Kawasaki Journal of Medical Welfare Vol. 30, No. 2, 2025 69－75

Original Paper

Effect of Knee Blocks as Postural Support Devices Aimed at Reducing Shear Force Applied to the Buttocks during the Use of Reclining Wheelchairs

Yasuyuki NAGATA*1, Kenichi KOBARA*1 and Daisuke FUJITA*1

(Accepted October 31, 2024)

Key words: knee blocks, postural support, shear force, reclining wheelchairs, seating posture

Abstract

This study investigated the effectiveness of knee blocks as postural support devices in reducing shear force applied to the buttocks during the use of reclining wheelchairs. The frequent operation of reclining wheelchairs can cause forward sliding of the buttocks and thighs, leading to poor posture and an increased risk of pressure sores. To address these issues, knee block prototypes were tested on 12 healthy male adults. The shear force applied to the buttocks was measured under three conditions: without support, with a thigh belt, and with the knee blocks. The knee blocks significantly reduced shear force at the initial and return positions when compared to the thigh belt ($p < 0.01$). This indicates that knee blocks effectively prevent forward displacement of the pelvis and enhance postural stability during reclining. This study suggests that knee blocks, as an additional postural support device, offer a practical solution to improve the seating dynamics in reclining wheelchairs without requiring significant structural modifications.

1. Introduction

In recent years, there have been significant developments in the manufacturing of wheelchairs equipped with a reclining functionality to improve posture, prevent pressure sores, and address blood pressure fluctuations, particularly in older adults and individuals with severe disabilities. However, a significant challenge arises when reclining wheelchairs are used. Repeated operation of the reclining mechanism results in a misalignment between the hip joint position, which serves as the pelvic rotation axis and the wheelchair's rotational center. This misalignment leads to forward sliding of the buttocks and thighs[1]. Furthermore, Huang et al.[2] highlighted that immediately upon leaning the trunk against the backrest, a forward shear force is generated due to the reactive force from the back support. In other words, even with reclining functionality, wheelchair users must appropriately manage their seating postures. Failure to do so may result in repeated reclining movements, causing a shear force and leading to forward sliding of the buttocks and thighs, akin to conventional wheelchairs. Therefore, prolonged periods of poor posture may ensue, diminishing seating comfort and causing issues such as pressure sores and joint contractures[3].

Strategies addressing these concerns include the introduction of wheelchairs that combine reclining and

*1 Department of Physical Therapy, Faculty of Rehabilitation
Kawasaki University of Medical Welfare, 288 Matsushima, Kurashiki, 701-0193, Japan
E-Mail: nagata@mw.kawasaki-m.ac.jp

tilt functions, as well as adjusting the lumbar support of the backrest, which have been reported to be effective[4-6]. However, medical institutions and facilities incorporating tilt-reclining wheelchairs with both tilt and reclining features are relatively scarce. Moreover, implementing measures, such as changing to lumbar support with adjustment functions, involves significant time and effort, as it requires altering the fundamental structure. Therefore, instead of modifying the existing fundamental structure (such as the frame structure), it is crucial to provide a stable seating posture by employing additional postural support devices that can be attached to various wheelchairs. These devices include specialized belts, cushions, and similar devices designed to maintain a seated posture, which can be attached to existing reclining wheelchairs and other models, offering a practical solution that does not require substantial structural modifications. This streamlines the process of enhancing wheelchair functionality, ensuring a more accessible and adaptable solution for users requiring a stable and comfortable seated position. Within this context, we posited that knee blocks, as lower-limb support devices, are effective in addressing increased shear force applied to the buttocks and poor seated posture[7].

Knee blocks, considered as additional postural support devices, exert force toward the direction of the hip joint through the anterior aspect of the knee, facilitating simultaneous control of the pelvis and hip joint. Previously, knee blocks have faced challenges such as integration into a single unit on both sides and lack of compatibility with various wheelchair models. Considering these issues, we constructed prototype knee blocks with separate and adjustable left and right devices to ensure compatibility with a wide range of wheelchairs. This innovation may enhance the flexibility and adaptability of users across different wheelchair types.

We, therefore, aimed to investigate whether the prototype knee blocks can mitigate increased shear force applied to the buttocks and improve seated posture, addressing common issues in daily use. The focus was on evaluating the effectiveness of knee blocks, considered as additional postural support devices, in reducing the force causing buttock shear when compared to the commonly acknowledged thigh belt. This comparison aimed to determine the efficacy of knee blocks in alleviating issues related to increased shear force of the buttocks and poor seated posture. The findings of this investigation provide valuable insights into the potential benefits of knee blocks as a solution for enhancing wheelchair seating dynamics.

2. Methods

2.1 Participants

This study included 12 healthy adult males (mean age, 37.0 ± 6.7 years; height, 171.9 ± 5.4 cm; body weight, 66.4 ± 9.6 kg). Written informed consent was obtained from all participants. Participant recruitment was conducted through public announcements on bulletin boards. Potential participants were informed about the significance and objectives of the research, both verbally and in writing. After obtaining their informed consent, the study was conducted in accordance with the approved ethical guidelines.

2.2 Procedures

The experimental conditions comprised three setups: without any postural support components, a thigh belt condition, and a knee block condition (Figure 1). The thigh belt is attached using two belts fixed to the bottom of the seat cushion on both sides, which are then secured to the middle of the thighs with Velcro. The belt is made of non- stretchable material, with a width of 50 mm, and can be adjusted to fit a thigh circumference ranging from 300 mm to 400 mm. The knee blocks are attached to the wheelchair's frame and apply force toward the hip joint through cushions (pads) placed in front of the knees (Figure 2). Measurements of shear force applied to the buttocks during reclining operations were conducted. The objective assessment of forward buttocks shear force was quantified using a shear force measurement device (Vicair B.V., AX Wormer, The Netherlands) as illustrated. This measurement device can quantify the shear force exerted on the seating area while sitting in a wheelchair[8]. In this study, we used an experimental chair with electrical controls that recline the back support (Hashimoto Artificial Limb

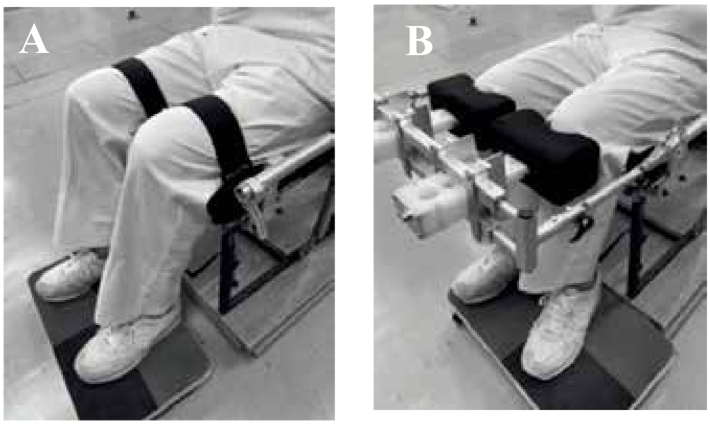

Figure 1　Experimental conditions

A: Thigh belt condition
B: Knee block condition

Figure 2　Adjustment of lateral mobility and compression when using knee blocks

Knee blocks were designed to allow lateral adjustability and to apply incremental pressure, enabling gradual control of compression.

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. This electric reclining experimental chair features a vinyl leather material for the back support, lacks backrest adjustment, and employs a flat board beneath the cushion (400 mm × 400 mm single layer of low rebound flexible urethane foam cushion with a thickness of 30 mm) to eliminate the influence of seat flexion. Additionally, to prevent moving the buttocks forward and to oppose lower-limb extension, the feet were positioned on a roller board, making an effort to minimize its shear impact (Figure 3). 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 (85% polyester, 15% cotton) and experimental underwear (100% polyester).

The measurement was conducted according to the method of Kobara et al.[6], which included the following steps: the back support of the experimental chair was inclined at increasing angles, starting from an upright position of 10° from the vertical (initial upright position [IUP]) view, followed by a fully reclined position (FRP) of 40° from the vertical view, and returning to the upright position (RUP).

Subsequently, the shear force on the buttocks was compared for the IUP, FRP, and RUP under each condition. The measurement duration per trial encompassing each holding position was approximately 40 s. Furthermore, the shear force on the buttocks was normalized by dividing it by the respective body

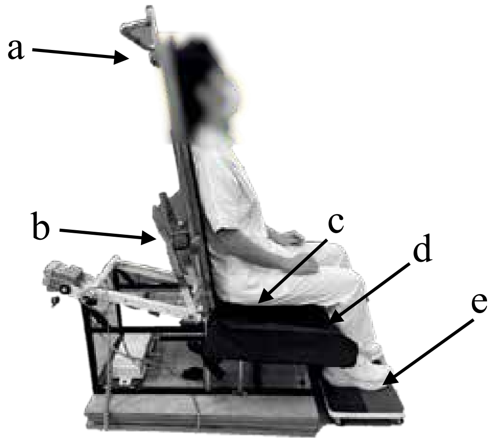

Figure 3 Sitting posture measurement position

a. Experimental chair with electrical controls b. Level goniometer c. Urethane foam cushion
d. Shear force exerted on the buttock measuring instrument e. A roller board

weights of each participant to account for variations in body size. The resulting values were presented as normalized units (percent body weight: %BW).

2.3 Statistical analysis

A repeated measures analysis of variance was employed to compare the shear forces of the buttocks at the IUP, FRP, and RUP. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using the IBM SPSS Statistics ver. 24.0 (IBM Co., Armonk, NY). In addition, the effect size and power of the test were determined for the values measured using G*Power 3.1.9.7(Faul, Erdfelder, Lang & Buchner).

3. Results

Table 1 presents the shear force applied to the buttocks measurement values for the three conditions at the IUP, FRP, and RUP. Figure 4 illustrates typical examples of the shear force waveforms of the buttocks measured under each condition. The shear force applied to the buttocks at the IUP and RUP was significantly lower when using knee blocks when compared to conditions without postural support devices and with a thigh belt ($p < 0.01$).

4. Discussion

The knee blocks used in this study significantly reduced the shear force on the buttocks during the IUP and RUP. This suggests that the knee blocks effectively inhibited the forward displacement of the center of seat pressure caused by leaning the trunk against the back support. Furthermore, the blocks likely mitigate the increase in the shear force applied to the buttocks resulting from the reactive force exerted by the back support during the reclining operation, thereby preventing the body from being pushed forward and reducing the sliding of the buttocks and thighs forward from the anterior aspect of the knees.

As for the fluctuation of the shear force applied to the buttocks while the back support is tilted, the center position of the seat pressure starts to shift forward immediately after the trunk leans against the back support (IUP), resulting in the generation of a forward shear force. Subsequently, upon returning the back support to its original position (RUP), the shear force sharply increases[9]. This is because the reclining operation creates static friction between the back support and the back, resulting in an increase in the shear force of the buttocks owing to the reactive force from the back support, causing the body to slide forward. This increases the risk of developing pressure ulcers and exacerbates postural misalignment.

Table 1 Shear force applied to the buttocks measurement values for the three conditions at IUP, FRP, and RUP

n=12

	Without any postural support devices	Thigh-belt condition	Knee block condition	Effect size	Power
IUP	7.4 ± 1.1	7.4 ± 1.7	4.9 ± 1.5**	0.60	0.80
FRP	7.7 ± 1.2	7.5 ± 1.5	6.3 ± 2.6	0.22	0.80
RUP	17.7 ± 4.1	19.0 ± 3.6	12.1 ± 2.1**	0.62	0.83

IUP: Initial upright position, FRP: Fully reclined position, RUP: Return to the upright position

mean ± SD (%BW)

**: $p < 0.01$, repeated measure analysis of variance and Bonferroni multiple comparison test (compared knee block condition with the other conditions)

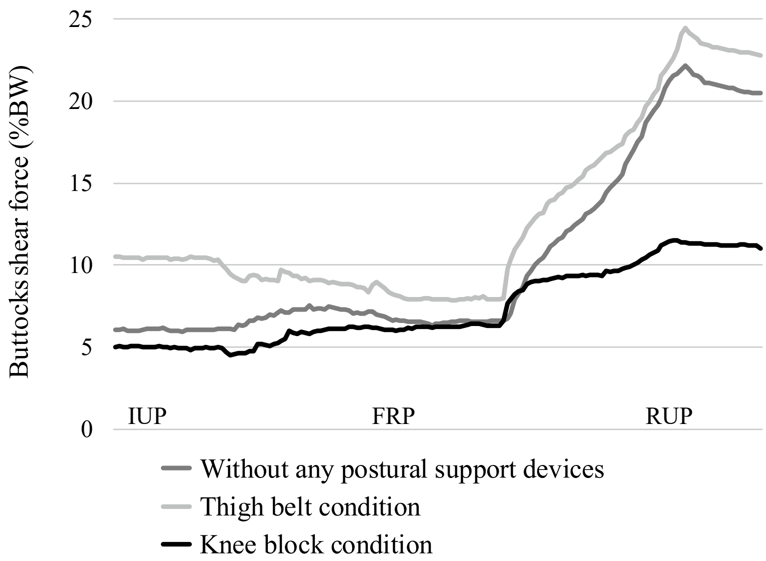

Figure 4 Typical examples of shear force applied to the buttocks waveforms

IUP, Initial Upright Position; FRP, Fully Reclined Position; RUP, Return to Upright Position

Regarding the increase in buttocks shear force in reclining wheelchairs, previous studies have reported that the center of seat pressure starts to shift forward immediately after the trunk leans against the back support (IUP), resulting in the generation of forward shear force[2]. Conversely, after sitting in a reclining wheelchair, using back support to stabilize the seated posture can lead to the generation of shear force applied to the buttocks that attempts to slide the pelvis forward. However, the knee blocks used in this study demonstrated a significant potential to reduce the shear force of the buttocks compared with the thigh belt. This effect is likely influenced by the relative positioning of the pelvic rotational axis and the supporting pads or belts. In the seated posture, the rotational axis of the pelvis is located at the position of the hip joint[10], and when the pelvis tilts backward around the hip joint, the ischial region, which is positioned behind the rotational axis, moves forward. Therefore, the force that causes the buttocks to slide forward can be reduced by positioning the point of action of the supporting belt or cushion below (or more distally) the rotational axis of the pelvis. In terms of supporting the thighs from the front, the knee blocks were more effective than the thigh belt in reducing the shear force applied to the buttocks at the initial position.

These results suggest that using knee blocks in the IUP can reduce the shear force on the buttocks. Furthermore, knee blocks significantly reduce the increase in shear force applied to the buttocks that occurs after reclining operations (RUP). In this study, an experimental chair was used, in which the rotation axis of the back support was positioned at the intersection of the lower edge of the back support and the rear edge of the seat surface. In this setup, a discrepancy occurs between the position of the hip joint, which serves as the pelvic rotation axis in the seated posture and the back support rotation axis. Consequently, when the back support is returned from a reclined to an upright position, the body, which has shifted downward, does not return to its original position, and is instead pushed by the back support[9]. This caused an even stronger shear force applied to the buttocks than at the initial position. Using only a thigh belt is insufficient to address the increase in shear force applied to the buttocks[11]. However, the knee blocks used in this study suppressed the strong shear force applied to the buttocks caused by static friction between the buttocks and seat surface at the RUP. This indicates that using a reclining wheelchair without any countermeasures, or relying solely on a thigh belt as a postural support device, may contribute to postural deterioration. To address this issue, it is essential to focus on reducing the shear force on the buttocks and consider the use of knee blocks.

When using reclining wheelchairs, it is essential to focus on the shear force on the buttocks to achieve and maintain a stable and comfortable seated posture. However, significantly altering the basic structure of a wheelchair is challenging and requires considerable time and effort. Therefore, this study suggests that by using knee blocks, which are postural support devices, it is possible to reduce the shear force on the buttocks and contribute to postural stability without changing the fundamental structure of the wheelchair.

This study has several limitations. Firstly, the sample comprised only healthy adult males, which may limit the generalizability of the findings to individuals with specific medical conditions or disabilities. Therefore, future research should include a more diverse participant pool to assess the applicability of the results across different populations. Secondly, the study was conducted over a relatively short duration, which may not fully capture the long-term effects and clinical applicability of the knee blocks. Further research is needed to evaluate how knee blocks are integrated into clinical practice and their effectiveness in real-world settings. Additionally, it is important to investigate the potential impact of knee blocks on other physical functions and activities of daily living.

Ethical considerations

This study was conducted in accordance with the Helsinki Declaration and was approved by the local ethics committee (21-026) of Kawasaki University of Medical Welfare.

Acknowledgements

This work was supported by JSPS KAKENHI (Grant Number JP19K19896).

References

1. Huang HC, Lin YS, Chen JM, Yeh CH and Chung KC : The impact of abnormal muscle tone from hemiplegia on reclining wheelchair positioning: A sliding and pressure evaluation. *European Journal of Physical and Rehabilitation Medicine*, 49(5), 619-628, 2013.
2. 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, https://doi.org/10.1186/1743-0003-8-40.
3. Sabol TP and Haley ES : Wheelchair evaluation for the older adult. *Clinics Geriatric Medicine*, 22(2), 355-375, 2006, https://doi.org/10.1016/j.cger.2005.12.013.
4. Koda H, Okada Y, Fukumoto T and Morioka S : Effect of tilt-in-space and reclining angles of wheelchairs on normal force and shear force in the gluteal region. *International Journal of Environmental Research and Public Health*, 19(9), 5299, 2022, https://doi.org/10.3390/ijerph19095299.
5. Kobara K, Nagata Y, Fujita D, Takahashi H, Osaka H and Suehiro T : Effect of an improved seat cover on back support for reducing shear force applied to the buttocks when back support is reclined. *Bulletin*

of the Japanese Society of Prosthetics and Orthotics, 35(1), 52-58, 2019. (In Japanese with English abstract)
6. Kobara K, Nagata Y, Takahashi H, Osaka H and Fujita D : Influence of an adjustable tension back support for wheelchairs on the shear force applied to the buttocks and trunk sliding distances and usability of the adjustable tension function when the back-support inclined. *The Japanese Journal of Wheelchair Seating*, 4, 2-8, 2019. (In Japanese with English abstract)
7. Nagata Y : Evaluation of the use of a kneeblock in a seating system for children with severe motor and intellectual disabilities. *Japanese Journal of Severe Motor and Intellectual Disabilities*, 42(3), 385-390, 2017. (In Japanese with English abstract)
8. LAC Healthcare LTD : i Shear. https://www.lac-hc.co.jp/products/seating/ishear, 2016. (August 27, 2024)
9. Kobara K, Osaka H, Suehiro T, Takahashi H and Fujita D : Development of a seat cover for a wheelchair on back support for decreasing shear force applied to the buttocks during reclining back support. *Kawasaki Journal Medical Welfare*, 24(2), 61-69, 2019.
10. Kobara K, Nagata Y, Takahashi H, Suehiro T, Osaka H and Fujita D : Relationship between the fluctuation of the shear force applied to the buttocks and the timing just before sliding the trunk upward on the back-support during back-support inclination. *Bulletin of the Japanese Society of Prosthetics and Orthotics*, 35(4), 302-308, 2019. (In Japanese with English abstract)
11. Nagata Y, Kobara K and Fujita D : Postural support devices in reducing shear force applied to buttocks in individuals using reclining wheelchair. *Rehabilitation Engineering*, 38(3), 174-180, 2023. (In Japanese with English abstract)