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Original Paper

Development of a Seat Cover for a Wheelchair on Back Support for Decreasing Shear Force Applied to the Buttocks during Reclining Back Support

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Abstract

The purpose of this study was to investigate the influence of the friction force between back support and the back of the body on the shear force applied to the buttocks. The subjects were 19 healthy adult males without leg and/or trunk diseases. Horizontal force as a substitute for shear force was measured. A comfortable sitting posture in the experimental chair was selected for measurement. The experimental conditions were carried out under two conditions. In the low friction condition, the coefficient of friction was 0.1 between the seat cover and inside, and the seat cover developed by the researchers was used to reduce this friction. In the control condition, the coefficient of friction was 0.5 between the surface of the back support and the clothing. In returning the back support to an upright position, 16.2 ± 2.3 % Body Weight in the low friction as the horizontal force value was significantly lower than 18.5 ± 2.7 % Body Weight in the control condition. The results of this study substantiated the hypothesis that there is a relationship between increased horizontal force while reclining the back support of a wheelchair and the friction force between the back support and the back of the body.

1. Introduction

Treating decubitus ulcers is very costly for healthcare organizations. The Center for Medicare Services[1] reported that in the fiscal year 2007, the average cost per ulcer for Medicare patients with decubitus ulcers was $43,180. In 2006, Reddy et al. estimated that US $11 billion was spent on the treatment of decubitus ulcers in the USA[2], and decubitus ulcers are estimated to cost the National Health Service in the UK, between £1.4 and £2.1 billion a year[3]. In addition, Brem et al.[4] illustrated the high costs associated with stage IV decubitus ulcers. Thus, the outbreak of decubitus ulcers is a social problem due to the high cost of treatment. Moreover, because decubitus ulcers do not heal easily, preventing them is of the utmost importance. Therefore, decubitus ulcers are a serious health problem.

External loads, which include pressure, friction, and shear force, contribute to the occurrence of decubitus ulcers, and Husain[5] reported that the tolerance of tissue to external loads depends on the duration of the exerted load. Although seemingly innocuous, Hanson et al. described that friction and shear force can

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increase patients' risk of clinical injury[6]. Therefore, reducing shear force is important to prevent decubitus ulcers.

Wheelchairs with reclining back support are often used by individuals with leg and trunk disorders, such as those with post-apoplectic hemiplegia or spinal cord injuries. However, there are concerns regarding the use of reclining wheelchairs. First, individuals with flaccid hemiplegia often slide forward in these wheelchairs when returning to a seated position from a reclined position. Many wheelchair users who need reclining back support cannot correct this slouching posture unassisted; this leads to a sacral sitting posture and results in increased shear force on the sacrum, predisposing the individual to developing a sacral decubitus ulcer[7]. By using a chair with a combined reclining and tilting function, Chen et al.[8] reported that the pressure applied to the ischial interface was significantly decreased and the pressure applied to the coccygeal interface was not changed. Jan et al.[9,10] investigated the influence of this combination from the view-point of skin perfusion. Skin perfusion over the ischial tuberosities was significantly increased and the skin perfusion over the sacrum was not changed by the use of this combination. Furthermore, currently in Japanese medical institutions and nursing homes, the number of wheelchairs with reclining and tilting functions is extremely small compared with the number of individuals with leg and trunk disorders and elderly people. Therefore, it is important to consider how to reduce the shear force applied to the buttocks, including the sacrum, when the back support of reclined wheelchairs with only a reclining function in order to reduces the risk of developing decubitus ulcers on the sacrum.

In our previous study, we reported that shear force applied to the buttocks while the wheelchair back support was reclined fluctuated between the rotational axis position of the back support and the hip joint, similar to that of the trunk-pelvis[11]. Moreover, we reported that while closing the back support rotational axis located on the hip joint, the shear force that was sustained when returning to the upright position from the fully reclined position was about 40% lower than when the back support position was at the point farthest back in the seat[12]. As above, the shear force applied to the buttocks could be decreased to a certain degree by closing the back support rotational axis located on the hip joint. Nevertheless, this method cannot decrease the shear force when using a reclining wheelchair, because changing the rotational axis position of the reclining wheelchair, which is already used in many medical institutions and nursing homes, is not easy due to the wheelchair's structure. Thus, the solution to the problem of the increase of the shear force increasing must be to use a device that can be mounted on an already used reclining wheelchair.

We reported that in the sitting posture in which the buttocks slides forward on the reclining wheelchair with the rotational axis of the back support located at the point farthest back in the seat, shear force applied to the buttocks is remarkably increased when returning the back support from the fully reclined position to the upright position[13]. The pressure on the back support's surface is greater because the inclination angle of the trunk is larger in the sitting posture in which the buttocks slides forward. Increasing this pressure led to an increase in the static friction force between the back support surface and the back of the body[14]. Therefore, this previous study hypothesized that there is a relationship between increased horizontal force when the back support is reclined and the friction force between the back support and the back of the body. However, studies have not investigated the relationship between the shear force and the friction force between the back support surface and the back of the body. We developed a seat cover mounted on the back support of a wheelchair to decrease the shear force applied to the buttocks while reclining. The purpose of this study was to investigate the influence of the friction force between the back support and the back of the body on the shear force applied to the buttocks, and the effect of the seat cover on decreasing the shear force applied to the buttocks.

2. Methods

2.1 Participants

The participants included 19 healthy, adult men without leg and/or trunk disease (mean age, 21.4 ± 3.0 years; height, 170.2 ± 3.6 cm; and body weight, 61.0 ± 7.1 kg). Participants were excluded from the study if they experienced pain while sitting on a chair, or back pain, had undergone surgery, or had rheumatism or neurologic disorders. The study was conducted with the approval of the Research Ethics Committee at Kawasaki University of Medical Welfare (17-064), and informed consent was obtained from all participants.

2.2 Equipment and materials

We used an experimental chair with electric controls for reclining the back support (Hashimoto Artificial Limb Manufacturer, Okayama, Japan). The dimensions of the experimental chair were: back support height, 97 cm; depth of seat, 40 cm; backward angle of seat, 0° ; reclining angle of back support, 10°-40° from the vertical line; and angular velocity at which the back support reclined, 3°/s. The chair's back support was covered with artificial leather. For measurements, the subjects were made to sit comfortably with bilateral symmetry and to rest on the back support and the force plate. Hirose[15] reported that the inclination of the sternum and abdominal line correlated with that of the thoracic and lumbar spine in both the frontal and sagittal planes. Thus, the examiner visually and manually inspected the sternum and abdominal line of the participants' posture to check that the inclination of the thoracic and lumbar spine in the frontal plane did not lean laterally. In addition, to achieve constant friction between the participants' clothing and the surfaces of the seat, all subjects wore clothing made of 100% cotton. As the smooth metal surface of the force plate made the participant slide forward in the chair, a rubber net was laid over the plate to minimize sliding and the risk of postural collapse. The coefficients of friction were 0.9 between the clothing and the rubber net, 0.8 between the rubber net and the surface of the force plate, and 0.5 between the surface of the back support and the clothing. These coefficients of friction were calculated based on the maximum static friction force, measured using a pull tension gauge and weight. On the position of lower extremities, the horizontal and normal forces applied to the buttocks were changed by elevating the foot support[16]. Thus, to reduce the effects of differences in the positions of the lower extremities, the horizontal thigh angle was adjusted by elevating the feet with wooden boards stacked under the chair[17], and the foot position was adjusted so that the lower legs were perpendicular to the feet[18]. Furthermore, to reduce resistance of the lower extremities, a roller board was placed under the subjects' feet. Participants were instructed to fold their arms in front of their chest in a relaxed state and not to intentionally change their body position during the experiment. Kemmoku et al.[19] reported that the vertical and horizontal forces applied to the sacrococcygeal and ischial tuberosity area were increased in the seated posture by increasing the angle of pelvic tilt. Thus, each participant's buttocks was positioned so that the back support and the dorsal surface were in contact in order to avoid differences of the pelvic tilt angle between the experimental conditions (Figure 1).

To reduce friction between the surface of the back support and of the back of the body, we developed and used a seat cover to reduce friction between the chair and the participant. The seat cover had a double tube structure. In addition, because the coefficient of friction was 0.1 between the seat cover and the inside, the body easily slid on the back support. The seat cover was placed and fixed on the back support using a fixing belt. To keep the body and the seat cover from moving downward when the participant sat on the chair used in the experiment, the top of the seat cover that contacted the back of the body was fixed at the top of the back support. The body could therefore slide upward on the back support and not slide downward. Furthermore, to keep the body from sliding downward on the seat cover's surface, a strong friction seat in which the coefficient of friction was 0.8 between the surface of this seat and the clothing was attached on the surface of the seat. In this study, two experimental conditions were tested. In the low friction condition, the coefficient of friction was 0.1 between the seat cover and the inside, and we used the seat cover to reduce friction (Figure 2). In the control condition, the coefficient of friction was 0.5 between the surface of the back support and the clothing; therefore, we did not use the seat cover.

2.3 Measurement of the forces applied to the buttocks and the trunk sliding distance along the back support

The shear force is difficult to measure. Thus, in this study, we measured the horizontal and normal forces

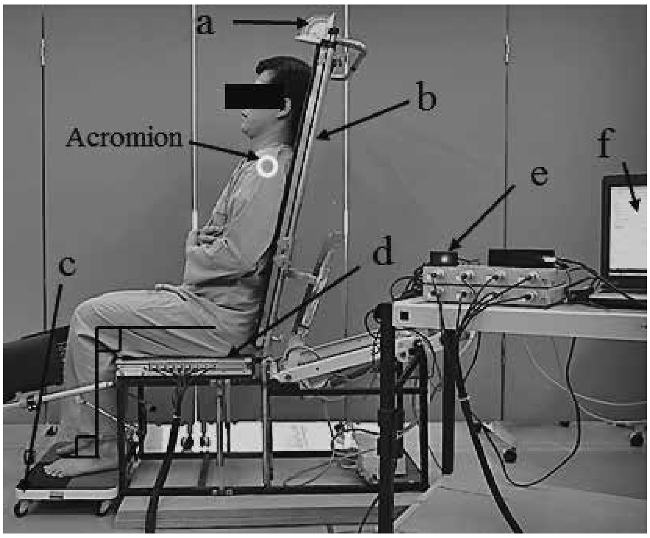

Figure 1 Measurement posture

a. Level goniometer, b. Experimental chair (height of back support: 97 cm, depth of seat: 40 cm, backward angle of seat: 0°, reclining angle of back support: 10°- 40°, and angular velocity at which back support reclines: 3°/s),
c. Roller board, d. Force plate,
e. Lump to synchronize between a reaction force and a movie file,
f. Personal computer for a force plate

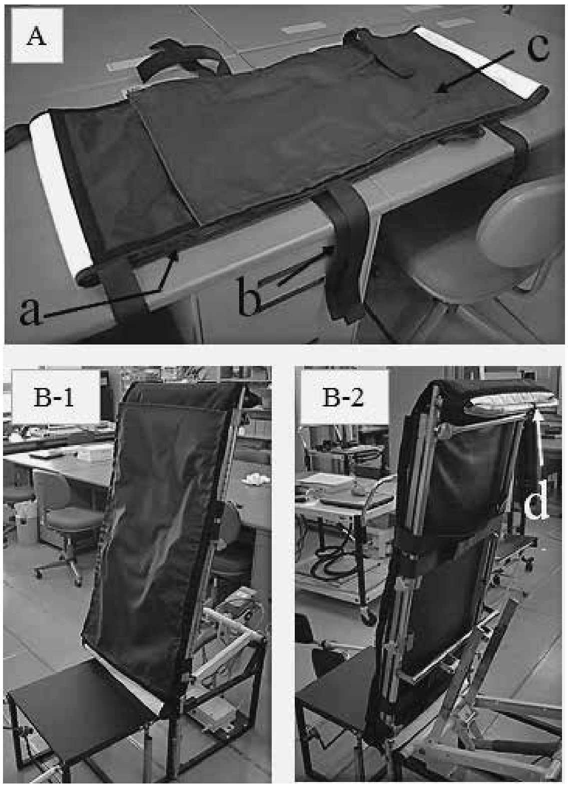

Figure 2 The seat cover

A. Before mount on the back support, B. After mount on the back support
a. The coefficient of friction was 0.1 between the seat cover and the inside which had a double tube structure.
b. A fixing belt
c. A strong friction seat in which the coefficient of friction was 0.8 between the surface of this seat and the clothing which was attached on the surface of the seat.
d. The top of the seat cover that contacted the back of the body was fixed at the top of the back support.

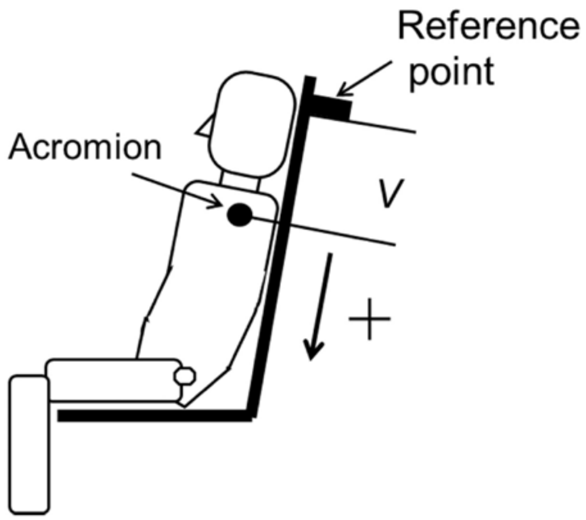

Figure 3 The definition of sliding distance along the back support
V. The distance between the acromion and the reference point
A positive value indicates that the trunk slides downward.
BS = $V_{FRP\ or\ RUP}$ - V_{IUP}

as substitutes for the shear force. The horizontal and normal forces applied to the buttocks were measured using a force plate (Kyowa Electronic Instruments, Tokyo, Japan). The force plate measured the reaction force in the posterior direction, which is equivalent to the horizontal force in the anterior direction, with a sampling frequency of 100 Hz. The trunk and back support were filmed from the left side using a digital video camera (Panasonic Corp., Osaka, Japan) for the duration of the back support movement. The video-analysis software Dartfish TeamPro Data 6.0 (Dartfish, Fribourg, Switzerland) was used to measure the trunk sliding distance along the back support (BS), which are standard measures also used by Aissaoui et al.[20] and are defined as follows (Figure 3):

$BS = V_a - V_i$ where V_a and V_i correspond to the distance between the acromion and the reference point projected on the back support plane, respectively, after back support during the reclined (*a*) and initial upright position (*i*).

2.4 Experimental protocol

To correct for the influence of each subject's postural collapse while making measurements, we performed the measurements 10 s after the posture was set. Regarding the angle of back support inclination, Park and Jang[21] reported that decubitus ulcers may be prevented or decreased in tetraplegia patients when the back support angles of their wheelchair are more than 120° that is similar to 30° from the vertical position. Thus, the experimental back support in our study was reclined at increasing angles, beginning at the fully upright position of 10° from the vertical (initial upright position [IUP]), proceeding to a fully reclined position (FRP) of 40° from the vertical, and returning to the upright position (RUP). The time required to measure the shear force in each phase was 5 s in the IUP, 10 s in the FRP, and 5 s in the RUP. For each condition, we used the average value for the horizontal and normal forces applied to the buttocks after measuring 201 stable samples for each subject. The two conditions were measured in random order with three trials for each condition. If the participants could not continue sitting due to intolerance or the danger of sliding out of the wheelchair, the experiment was stopped for safety reasons. Between each trial, the participants were asked to stand up and relax for a one-minute break.

2.5 Statistical analyses

The measured horizontal and normal forces applied to the buttocks were normalized with body weight (percent body weight [%BW]), based on the raw data from the force plate in order to correct the effects of body weight. We used Shapiro-Wilk's normality test to preliminarily analyze the horizontal and normal forces applied to the buttocks. To investigate the influence of the coefficient of friction between the back support and the back of the body, we compared the forces applied to the buttocks and the trunk sliding distance along the back support between the two experimental conditions. For statistical analysis, a paired *t*-test was performed with the level of significance set at $p<0.05$. The statistical analyses were performed using the IBM SPSS Statistics ver. 24.0J for Windows (IBM, USA).

3. Results

Table 1 shows the measured forces applied to the buttocks and the trunk sliding distance along the back support.

Regarding the horizontal force applied to the buttocks, a significant difference in the horizontal force applied to the buttocks appeared in the RUP when comparing between the two experimental conditions (p<0.01). In FRP, the horizontal force in the low friction condition tended to be reduced compared with that in the control condition (p=0.07). Regarding the normal force applied to the buttocks, a significant difference in the normal forces applied to the buttocks appeared in the FRP when comparing the two experimental conditions (p<0.01). In the RUP, the normal force in the low friction condition tended to be reduced compared with that in the control condition (p=0.12). Regarding the trunk sliding distance along the back

Table 1-1 Horizontal force applied to buttocks on various back angles

n = 19

	Low friction	Control
IUP	11.8 ± 1.7	11.7 ± 1.7
FRP$$	8.8 ± 1.8	9.8 ± 2.5
RUP**	16.2 ± 2.3	18.5 ± 2.7

mean ± SD (%BW)

**: p <0.01, $$: p <0.10 (paired t-test)

Table 1-2 Normal force applied to buttocks on various back angles

n = 19

	Low friction	Control
IUP	72.1 ± 2.1	71.8 ± 1.7
FRP**	83.3 ± 4.6	56.5 ± 3.6
RUP$	76.0 ± 2.0	78.2 ± 6.3

mean ± SD (%BW)

**: p <0.01, $: p <0.15 (paired t-test)

Table 1-3 Sliding distance along the back support on various back angles

n = 19

	Low friction	Control
FRP$$	8.6 ± 1.1	8.4 ± 1.0
RUP**	0.3 ± 1.3	1.9 ± 1.6

mean ± SD (cm)

**: p <0.01, $$: p <0.10 (paired t-test)

A positive value indicates that the trunk slides downward.

support a significant difference in the trunk sliding distance along the back support appeared in the RUP when comparing the two experimental conditions ($p<0.01$).

4. Discussion

A novel seat cover was developed by this research group that was mounted on the back of a wheelchair and investigated the influence of the friction force between the chair's back support and the back of the body on the shear force applied to the buttocks and the effect of the seat cover on decreasing the shear force applied to the buttocks, for the possible prevention of decubitus ulcers. Regarding the forces applied to the buttocks in the FRP, the results of this study showed that the horizontal force in the low friction condition tended to be reduced when compared with that in the control condition, and the normal force in the low friction condition was significantly lower than that in the control condition. Our result supports that of Gilsdorf et al.[22], who reported that horizontal force applied to the buttocks decreased when the back support reclined when the rotational axis of the back support was located at the point farthest back in the seat. In locating the point farthest back in a seat such as the chair used in our experiment, the trunk of the body slid downward relative to the back support, leading to reclined back support[20]. The downward slide of the trunk might have occurred due to the difference of the rotational locus between the back support and the trunk and pelvis[12]. This difference of the rotational locus is due to the divergence of the rotational axis position of the back support and the trunk and pelvis. Then, the friction force between the back of the trunk and the back support surface arose against the trunk sliding downward, and the trunk was stopped by the friction force at its initial position. The force on the downward slide of the trunk was decreased, as the friction force was strong. This seat cover could prevent the trunk from sliding downward. Furthermore, the coefficient of friction between the seat cover's surface and the participant's clothing was higher in the experimental condition than that between the back support's surface and the clothing in the control condition. Because of these reasons, the downward sliding force of the trunk when the back support was reclined might have been lower in the low friction condition than that in the control condition. This force could be divided into perpendicular and parallel directions to the seat surface, and this parallel force became the horizontal force applied to the buttocks[23]. Therefore, the horizontal force applied to the buttocks in the low friction condition tended to be reduced when compared with that in the control condition in the FRP. Nevertheless, the trunk sliding distance along the back support did not show a significant difference between the two experimental conditions in the FRP. Against the force that occurred, the downward slide of the trunk led to reclined back support, and the friction force in both conditions was also insufficient to stop the trunk sliding. Thus, the trunk might have slid downward while the sliding was reduced by the friction force.

Regarding the forces applied to the buttocks in the RUP, the results of this study showed that the horizontal force in the low friction condition was significantly lower than that in the control condition, and the normal force in the low friction condition tended to be reduced when compared with that in the control condition. As mentioned previously, the trunk slid downward relative to the back support, leading to reclined back support. Thereafter the trunk slid upward and returned to the starting position when the angle of the back support returned to the starting position. However, the horizontal force applied to the buttocks was remarkably increased because the trunk had been pushed forward by the back support, and it resisted the trunk due to the high friction coefficient between the back support surface and the back of the body[11]. Then, if the friction force between the buttocks and the seat surface was low, this increase of the horizontal force led the buttocks to slide forward; this could be a factor of collapsed sitting posture[24]. On the other hand, if the friction force was high value, the trunk sustained a pressing force instead of sliding the buttocks not forward when the trunk was pushed forward by the back support. These forces are very uncomfortable. Gilsdorf et al.[22] reported that the wheelchair user should momentarily lean forward after reclining to reduce undesired force. However, the person who cannot move independently is not able to release the undesired force after reclining back support. Thus, it is necessary to reduce the friction coefficient between the back support's surface and the back of the body. Due to this seat cover, the trunk slid upward smoothly when the participant moved from the FRP to the RUP because of the low friction coefficient. Therefore, by using this seat cover in this study, the low friction coefficient between the back support surface and the back of the body restrained the horizontal force applied to the buttocks remarkably when moving from the FRP to the RUP.

A limitation of this study was that it included only healthy, adult males. In addition, because the measurement times were short, we could not evaluate the effect of delayed postural collapse. This study also did not consider the force peak values and fluctuations of these forces during two phases of transition when reclining the back support. Moreover, we could not consider microclimate factors (i.e., urinary incontinence and sweat) that interact with the frictional force; these problems affect many wheelchair users. Therefore, direct extrapolation of the results of this study to all wheelchair users is difficult. Further studies should be performed to evaluate the use of our device in patients with decubitus ulcers, as well as evaluate microclimate factors.

The results of this study substantiated the hypothesis that there is a relationship between increased horizontal force while reclining the back support of a wheelchair and the friction force between the back support and the back of the body. In addition, this seat cover could decrease the horizontal force applied to the buttocks while reclining the chair's back support. In the future, these results could be adapted for all wheelchair users.

Conflict of interest

The authors report no conflicts of interest.

Acknowledgements

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References

1. Armstrong DG, Ayello EA, Capitulo KL, Fowler E, Krasner DL, Levine JM, Sibbald RG and Smith AP : New opportunities to improve pressure ulcer prevention and treatment: Implications of the CMS inpatient hospital care Present on Admission (POA) indicators/ hospital-accquired conditions (HAC) policy. A consensus paper from the International Expert Wound Care Advisory Panel. *Journal of Wound Ostomy Continence Nursing*, **35**(5), 485-492, 2008.
2. Reenalda J, Jannink M, Nederhand M and IJzerman M : Clinical use of interface pressure to predict pressure ulcer development: A systematic review. *Assistive Technology*, **21**(2), 76-85, 2009.
3. Bennett G, Dealey C and Posnett J : The cost of pressure ulcers in the UK. *Age and Ageing*, **33**(3), 230-235, 2004.
4. Brem H, Maggi J, Nierman D, Rolnitzky L, Bell D, Rennert R, Golinko M, Yan A, Lyder C and Vladeck B : High cost of stage IV pressure ulcers. *American Journal of Surgery*, **200**(4), 473-477, 2010.
5. Husain T : An experimental study of some pressure effects on tissue, with reference to the bed-sore problem. *The Journal of Pathology and Bacteriology*, **66**(2), 347-363, 1953.
6. Hanson D, Langemo DK, Anderson J, Thompson P and Hunter S : Friction and shear considerations in pressure ulcer development. *Advances in Skin and Wound Care*, **23**(1), 21-24, 2010.
7. Sabol TP and Haley ES : Wheelchair evaluation for the older adult. *Clinics in Geriatric Medicine*, **22**(2), 355-375, 2006.
8. Chen Y, Wang J, Lung CW, Yang TD, Crane BA and Jan YK : Effect of tilt and recline on ischial and coccygeal interface pressure in people with spinal cord injury. *American Journal of Physical Medicine and Rehabilitation*, **93**(12), 1019-1026, 2014.
9. Jan YK, Liao F, Jones MA, Rice LA and Tisdell T : Effect of durations of wheelchair tilt-in-space and recline on skin perfusion over the ischial tuberosity in people with spinal cord injury. *Archives of Physical*

Medicine and Rehabilitation, **94**(4), 667-672, 2013.

10. Jan YK and Crane BA : Wheelchair tilt-in-space and recline dose not reduce sacral skin perfusion as changing from the upright to the tilted and reclined position in people with spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, **94**(6): 1207-1270, 2013.
11. Kobara K, Fujita D, Osaka H, Ito T, Yoshimura Y, Ishida H and Watanabe S : Mechanism of fluctuation in shear force applied to buttocks during recline back support on wheelchair. *Disability and Rehabilitation: Assistive Technology*, **8**(3), 220-224, 2013.
12. Kobara K, Fujita D, Osaka H, Takahashi H, Ito T, Suehiro T, Kuniyasu K and Watanabe S : Fluctuation mechanism of horizontal force applied to buttocks varies depending on difference in rotational axis position of back support in a reclining wheelchair. *Kawasaki Journal of Medical Welfare*, **21**(2), 13-22, 2016.
13. Kobara K, Fujita D, Osaka H, Ito T and Watanabe S : Influence of distance between the rotation axis of back support and the hip joint on shear force applied to buttocks in a reclining wheelchair's back support. *Prosthetics and Orthotics International*, **37**(6), 459-464, 2013.
14. Goossens RHM, Snijders CJ, Holscher TG, Heerens WC and Holman AE : Shear stress measured on beds and wheelchairs. *Scandinavian Journal of Rehabilitation Medicine*, **29**(3), 131-136, 1997.
15. Hirose H : Development of clinical methods for measuring geometric alignment of the thoracic and lumbar spines of wheelchair-seated persons. *Journal of Rehabilitation Research and Development*, **42**(4), 437-446, 2005.
16. Kobara K, Takahashi H, Fujita D, Osaka H, Ito T, Suehiro T and Watanabe S : Investigation of effect of leg support elevation timing on the horizontal force acting on the buttocks in a reclining wheelchair. *Journal of Physical Therapy Science*, **27**(8), 2605-2610, 2015.
17. Kobara K, Shinkoda K, Eguchi A, Watanabe S, Fujita D and Nishimoto T : Influence of thigh angle from a level on shear and normal force occurred under the buttocks of subjects sitting comfortably on a chair. *Bulletin of the Japanese Society of Prosthetics and Orthotics*, **25**(2), 108-110, 2009. (In Japanese)
18. Kobara K, Eguchi A, Watanabe S and Shinkoda K : The influence of distance between the backrest of a chair and the position of the pelvis on maximum pressure of the ischium and estimated shear force. *Disability and Rehabilitation: Assistive Technology*, **3**(5), 285-291, 2008.
19. Kemmoku T, Furumachi K and Shimamura T : Force on the sacrococcygeal and ischial areas during posterior pelvic tilt in seated posture. *Prosthetics and Orthotics International*, **37**(4), 282-288, 2013.
20. Aissaoui R, Lacoste M and Dansereau J : Analysis of sliding and pressure distribution during a repositioning of persons in a simulator chair. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, **9**(2): 215-224, 2001.
21. Park UJ and Jang SH : The influence of backrest inclination on buttock pressure. *Annals of Rehabilitation Medicine*, **35**(6), 897-906, 2011.
22. Gilsdorf P, Patterson R, Fisher S and Appel N : Sitting forces and wheelchair mechanics. *Journal of Rehabilitation Research and Development*, **27**(3), 239-246, 1990.
23. Kobara K, Shinkoda K, Watanabe S, Eguchi A, Fujita D and Nishimoto T : Investigation of validity of model for estimating shear force applied to buttocks in elderly people with kyphosis while sitting comfortably on a chair. *Disability and Rehabilitation: Assistive Technology*, **6**(4), 299-304, 2011.
24. Huang HC, Yeh CH, Chen CM, Lin YS and Chung KC : Sliding and pressure evaluation on conventional and V-shaped seats of reclining wheelchairs for stroke patients with flaccid hemiplegia: A crossover trial. *Journal of Neuroengineering and Rehabilitation*, **8**, 40, 2011.