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Original Article

Impact of wheelchair reclining and leg rest angles on pressure distribution in back, buttocks, and feet: an experimental study in healthy adults

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Abstract. [Purpose] This study aimed to determine the effects of reclining angle and leg rest angle adjustments on pressure distribution in the back, buttocks, and feet in a wheelchair sitting position. [Participants and Methods] Twenty-six healthy young adults participated in this study. Pressures on the back, buttocks, and feet were measured under nine postural conditions with a combination of reclining angles (10°, 30°, and 50°) and leg rest angles (20°, 40°, and 60°). Body pressure distribution was measured for 30 s in each posture using a pressure distribution measuring device, followed by statistical analysis. [Results] Posture adjustments significantly impacted pressure distribution. Pressure was increased on the back and reduced on the buttocks of participants when in the reclining position. The leg rest angle had a minimal effect on foot pressure, but changes in the leg rest angle influenced the balance of pressure between the back and buttocks. [Conclusion] Adjusting wheelchair posture can effectively manage pressure distribution and reduce the risk of pain and pressure ulcers, especially on the back and buttocks. The reclining angle plays a key role in redistributing pressure, making it important for comfort and the prevention of bedsores.
Key words: Wheelchair seated, Body pressure, Distribution pressure ulcer prevention

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INTRODUCTION

Wheelchair weaning is an effective method for maintaining activity and preventing bedsores as part of the rehabilitation for long-term bedridden patients. Daytime wheelchair use plays an important role, especially in the elderly and in patients with progressive deterioration of systemic symptoms[1, 2]. However, prolonged sitting in a wheelchair can cause uneven body pressure, resulting in pain, and bedsores.

Increased physical and emotional burdens on patients have been reported[3–6]. Previous studies have shown that the pressure applied to the seat surface changes as the reclining angle of the wheelchair is adjusted[7]. It has also been confirmed that the adjustment of the footrest angle and height changes the pressure distribution in a similar manner[8, 9]. These studies provide insights into pressure relief for the buttocks. However, there have been few studies on pressure changes in other important regions such as the back and heels. However, clinically, it is also important to consider the pressure distribution at the back and heels. Consideration of these areas is necessary to prevent pain and pressure ulcers. The back and heels are areas where

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blood flow is easily restricted by continuous pressure. In particular, the heel is known to be at a high risk of pressure ulcers because of the lack of cushioning tissue between the skin and bone, which can easily concentrate pressure on the heel[10–12]. The back is also a weight-bearing part of the body, and maintaining the same posture for a long period of time can concentrate pressure and cause pain[13, 14]. Therefore, the study of pressure distribution in these areas is very important for the comfort of wheelchair users and the prevention of bedsores.

The purpose of this study was to determine the effects of postural conditions on pressure changes in the whole body, back, buttocks, and feet in the wheelchair sitting position. In particular, we aimed to elucidate how pressure concentrations on the back and heels affect the risk of pain and pressure ulcers. However, by analyzing the pressure changes in the back and heels, effective postural adjustment methods can be proposed to improve the comfort of wheelchair users and prevent bedsores.

PARTICIPANTS AND METHODS

The participants in this study were 26 healthy young adults with no neurological or orthopedic diseases undergoing treatment. The participants were recruited using convenience sampling. The participants were physically fit because of the nature of the experiment.

In addition to the presence or absence of disease, the exclusion criteria were no history of pressure ulcers and weight not exceeding wheelchair load-bearing capacity. The mean age of the participants finally selected was 21.0 ± 1.1 years, of which 14 were male and 12 were female. The physical characteristics of the participants were as follows: mean height was 164.5 ± 7.9 cm, mean weight was 57.7 ± 10.0 kg, and mean BMI was 21.2 ± 2.5. Participants whose weights exceeded the load-bearing capacity of the wheelchair were excluded to ensure device safety and data consistency.

This study was conducted in accordance with the Declaration of Helsinki after obtaining prior approval (approval number: 23-Ig-177) from the Ethical Review Board of the institution where the study was conducted. Procedures to ensure the safety and dignity of the participants were followed and the purpose, methods, risks, and benefits of the study were explained both orally and in writing. They also explained that participation in the study was voluntary and that they could withdraw at any time. Data were anonymized to ensure participant privacy.

The pressure distribution (average pressure) and pressure area (average pressure area) were measured at four measurement sites (whole body, back, buttocks, and feet) in the wheelchair sitting position. The measurement device used was a body pressure distribution measuring device (SR Soft Vision whole body version, Sumitomo Science and Engineering,Japan).

The changes in body pressure under each postural condition were also examined. The posture conditions consisted of a combination of reclining angles (10°/30°/50°) and leg rest angles (20°/40°/60°) for nine conditions. Specifically, the conditions were (1) 10°/20°, (2) 10°/40°, (3) 10°/60°, (4) 30°/20°, (5) 30°/40°, (6) 30°/60°, (7) 50°/20°, (8) 50°/40°, (9) 50°/60°. Each posture condition is illustrated in Fig. 1. The measurement procedure used a standard reclining wheelchair with armrests removed. The wheelchair used in this study was a T60 reclining wheelchair manufactured by Paramount Bed (Tokyo, Japan). The default angle of this wheelchair was, with the reclining angle set to 10° backward, and the leg rest tilted forward at 20°. This is the so-called neutral state with the smallest angle in the wheelchair. The participants were asked to stand still with their hands on their chests and measurements were taken randomly for 30 s under each condition. The leg rest angle was set such that the thighs and seat surfaces were level when the leg rest angle was adjusted[7].

Statistical analysis software (Free JSTAT 22.1J) was used for data analysis. To clarify the main effects and interactions of the measurement site and postural conditions, a repeated two-way analysis of variance was conducted using repeated measurements for both the average body pressure and pressure area. In addition, to check the changes in the average body pressure and pressure area of each part for each measurement condition, we performed repeated-measurement one-way analysis of variance and used the Bonferroni method for the post-test to check for statistically significant differences. This enabled us to compare the effects of the reclining and leg-rest angles on the average body pressure and pressure area of each part of the body in detail.

RESULTS

The detailed analysis results for the mean pressure are listed in Table 1.

Repeated two-way analysis of variance for mean pressure showed the main effects of the measurement site and posture condition. Furthermore, a significant interaction effect was observed between the two variables. In particular, the whole-body and back pressures tended to be predominantly higher, and the buttock pressure was predominantly lower in postural conditions (7) to (9) than in (1) to (6).

Repeated one-way analysis of variance was used to compare the body pressure distribution for each postural condition by measurement site. Significant differences were found for the whole body, back, and buttocks. The values were predominantly higher in conditions (7) to (9) (unit: mmHg, mean ± SD).

The detailed analysis results for the pressure area are listed in Table 2.

Repeated two-way analysis of variance showed a main effect of measurement site and posture condition, as well as mean pressure. Furthermore, a significant interaction effect was observed between the two variables.

Repeated-measures one-way analysis of variance revealed significant differences in the whole body, back, and buttocks. In condition (9), the pressure area showed a maximum value for both the entire body and the back, and a minimum value for the buttocks. In this study, we examined the effects of posture conditions on body pressure during wheelchair seating. These results confirmed the main effects of the site and postural conditions.

DISCUSSION

A comparison of the mean pressure and pressure area showed that each factor had an effect on the others, in addition to the interactions. Specifically, the analysis by region showed the highest average pressure on the buttocks and the lowest pressure on the back. The main reason for this site-specific effect was the persistence of vertical pressure in the buttocks despite changes in postural conditions. In addition, as reported in a previous study[9)], an increase in pressure on the ischial tuberosity

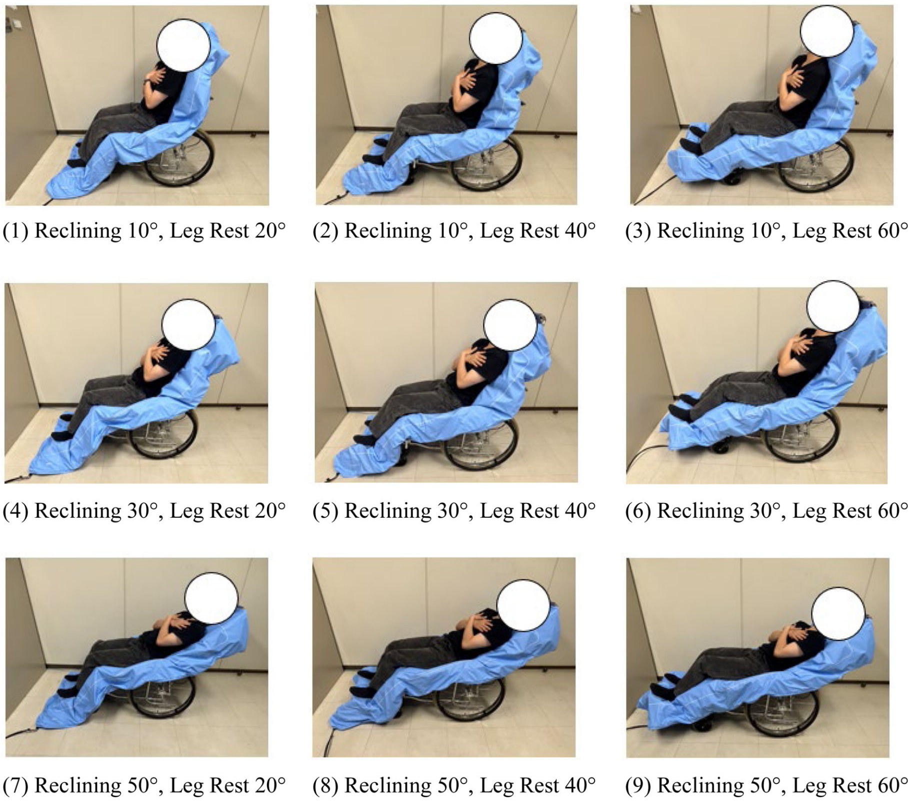

Fig. 1. Posture conditions (1) to (9).

Table 1. The impact of postural conditions in wheelchair sitting on the average pressure by measurement site

	Whole body	Back	Buttocks	Feet
(1) Reclining 10°, Leg Rest 20°	35.9 ± 2.6	15.9 ± 2.7	47.9 ± 4.7	32.9 ± 5.9
(2) Reclining 10°, Leg Rest 40°	36.2 ± 3.1	16.8 ± 3.0	48.8 ± 4.8	34.3 ± 6.4
(3) Reclining 10°, Leg Rest 60°	35.9 ± 3.8	18.4 ± 3.0[1]	49.2 ± 5.6	35.7 ± 7.3
(4) Reclining 30°, Leg Rest 20°	34.6 ± 2.6[2]	19.2 ± 2.4[1, 2]	45.7 ± 4.7[1, 2, 3]	33.3 ± 5.0
(5) Reclining 30°, Leg Rest 40°	34.8 ± 2.8	18.9 ± 2.8[1, 2]	46.3 ± 4.7[2, 3]	35.0 ± 6.6
(6) Reclining 30°, Leg Rest 60°	32.2 ± 3.8[2, 3]	19.2 ± 3.0[1, 2]	46.8 ± 5.6[3]	33.5 ± 7.0
(7) Reclining 50°, Leg Rest 20°	32.3 ± 3.3[1, 2, 3, 4, 5, 6]	23.1 ± 3.2[1, 2, 3, 4, 5, 6]	40.8 ± 5.4[1, 2, 3, 4, 5, 6]	33.3 ± 6.0
(8) Reclining 50°, Leg Rest 40°	32.2 ± 3.3[1, 2, 3, 4, 5, 6]	22.7 ± 3.2[1, 2, 3, 4, 5, 6]	41.0 ± 4.9[1, 2, 3, 4, 5, 6]	33.4 ± 7.2
(9) Reclining 50°, Leg Rest 60°	32.4 ± 4.2[1, 2, 3, 4, 5, 6]	22.9 ± 3.5[1, 2, 3, 4, 5, 6]	41.8 ± 6.3[1, 2, 3, 4, 5, 6]	32.4 ± 9.1

n=26, Average value of average body pressure ± SD.
[1]:p<0.05(vs.(1)), [2]:p<0.05(vs.(2)), [3]:p<0.05(vs.(3)), [4]:p<0.05(vs.(4)), [5]:p<0.05(vs.(5)), [6]:p<0.05(vs.(6)), [7]:p<0.05(vs.(7)), [8]:p<0.05(vs.(8)), [9]:p<0.05(vs.(9)).

Table 2. The impact of postural conditions in wheelchair sitting on the pressure area by measurement site

	Whole body	Back	Buttocks	Feet
(1) Reclining 10°, Leg Rest 20°	263.7 ± 30.8	65.6 ± 17.8	151.1 ± 16.9	22.1 ± 5.8
(2) Reclining 10°, Leg Rest 40°	265.5 ± 31.4	69.7 ± 15.1	145.0 ± 17.3[1]	23.8 ± 5.2
(3) Reclining 10°, Leg Rest 60°	280.0 ± 31.7[1]	82.0 ± 18.4[1]	139.3 ± 16.0[1, 2]	23.7 ± 5.4
(4) Reclining 30°, Leg Rest 20°	275.0 ± 31.7	77.1 ± 15.1[1]	150.8 ± 15.3[2, 3]	21.6 ± 5.8
(5) Reclining 30°, Leg Rest 40°	274.2 ± 31.9	79.0 ± 17.4[1, 2]	144.5 ± 17.4[1, 4]	23.4 ± 6.5
(6) Reclining 30°, Leg Rest 60°	285.0 ± 33.8[1, 2]	89.4 ± 21.6[1, 2, 4, 5]	137.8 ± 16.8[1, 2, 4, 5]	22.7 ± 5.1
(7) Reclining 50°, Leg Rest 20°	284.2 ± 29.1[1, 2]	87.0 ± 18.9[1, 2, 4]	146.7 ± 16.3[2, 3, 4, 5, 6]	21.2 ± 6.4
(8) Reclining 50°, Leg Rest 40°	286.3 ± 33.6[1, 2]	88.6 ± 19.6[1, 2, 4]	141.0 ± 17.0[1, 7]	20.8 ± 6.5
(9) Reclining 50°, Leg Rest 60°	290.2 ± 33.7[1, 2, 4, 5]	91.8 ± 19.8[1, 2, 3, 4, 5]	134.5 ± 17.0[1, 2, 4, 5, 7, 8]	20.3 ± 6.8

n=26, Average value of pressure area ± SD.
[1]:p<0.05(vs.(1)), [2]:p<0.05(vs.(2)), [3]:p<0.05(vs.(3)), [4]:p<0.05(vs.(4)), [5]:p<0.05(vs.(5)), [6]:p<0.05(vs.(6)), [7]:p<0.05(vs.(7)), [8]:p<0.05(vs.(8)), [9]:p<0.05(vs.(9)).

due to an increase in the footrest angle may have had an effect. The reason for the difference in the mean pressure between the feet and buttocks is that the contact area of the buttocks is larger than that of the feet. This is presumably due to the more dispersed pressure. This result indicates that there is a relationship between the mean pressure and pressure area. This main effect was also observed in the postural condition. In particular, the pressure at the back tended to increase significantly as the reclining angle increased. This is thought to be the result of backward movement of the upper body caused by reclining, which directly increases the pressure applied to the back.

In contrast, on the buttocks, the pressure decreased as the reclining angle increased. This phenomenon is thought to be due to the fact that the pressure area of the back is expanded by reclining, and the pressure on the buttocks is dispersed to the back[7)].

Therefore, it was suggested that the back and buttock pressure distribution could be effectively controlled by adjusting appropriate postural conditions.

However, in the foot, there were no significant differences in the mean pressure and pressure area between postural conditions. This is because the height of the footrest was measured by changing the height of the footrest with respect to the thigh while adjusting the angle of the leg rest. Adding the presence or absence and height of footrests to the conditions may change the mean pressure in the foot and the pressure area in the thigh, suggesting that the pressure distribution may change more clearly.

The wheelchair used in this study has a reclining function. However, changes in body pressure distribution in wheelchairs with a tilt function have not been examined.

In a wheelchair with a tilt function, the pressure transfer associated with changes in sitting posture is different from that of a reclining wheelchair, and the pressure applied to each part of the body is expected to be affected differently. In the future, it will be necessary to evaluate the body pressure distribution using a wheelchair with a tilt function and compare it with a wheelchair with a reclining function. Therefore, an optimal posture management method needs to be clarified. Furthermore, although this study was conducted on healthy young participants, it is necessary to examine trends in body pressure changes in participants with diseases. In participants with diseases, muscle weakness, sensory disturbance, and skeletal deformity were likely to have a significant impact on body pressure distribution. We will elucidate the mechanism of pressure distribution specific to this disease by conducting research on spinal cord injury in elderly people, who are particularly at a high risk of pressure ulcers. This will lead to the establishment of more practical measures for preventing bedsores.

In the future, the findings of this study are expected to provide a basis for new measures to reduce the risk of pressure ulcer occurrence in seated wheelchair positions. The appropriate use of a wheelchair with reclining and tilt functions allows body pressure to be distributed effectively through postural adjustments. This approach will contribute to improving the quality of life of wheelchair users and preventing pressure ulcers. In addition, this study may contribute to the development of new treatment strategies for individualized postural management and pressure ulcer control.

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Conflicts of interest

There are no conflicts of interest to disclose for this paper.

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