumbar part and the curvature of the lumbar part is estimated by reading the change in the output voltage. With this method measurement can be done relatively easily without damaging the body. Since the bending sensor is thin, cheap and wearable, it can be worn in everyday life. The proposed method has a possibility of developing a new system using the biofeedback based on the lumbar disk load, and in the future, this system could be used for preventing low back pain and improving the posture. In this paper, the radius of curvature of lumbar spine is estimated using the same position that Nachemson did in his experiment. The validity of the proposed method is considered by comparing the intervertebral disc load estimation result of Nachemson and the proposed method.

2 METHODS

Fig.1 shows a schematic diagram of spine, lumbar part and vertebrae. As the Fig.1 indicates, disc exists between the vertebrae and has the role of cushioning material. Upper and lower vertebrae are connected with a pin at the facet joints. Vertebrae should be considered as a rigid body[3] because the Young's modulus is larger than the disc and the human body. The elastic deformation in the zygapophysial joint is contravened because it is very small. If attitude changes, the gap between the vertebral bodies changes as vertebrae move. That is to say, change of the disk load is caused by the gap change between the vertebral bodies. Let us consider that the lumbar spine moves uniformly, and that the internal pressure in the lumber disc is also uniform. The radius of curvature is obtained by the approximation by arc of the surface shape of body. The average intervertebral disk load is derived[3] by estimating the gap variation between the average vertebrae using the changes of the radius of curvature in the lumbar system with the posture change.

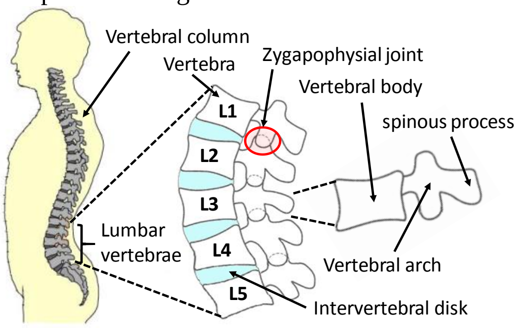

Fig. 1. Lumbar vertebrae

Bending sensor is a variable resistance. Resistance value changes according to the force applied to it. The radius of curvature is estimated from the change in the resistance value of the bending sensor attached on the skin surface of lumbar. Bending sensors are attached along vertebral end from the first lumbar spine to the fifth lumbar spine (L1-L5). The resistance value is calculated from output voltage and the radius of curvature of the lumbar spine is estimated. Figure2 shows calibration curve which represents the relationship between the known radius of curvature and the resistance value.

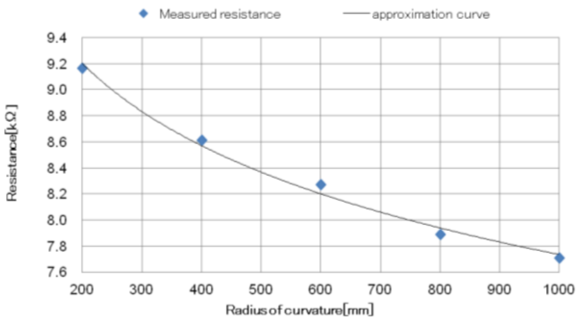

Fig. 2. Calibration curve

The resistance value obtained from the bending sensor is substituted into the calibration curve to estimate the radius of curvature when the bending sensor is attached to the lumbar part of the human body. The test is administered in four different positions, two standings and two sittings (Fig.4). These are the same as Nachemson used in his experiment, where the electrodes were inserted directly[1]. A measurement was done four times with each position to all three subjects.

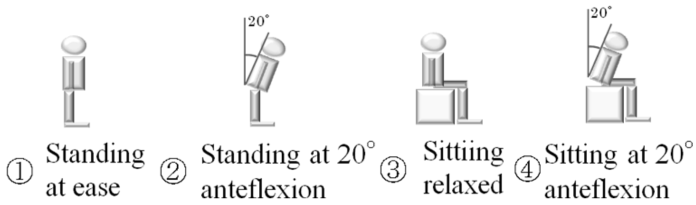

Fig. 3. Measurement static postures

Table 1. Information of subjects

Subject	Age	Height[m]	Weight[kg]	BMI
A	22	1.67	66	23.70
B	22	1.69	54	18.90
C	22	1.72	70	25.40

3 RESULTS

Fig.4 shows comparison of the lumbar load estimation of experimental results by Nachemson and the proposed method. The same tendency as Nachemson was obtained in all subjects that the lumbar disk load is large when taking the bending forward positions.

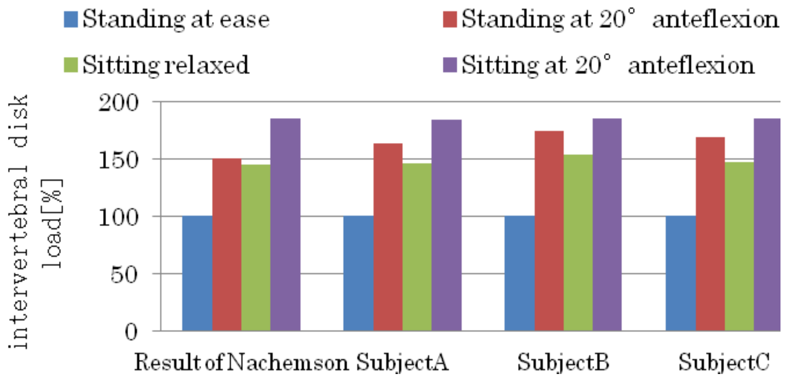

Fig. 4. Comparison of the lumbar load estimation of experimental results

4 DISCUSSION

The some variations in intervertebral disk load are found. This is because body movements of the subjects were slightly different and also because a curve of the data sheet is approximated by a quadratic function. It could be considered that the estimating of the radius of curvature of lumbar spine is possible with static posture using the measurement method proposed in this study. The proposed sensing system can be applied to car seats and their use is not limited due to measurement environment. The proposed method has a possibility of developing a new system using the biofeedback based on the lumbar disk load, and in the future, this system could be used for preventing low back pain and improving the posture.

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