Brief Report

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Padding the seat of a wheelchair reduces ischial pressure and improves sitting comfort

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SUMMARY In this study, we aimed to examine whether a wheelchair cushion placed directly atop a sling seat or deflection of the sling seat compensated by a pad along with the placement of a wheelchair cushion changed sitting pressure. Additionally, we examined whether these additions changed sitting comfort. For twenty healthy adults who consented to participate, measurements were taken for three types of cushions, each with and without padding, under six conditions. The cushion types tested included air (cushion A), urethane foam (cushion U), and three-dimensional thermoplastic elastomer (cushion T). A pressure distribution measurement equipment was used for the measurements. Following the measurement, the comfort of the wheelchair cushion was measured. The ischial area pressure of the cushion A pad was significantly lower than that without the pad. Cushions U and T were for ischial area pressure with a pad, resulting in a decreasing trend in ischial area pressure with a pad compared to that without a pad; however, the difference was insignificant. For all cushions, sitting comfort was significantly better in all groups with padding than in those without. In conclusion, ischial pressure can be dispersed by placing a pad on the seat surface of a wheelchair cushion, and pads were suggested to improve sitting comfort for all cushions.

Keywords wheelchair cushion, pressure redistribution, sling seat

1. Introduction

Pressure ulcers occur when soft tissues are compressed between the bony prominence and external surface for a prolonged period or when blood flow is obstructed by external forces such as misalignment (*1*). Although some studies have posited pressure ulcers as preventable, their incidence remains high (*2-4*). In addition, when pressure ulcers develop, long-term treatment is required before healing, resulting in significant medical and economic losses (*5-7*).

Pressure ulcers are more common in wheelchair users who are at long-term risk of developing these sores (*8*). When an individual sits in a wheelchair, external forces are concentrated on the bony prominences of the ischium and tailbone, increasing the risk of pressure ulcers (*8*). Thus, wheelchair users should remove external forces every 15-30 min (*9*); however, individuals of advanced age have difficulty removing external forces by themselves. Therefore, the pressure ulcer prevention guidelines recommend the use of wheelchair cushions for pressure ulcer prevention (*1,10*). We have previously reported that the use of wheelchair cushions enables pressure dispersion (*11*).

However, because the seat of a wheelchair is a sling, deflection of its surface is prone to occur, contributing to pelvic tilt, which in turn increases local pressure and leads to pressure ulcers (*12*). In addition, because the level of seat deflection of a wheelchair varies from model to model, wheelchair cushions cannot accommodate all deflections, and the effect of seat pressure dispersion of the wheelchair cushion is reduced by half. In our previous study, the pressure dispersion effect of wheelchair cushions with padding to compensate for deflection was high (*11*). Another study evaluated the insertion of a pad under the wheelchair cushion, referred to as the "pelvic well pad" study (*13*). In that study, researchers created and inserted a pad with the ischial area cut off and reported a decrease in the mean and peak pressures and an increase in the contact area in the buttocks and thighs. These results suggest that inserting a pad that compensates for the deflection under a wheelchair cushion can increase sciatic pressure and contribute to the prevention of pressure ulcers.

Therefore, in this study, we aimed to examine whether sitting pressure changes when a wheelchair cushion is placed directly on top of a sling seat or when a pad and a wheelchair cushion compensate the deflection of the sling seat is placed on top of the sling seat. Additionally, we examined whether there was a change in sitting comfort with and without a pad.

2. Materials and Methods

2.1. Participants

The number of participants in this study was calculated using the G Power software. Based on a previous study (*11*), with an effect size of 0.7, an alpha error of 0.05, and a power of 0.8, the required sample size was 19. Therefore, 20 participants were included in this study, after excluding those who withdrew consent and those with missing data. The inclusion criteria for this study were a sitting girdle width of 34–40 cm and a sitting base length of 41–49 cm. In contrast, the exclusion criteria were a sitting girdle width of ≥ 41 cm and ≤ 33 cm, sitting base length of ≥ 50 cm and ≤ 40 cm, and the presence of back or lower limb disease. The final sample included 20 healthy adults (10 male and 10 female).

2.2. Ethics

This study was conducted in accordance with the Declaration of Helsinki. Its purpose and significance were fully explained to all participants, who all provided their signatures on a consent form before the study. This study was approved by the Ethics Committee of Naragakuen University (approval number/ID 3-R003).

2.3. Devices and equipment used

A CONFORMat (Nitta Corp., Osaka, Japan) was used to measure body pressure, which is a sensor mat with previous testing for reliability and validity (*11,14-16*). The specifications of the sensor sheet were as follows: depth, 471 mm × width, 471 mm; 1024 sensors (32 rows × 32 columns); thickness of 1.8 mm, and a resolution of 14.7 mm. A standard wheelchair (MATSUNAGA MANUFACTORY Co., Ltd., Tokyo, Japan) was used. Three types of cushions were tested: an air material (ROHO; Permobil Co., Ltd., Västernorrland Sweden: single-valve low-profile air material, 40.5 × 43 × 5.5 cm: cushion A), urethane foam material (Moderate cushion; LAC Healthcare Ltd., Osaka, Japan: special urethane material, 40 × 40 × 6 cm: cushion U), and a three-dimensional (3D) thermoplastic elastomer material (Geltron; Pacific wave Co., Ltd., Japan: 3D thermoplastic elastomer material, 38 × 38 × 3.5 cm: cushion T). The seat deflection was measured beforehand, and urethane foam pads were prepared to match the deflection.

2.4. Measurements

Measurements were taken for the three cushion types, each with and without padding, under six conditions. After the participant's seated lower leg length was measured and foot support was adjusted, they were assessed for 5 min without a wheelchair cushion to determine the reference value. The order of the six conditions was randomly assigned using the envelope method. The participants then sat in a wheelchair in the assigned order, and the position of the ischial region was identified. The measurement position was taken with the pelvis positioned as far back in the seat as possible, and the seat and thighs were positioned horizontally. The feet were placed on footrests, and both upper limbs were positioned on the thighs instead of the arm supports. Measurements were taken after the sitting pressure stabilized (after approximately 5 min) for 10 min. After the measurement, the sitting comfort of the wheelchair cushion was measured using a numerical rating scale (NRS). Using the NRS, the participants were then instructed to rate their sitting comfort on a scale of 10, with 10 being "very poor" and 0 being "very good and comfortable." When the state of sitting comfort without the standard cushion was set to 10 (very poor), the

Figure 1. Measuring and padding wheelchair seat deflection. (**A**) Measurement of wheelchair seat deflection. Wheelchair (**B**) with deflection compensation pad and (**C**) without deflection compensation pad.

participants were instructed to indicate how comfortable they felt in the target group. The wheelchair cushion and pad were replaced after the NRS score assessment, and a 5-min break was allowed between measurements.

2.5. Analyses

For assessing pressure at the ischium, the mean value of the four sensors around the maximum pressure area (peak pressure index) was calculated for each condition. Sciatic pressure and NRS scores with and without deflection correction in each condition were compared using a paired *t*-test. In addition, 95% confidence intervals and effect sizes were calculated. Effect sizes were calculated using Field's r to measure the standardized mean difference between the two groups, calculated as $r = \sqrt{t2/(t2+df)}$ (*17*). All analyses were performed using the R (version 4.0.3, R Foundation) for Windows. Statistical significance was set at a Bonferroni-corrected $P < 0.015$.

3. Results and Discussion

The ischial area pressures of cushion A were 34.2 ± 6.2 mmHg without a pad and 31.0 ± 7.1 mmHg with a pad. The ischial area pressure with a pad was significantly lower than that without a pad ($P = 0.0021$), and the effect size was large ($r = 0.63$). The ischial area pressures of cushion U were 26.4 ± 4.4 mmHg without a pad and 24.2 ± 5.1 mmHg with a pad, showing a decreasing trend in ischial area pressure with a pad compared to that without a pad. However, the difference was not significant ($P = 0.018$). However, the effect size was large ($r = 0.51$). The ischial area pressures of cushion T were 37.9 ± 8.4 mmHg without a pad and 33.4 ± 8.3 mmHg with a pad, showing a decreasing trend in ischial area pressure with a pad compared to that without a pad, but without significant difference ($P = 0.031$). The effect size was moderate ($r = 0.47$) (Table 1). As the use of wheelchair cushions for wheelchair users decreases sciatic pressure ulcers and reduces the risk of pressure ulcers (*1,10*), these devices should be used to reduce and prevent ischial pressure ulcers. However, as the seat surface of a wheelchair is a sling, deflection occurs and is believed to reduce the performance of the wheelchair cushion. In a previous study, Shin *et al.* reported that padding the seat surface reduces peak pressure (*13*). However, adding a seat surface increases ischial pressure (*18*). Therefore, unlike the previous study, this research was conducted with a pad placed on the seat surface of a wheelchair following the deflection of the seat surface. Consequently, ischial pressure was significantly reduced when the wheelchair cushion was used with padding compared with when it was used without padding; however, no significant reduction was observed in cushions U and T, the effect sizes were high (cushion U), and medium (cushion T) and ischial pressure tended to decrease. In our previous wheelchair cushion study, a hybrid-type wheelchair cushion was padded, resulting in lower ischial pressure (*11*). Although the ischial pressure was shown to increase in a study by Kamegaya *et al*. (*18*), this may have been due to different materials. Wood was used in their study, whereas urethane was used in ours. It is possible that the urethane foam material dispersed the pressure while compensating for the deflection as it is a porous material used for cushions (*19*). Based on the aforementioned findings, placing a pad on the seat surface of a wheelchair when using a wheelchair cushion can reduce the ischial pressure ulcer pressure and contribute to the prevention of pressure ulcers.

Regarding seating comfort, the three cushions had the following values: cushion U (without pad, 5.0 ± 1.1; with pad, 4.1 ± 0.9), cushion T (without pad, 5.1 ± 0.9; with pad, 4.0 ± 0.6), and cushion A (without pad, 5.5 ± 1.0; with pad, 4.5 ± 0.8). The sitting comfort was significantly better in all groups with padding than in those without padding ($P < 0.015$; cushion U: $r = 0.66$, effect size,

Table 1. Comparison of ischial area pressure with and without a pad

Cushions	Without pad	With pad	*P* value	Effect size: r
U	26.4 ± 4.4 (24.3–28.5)	24.2 ± 5.1 (21.3–26.6)	0.018	0.51
T	37.9 ± 8.4 (34.0–41.8)	33.4 ± 8.3 (29.5–37.3)	0.031	0.47
A	34.2 ± 6.2 (31.3–37.1)	31.0 ± 7.1 (27.7–34.3)	< 0.015	0.63

Values are expressed as means±standard deviations (95% confidence intervals). Abbreviations: U, urethane foam material; T, three-dimensional thermoplastic elastomer material; A, air material.

Table 2. Comparison of seating comfort with and without a pad

Cushions	Without pad	With pad	*P* value	Effect size: r
U	5.0 ± 1.1 (4.5–5.5)	4.1 ± 0.9 (3.7–4.5)	< 0.015	0.66
T	5.1 ± 0.9 (4.7–5.5)	4.0 ± 0.6 (3.7–4.2)	< 0.015	0.88
A	5.5 ± 1.0 (5.0–6.0)	4.5 ± 0.8 (4.1–4.9)	< 0.015	0.83

Values are expressed as means±standard deviations (95% confidence intervals). Abbreviations: U, urethane foam material; T, three-dimensional thermoplastic elastomer material; A, air material.

large; cushion T: $r = 0.88$, effect size, large; cushion A: $r = 0.83$, effect size, large) (Table 2). This result confirmed the comfort of the wheelchair seating position using pads. Regarding wheelchair seating comfort, Harms reported that wheelchair sling seats promoted a kyphotic posture and caused neck and back discomfort in able-bodied and disabled participants (*20*). Wheelchair sitting in a sling seat also promotes scoliosis and poor posture (*21*), which can contribute to deformities (*22*) and increase the risk of neck and back pain due to muscle strain (*23,24*). Therefore, sitting comfort is important. This study showed that padding compensated for the deflection and increased the contact area of the buttocks to maintain a stable posture, resulting in significantly better seating comfort for all cushions. This suggests using pads to compensate for the deflection and improve sitting comfort.

Nevertheless, this study has some limitations. First, the participants were healthy. Therefore, in the future, we would like to conduct studies on older individuals with atrophied gluteal muscles and patients with spinal injuries to confirm the prevention of pressure ulcers. Second, the sitting time was approximately 10 min. Wheelchair users are forced to sit for long periods. Therefore, it is necessary to observe changes in ischial pressure and sitting comfort when sitting for long periods. Third, only ischial pressure was measured as an external force in this study. Because the external force can be misaligned, we believe that verifying misalignment is also necessary in the future. In conclusion, ischial pressure can be dispersed by placing a pad on the seat surface of the air material. Although no significant pressure-reducing effect was observed for the urethane and 3D thermoplastic elastomer material cushions, a pressure-reducing effect was confirmed. In addition, the pads improved the sitting comfort of all the cushions.

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