J. Phys. Ther. Sci. 33: 401–405, 2021

The Journal of Physical Therapy Science

Original Article

Effect of asymmetrical buttock pressure on forces exerted in buttock movement when using a reclining chair

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Abstract. [Purpose] To clarify the effect of asymmetrical buttock pressure on the shear forces exerted on a buttock. [Participants and Methods] Sixteen healthy adult males participated in this study. A cushion 0 or 2 cm high was placed on the left side of the seat for all participants. The 0- and 2-cm height conditions were called "without difference condition" and "difference condition", respectively. The back support was inclined at increasing angles, starting at the upright position, to a fully reclined position, and back to the upright position. [Results] With the "difference condition", the force on the left buttock was 147.4% body weight and that on the right buttock was 105.6% body weight. In contrast, with the "without difference condition", there was no significant difference in the force on the left buttock and right buttock in terms of percent body weight. [Conclusion] Our results suggest that asymmetrical buttock pressure while in the sitting position causes a difference in shear force exerted on the left and right buttocks when using a reclining chair.

Key words: Reclining wheelchair, Buttocks pressure, Side inclination of the pelvis

(This article was submitted Jan. 4, 2021, and was accepted Feb. 4, 2021)

INTRODUCTION

Wheelchairs are often used for elderly people and those with disabilities who cannot hold their own seats. Moreover, the time spent sitting on a wheelchair in a day is very long because a wheelchair is often used for purposes of comfort and reducing the amount of human assistance during a recuperation period[1)]. Therefore, wheelchairs with tilt and reclining functions have been developed and manufactured for all assistance levels where standing and walking ability are reduced and posture conversion to maintain long sitting times is impossible to be made by the disabled patients themselves. Thus far, the effectiveness of the tilt function has been reported in many previous studies[2, 3)].

However, wheelchairs with reclining function have various problems, and it has been that there is a gap between the back support of the body and the wheelchair because of the position of the hip joint, which is the center of rotation of the human body when the trunk is tilted backward. Moreover, position of the center of rotation during reclining of the wheelchair do not match[4)]. In other words, even in a wheelchair with a reclining function, as with a normal wheelchair, if an appropriate sitting posture is not managed, the buttocks slip forward due to the shear force caused by repeated reclining operations[5)]. Consequently, the bad posture persists for an extended period of time, subsequently resulting in a decrease in sitting comfort and an increase in the occurrence of pressure ulcer, joint contraction, and difficulty in nursing care. Additionally, the main factors that cause the buttocks to slide forward are the pelvic post-tilt and the side inclination of the pelvis[6–8)]. For the pelvic post-tilt in the sitting position, Kemmoku et al.[8)] state that the vertical and shear forces of the sacral part change due to back inclination of the pelvis. Furthermore, it has been clarified that the pelvic post-tilt position when using a reclining wheelchair promotes the shear force of the upper part and thigh. However, to date, research reporting on the shear forces exerted onto

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buttocks generated by the side inclination of the pelvis is scarce.

Therefore, in this study, we measured the shear forces exerted onto buttocks for healthy adults and conducted an experiment to clarify the effect of reclining function in a wheelchair on the shear forces exerted onto buttocks in an asymmetrical ischium.

PARTICIPANTS AND METHODS

Sixteen healthy adult males (mean age: 25.0 ± 6.7 years, height: 170.1 ± 5.2 cm, weight: 60.2 ± 5.4 kg) participated in this study. We used a seat cushion (Hashimoto Artificial Limb Manufacturer, Okayama, Japan) in which pressure exerted on the buttocks, such as that exerted in patients with severe physical disabilities, is asymmetrically exerted, and the patient is sitting in a left-right asymmetric state. This cushion was set up so that the urethane form was covered with a 100% polyester cover, and there was a left-right difference in the pressure applied to the buttocks (Fig. 1). The study was approved by the 2017 ethics committee of the Kawasaki University of Medical Welfare (Approval No. 17-091), and written consent was obtained from all participants.

When the sciatica is sloping on a certain side, there is a left-right difference in the pressure exerted on the sciatica. In this study, we used a urethane cushion (density: 80 ± 12 kg/m^3, hardness: 250 ± 50 N) with a height difference of 0 or 2 cm on the seat surface so that a left and right difference occurs in the buttocks pressure. To confirm that there is left and right difference in buttocks pressure, the supposed distribution was measured. For the measurement, we used a squeal distribution measuring instrument (Sumitomo Riko Co., Ltd., SR Soft Vision, Aichi, Japan). Distribution can be measured from 256 measurement points with 450 × 450 mm in length and width (sensing area: 350 × 350 mm) and a measurement range of 20 to 200 mmHg; the sampling frequency was 5 Hz. The measured limb position at that time was an easy sitting position in which the back of the body was in contact with the back support, and the seat pressure distribution at the left and right height differences of 0 and 2 cm of the seat surface cushion, respectively, was measured. Moreover, the height difference was set so that the left side was high for all participants, and the maximum value of the left and right buttocks pressure was adopted. For the results of the supposition measurement (mmHg), the median and interquartile ranges are shown in the order of the left buttock pressure measurement and the right buttock pressure measurement. The left and right height difference of the seat cushion was 0 cm (156.5 [137.5–162.5], 149.5 [137.5–165.3]), and the difference between the left and right height was 2 cm (154.5 [140.0–167.0], 127.0 [119.8–144.0]). As a result of statistically comparing the measured values of the left and right buttocks pressure using Wilcoxon's code rank test, there was no significant difference in the pressure measurements required for the left and right buttocks when the left and right height differences of 0 cm of the seat surface cushion were observed as 0.513. In contrast, in the left and right height differences of 2 cm, the pressure exerted on the left buttock was significantly higher than that of the right buttock (Table 1). Therefore, the height difference of 0 cm, indicating that there was no difference in the left and right buttocks pressure, was defined as the symmetrical sciatic pressure without the side inclination of the pelvis (the without difference condition), and the height difference of 2 cm, where the difference was observed in the left and right sciatic pressure, was defined as the left and right asymmetric buttocks pressure (the difference condition), and the experiment was conducted.

The experimental conditions were two conditions with the "without difference condition" and the "difference condition", and the shear forces exerted onto the buttocks was measured during the reclining operation. The shear forces exerted onto the buttocks measuring instrument (Vicair B.V., AX Wormer, The Netherlands) was used. It is possible to measure a seat width of 35–50 cm and a depth of 30 cm, and the load bearing is 45–120 kg. The sampling frequency was 4 Hz, and the shear forces exerted onto buttocks was measured, once using the buttocks as an index, at 0 and 2 cm in height difference between the left and right sides of the seat cushion, respectively. In this study, we used an experimental chair with electrical controls that reclined the back support (Hashimoto Artificial Limb Manufacturer, Okayama, Japan). The dimensions of the experimental chair are as follows: back support height, 97 cm; seat depth, 40 cm; backward angle of the seat: 0°; back support reclining angle, 10°–40° from the vertical line; and angular speed at which the rear support reclines, 3°/s. To unify the back support and coefficient of static friction between the seat surface and body, each participant was allowed to wear an experimental top (65% polyester, 35% cotton) and experimental underwear (100% polyester) (Fig. 2).

The measurement was conducted by referring the method of Kobara et al.[9], which included the following steps: back support of the experimental chair was inclined at increasing angles, starting from the upright position of 10° from a vertical (initial upright position [IUP]) view, then proceeding to a fully reclined position (FRP) of 40° from a vertical view, and returning to the upright position (RUP). The times at which the shear forces were measured were 5, 10, and 5 seconds (s) in the IUP, FRP, and RUP, respectively. Shear forces exerted onto the buttocks were measured from the IUP to the RUP; the maximum value of the the shear forces exerted onto the buttocks was also measured, and the RUP to the IUP was adopted as the part shear force[9]. The shear forces exerted onto buttocks varies greatly depending on the position of the upper part in sitting position[10]. In this study, a marking was made to unify the position of the upper part in each enforcement, but it was thought that the position of the marking may deviate. Therefore, to exclude the effect of misalignment of the position, the rate of change (%) in the RUP normalized relative to the IUP was calculated on the left and right side respectively. Furthermore, the measure of shear forces exerted onto buttocks was compared. We normalized the measured shear force by body weight (percent body weight [%BW]) based on raw data from the shear forces exerted onto the buttocks measuring instrument to

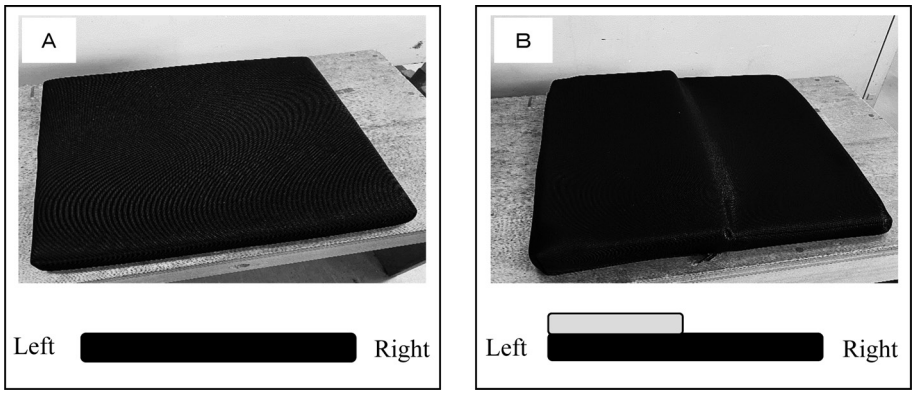

Fig. 1. Setting the seat surface cushion.
A. The seat surface cushion with the height difference of 0 cm.
B. The seat surface cushion with the height difference of 2 cm.
A seat cushion with a urethane covered with a 100% polyester cover was used.

Table 1. Measurements of left and right buttock pressure (mmHg)

Height difference	Left buttok	Right buttock	p-value compared with left and right buttocks
0 cm	156.5 (137.5–162.5)	149.5 (137.5–165.3)	0.513
2 cm	154.5 (140.0–167.0)	127.0 (119.8–144.0)	0.001**

Median (quartered range).
**p<0.01 (Wilcoxon singed-rank test).

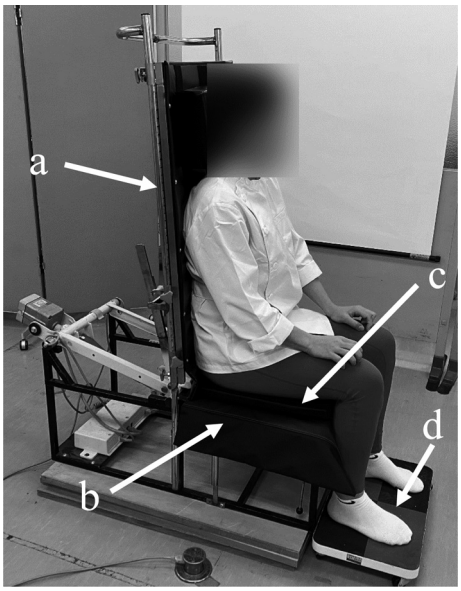

Fig. 2. Sitting posture during measurement.
a: Experimental chair with electrical controls, b: A seat cushion with a urethane, c: The shear forces exerted onto the buttocks measuring instrument, d: A roller board.

compensate for the body weight effect.

As a result of checking normality using the Shapiro-Wilk test, normality was not observed in shear forces exerted onto buttocks rate of change. Therefore, by using a Wilcoxon's sign rank test, buttocks movement rate of change normalized relative to IUP was compared between the "without difference condition" and the "difference condition". A $p<0.05$ was

considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics ver. 24.0 (IBM Co., Armonk, NY, USA).

RESULTS

Tables 2 and 3 show the measured shear forces exerted onto the buttocks.

Regarding the total shear force exerted onto the buttocks, the "without difference condition" resulted in a median (quartered range) value of 128.9 (104–145.3) %BW, and the "difference condition" resulted in a median value of 123.6 (98.8–155.1) %BW. There was no significant difference in the shear forces between the two conditions in total (p=0.756). However, when we focused on the left and right measured shear forces exerted onto the buttocks, in the "difference condition," the left buttock had a value of 147.4 (115.1–164.1) %BW and the right buttock had a value of 105.6 (74.5–161.4) %BW. Moreover, the left side showed significantly higher values (p=0.020) than the right side. Coversely, in the "without difference condition", there was no significant difference in left buttock 120.3 (110.2–155.8) %BW and right buttock 119.5 (103.9–148.6) %BW (p=0.796).

DISCUSSION

Studies focusing on the pelvic post-tilt position have been scattered thus far. However, the asymmetrical buttocks surface pressure, which is one of the factors that causes the buttocks to slide forward, has not been mentioned using clear data. As per the results of this study, there was no significant difference in the measured shear forces exerted onto the buttocks between the "without difference condition" and the "difference condition". However, when we focused on the detailed left and right measured shear forces exerted onto the buttocks, the buttocks pressure was significantly higher in conditions with left and right differences. The lower the buttocks pressure, the lower the measured shear force value. In other words, by using a reclining wheelchair and performing a reclining operation called back support and wake-up after knocking down the trunk, it was clarified that the left and right shear forces increased on the side with higher buttocks pressure and decreased on the side with lower buttocks pressure.

Regarding variation of the shear forces exerted onto the buttocks during the back-support inclination, the seat pressure center position begins to shift forward immediately after the trunk is placed on the back support (IUP), and a forward shear forces exerted onto the buttocks is generated. The shear forces exerted onto the buttocks of the load shift is reported to increase rapidly when the back support is defeated and returned to RUP[11, 12]. In this study, both the "without difference condition" and the "difference condition" are generated from the IUP, and the maximum value is shown at the RUP. The back support of the reclining wheelchair enlarges the support base in the sitting position and increases the stability of the sitting position posture[13]. Moreover, it becomes a factor of generating the forward shear forces exerted onto the buttocks in the main part. In this study, the left side was set to be high in all participants in the "difference condition". Consequently, it has been suggested that the left-right difference in which the left shear forces exerted onto the buttock change rate increases more than the right shear forces exerted onto the buttock change rate when returning from reclining FRP to RUP has increased.

Moreover, the left shear forces exerted onto the buttock change rate showed a high price in all conditions. Kobara et al.[14, 15] states that the body is pushed forward by the reaction force from the back support at the RUP, and the buttocks also try to move forward, but the surface of the buttocks is deformed by the stationary frictional force between the buttocks and the seat surface; however, the buttocks do not move greatly. Among them, it is considered that the buttock shear force change rate on the left side of the "difference conditions", in which the buttock surface pressure showed a high value, increased in the range below the maximum stationary frictional force of the buttocks and the seat surface when trying to be pushed

Table 2. The total shear force exerted onto the buttocks at the IUP to the RUP (%BW)

	The without difference condition	The difference condition	p-value compared with two condition
Total	128.9 (104–145.3)	123.6 (98.8–155.1)	0.756

%BW: percent body weight.
Median (quartered range).
Wilcoxon singed-rank test.

Table 3. The left and right measured shear forces exerted onto the buttocks at the IUP to the RUP (%BW)

	Left buttock	Right buttock	p-value compared with two condition
The without difference condition	120.3 (110.2–155.8)	119.5 (103.9–148.6)	0.796
The difference condition	147.4 (115.1–164.1)	105.6 (74.5–161.4)	0.020*

%BW: percent body weight. Median (quartered range).
*p<0.05 (Wilcoxon singed-rank test).

forward by a back support. It is speculated that this condition causes an increased risk of pressure ulcers, discomfort, and pain. Additionally, the rate of change in the shear force change on the right side of the difference conditions, in which the buttocks pressure showed a low value, demonstrated a significantly lower value. This is because the buttocks surface pressure on the right side is lower than the left side, and the vertical force is also smaller, so that the maximum static friction force is lower than the left side. Moreover, it is considered that the moving friction force changes, and the buttocks shear force is also lowered by becoming a range more than the maximum stationary friction force of the buttocks and the seat surface. In this way, it is considered that the left and right dorsal shear forces are different, the sliding forward is suppressed in one side, and the left and right asymmetry, such as encouraging the sliding forward in the other, can cause the sitting posture to collapse greatly. From the results of this study, it was suggested that the left and right differences in buttocks pressure in the sitting position increased or decreased the shear forces exerted onto the buttock change rate, and the asymmetry promoted the increased risk of pressure ulcers and the collapse of posture. Pressure ulcers occur when biological factors (the sensation of the buttocks, the circulatory state of the skin, etc.) are affected in a complex way. Moreover, external factors (friction of the seat surface, thickness of clothes, sitting time, etc.) are added. The shear forces exerted onto the buttock change rate is also one of the external factors, and the expansion of the left-right difference in the shear forces exerted onto the buttock change rate and the left-right difference in the pelvis may cause an increase in the risk of pressure ulcer occurrence and an unstable sitting posture for a long time, leading to a decrease in the quality of life and daily life activities of wheelchair users. Therefore, it is necessary to pay attention not only to the measurement of the buttocks surface pressure but also to the shear force of the buttocks surface so that reclining wheelchair users can live easily.

From the results of this study, it was suggested that maintaining the sitting position posture with asymmetrical buttocks pressure for healthy adults causes a left–right difference in the buttocks shear force when using a reclining wheelchair. This left–right difference in the buttocks shear force encourages the left–right asymmetry of the sitting position posture and may be a factor that causes the sitting position posture to collapse. For elderly people and those with disabilities who cannot hold a sitting position on their own, there are often left and right differences in asymmetrical buttock pressure and the buttock shear force, which causes the collapse of the sitting posture and the occurrence of pressure ulcers. Therefore, it is important to maintain an appropriate seating posture so as not to strengthen the asymmetrical posture in such situations.

Funding

This study was supported by JSPS KAKENHI Grant Number 19K19896 for publication.

Conflict of interest

There is no conflict of interest.

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