

# Development of a System for Measurement on Asymmetric Sitting Posture

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**Abstract**— Sitting posture measurement system using the unstable board with accelerometer was developed. And, postural balance was assessed to determine the effect of asymmetry on sitting posture between patients with pelvic asymmetry and healthy subjects. 10 subjects (pelvic asymmetry patients:5, healthy controls:5) were participated in this study. We performed experiment under static and dynamic sitting condition. Angular variation in the anterior-posterior and left-right direction was measured in both two conditions. Also, intra class correlation coefficient was used to evaluate the reliability of the system. The value of angle of pelvic asymmetry patients was more tilted significantly to the left side than right side during static and dynamic sitting. The reliability of the system was excellent. This paper suggested that a system for measurement on asymmetric sitting posture can be utilized to provide useful information about patients with pelvic asymmetry in rehabilitation medicine. Furthermore, results from this study can be used to develop the new clinical quantitative measurement system.

**Keywords**—asymmetric sitting posture; pelvic asymmetry; leg length discrepancy; accelerometer; unstable board

## I. INTRODUCTION

Postural control is a processing in which complex interaction about various tissues inside the human body and external force is generated [1], [2]. Maintaining correct posture is essential to provide normal biomechanical function of the body effectively in daily life. Postural imbalance which is associated with habitual bad posture during sitting may result

in low back pain (LBP), scoliosis, and musculoskeletal disorder caused by asymmetry of pelvis and trunk muscle [3]-[5]]. Also, bad sitting posture over a long period of time can lead to long term complications such as osteoarthritis [6].

Prevalence of patients with pelvic asymmetry induced by leg length discrepancy (LLD), is defined as a condition in which a disparity of length between the legs, increased by approximately 40~70% in the general population [7]. Several studies have suggested that LLD cause asymmetry in the lower extremity and pelvis, leading to arthritic changes in the lumbar spine, LBP, pelvic tilt, altered lordosis, and postural change, depending on the discrepancy of 10mm or less [8]-[11]. If the postural asymmetry leads to changed movement patterns that might negatively affect the individual's activities, then there is a need to better understand about this.

Most people actually have mild asymmetry with no noticeable symptoms and they spend more time sitting with change of working conditions. Prolonged sitting during working can influence on forming bad sitting posture, and it is connected to continuous functional damage to balance control system [12]. Although there is evidence that how pelvic asymmetry affect the postural stability in static standing [13-15], sitting [16], [17], and during walking [18], [19], the differences of postural balance in unstable sitting posture between symptomatic and asymptomatic person has not been studied.

In recent years, many studies related to the measurement of physical activity using accelerometer have been conducted [20-

21]. Accelerometers are commonly utilized to detect the motion in various clinical fields as its convenience and effectiveness. Bliley et al. [22] measure body posture and movement using MEMS accelerometer. Luo et al. [23] developed posture monitoring system based on an accelerometer for training people to improve posture and demonstrated that this device can be used to detect postural changes. Curone et al. [24] detected human activity using new algorithm based on real-time three-axis accelerometer data placed on the trunk. Clinical quantitative measurement system using accelerometer which is a promising technique can be used to provide postural information while sitting for individual and to prevent progression in patients with pelvic asymmetry.

The aim of this study was to assess the seated balance of patients with pelvic asymmetry and healthy subjects using new measurement system with accelerometer. Also, we confirmed the reliability of this system for evaluation its usefulness in clinical medicine.

## II. METHODS & MATERIALS

### A. Measurement Instrument

Shape and appearance of sitting posture measurement system was hemisphere (radius: 320 mm), creating instability and maximum around 20 degrees in all directions as shown in Fig. 1. Seat surface of this unstable board was covered with soft material to provide comfort during sitting. MEMS accelerometer (MMA7331L, Freescale Semiconductor Inc., Austin, Texas) measure acceleration in a range of  $\pm 4 g$  and sensitivity was about 86.3 mV/g. And, it was positioned to middle bottom of the board. This position of sensor facilitated measurement on neutral and asymmetry sitting posture. Photo sensors (SG-23FF, Kodenshi Co., Tokyo, Japan) were also attached to the surface of both sides in board to check sitting state of subjects by measuring the gap between the tip and the plate.

Accelerometer output included the acceleration of gravity, vibration, and acceleration transformation. Therefore, a third-order digital finite impulse response (FIR) low-pass filter at 2 Hz was used to correct the sensor output. Tilting angle was calculated using acceleration of gravity.

### B. Subjects

5 male pelvic asymmetry patients (PA) and 5 male pelvic symmetry subjects (PS) were participated in the experiment. Their mean age was  $14.4 \pm 1.34$  years, mean height  $165.8 \pm 10.54$  cm, and mean body mass  $61.4 \pm 12.48$  kg. The patients, which were diagnosed pelvic asymmetry with LLD, were recruited from an outpatient foot clinic. Height of the right pelvis was larger than left pelvis and the difference of length between the legs was  $6.99 \pm 2.91$  mm. Subjects in the PA group were excluded if they had pain of the lower extremity, had experience of pelvic or LLD correction, or had any postural training. Subjects in the PS group had no history of injury in the musculoskeletal system or disease related to asymmetry of the lower extremity. All subjects were informed a full explanation regarding the protocol and provided written consent prior to their participation.

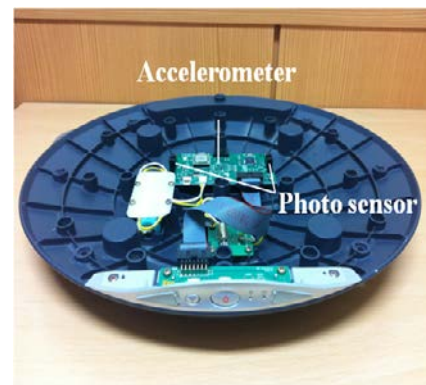


Fig. 1. Sitting posture measurement system

### C. Experimental Protocol

To measure the asymmetry of sitting posture, experiment procedure was divided into two conditions: static and dynamic sitting. In static sitting condition, subjects were instructed to sit in their usual manner on the sitting posture measurement system, which is located in the center of stool, with their arms crossed on contra-lateral shoulders for 30 seconds as shown in Fig. 2. In dynamic sitting condition, subjects were asked to perform anterior, posterior, left, and right pelvic rotation with trying to fix their upper trunk, and then sitting posture was hold for 5 seconds, respectively, as shown in Fig. 3. A foot support was used to prevent the influence of leg movement, and it was adjusted to support the feet by keeping knee and ankle angles at  $90^\circ$  [25]. Before the experiment, all subjects practiced all testing procedures until they could understand about all postures. To prevent fatigue, subjects took a 5 minute rest in between experiments.

### D. Data Analysis

Angle variation data (sampling rate: 100 samples/s) in the frontal and sagittal planes collected by sitting measurement system were analyzed using LabVIEW 2010 (National Instrument Co., Austin, Texas). X-axis was presented to right (+) and left (-) direction in frontal plane, and Y-axis was presented to anterior (+) and posterior (-) direction in sagittal plane. The COP (center of pressure) of the subject was computed using accelerometer.



Fig. 2. Static sitting posture

To assess the repeatability of the system, the average distance of the COP sway path and total COP sway area was analyzed [26]. COP sway path and sway area was calculated as follow Eq. (1) ~ (6):

$$COP_{path} = \sum_{n=1}^{N-1} \sqrt{(COP_{n+1}^{AP} - COP_n^{AP})^2 + (COP_{n+1}^{ML} - COP_n^{ML})^2} \quad (1)$$

$$a_n = \sqrt{(COP_n^{AP})^2 + (COP_n^{ML})^2} \quad (2)$$

$$b_n = \sqrt{(COP_{n+1}^{AP} - COP_n^{AP})^2 + (COP_{n+1}^{ML} - COP_n^{ML})^2} \quad (3)$$

$$c_n = \sqrt{(COP_{n+1}^{AP})^2 + (COP_{n+1}^{ML})^2} \quad (4)$$

$$S_n = \frac{a_n + b_n + c_n}{2} \quad (5)$$

$$S_n = \frac{a_n + b_n + c_n}{2} \quad (5)$$

$$COP_{area} = \sum_{n=1}^{n-1} \sqrt{S_n \cdot (S_n - a_n) \cdot (S_n - b_n) \cdot (S_n - c_n)} \quad (6)$$

where  $N$  was the total number of samples,  $n$  was the sample number,  $a_n$  was the length from center (0,0) to  $n$ ,  $b_n$  was the length from  $n$  to  $n+1$ ,  $c_n$  was the length from center (0,0) to  $n+1$ , and  $s_n$  was total sum of  $a_n$ ,  $b_n$ , and  $c_n$  divided by 2. Data from all 3 trials were analyzed.

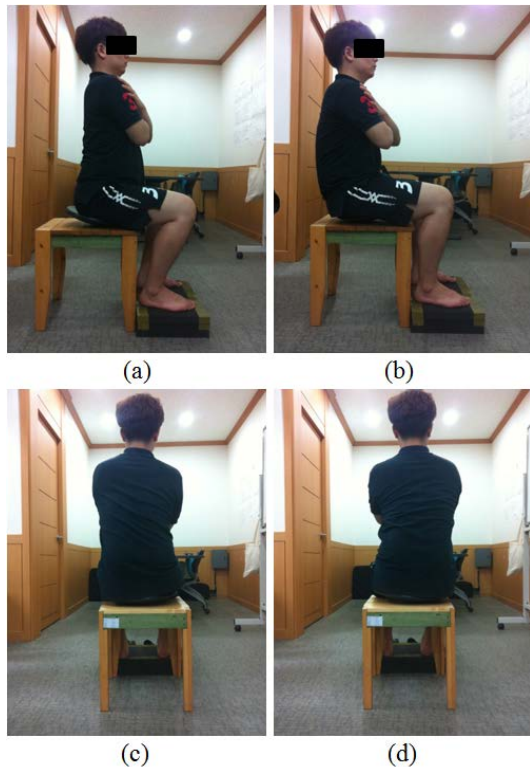


Fig. 3. Dynamic sitting posture  
 (a) Anterior pelvic rotation, (b) Posterior pelvic rotation,  
 (c) Left pelvic rotation, (d) Right pelvic rotation

Statistical analysis was performed using SPSS 18.0 statistical software (SPSS Inc., Chicago, IL). Independent t-test was used to examine the difference in angle variation between PA and PS group, at  $p < 0.05$  level. Also, intra-class correlation coefficient (ICC) was analyzed to evaluate the reliability of the system.

### III. RESULTS

#### A. Static Sitting Posture

Mean angular variation in anterior-posterior (AP) and left-right (LR) direction is shown in Fig. 4 and 5, respectively. Mean angle of both groups were tilted to posterior and left side. Tilting angle of PA group was smaller than PS group in AP direction. In contrast, tilting angle of PA group was significantly larger than PS group in LR direction ( $p=0.013$ ).

#### B. Dynamic Sitting Posture

There was a difference in angular variation between PA and PS group during anterior and posterior pelvic rotation as shown in Fig. 6. Posterior pelvic tilt angle of PA group and anterior pelvic tilt angle of PS group was larger than pelvic tilt angle in angle between PA and PS group.

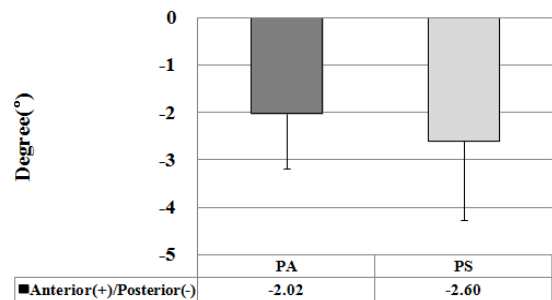


Fig. 4. Anterior and posterior tilt angle in static sitting

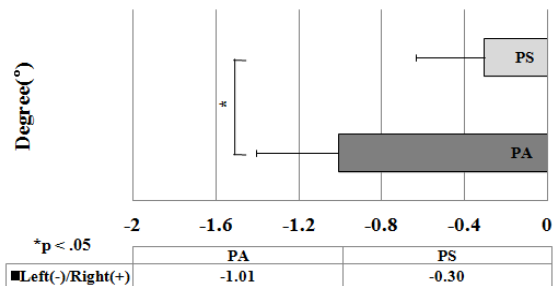


Fig. 5. Left and right tilt angle in static sitting

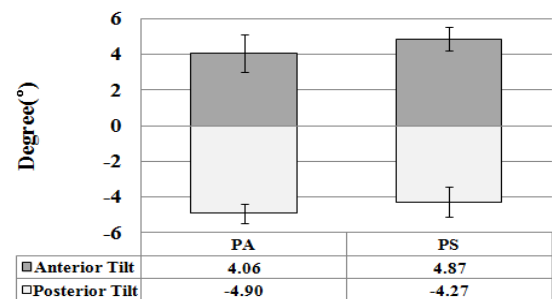


Fig. 6. Anterior and posterior tilt angle in dynamic sitting

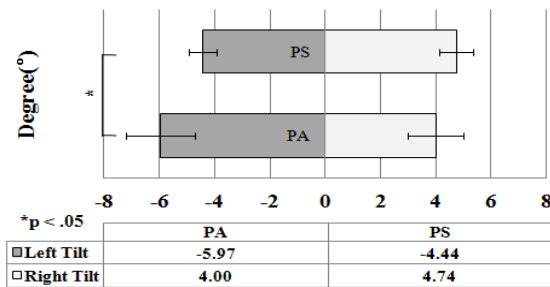


Fig. 7. Left and right tilt angle in dynamic sitting (\*p < 0.05)

Difference in angular variation during left and right pelvic rotation is presented in Fig. 7. The major difference in the angle was evident in the left and right pelvic tilt of PA group. In PA group, value of angle was significantly more tilted to left than right side while there is a little difference in tilting angle between left and right side in PS group

C. Repeatability of the system

Average distance of COP sway path and area did not differ significantly in the first test as compared with the second test as shown in Fig. 8. By observing the ICC of COP sway path and area between first and second test for static and dynamic sitting posture, we could confirm the reliability of the system. The ICC values for COP sway path ranged from 0.88 to 0.96 and COP area ranged from sitting posture measurement system ranged from 0.81 to 0.95.

I. DISCUSSTION

We compared static and dynamic sitting posture between PA and PS group using measurement system with accelerometer. Height of right pelvis was high compare with left pelvis in PA group. In static sitting, PA group showed an asymmetry which is more tilted 1.01° to left side than right side, and there is a significant difference between both groups.

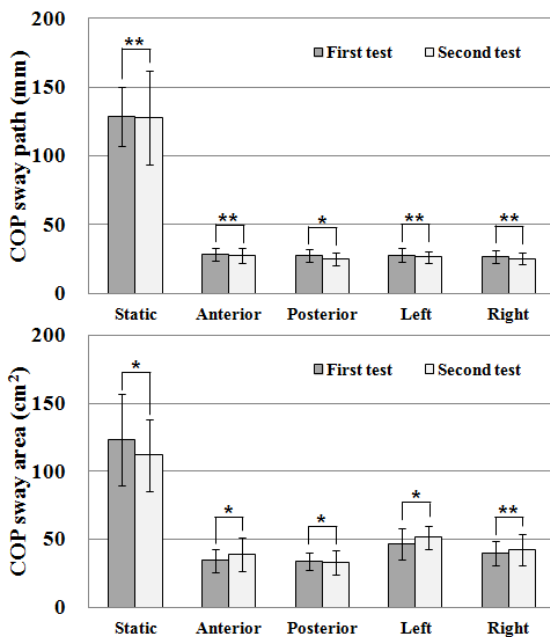


Fig. 8. Test-retest of COP sway path and area (\*p < 0.05)

Postural asymmetry during static sitting may affect to perform anterior, posterior, left, and right pelvic rotation. Significant angular difference in LR direction was 1.97° with left tilt in PA group during dynamic sitting. Generally, in case of difference in length exist between the legs, length asymmetry is not reduced while it can cause pelvis deformation in frontal and sagittal plane, and negatively influence on standing posture as well as sitting posture by compensation [27], [28]. From these results, PA group have asymmetrical balance induced by pelvic asymmetry during static and dynamic sitting.

It has been suggested that ICC values in a range of 0.75 to 1.00 was considered as excellent; 0.60 to 0.74 as good; 0.40 to 0.59 as fair; less than 0.40 as poor [29]. Our results showed excellent reliability in both static and dynamic sitting. Test-retest reliability of the measurement system demonstrated high ICC values ranged from 0.81 to 0.96. It means that this sitting posture measurement system may be useful for measuring the postural asymmetry.

II. CONCLUSION

In this study, we developed sitting posture measurement system using accelerometer and evaluated the difference in posture between patients with pelvic asymmetry and healthy subjects during unstable sitting. The value of angle was tilted with the degree of asymmetry of the pelvis in both static and dynamic sitting condition. The reliability results for the measurement system were excellent. The results indicate that measurement system for asymmetric sitting posture can be used to assess the sitting postural balance for individual and to evaluate the postural change of patients with disease such as LBP, scoliosis, and disc. Further research is required to compare the trunk muscle activation pattern and kinematics between patients with pelvic asymmetry and normal subjects.

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