Real-time Sitting Posture Monitoring System for Functional Scoliosis Patients

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Abstract. In recent years, with the increase in sitting time, real-time posture monitoring system is needed. We developed sitting posture monitoring system with accelerometer to evaluate postural balance. Unstable structure of the system was designed to assess asymmetrical balance caused by habitual sitting position. Postural patterns of normal group and patients with functional scoliosis group were analyzed. Consequently, inclination angle of scoliosis group were tilted to the posterior and left side. From these results, we concluded that real-time sitting posture monitoring system can be utilized to measure asymmetrical balance of patients and provide accurate diagnosis as well as treatment for individuals.

Keywords: Real-time monitoring system, Functional scoliosis, Postural balance, Sitting.

1 Introduction

The ability to keep balance is one of the most essential factors in activities of daily living. Human body can adjust the posture in response to continuous external perturbations for maintaining good posture. Good posture provides normal

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biomechanical functions of the musculoskeletal system. On the contrary, postural changes caused by habitual bad posture with prolonged static working environment have a crucial influence on body asymmetry, muscle imbalance, and structural problem in the spine.

As the social interest in healthcare increases, many devices were developed to evaluate balance of individuals during standing and walking for preventing damage to the skeletal muscle pathologies [1,2]. Especially, in recent years, studies related to real-time measurement technology for health monitoring have been conducted in various clinical fields [3]. Accelerometer is a practical device to perform long-term monitoring of human balance and posture control in the real-life [4]. Due to advantage of its price, size, and weight, these devices are utilized to detect the motion of upper and lower extremities and trunk while static and dynamic conditions [5,6,7].

To date, there are few clinical quantitative real-time measurement systems for sitting posture. It is very important to record the movement patterns while sitting as most people spend more time sitting with change of working condition. Functional scoliosis (non-structural) patients have a temporary mild curvature caused by different leg length and life habits including lack of exercise. Real-time monitoring and analysis data of these patients can be utilized to correct bad posture as well as improve their postural balance in daily life. Accordingly, real-time sitting posture monitoring system for patients with asymmetrical balance is necessary to evaluate the effects of functional scoliosis on balance performance and to provide appropriate treatment methods for individuals.

In this paper, we suggest real-time sitting posture monitoring system with accelerometer to observe postural pattern of patients with body asymmetry caused by functional scoliosis.

2 Methods

2.1 System Configuration

The upper side of the system has soft curve shape to accommodate the hip area during sitting. Two photo sensors (SG-23FF, Kodenshi Co., Tokyo, Japan) was located to the surface of left and right side, leaving approximately 10 cm space between sensors, for the purpose of checking sitting state of users. Seat surface of the system was covered with soft material to provide comfort. The lower side was shape of a hemisphere with diameter 32 cm to observe the change of natural postural balance pattern according to prolonged sitting condition, as shown in Fig. 1. To detect inclination angle in the frontal and sagittal plane, 3-axis accelerometer (MMA 7331L, Freescale Semiconductor Inc., Austin, Texas) was attached in the middle of main board. A digital finite impulse response (FIR) low pass filter at 2 Hz was used to correct the sensor output. Acquiring data from sensors were converted to angle value in Microcontroller (MCU) and then transformed ASCII codes were transmitted to PC wirelessly by using Bluetooth communication module.

Balance evaluation program was developed to analyze sitting patterns of subjects based on accelerometer data at 100 Hz sampling rate using LabVIEW software (National Instrument Corp., Austin, Texas). The signal was presented as a two-dimensional graph in which the X-axis represents roll angle in the frontal plane and the Y-axis represents pitch angle in the sagittal plane.

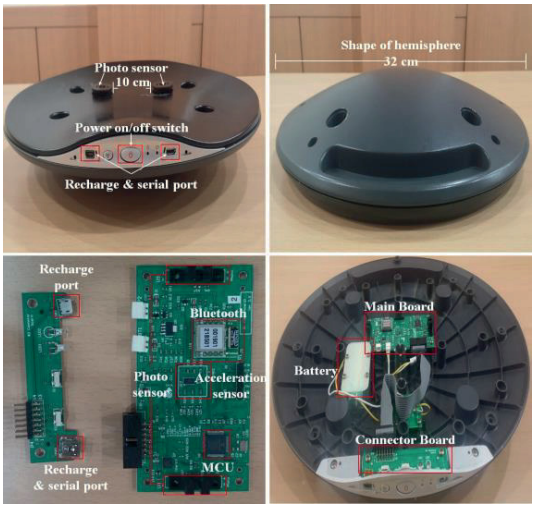

Fig. 1. Structure of sitting posture monitoring system

2.2 Experimental Procedure

10 female subjects who were diagnosed functional scoliosis using posteroanterior full spine standing X-ray were included in this study. They were recruited from the Department of Rehabilitation Medicine of Chungnam National University Hospital in Daejeon, South Korea. All participants were all informed fully about the experiment, and provided written consent prior to their participation. Characteristics of subjects are shown in Table 1.

Table 1. Characteristics of subjects

Variable	Normal Group (n=5)	Patients with scoliosis and pelvic asymmetry Group (n=5)
Age (years)	14.4±1.9	15.4±2.3
Height (cm)	155.4±7.3	165.1±11.7
Weight (kg)	45.4±8.9	57.8±17.6
Cobb angle (°)	-	13.4±4.4
Difference in height of the pelvis (mm)	-	7.9±2.6

Measurement procedure of the system was shown in Fig. 2. Real-time sitting monitoring system was located in the center of a normal wood chair without soft cushion, backrest, and armrests. All subjects were asked to sit on the calibrated system with their usual sitting position. And they kept this posture for 1 minute. Before experiment, they had enough time to adapt unstable state caused by lower part structure of the system. Independent t-test was used to examine the differences in inclination angles between normal and scoliosis group, at $p < 0.05$ level.

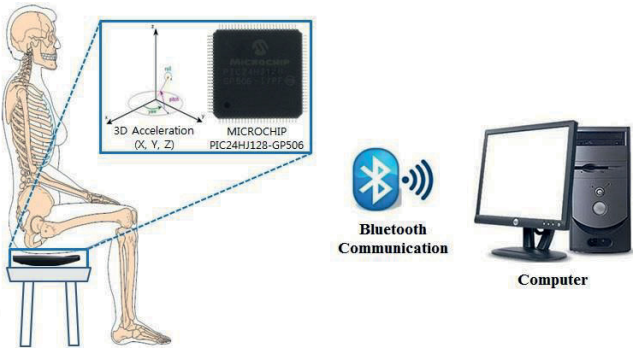

Fig. 2. Measurement procedure of the system

3 Results

Table 2 shows the results of inclination angle while sitting on the real-time posture monitoring system. As compared with inclination angles in the sagittal plane between normal and scoliosis group, tilting angle of scoliosis group more increased on the posterior than normal group. However, there was no significant difference between the groups. In contrast, the opposite tendency was observed in the frontal plane. Inclination angle of normal group increased on the right side, while lateral tilting angle of scoliosis group significantly increased on the left side.

Table 2. Results of inclination angle between normal and scoliosis groups

Inclination angle (°)	Normal Group	Patients with scoliosis and pelvic asymmetry Group	p-value
Anterior (+) / Posterior (-)	-0.88±2.03°	-2.41±4.37°	0.23
Right (+) Left (-)	0.28±0.75°	-1.06±0.69°	0.00*

Functional scoliosis patients in this study have C-shaped lumbar curve to the left side defined by cobb angle and pelvic asymmetry on the right side. Postural balance of patients was tilted to the posterior and left side during sitting. It means that pelvic

position in functional scoliosis patients could be associated with spinal alignment and sitting balance due to the lumbar spine being connected to the pelvis directly [8]. Therefore, abnormal lateral curvature of the spine and length asymmetry may negatively influence balance function in compensation.

4 Conclusion

Real-time sitting posture monitoring system with accelerometer was developed to determine postural pattern of patients with functional scoliosis. The results obtained in this study indicated that spinal deformity caused by pelvic inequality can affect the postural balance in the frontal and sagittal planes during sitting. From these results, we confirmed that this system can be applied to monitor natural and comfortable posture with prolonged sitting in the office and at home for accurate diagnosis and treatment on various asymmetrical posture patterns according to the site and type of scoliosis.

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