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Original Article

Relationship between the duration and trunk inclination and hip angle during car transfer in individuals with tetraplegia

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Abstract. [Purpose] The purpose of the present study was to investigate the relationship between the duration of the car transfer (CT) movement and trunk inclination and hip angles during this movement in individuals with tetraplegia. [Subjects and Methods] Eleven adult males with C6 tetraplegia participated in this study. The CT movement was recorded from the passenger side of the car using a digital video camera. From the video, the duration and trunk inclination and hip joint angle were recorded, and correlation coefficients were calculated. [Results] No correlation was found between the trunk inclination angle and the duration of the CT movement. However, a significant correlation was found between the hip angle and the duration of the CT movement: when the duration was short, the hip flexion angle was substantial. [Conclusion] The trunk inclination angle probably showed no effect on the duration of the CT movement because the movement was performed in a limited space and because the trunk muscles of the subjects were paralyzed. In contrast, C6 tetraplegia enabled smooth CT by allowing for control of trunk inclination, such as placing the lower extremities in the car, whereby the pelvis backward tilt angle increased.
Key words: Spinal cord injury, Transfer, Car

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INTRODUCTION

The car is a convenient means of transport and enables people to expand their range of activity. In particular, for people with disability of the lower extremities who must use a wheelchair have limited use of public transportation, it is very important to be able to drive a car. The ability to drive is associated with employment, community participation, and overall satisfaction in individuals with spinal cord injury[1–4)]. To be able to drive independently, these individuals need to transfer to the driver's seat (i.e., car transfer [CT]), operate the steering wheel, and load their wheelchairs in their car by themselves. Among these activities, the CT movement to the driver's seat is particularly important because it is related to other transfer movements in daily living. Kinematic analysis of the CT movement in individuals with C6 tetraplegia showed that these individuals prefer the rotatory movement pattern in which their head moves in the opposite direction to their buttocks[5)]. In an analysis of the CT movement in individuals with tetraplegia, the subjects confirmed that they could move their buttocks by inclining their trunk forward inclination by via neck control, because of trunk muscle paralysis[5)]. However, this previous study only analyzed the head, trunk, and buttocks during CT movement in individuals with tetraplegia, and it did not examine the position of the lower limbs whereby individuals with C6 tetraplegia could control their paralyzed trunks.

Several studies have been conducted on transfer movement in individuals with spinal cord injury. These earlier studies

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Table 1. Subject characteristics

Subjects	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time since injury (years)	ASIA motor score of upper extremities (/50)	Height of wheelchair seat (cm)	Height of driver's seat (cm)
A	41	168.5	60.0	21.1	21	19	50	53
B	26	175.0	55.0	18.0	12	20	50	53
C	39	182.0	66.5	20.1	22	22	53	54
D	51	168.0	56.0	19.8	31	20	53	58
E	51	174.0	55.0	18.2	27	18	53	54
F	28	167.0	45.0	16.1	10	20	52	52
G	39	180.0	65.0	20.1	19	24	53	60
H	33	172.0	47.0	15.9	11	21	54	52
I	42	183.0	50.0	14.9	22	21	50	60
J	43	178.0	51.6	16.3	27	20	55	54
K	42	174.0	57.0	18.8	18	20	52	53
Mean ± SD	39.6 ± 8.1	174.7 ± 5.6	55.3 ± 6.8	18.1 ± 2.1	20.0 ± 6.9	20.5 ± 1.6	52.3 ± 1.7	54.8 ± 3.0

indicated the importance of the eccentric control of trunk forward flexion and the coordinated flexion movement between the head and trunk to assist the buttocks to lift off the seat during transfer movement[6–9].

Individuals with tetraplegia used a variety of methods to facilitate the CT movement. For example, they perform CT after placing one or both legs in the car or they fix their head against the door during the movement. For individuals with tetraplegia to participate socially, it is very important them to achieve more efficient CT movement. However, few studies have kinematically examined CT movement in individuals with tetraplegia.

The purpose of the present study was to examine the kinematic characteristics and explore the most efficient methods of CT movement in individuals with tetraplegia, focusing on trunk and hip joint movement.

SUBJECTS AND METHODS

Eleven adult males with C6 tetraplegia, with grade A impairment according to the American Spinal Injury Association (ASIA) guidelines, participated in this study. Their ASIA motor scores ranged from 18 to 24, while the time since injury was 11–31 years (age: 39.6 ± 8.1yerars, height: 174.7 ± 5.6 cm, weight: 55.3 ± 6.8 kg). The inclusion criteria were as follows: no limitation in range of motion or pain in the upper extremities and inability to lift themselves off the buttocks. Subject characteristics are presented in Table 1.

This study was approved by the Ethics Committee of the School of Comprehensive Rehabilitation, Osaka Prefecture University (2013-108). The purpose of the study was explained to the subjects orally and in writing, and written informed consent was obtained from all participants.

Subjects were instructed to perform CT movement as they would usually from their own wheelchairs to their own cars. The difference between the height of the driver's seat and the seat surface of the wheelchairs was less than 10 cm (Table 1). The wheelchair was positioned on the correct side of the car, and the subjects attempted to transfer themselves from the wheelchair into the driver's seat. The passenger-side door was held open maximally, and a digital video camera (30 Hz) was placed on the passenger side (Fig. 1).

The duration of the movement, defined as the total time of buttocks movement from the wheelchair to the driver's seat was determined from videos recorded on the camera. The starting point was the moment that the buttocks movement was visible, when the left great trochanter was confirmed to have moved forward. The end point was the moment that the buttocks movement was completed when the participant was in the driver's seat.

On the basis of the videos, the duration and the trunk inclination and hip angles were recorded, and correlation coefficients were calculated. The trunk inclination and hip angles were calculated using Image-J (NIH) from static images. The trunk inclination angle was defined as the angle from the left acromion process to the great trochanter and the vertical line. The hip angle was defined as the angle between the left acromion process to the great trochanter and the left great trochanter to the knee (Fig. 2). In other words, a small hip angle indicates a high hip flexion angle. In the case of multiple buttocks movements, these angles were calculated for each movement, and the maximum angle was used in the data analysis. After the buttocks movement, the angles of the moment their acromion and knee position closing were measured as the maximum angle.

The relationship of the trunk inclination and hip angles with duration were analyzed using Spearman's rank-correlation coefficient. The significance level was set at $p<0.05$. PASW Statistics 18 was used for statistical analysis.

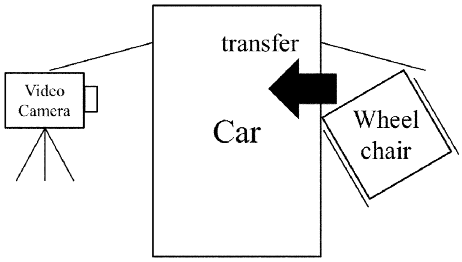

Fig. 1. Method for recording transfer movement from a wheelchair to a car
The passenger-side door was held open maximally, and a digital video camera was placed on the passenger side.

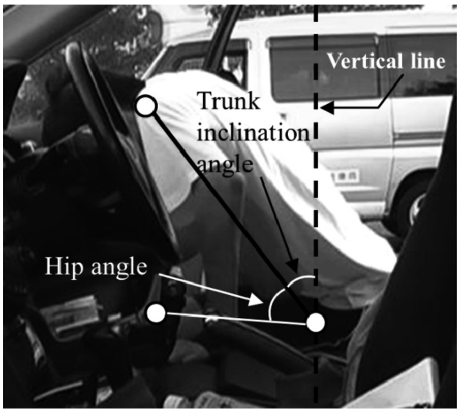

Fig. 2. Definition of trunk inclination angle and hip angle
The trunk inclination angle was defined as the angle from the left acromion process to the great trochanter and the vertical line. The hip angle was defined as the angle between the left acromion process to the great trochanter and the left great trochanter to the knee.

Table 2. Duration of the CT movement, trunk inclination angle, and hip angle recorded for all subjects

Subject	ASIA motor score (/50)	Duration of the CT movement (s)	Maximum trunk inclination angle (degrees)	Maximum hip angle (degrees)
A	19	32	45.4	61.9
B	20	36	35.0	64.9
C	22	9	37.7	46.4
D	20	22	34.0	58.3
E	18	18	42.5	64.1
F	20	13	36.2	57.7
G	24	39	32.0	66.9
H	21	26	31.5	61.5
I	21	19	40.5	81.8
J	20	20	41.0	58.0
K	20	17	37.6	54.8
Mean ± SD	20.5 ± 1.6	22.8 ± 9.5	37.6 ± 4.4	61.5 ± 8.8

RESULTS

The duration of the CT movement ranged from 9 to 39 s (Table 2). No correlation was found between the ASIA motor score and duration (ρ=0.07, $p>0.05$). The maximum trunk inclination angle ranged from 31.5 to 45.4 degrees, while the maximum hip angle ranged from 46.4 to 81.8 degrees (Table 2).

No correlation was observed between the trunk inclination angle and the duration of CT movement. However, a significant correlation was observed between the hip angle and duration (ρ=0.67, $p<0.05$). In other words, the duration was short when the extent of hip flexion was substantial.

DISCUSSION

Transfer movements are very common in daily life, and the ability to perform these movements is one of the most important and meaningful skills for individuals with tetraplegia. Independence in transfer movement would encourage individuals with tetraplegia to participate more fully in the community by allowing them to use a car. Thus, understanding the kinematic characteristics of patients with C6 tetraplegia is important in order to promote their participation in the community.

The purpose of this study was to examine the kinematic characteristics of individuals with tetraplegia and identify the most efficient method of CT movement for them, with a focus on trunk and hip joint movement. Previous studies showed that coordinated flexion movement between the head and trunk assist the buttocks to lift off the seat[6–8]. Additionally, the strategy of neck flexion and forward inclination of the trunk was found to differ among subjects with C6 tetraplegia during CT movement[5].

In the present study, no correlation was found between the ASIA motor score and the duration of the CT movement. A reason for this could be that all subjects with C6 tetraplegia have paralyzed triceps brachii muscles, and the ASIA motor score of the upper limbs does not significantly affect the CT movement. In addition, it has been reported that the pectoralis major, latissimus dorsi, and serratus anterior muscles are important for the CT movement in individuals with spinal cord injury[8] and that in order to analyze the CT movement in individuals with C6 tetraplegia, these muscles should be tested in addition to those tested to determine the ASIA motor score. Further, the present study showed no correlation between the trunk inclination angle and the duration of the CT movement. This could be because of the limited space in which the movement was performed and because the subjects had paralyzed trunk muscles. Cars have several obstacles, such as the door, handle, and dashboard, and the subjects had to incline their trunks forward in a limited space. However, these obstacles might actually assist the subjects in inclining their paralyzed trunks forward and control them.

On the other hand, a significant correlation was observed between the hip angle and duration of the CT movement. This could be because C6 tetraplegia enabled smooth CT by allowing for control of trunk inclination, such as placing the lower extremities in the car in order to tilt pelvis backward.

Although the hip flexion angle was high, the trunk inclination angle was low, despite which the individuals with tetraplegia could perform the dynamic CT movement. As mentioned above, it has been reported that for transfer movement among individuals with tetraplegia, head and trunk flexion may facilitate efficient buttocks movement. However, with regard to transfer movement in confined spaces such as CT movement, it has been suggested that the magnitude of the hip flexion angle affects smooth movement of the buttocks. Kim et al. compare the changes in the trunk and shoulder angles and reaction forces under the two hands elicited by different hand base-of-support positions during sitting pivot transfer[10]. They reported that the lower hand position should be recommended as an effective and safe method for sitting pivot transfer for patients with spinal cord injury, because this position was associated with a significantly high trunk angle of forward and lateral flexion, even though the angle of rotation while transferring to the 20-cm lower support position was reduced. In the present study, the difference between the height of the driver's seat and the seat surface of the subjects' wheelchair was less than 10 cm. However, since even a small difference in these levels is considered to influence the CT movement in individuals with C6 tetraplegia who have paralyzed upper limbs, this factor needs further investigation.

The trunk inclination angle probably showed no effect on the duration of the CT movement because the movement was performed in a limited space and because the trunk muscles of the subjects were paralyzed. In contrast, C6 tetraplegia enabled smooth CT by allowing for control of trunk inclination, such as placing the lower extremities in the car, whereby the pelvis backward tilt angle increased. A drawback of the present study was that the CT movement was examined in a limited space, and the differences in the cars and wheelchairs used by the subjects were not taken into consideration. Third, the experimental conditions were not fixed, and the subjects were allowed to select their own strategy for CT movement. Further, the motions of the CT movement, including rotational motion, were examined by two-dimensional analysis. The angles in the sagittal plane were determined, and the numerical values of these angles are not precise. Thus, although the trends of the trunk inclination angles and hip angles required for the CT movement have been understood, further studies are needed for a more accurate analysis with a greater number of subjects.

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REFERENCES

1) Carpenter C, Forwell SJ, Jongbloed LE, et al.: Community participation after spinal cord injury. Arch Phys Med Rehabil, 2007, 88: 427–433. [Medline] [CrossRef]
2) Ku JH, Jang DP, Lee BS, et al.: Development and validation of virtual driving simulator for the spinal injury patient. Cyberpsychol Behav, 2002, 5: 151–156. [Medline] [CrossRef]
3) Norweg A, Jette AM, Houlihan B, et al.: Patterns, predictors, and associated benefits of driving a modified vehicle after spinal cord injury: findings from the National Spinal Cord Injury Model Systems. Arch Phys Med Rehabil, 2011, 92: 477–483. [Medline] [CrossRef]
4) Kiyono Y, Hashizume C, Matsui N, et al.: Car-driving abilities of people with tetraplegia. Arch Phys Med Rehabil, 2001, 82: 1389–1392. [Medline] [CrossRef]
5) Kataoka M, Yasuda T, Kataoka T, et al.: Movement strategies during car transfers in individuals with tetraplegia: a preliminary study. Spinal Cord, 2012, 50: 440–445. [Medline] [CrossRef]
6) Allison GT, Singer KP, Marshall RN: Transfer movement strategies of individuals with spinal cord injuries. Disabil Rehabil, 1996, 18: 35–41. [Medline] [CrossRef]

7) Allison G, Singer K, Marshall R: Muscle activation patterns during transfers in individuals with spinal cord injury. Aust J Physiother, 1995, 41: 169–176. [Medline] [CrossRef]
8) Gagnon D, Nadeau S, Gravel D, et al.: Movement patterns and muscular demands during posterior transfers toward an elevated surface in individuals with spinal cord injury. Spinal Cord, 2005, 43: 74–84. [Medline] [CrossRef]
9) Gagnon D, Nadeau S, Noreau L, et al.: Trunk and upper extremity kinematics during sitting pivot transfers performed by individuals with spinal cord injury. Clin Biomech (Bristol, Avon), 2008, 23: 279–290. [Medline] [CrossRef]
10) Kim SS, Her JG, Ko TS: Effect of different hand positions on trunk and shoulder kinematics and reaction forces in sitting pivot transfer. J Phys Ther Sci, 2015, 27: 2307–2311. [Medline] [CrossRef]