Analysis of body imbalance in various writing sitting postures using sitting pressure measurement

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Abstract. [Purpose] This study set out to substantiate the importance of the right sitting posture by measuring the sitting pressure. It also described the influence of an imbalanced sitting posture on the body. [Subjects and Methods] The subjects included 30 healthy adults. A pressure mapping system was used to measure the sitting pressure in the right, one side prone, chin propped, and slumped sitting positions. [Results] The WDI (X AP) showed a statistically significant difference between the 3 incorrect postures (one side prone, chin propped, and slumped sitting) and the right sitting posture. With regard to the WDI (X LR), there was a statistically significant difference between the right sitting posture and the one side prone sitting posture only. [Conclusion] One side prone sitting was found to affect the body balance most adversely. This imbalanced posture may have an indirect effect on chronic diseases. The results prove that it is important to assume a proper posture to maintain body balance. 

Key words: Imbalanced posture, Sitting pressure, Pressure mapping system

INTRODUCTION

Today, most students lead sedentary lifestyles[1]. Previous studies have shown that 83% of students sit at a desk for more than 10 hours a day[2]. These increasingly sedentary lifestyles are associated with reduced physical activity, a higher incidence of metabolic diseases linked to obesity, and the onset of musculoskeletal disorders[1,3]. They are also an indirect cause of backache and dysfunction[3], and carry an increased risk of nerve conduction and of dysfunction from structural defects of the pelvis during weight-bearing[4]. Moreover, they can cause physical anomalies including the neck and back discs, shoulder muscle abnormalities, headaches, and mental anomalies[5]. Conversely, a balanced posture benefits individuals’ physical growth and development, work capacity, and athletic performance, and induces normal alignment of the spine by balancing the weight distribution directly or indirectly[6,8]. This study set out to substantiate the importance of a correct sitting posture by measuring the sitting pressure using a pressure mapping system. It also analyzed the influence of an imbalanced sitting posture on the body. In addition, we aimed to uncover data to confirm that maintaining a balanced posture can help to prevent backache and spinal deformity.
SUBJECTS AND METHODS

The subjects of this study included 30 healthy adults (15 males and 15 females) who understood the study. Written informed consent was obtained from each subject. Patients with musculoskeletal disorders of the hip or pelvis, those who were receiving physical therapy, and those who were left-handed were excluded. The mean age of the subjects was 20.3 ± 1.1 years. Their mean height was 167 ± 7.4 cm, and their body weight 56.2 kg. The pressure mapping system (Boditrak, Canada) was used to measure the sitting pressure in order to analyze the body imbalance in each posture. The pressure was measured in the right, one side prone, chin propped, and slumped sitting postures, which were the predominant postures adopted during the study. These are heavily used sitting postures by Korean students during their studying time. In the right sitting posture, the waist is vertical, the spine is in standing conditions, the angulations of the hip joint, knee joint, and ankle joint are 90°, and the feet touch the floor. The note should be parallel to the center line (i.e., the line that divides the table vertically in its center). In the one side prone sitting posture, the left arm is stretched on the table, the armpit touches the desk, and the head leans on the upper arm. The angulations of the knee joint and ankle joint are 90°, and the feet touch the floor. The note is tilted 45° to the left of the center line. In the chin propped sitting posture, the elbow of the left arm adheres to the table surface, the chin rests on the left hand, and the waist is flexed in the direction of the left arm. The angulations and note are the same as in the one side prone sitting posture. In the slumped sitting posture, the waist is in a posterior banding state, and the angulations of the knee joint and ankle joint are 90°. The subjects were placed at a desk with a height of 72 cm and a vertical length of 50 cm, sitting on a chair with a height of 46 cm, a width of 60 cm, and a backrest height of 34 cm. Environmental factors other than the posture were controlled. After the pressure mapping system was pre-installed, the subjects were made to sit for 1 minute, and the sitting pressure was measured in 4 writing postures. The subjects wrote something while the measurements were taken. A tape line was displayed by the pressure mapping system, and the subjects’ posture was corrected without leaving the area. In this experiment, the seat of the chair was divided into 4 sections, as shown in Fig. 1. After calculating the average pressure in each zone to analyze the pressure measurements of the chair ($X_P$, $X_A$, $X_R$, $X_L$), pressure sensor values above 5 mmHg were detected. In order to compare the 3 incorrect postures with the right posture, the weight distribution index (WDI) was manipulated to analyze the average pressure in each posture. The formula for the WDI was as follows:

$$WDI (X_P) = \frac{X_P}{X_{\text{平均}}}, \quad WDI (X_A) = \frac{X_A}{X_{\text{平均}}}, \quad WDI (X_R) = \frac{X_R}{X_{\text{平均}}}, \quad WDI (X_L) = \frac{X_L}{X_{\text{平均}}}$$

Fig. 1. Pressure mapping system results.
The subjects were made to sit on a mat to measure the sitting pressure.
Direction (A: anterior, P: posterior, L: left, R: right).
Pressure index (average pressure in each zone; $X_P$: anterior sitting pressure, $X_A$: posterior sitting pressure, $X_R$: left sitting pressure, $X_L$: right sitting pressure).
A corresponding sample t-test was used to compare the results, with the statistical significance level set at α=0.05. The SPSS 21.0 program for Windows was used to process the data.

RESULTS

The WDI (X_AP) was 3.37 ± 0.82 in the right sitting position, 2.64 ± 0.73 in the one side prone sitting position, 3.08 ± 0.79 in the chin propped sitting position and 3.03 ± 0.73 in the slumped sitting position (Table 1). There was a statistically significant difference between the WDI index of the 3 incorrect postures and that of the right sitting posture (p<0.05). The WDI (X_LR) was 0.99 ± 0.11 in the right sitting position, 0.54 ± 0.20 in the one side prone sitting position, 0.97 ± 0.10 in the chin propped sitting position and 0.98 ± 0.11 in the slumped sitting position. The comparison of the WDI (X_LR) showed a significant difference between the right sitting position and the one side prone sitting position (p<0.05), but no differences between the right sitting position and the chin propped sitting position (p=0.071), or between the right sitting position and the slumped sitting position (p=0.389) (Table 2).

DISCUSSION

The spine and pelvis are connected by a spinal-pelvic complex. Therefore, the position of the pelvis in a sitting posture has a great effect on the spine10). For example, spinal lordosis is caused by anterior tilting of the pelvis, which increases the anterior angle of the lumbar spine and the posterior angle of the thoracic vertebrae due to the body’s compensatory action to maintain trunk stability11). Conversely, posterior tilting of the pelvis leads to kyphosis—i.e., a slumped posture. As another example, an asymmetric pelvic tilt induced by placing a wallet in the side back pocket of pants can lead to the asymmetrical use of the erector spinae muscle and cause spinal imbalance12). However, many students assume a variety of sitting postures (right, one side prone, chin propped, and slumped sitting) while studying, which causes spinal imbalance. The comparison of the anterior and posterior pressures showed statistically significant differences between the WDI (X_AP) of the 3 incorrect postures and that of the right sitting posture (p<0.05). The WDI (X_AP) was 3.37 ± 0.82 in the right sitting posture, while it was lower in imbalanced postures (one side prone sitting: 2.64 ± 0.73, chin propped sitting: 3.08 ± 0.79, and slumped sitting: 3.03 ± 0.73, respectively). The lower WDI in imbalanced postures than in the right sitting posture indicated that in incorrect postures, the pressure is moved to the anterior area, which can cause a posterior pelvic tilt. The statistically significant difference observed for all 3 postures reveals that the pressure distribution was moved to the anterior area in all subjects. When comparing the left and right pressures, a significant difference was observed between the right sitting posture and the one side prone sitting posture (p<0.05), but not between the right sitting posture and the chin propped sitting posture, or between the right sitting posture and the slumped sitting posture (p>0.05). The WDI (X_LR) was 0.99 ± 0.11 in the right sitting posture

| Applied posture          | Measured value (m ± sd) | Gap value (m ± sd) | Significance probability |
|--------------------------|-------------------------|--------------------|--------------------------|
| Right sitting            | 3.37 ± 0.82             | 0.73 ± 0.48        | 0.00                     |
| One side prone sitting * | 2.64 ± 0.73             |                    |                          |
| Right sitting            | 3.37 ± 0.82             | 0.29 ± 0.39        | 0.00                     |
| Chin propped sitting *   | 3.08 ± 0.79             |                    |                          |
| Right sitting            | 3.37 ± 0.82             | 0.34 ± 0.34        | 0.00                     |
| Slumped sitting *        | 3.03 ± 0.73             |                    |                          |

Mean values ± standard deviation for variables.
*Significant results.

| Applied posture          | Measured value (m ± sd) | Gap value (m ± sd) | Significance probability |
|--------------------------|-------------------------|--------------------|--------------------------|
| Right sitting            | 0.99 ± 0.11             | 0.45 ± 0.20        | 0.00                     |
| One side prone sitting * | 0.54 ± 0.20             |                    |                          |
| Right sitting            | 0.99 ± 0.11             | 0.02 ± 0.07        | 0.07                     |
| Chin propped sitting     | 0.97 ± 0.10             |                    |                          |
| Right sitting            | 0.99 ± 0.11             | 0.01 ± 0.09        | 0.39                     |
| Slumped sitting          | 0.98 ± 0.11             |                    |                          |

Mean values ± standard deviation for variables.
*Significant results.
and 0.54 ± 0.20 in the one side prone sitting posture. The lower value of the WDI (XLR) in the one side prone sitting posture than in the right sitting posture indicated an increase in the left sitting pressure, which can cause a left pelvic tilt. The WDI measurement results for the anterior, posterior, left, and right sitting pressures showed that the one side prone sitting posture may induce a posterior pelvic tilt as well as a left pelvic tilt. Therefore, it is more likely to cause an imbalance of the pelvis than the other postures. On the other hand, the slumped and chin propped sitting postures may induce a posterior pelvic tilt, causing an imbalance of the spine. In conclusion, posterior pelvic tilting and lateral pelvic tilting can cause kyphosis and scoliosis, respectively. Therefore, all 3 imbalanced postures can cause spinal imbalances. An increased tilt angle can also activate the muscles opposite the tilt direction\(^{13}\), so that imbalanced postures can cause pathological symptoms such as pelvic asymmetry. Pelvic asymmetry and idiopathic scoliosis can lead to postural asymmetry, unequal weight distribution, and muscular imbalance\(^{14}\), or even cause more serious physical imbalances. Therefore, it is important to maintain a correct sitting posture to ensure a healthy spine and pelvis.

This study has 2 limitations: (1) the sample size was small; (2) pressure becomes larger than the initial while being seated for a long time. Future research will require continuous including meta-analysis using larger groups and fine adjustment of pressure distribution.

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**Conflict of interest**

None.

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