Influence of sacral sitting in a wheelchair on the distribution of contact pressure on the buttocks and back and shear force on the ischial region

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Abstract. [Purpose] The purpose of this study was to investigate the influence of sacral sitting in a wheelchair on contact pressure on the buttocks and back, and shear force on the ischial region. [Subjects and Methods] Twenty-six healthy adults assumed two postures while seated in a wheelchair: a basic sitting posture, and sacral sitting with the pelvis tilted posteriorly and the ischium slid forward by 5 cm relative to its position in the basic sitting posture. The inclination angle of the sagittal pelvic line, contact pressures and contact areas on the buttocks and back, and the shear force generated by sliding the ischial region forward were measured. [Results] Posterior pelvic tilt was significantly greater during sacral sitting. Maximum contact pressures on the buttocks and ischial region were significantly lower during sacral than during basic sitting. However, maximum contact pressure on the back, the contact areas of the buttocks and back, and the shear force generated by sliding the ischial region forward were significantly greater during sacral sitting. [Conclusion] Sacral sitting in a wheelchair increases the maximum contact pressure on the back, contact areas of the buttocks and back, and the shear force generated by sliding the ischial region forward.

Key words: Wheelchair seating, Sacral sitting, Posterior pelvic tilt

INTRODUCTION

Sacral sitting is a poor seated posture with a posterior pelvic tilt and thoracic kyphosis\(^1\). It is typically observed in frail older adults using a wheelchair, and occurs when they lack the ability to retain a seated posture and/or their body size and function do not match the size and structure of the wheelchair\(^2\). In some cases, the size of the standard wheelchair used in hospitals and elderly care facilities is not suitable for individual wheelchair users\(^3\); however, there are also structural problems with wheelchair design that can make it difficult to maintain a seated posture, such as the hammocking effect of sling seats and poor back support\(^2\), both of which are likely to cause sacral sitting. Patients in care facilities often sit in wheelchairs with poor seated posture, including sacral sitting, for long periods of the day\(^4\) and it has been reported that sacral sitting with a posterior pelvic tilt increases the risk of pressure ulcers on the buttocks in frail older adults\(^5\). A pressure ulcer is a localized injury caused by contact pressure or pressure in combination with shear force on the skin and/or subcutaneous tissues over a bony prominence\(^3\). The vertical and horizontal forces that load the sacrococcygeal region during sitting increase with an increase in the posterior inclination angle of the pelvis\(^5\). However, the influence of sacral sitting on the contact pressure and shear force load on the buttocks while seated in a wheelchair has not been clarified.

In this study, the pelvic inclination angle, contact pressures on the buttocks and back, and shear force of healthy subjects who adopted a sacral sitting posture in a wheelchair were quantitatively measured. The goal of this investigation was to determine the influence of sacral sitting on factors likely to predispose to the development of pressure ulcers.
SUBJECTS AND METHODS

Twenty-six healthy adults (5 males, 21 females; mean age, 21.0 ± 0.9 years) participated in this study. Their body sizes were as follows: mean height: 159.3 ± 7.4 cm; mean thigh length (the distance from the sacrum to the popliteal fossa): 44.4 ± 2.7 cm; mean axilla height (from the seat surface to the axilla while in a sitting position): 42.8 ± 3.1 cm; mean lower leg length (from the popliteal fossa to the heel while in a sitting position): 39.7 ± 2.5 cm; and mean elbow height (from the seat surface to the elbow while in a sitting position): 21.2 ± 2.7 cm. Measurements were performed using a modular wheelchair (Revo Next; ETAC Co., Ltd., Stockholm, Sweden), each part of which was adjustable to the body size of the user. After the initial measurements, a wheelchair cushion (Type 5 TC-045; Takano Heartworks Co., Ltd., Nagoya, Japan) was placed on the seat and the wheelchair was adjusted to the body size of each subject as follows: seat depth was adjusted to thigh depth minus 5 cm; back height was adjusted to axilla height minus 10 cm; leg length was adjusted to the lower leg length; and the height of the arm supports was adjusted to the elbow height of each subject.

The subjects assumed two postures: a basic sitting posture with the buttocks placed far back on the wheelchair seat and sacral sitting with a posterior pelvic tilt and the ischium slid forward by 5 cm relative to its position in the basic sitting posture (Figs. 1, 2). The subjects assumed the basic sitting posture first, and then transitioned from the basic to the sacral sitting posture. In each posture, the inclination angle of the sagittal pelvic line, contact pressure on the ischial region, and maximum contact pressures and contact areas on the buttocks and back were measured. In addition, the shear forces generated by sliding the ischial region forward during basic sitting and during the transition from basic to sacral sitting were measured.

The forward displacement of the ischium was measured by placing the end of a 30-cm steel carpenter’s square ruler against the lower edge of the subject’s patella while the ruler was held parallel to the thigh in a horizontal position. The distance from the patella to the point where the ruler and the front of the seat met was considered to be the forward displacement of the ischium. The inclination angle of the sagittal pelvic line was measured using an inclination angle-measuring device (HORIZON; Yuki Trading Co., Ltd., Tokyo, Japan), which is a seated posture-measuring device, in accordance with the ISO16840-1 standard. When the sagittal pelvic line tilted backwards from the vertical with a posterior pelvic tilt, the values measured with HORIZON became negative. In contrast, when the sagittal pelvic line tilted forward from the vertical with an anterior pelvic tilt, they became positive. The contact pressures and contact areas on the buttocks and back were measured using an SR Soft Vision sensor pad (Fukoku Bussan Co., Ltd., Tokyo, Japan), which was placed on the wheelchair cushion. SR Soft Vision is a seat-type sensor pad with 256 pressure-sensing points indicating the pressure load on each point. The number of responding sensing points was considered to be the size of the contact area. The contact pressure on the ischial region and shear force generated by sliding the ischial region forward were measured using a Predia sensor (Molten Co., Ltd., Hiroshima, Japan), which was placed on the wheelchair cushion.

The paired t-test was used to analyze between-posture differences in the mean values of each measurement when the measured values were normally distributed, and the Wilcoxon signed-rank test was used when the distribution was not normal. Correlations between the inclination angle of the sagittal pelvic line and the contact pressure on the ischial region, maximum contact pressures and contact areas on the buttocks and back during basic and sacral sitting, and shear force during basic sitting and during the transition from basic to sacral sitting were investigated using Spearman’s correlation coefficient when the measured values were normally distributed, and Pearson’s rank correlation coefficient when their distribution was not normal. All analyses were performed using the Japanese version of SPSS version 21 (IBM, Armonk, NY, USA). Values of p<0.05 were accepted as significant.

Fig. 1. Basic sitting posture
The subject sits up straight with the buttocks placed far back on the wheelchair seat.

Fig. 2. Sacral sitting posture
The subject sits with a posterior pelvic tilt and the ischium slid forward by 5 cm compared with the basic sitting posture.
The Medical Ethics Committee of Gunma University approved this study (26-43), and written informed consent was provided by subjects.

RESULTS

The inclination angles of the sagittal pelvic line were $-16.4 \pm 4.0^\circ$ and $-30.3 \pm 4.3^\circ$ during basic and sacral sitting, respectively, which indicates that posterior pelvic tilt was significantly greater during sacral sitting than during basic sitting ($p<0.001$; Table 1). Maximum contact pressures on the buttocks ($p<0.001$) and ischial region ($p<0.001$) were significantly lower during sacral sitting than during basic sitting. In contrast, maximum contact pressure on the back ($p<0.001$), contact area on the buttocks ($p<0.001$), contact area on the back ($p<0.001$) were significantly greater during sacral sitting than during basic sitting (Table 1). The shear force generated by sliding the ischial region forward to a sacral sitting position was significantly greater than the shear force during basic sitting ($p=0.003$). The inclination angle of the sagittal pelvic line was significantly correlated with the back contact area during the transition from a basic to a sacral sitting posture ($|r|=0.451$, $p=0.003$). None of the other pairs of items showed significant correlations.

DISCUSSION

The major findings of this study were that, during sacral sitting, the pressures on the buttocks were lower while pressures on the back were higher than during basic sitting. In addition, significant shear forces were generated by sliding the ischium forward from a basic sitting posture into a sacral sitting position. These findings are consistent with those of previous studies that investigated the influence of sacral sitting on subjects without using wheelchairs.

Since the posterior tilt of the pelvis was greater during sacral sitting than in a basic sitting posture, the combined center of gravity of the head, arms, and trunk may have shifted back relative to its position during basic sitting; this may have increased in the force pressing the back against the back support during sacral sitting and the maximum contact pressure on areas of the back. The results of this study are consistent with those of a previous report, which also found that the weight borne by a wheelchair seat supporting the buttocks decreased as the combined center of gravity shifted back during sacral sitting with a posterior pelvic tilt, while the load on the back support increased\(^\text{11}\). Concomitantly, maximum contact pressure on the buttocks decreased and maximum contact pressure on the back increased. This is also likely due to the posterior tilt of the pelvis and backwards shift in the center of gravity during sacral sitting, as is shown by the positive correlation between the pelvic posterior tilt angle and back contact area.

The act of pressing the trunk against the back support produces a counterforce that shifts the buttocks forward\(^\text{12}\). The back support converts backward angular momentum of the trunk produced by posterior pelvic tilt to shear force in the forward direction\(^\text{13, 14}\). In this study, posterior pelvic tilt markedly increased in sacral sitting compared with that in basic sitting, which may have increased the force pressing the trunk against the back support and shear force generated by sliding the ischial region forward, compared to basic sitting. In a previous study, the shear force in the sacrococcygeal and ischial regions, measured on the seat surface of a chair created specifically for the measurement, was shown to increase with an increase in the posterior pelvic tilt angle in a sitting position\(^\text{15}\). In the present study, shear force was measured on the seat surface of a wheelchair, and the forward force in the ischial region increased when adopting a sacral sitting posture with the pelvis tilted.

### Table 1. Measurement values during basic and sacral sitting (n=26)

|                                  | Basic sitting posture | Sacral sitting |
|---------------------------------|-----------------------|---------------|
|                                 | Mean ± standard       | Mean ± standard |
|                                 | deviation             | deviation     |
| Inclination angle of the sagittal pelvic line (degree) † | $-16.4 \pm 4.0$ | $-30.3 \pm 4.3$*** |
| Contact pressure on the ischial region (mmHg) † | 72.5 ± 14.4 | 61.1 ± 14.3*** |
| Buttocks                         |                       |               |
| Maximum contact pressure (mmHg) † | 92.1 ± 18.3          | 78.6 ± 19.4   |
| Size of contact area (point) †    | 137.3 ± 30.4          | 150.1 ± 28.1  |
| Back                             |                       |               |
| Maximum contact pressure (mmHg) † | 36.1 ± 9.4           | 50.9 ± 13.5*** |
| Size of contact area (point) †    | 17.2 ± 10.0           | 29.3 ± 10.1*** |
| Shear force generated by sliding the ischial region forward (newton) † | 6.1 ± 3.0            | 7.1 ± 3.6*** |

†Significance was tested using the paired t-test, ‡Significance was tested using the Wilcoxon signed-rank test.
**p<0.01, ***p<0.001
backwards, confirming the previously published finding.

To reduce contact pressure and shear force and prevent pressure ulcers, it is recommended that wheelchair users maintain proper posture and postural control, and that they sit on a supportive surface appropriate for their individual needs. The results of the current study indicate that the shear force load on the ischial region increases with the increase in posterior pelvic tilt during sacral sitting. The decreases in contact pressure on the ischial region and maximum contact pressure on the buttocks during sacral sitting may reduce the risk of pressure ulcers; however, the increased shear force generated by sliding the ischial region forward remains a risk factor for ulcer development.

The present study used healthy young participants; however, similar measurements should be taken of frail older individuals who use a wheelchair daily, in order to verify that these results are applicable to more typical wheelchair users. Furthermore, while a sacral sitting posture was defined as sitting with the ischium slid 5 cm forward relative to its position in the basic sitting posture, additional measurements should be performed at various posterior pelvic tilt angles in future studies, in order to clarify the influences of these angles on wheelchair users.

In conclusion, sacral sitting in a wheelchair increases the maximum contact pressure on the back, contact areas of the buttocks and back, and the shear force generated by sliding the ischial region forward. These factors may contribute to the development of pressure ulcers, and improvements in wheelchair seating that reduce sacral sitting by frail older adults may reduce the risk of ulcer development.

ACKNOWLEDGEMENTS

The author would like to thank all of the participants in this study, and Tatsuya Oguchi and Aya Saito (occupational therapy students of Gunma University Faculty of Medicine School of Health Science) for their assistance. There is no conflict of interest with regard to this study.

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