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# Characteristics of thoracic and lumbar movements during gait in lumbar spinal stenosis patients before and after decompression surgery

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ABSTRACT

*Background:* Although gait analysis has been previously conducted for lumbar spinal stenosis patients, the vertebral segmental movements, such as of the thoracic and lumbar regions, and whether the spinal movement during gait changes after decompression surgery remain unclear.
*Methods:* Ten patients with lumbar spinal stenosis and 10 healthy controls participated. Clinical outcomes were assessed using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire and Visual Analogue Scale. Spinal kinematic data of the participants during gait were acquired using a three-dimensional motion analysis system. The trunk (whole spine), thoracic, and lumbar flexion and pelvic tilting values were calculated. Spinal kinematic data and clinical outcomes were collected preoperatively and 1 month postoperatively for the patients.
*Findings:* Compared to that observed preoperatively, the clinical outcomes significantly improved at 1 month postoperatively. In the standing position, the preoperative lumbar extension of the patients was significantly smaller than that of the controls. Moreover, during gait, the lumbar flexion relative to the standing position of the patients was smaller than that of the controls preoperatively, and increased at 1 month postoperatively. The sum of the thoracic and lumbar flexion values during gait negatively correlated with the score for leg pain.
*Interpretation:* The epidural pressure of lumbar spinal stenosis patients is known to be higher than that of normal subjects during gait, and to decrease during walking with lumbar flexion. Preoperatively, smaller thoracic and lumbar flexion movements during gait relative to the standing position cannot decrease epidural pressure; as a result, severe leg pain might be induced.



## 1. Introduction

Lumbar spinal stenosis (LSS) patients frequently complain of numbness and pain in the lumbar region and lower limbs, and neurogenic intermittent claudication, caused by compression of the nerve roots with narrowing of the spinal canal and the intervertebral foramen, may lead to gait disorders (Katz et al., 1995; Katz and Harris, 2008; Suri et al., 2010). Takahashi et al. (1995) measured epidural pressure by inserting a pressure transducer into the epidural cavity, and reported that, in LSS patients with neurogenic intermittent claudication, a frequent intermittent rise in epidural pressure was observed during gait, compared to in control subjects. Moreover, while walking with lumbar flexion, the peak epidural pressure was decreased compared to during normal walking in LSS patients. Therefore, the symptoms may be either relieved or worsened by the spinal flexion alignment during gait in LSS patients. Suda et al. (2002) and Garbelotti et al. (2014) conducted gait analyses for LSS patients and reported that LSS patients with intermittent claudication showed larger anterior sway of the trunk during gait. However, although the disturbance level for LSS is the lumbar spine, only kinematic data of the whole spine were examined. Therefore, the vertebral segmental movements, such as of the thoracic and lumbar regions, should be investigated separately to better understand the spinal kinematics of LSS patients during gait.

Several comparative studies support surgical treatment for patients with moderate-to-severe LSS (Amundsen et al., 2000; Athiviraham and Yen, 2007; Weinstein et al., 2007). In a meta-analysis (Turner et al., 1992), the average improvement in pain and mobility was 64% after decompression surgery. More recently, Jones et al. (2014) reported

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that not only leg pain but also low back pain improved at 6 weeks and 1 year following decompression surgery. Furthermore, radiological changes between before and after decompression surgery have been demonstrated. Fujii et al. (2015) and Jeon et al. (2015) reported that, in the standing position, thoracic kyphosis and lumbar lordosis increased and pelvic tilt decreased at 1 year postoperatively, with the spinal sagittal alignment in LSS patients approaching normal alignment postoperatively. However, gait analysis after decompression surgery has not yet been performed, and the relationship between the improvement of neurological symptoms after decompression surgery and the changes of the spinal movements during gait remain unclear.

With this in mind, the purposes of the present study were: (1) to investigate both thoracic and lumbar movements during gait in LSS patients, and (2) to demonstrate the changes in spinal movements during gait after decompression surgery. We hypothesized that the lumbar flexion during gait would be increased in LSS patients to avoid the appearance of neurogenic intermittent claudication, and that the spinal movement during gait after decompression surgery would approximate normal movement.

## 2. Methods

### 2.1. Participants

Ten LSS patients with neurogenic intermittent claudication who underwent decompression surgery at Hiroshima University Hospital between October 2014 and August 2015 were selected as the LSS group (Table 1). The inclusion criterion was a clinical diagnosis of LSS by orthopaedic surgeons. The diagnosis was based on a review of the patient history, physical examination, and confirmation of LSS by magnetic resonance imaging. All participants were required to have documented symptoms of neurogenic intermittent claudication (e.g., pain, numbness, weakness, or tingling in the lower extremities during lumbar extension, standing, or walking). Patients were excluded if they had a history of stroke, Parkinson's disease, cervical spondylotic myelopathy, severe cardiovascular disease, chronic obstructive pulmonary disease, or severe hip or knee osteoarthritis. The clinical outcomes and spinal kinematic data were collected preoperatively and 1 month postoperatively for the LSS group. The Control group comprised 10 healthy volunteers, with no significant differences in age, height, weight, body mass index, and sex compared to the LSS group (Table 1). This study was approved by the Epidemiologic Study Ethics Review Board of Hiroshima University (approval number: E Epd-1050-1) and conformed to the Declaration of Helsinki. All participants provided written informed consent.

### 2.2. Surgical procedure

Two decompression surgical methods were adopted. Five patients underwent the lumbar spinous process–splitting approach according to the technique developed by Watanabe et al. (2005). In this approach, decompression was performed after temporary detachment of the lamina using a chisel, followed by recapping of the detached lamina (recapping laminoplasty). The other 5 patients underwent microendoscopic laminotomy (Minamide et al., 2013). This endoscope-assisted procedure allows bilateral decompression of the central canal and bilateral lateral recesses via a unilateral approach. There were no differences between the patients in terms of the postoperative treatment and rehabilitation protocols.

**Table 1**
Demographic data for the LSS and Control groups.

| | LSS | Control | *p*-value |
|---|---|---|---|
| Age [years] | 75.3 (3.9) | 62.0 (19.1) | 0.057 |
| Body Height [cm] | 158.6 (8.3) | 162.3 (8.3) | 0.348 |
| Body Weight [kg] | 63.4 (6.0) | 60.7 (11.7) | 0.531 |
| Body Mass Index [kg/m$^2$] | 25.3 (2.4) | 22.9 (3.0) | 0.066 |
| Gender [Males : Females] | 5 : 5 | 6 : 4 | 0.653 |

Values are the mean (SD). LSS: lumbar spinal stenosis group (n = 10); Control: control group (n = 10).

### 2.3. Clinical outcomes

The Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) and Visual Analogue Scale (VAS) were evaluated preoperatively and 1 month postoperatively for the LSS group. The JOABPEQ comprises five parts: (1) low back pain, (2) lumbar function, (3) walking ability, (4) social-life function, and (5) mental health (Fukui et al., 2007, 2008, 2009). The JOABPEQ scores range from 0 to 100, with a higher score indicating a better health status.

For the VAS scores, the patients were asked to score their low back pain, leg pain, and leg numbness from 0 to 100, with a higher score indicating a more severe condition (Boonstra et al., 2008).

### 2.4. Motion analysis

Two tasks were assessed in this study. First, the participants were asked to stand in their normal position on the middle of the floor, twice. Second, they were instructed to walk, bare-footed, at a self-selected velocity along a 10-m walkway three times.

For motion analysis, a three-dimensional motion analysis system (VICON MX: Vicon Motion Systems, Oxford, UK) with 16 infrared cameras (operating at 100 Hz; Vicon Motion Systems, Oxford, UK) and eight force plates (1000 Hz; AMTI, Watertown, USA) were used. Ground reaction force data were synchronized with marker coordinate data. Passive reflective markers (diameter: 14 mm) were placed according to a commercially available kinematic model (Plug-in-gait, Vicon® Peak, Oxford, UK). Additionally, to examine the vertebral segmental motions during gait, eight markers were placed on the participants' backs: on the spinous processes of C7, T1, T12, and L1, and on the left and right sides of the spinous processes of T1 and L1 (Kim et al., 2014). The center-to-center distance between the markers was 3 cm (Fig. 1).

Marker coordinate data were low-pass filtered (Butterworth 4th-order filter; cut-off frequency, 6 Hz) with plug-in software (ButterPlug; Vaquita Software, Zaragoza, Spain). Gait velocity, cadence, and stride length were extracted from the biomechanical model output, and the stride length was normalized to the body height. The laboratory (global)

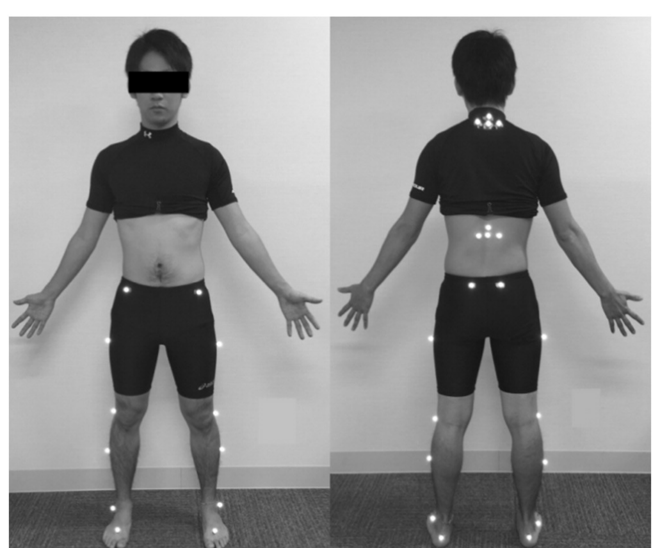

**Fig. 1.** Location of the reflective markers on the participants.