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Original Paper

Differences in the Effects of Reclining and Tilting on Respiratory Function While Sitting in a Wheelchair

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Abstract

This study investigated the effects of reclining and tilting on respiratory function and comfort while sitting in a wheelchair. Eight healthy adults (20.6 ± 1.4 years of age) were included. The experiments were conducted using a wheelchair capable of tilting and reclining. Before and after each movement, the participants' tidal volume, vital capacity, and forced expiratory volume were measured, and the participants were asked about the comfort of their sitting postures. The reclining movement inclined the back support rearward by 30°. The tilt movement tilted the back support and seat rearward by 30°. The reclining movement significantly increased vital capacity ($p < 0.01$) and improved comfort ($p < 0.05$). However, the tilt movement did not significantly affect any of the measured parameters. The rate of change in vital capacity based on the pre-movement value was significantly higher for the reclining movement than for the tilt movement ($p < 0.05$). These results suggested that the comfortable posture resulting from the reclining movement provided superior respiratory function and comfort compared to the tilt movement when the back-raising angle was the same.

1. Introduction

Disabled persons with difficulty walking often choose wheelchairs for transportation. Among the many types of wheelchairs, reclining wheelchairs are widely used to help easily fatigued people to get out of bed and to extend the sitting time of the elderly during the day. However, when the back support is inclined, the body slides down on the back support surface and the buttocks shift forward on the seat surface[1]. This postural collapse results in increased pressure and shear force on the buttocks, which can eventually cause pressure ulcers[2-4]. In their investigation of reclining angle on respiratory function in healthy subjects, Sasaki et al.[5] reported a significantly decreased reserve expiratory volume when the back support was inclined backward to an angle beyond which the subjects felt comfortable, indicating that the reclining movement may decrease respiratory function.

A tilt-in-space wheelchair was developed to prevent postural collapse due to the reclining movement. Koda et al.[6] reported the usefulness of the tilt-in-space wheelchair as tilting reduced the pressure and shear

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force to the buttocks compared to the reclining movement. The authors also reported that increasing the backward tilt increased the backward pressure and shear force applied to the buttocks. The tilt movement slid the body down on the backrest, while the buttocks slide backward on the seat surface. Therefore, the postural alignment after the tilt movement may differ from that after the recline movement.

Postural collapse is associated with decreased respiratory function. Sato et al.[7] investigated kyphosis in outpatient rehabilitation facilities and observed reduced forced vital capacity in subjects with strong kyphosis. Moreover, simulated kyphosis of the spinal column in healthy subjects suppressed respiratory function and reduced chest expansion[8]. Therefore, aging is not the only cause of suppressed respiratory function by kyphosis. When the back support of a reclining wheelchair is inclined, the body slides down on the back support such that the buttocks shift forward and the pelvis tilts backward to form a sacral seat. Shiomoto et al.[9] reported that tilting the pelvis backward from the middle position increased the kyphosis of the lower thoracic and lumbar spine. Thus, the postural collapse caused by the reclining movement may lead to decreased respiratory function. In contrast, as the tilt movement does not cause the buttocks to move forward on the seat surface, it may not cause decreased respiratory function.

While the effectiveness of the tilt movement has been reported from the viewpoint of pressure ulcers, no reports have assessed the effects of the tilt movement on respiratory function and comfort. Comfortable breathing and physical comfort while seated in a wheelchair are important for people who have difficulty adjusting their own posture. Therefore, this study clarified the effects of reclining and tilt movements on respiratory function and comfort using a tilt-in-space wheelchair.

2. Methods

2.1 Participants

The participants were eight healthy adult men (age: 20.6 ± 1.4 years). This study was conducted after obtaining approval from the Kawasaki University of Medical Welfare Ethics Review Committee (approval number: 16-075). The researcher explained the study outline to the subjects in advance of their participation using a document. After obtaining consent, the participants provided their signatures and seals on the consent form.

2.2 Measurements

A tilt-in-space wheelchair (MH-4R, Matsunaga Manufacturing Co., Ltd.) was used in the experiment. The reclining and tilt operations were performed by the examiner, and a metronome was used to maintain constant speeds for the tilt and reclining movements. To standardize the coefficients of static friction between the back support and seat, each subject was asked to wear the same clothing (85% polyester and 15% cotton). The maximum static friction force between the experimental clothing and the back support and seat surface was measured using a digital spring balance and weight. The coefficient of static friction was then calculated by dividing the value by the mass of the weight that was 0.3.

Each participant was asked to sit upright on a cushion in a symmetrical position. The buttocks were first placed in contact with the back support and were then shifted forward by 3 cm to unify the limb positions among the participants. The lower end of the head support was adjusted to the height of the mastoid process. The participants' feet were placed on the foot support of the wheelchair. The height of the footplate was adjusted according to the length of the lower limb. The subjects were instructed not to move during the experiment.

The experimental conditions were as follows: 1) reclining condition: only the reclining movement was performed and 2) tilt condition: only the tilt movement was performed (Figure 1). Hata et al.[10] investigated the effect of reclining angle on the oral transit time of food during swallowing. They found that the oral transit time for thickened water was not significantly different between the group with the back support inclined backward 0-30° and the group with the back support inclined backward 45-60°. If the goal is to improve the ADL ability of the patient, it is desirable to incline the back support 0-30° backward so that the patient can take meals by himself. Therefore, the back raising angle was set to 60° for both conditions. The start position was defined as the inclination of the back support of the wheelchair, which was 90° with respect to the horizontal plane. In the reclining condition, the end position was defined as the angle of back support, which was 30° backward. In the tilt condition, the end position was defined as a 30° tilt backward of both the back support and seat. In both conditions, the participants' blood pressure (BP) and pulse rate (PR) were measured using an automated BP machine (HEM-7131, Omron corporation) 5 min after the start position and 5 min after the end position. Respiratory function was measured in both conditions using a SpirometerPod (ML311, ADInstruments) and PowerLab2/28 (ML828, ADInstruments) 9 min after assuming the start position and 9 min after assuming the end position. After the participants had performed breathing at rest for 30 seconds, their maximum inhalation, maximum exhalation, effort inhalation, and effort exhalation were measured twice. The obtained data were analyzed using waveform analysis software (LabChart ver 7, ADInstruments) for tidal volume (TV), vital capacity (VC), and forced expiratory volume in one second as percent of FVC (FEV1.0%). The maximum values for the start and end positions were calculated. Furthermore, to examine the subjective comfort before and after the reclining and tilting movements, the participants completed a verbal sensory scale, with a range of ±5 centered on 0, with higher values indicating greater comfort (Figure 2).

2.3 Statistical analysis

IBM SPSS Statistics for Windows, version 24.0 (IBM Corp.) was used to perform the statistical analyses. Normality for all data was examined using the Shapiro-Wilk test. If the data were normally distributed, paired t-tests were used. If the data were non-normally distributed, a Wilcoxon test was performed. Significance was set at $p < 0.05$.

3. Results

Table 1 shows the results for respiratory function, BP, PR, and subjective comfort.

VC was significantly increased at the end position compared to that at the start position for the reclining condition ($p < 0.01$), while no significant difference was observed between the start and end positions for the tilt condition. The rate of VC change based on the start position was significantly higher in the reclining condition than that in the tilt condition. ($p < 0.05$, Table 2). No significant differences in TV and FEV1.0% were observed between the start and end positions for either condition. Similarly, the rates of change in the TV and FEV1.0% compared to the starting position also did not differ significantly.

Figure 1 End positions of the reclining and tilt condition

Left: In the reclining condition, the back support is inclined backward by 30°.
Right: In the tilt condition, both the back support and seat surface are tilted backward by 30°.
In both conditions, the back-raising angle was 60°.

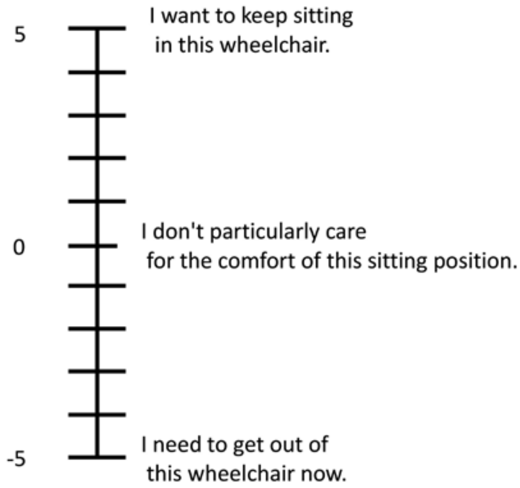

Figure 2 Comfort scale while sitting in a wheelchair

The comfort level is shown in a range of ±5 centered on 0. A higher value indicates a higher comfort level.

Table 1 Changes in TV, VC, FEV1.0%, BP, PR, and comfort

	Reclining condition		Tilt condition	
	Start position	End position	Start position	End position
TV(L)	0.76 ± 0.18	0.66 ± 0.18	0.75 ± 0.15	0.73 ± 0.12
VC (L)	4.14 ± 0.78	4.24 ± 0.76**	4.29 ± 0.70	4.26 ± 0.71
FEV1.0% (%)	79.9 ± 9.2	77.5 ± 10.5	78.3 ± 3.7	70.9 ± 15.8
SBP (mmHg)	108.8 ± 12.1	105.6 ± 17.0	109.1 ± 16.9	104.3 ± 14.1
DBP (mmHg)	67.4 ± 10.8	63.3 ± 7.8	67.1 ± 11.0	62.8 ± 11.8
PR (bpm)	82.5 ± 15.9	79.8 ± 16.2	81.6 ± 16.0	79.4 ± 16.3
Comfort	0 ± 1.3	2.3 ± 1.9*	0.4 ± 2.0	2.1 ± 2.2

*p < 0.05: Compared to the start position

**p < 0.01: Compared to the start position

TV: tidal volume, VC: vital capacity, FEV1.0%: forced expiratory volume in one second as percent of FVC

SBP: systolic blood pressure, DBP: diastolic blood pressure, PR: pulse rate

Table 2 Rates of change in TV, VC, and FEV1.0%

	Reclining condition	Tilt condition
TV	87.8 ± 17.0	98.5 ± 7.8
VC	102.5 ± 2.0	99.2 ± 1.7*
FEV1.0%	99.3 ± 17.1	90.9 ± 21.2

*p < 0.05: Compared to the reclining condition

TV: tidal volume, VC: vital capacity,

FEV1.0%: forced expiratory volume in one second as percent of FVC

Rates of change in TV, VC, and FEV1.0% are presented as the percentage changes relative to the start position values.

Systolic BP (SBP), diastolic BP (DBP), and PR did not differ significantly at the start and end positions for either condition.

In the reclining condition, subjective comfort improved significantly at the end position compared to that at the start position ($p < 0.05$). However, the subjective comfort did not differ significantly between the start and end positions in the tilt condition.

4. Discussion

In the reclining condition, the VC was significantly increased at the end position compared to that at the start position. While reclining the back support, the body slides down on the back support, the buttocks move forward on the seat surface[1], the pelvis tilts backward, and thoracic spine kyphosis appears due to the buttocks sliding on the seat surface. Regarding the change in pelvic girdle alignment when the back support of a wheelchair is reclined, Sakamura et al.[11] reported that the pelvis tilted forward relative to the body axis when the back support angle was reclined from 90° to 120°. Pelvic anteversion promotes lumbar and lower thoracic vertebrae extension[9], while lumbar lordosis increases lung capacity compared to the intermediate position[12]. Therefore, in the present study, the posterior tilt angle of the pelvis may have decreased during the process of shifting the body down on the back support when the back support was moved backward in the reclining condition.

The tilt condition showed no significant difference in VC at the end position compared to that at the start position. The rate of change in VC based on the start position was significantly smaller in the tilt condition than that in the reclining condition. Koda et al.[6] investigated the effect of tilt operation on the pressure and shear force on the buttocks in healthy persons sitting on a wheelchair, reporting significantly increased pressure and shear force to the buttocks when the back support and seat were tilted backward by 20°. As the tilt angle was set to 30° in this study, the pressure and shear force on the buttocks were likely stronger than those reported by Koda et al. Sakamura et al.[11] examined the effect of tilt operation on the anterior-posterior tilt of the pelvis in healthy subjects, reporting no significant difference in pelvis inclination relative to the trunk axis after tilt movement. In the present study, the differences in the effects of the reclining and tilting conditions on the pelvic tilt angle may have affected respiratory function.

The reclining condition showed a significant improvement in comfort at the end position compared to that at the start position. Yoshida et al.[13] examined the effect of different postures on body pain based on a working posture with the back support raised and a resting posture with the back support inclined backward. They reported lower pain and stress on the lumbar intervertebral disc in the resting posture compared to that in the working posture. The starting position in this study was similar to that of the working posture in the previous study, while the end position of the reclining condition was similar to the resting posture, in which the body was leaned on the back support according to gravity. Therefore, the distribution of pressure on the back and seat surfaces likely improved the participants' comfort in the reclining condition. In contrast, in the tilt condition, the buttocks slide backward on the seat surface, with increased pressure and shear force to the buttocks. This pressure and force may not have been distributed in the tilt condition compared to those in the reclining condition.

In the present study, the tilt condition tilted the seat and back support backward simultaneously. Reduced pressure and shear force on the buttocks have been reported by reclining the wheelchair after performing the tilt operation[14]. Additional studies are needed to assess the changes in respiratory function and comfort for different back support and seat angles. Kinematically, it is also necessary to examine how the pelvic tilt angle changes before and after both movements.

The results of this study showed that reclining the back support backward by 30° resulted in a significantly increased vital capacity, while tilting the back support and seat surface backward did not. In addition, the sitting posture in the reclining position significantly improved participant comfort, while the sitting posture with the tilt operation did not. Although the usefulness of tilt-in-space wheelchairs has been reported in the context of pressure ulcers, our results showed that reclining wheelchairs are useful in the context of respiratory function and comfort. If the aim is to prevent wheelchair users from collapsing their posture while sitting in a wheelchair, the use of the tilt-in-space wheelchair is considered appropriate. On the other hand, if the aim is to keep wheelchair users comfort while sitting in a wheelchair, the reclining wheelchair should be chosen.

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