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The Effect of Various Wheelchair Handle Directions on Muscle Activity of Adult Male Trunks When Climbing Ramps

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| Abstract |

Purpose: This study examined the effects of wheelchair handle directions on the trunk muscle activity of adult males when climbing ramps. It also evaluated the wheelchair attendant's physical discomfort during tasks.

Methods: Healthy males aged over 20 years were chosen and the direction of wheelchair handle grip was randomly selected. The grips included a general grip with ulnar deviation, a medial grip with wrist pronation, and a neutral grip with a neutral wrist. The trunk muscle activity was measured using surface electromyography. Furthermore, the physical discomfort of wheelchair attendants was subjectively evaluated using the Borg CR-10 Scale, which rates the perceived exertion. In addition, the SPSS 18.0 program was used perform repeated measure ANOVA to compare muscle activity and subjective discomfort during the interventions. The contrast test was also conducted with a significance level (α) of 0.05.

Results: There was significant difference between the general grip and the medial grip in the rhomboid major muscle and the lumbar erector spinae muscle ($p<0.05$). In addition, there was significant difference between the general grip and the neutral grip in the rhomboid major muscle and the lumbar erector spinae muscle ($p<0.05$). Further, there was significant difference between the general grip and the neutral grip in subjective discomfort ($p<0.05$).

Conclusion: In this study, adult male trunk muscle activity and subjective discomfort were lowest when using the neutral grip while climbing ramps. Accordingly, we suggest that neutral grips will help improve the function of the musculoskeletal system and reduce the subjective discomfort by putting less strain on the trunk muscles and maximizing efficiency with less force.

Key Words: Wheelchair, Ramp, Handle grip direction, Muscle activity

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Ⅰ. Introduction

According to a report by the Korea Institute for Health and Social Affairs (Kim et al., 2014), based on the 2014 Household Sample Survey, the total number of disabled in South Korea was approximately 2,727,000, 1,554,000 (57%) of whom were physically challenged or brain-disabled people who experienced inconvenience or limitations walking or performing daily living activities and 118,000 (6.8%) of whom were estimated to rely on manual wheelchairs. A wheelchair is an important tool for the disabled to move easily and to expand social participation by enhancing social accessibility. It is particularly essential for the disabled to use wheelchairs during vertical movement in daily life, such as moving from the ground to a building entrance (Kim et al., 2010). One of the most widely-used methods for assisting vertical movement is a ramp (Yoo, 1995), which is the easiest and most frequently used method by people in wheelchairs to move indoors and outdoors (Lee et al., 2010).

However, wheelchair propulsion on uphill ramps requires moving against gravity and enough force to overcome resistance (Kim, 2012), which is challenging to manual wheelchair users. In particular, patients who have difficulty using a wheelchair on their own should be supported by a caregiver (Lee et al., 2014). Yet, most caregivers are who have a relatively high incidence of musculoskeletal disorders stemming from repetitive movements, job stress, and uncomfortable living (Choi & Sim, 2012). Due to the caring service, repetitive work over a long period of time, such as pushing a wheelchair, causes minor damage to muscles, joints, and nerves, which can lead to damage to the trunk muscles it is possible to cause cumulative trauma syndrome, which is a work-related musculoskeletal disorder (Kim et al., 2008; NIOSH, 1997). Some disorders of the upper extremity and trunk of caregivers are also work-related and musculoskeletal in nature (Yun et al., 2001). The main risk factors for damage resulting from repetitive use of the upper extremity include the caregiver's degree of strength, posture, the frequency of repetition, and the vibration of the wheelchair (Sandres, 2004). Furthemore, damage to the upper limbs can affect the trunk. This is because the movement of the trunk during wheelchair propulsion plays an important role in the mechanism of force production and most of the weight is transmitted to the trunk (Vanlandewijck et al., 2001; Winter, 1990). In addition, physical strength varies based on the sizes and grips of wheelchair handles (Buchholz et al., 1988; Kuorinka & Forcier, 1995). Ahn (2018) reported that the trunk muscle activity of caregivers changes depending on the handle direction. In previous studies, there have been studies that affect the muscle activity of the muscles according to the shape of the handle grip (Heo et al., 2014).

However, there is a lack of research on the change of the muscle activity according to the direction of the handle grip. Within this context, we investigated the adult males trunks muscle activity and the subjective values of their physical inconvenience changes according to the direction of wheelchair grip when the attendants climbed an uphill ramp while propelling a wheelchair to which a 60kg sandbag had been attached (Yoo, 1995). The hypothesis of this study is that the general grip influences the trunk muscles when it goes up the ramp, so the medial grip or neutral grip will stabilize the trunk and reduce the risk of muscle skeletal damage.

Ⅱ. Method

1. Subjects

The subjects of this study were students at a university

located in Pusan, South Korea. The participants were males aged 20 years or older who had had no orthopedic or neurosurgical injuries during the six months prior to the experiment, had no surgical history, had not taken any medication for the prior three months, and submitted written consents of participation. This study was approved by the Bioethics Committee of Dong-Eui University (DIRB-201709-HR-R-026).

2. Measurement tools

1) Design of ramp

We constructed a ramp that was 45cm high, 100cm wide, and 360cm length (Ahn & Lee, 2018).

2) Design of wheelchair grips

We fashioned three types of wheelchair grips based on grip direction: a general grip of ulnar deviation, a medial grip that resulted in wrist pronation, and a neutral grip that provided for wrist neutrality (Fig. 1). Since the general grip is in a state in which the wrist is in the state of an ulna deviation, muscle pressure can be further increased to cause muscle and skeletal diseases. Therefore, medial grip and neutral grip were selected to reduce pressure on the wrist joint and contribute to stability. So we studied with three different grip types.

3) Surface electromyogram (EMG)

The Noraxon TeleMyo 2400 system (TM DTS, Noraxon, USA) was used to measure the EMG signals of the serratus anterior, the rhomboid major, and the lumbar erector spinae (Fig. 2). The attachment part of Serratus anterior attachment is A point of width of one finger in the ouward direction from the inferior scapular of the shoulder, the attachment part of rhomboid major is a point of width of one finger from a medial edge middle spot between the spine of scapula and the scapula interior angle, and the attachment part of lumbar erector spinae is the spot of 2 cm from the lateral spinous process of the second lumbar vertebra (Cram et al., 1998). Disposable surface electrodes made of Ag and AgCl were used as ground electrodes. The mean root mean square (RMS) value of the muscle activity signals evaluated in each muscle was calculated using the software program MR 3.6 Clinical Application Protocols (TM DTS,

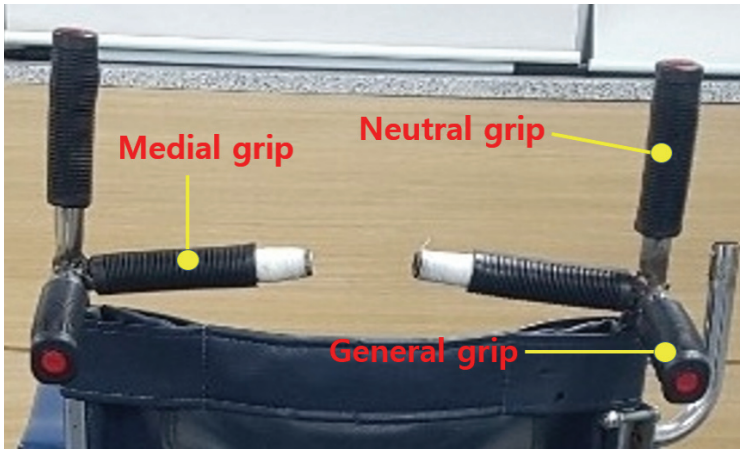

Fig. 1. Various direction of wheelchair handle.

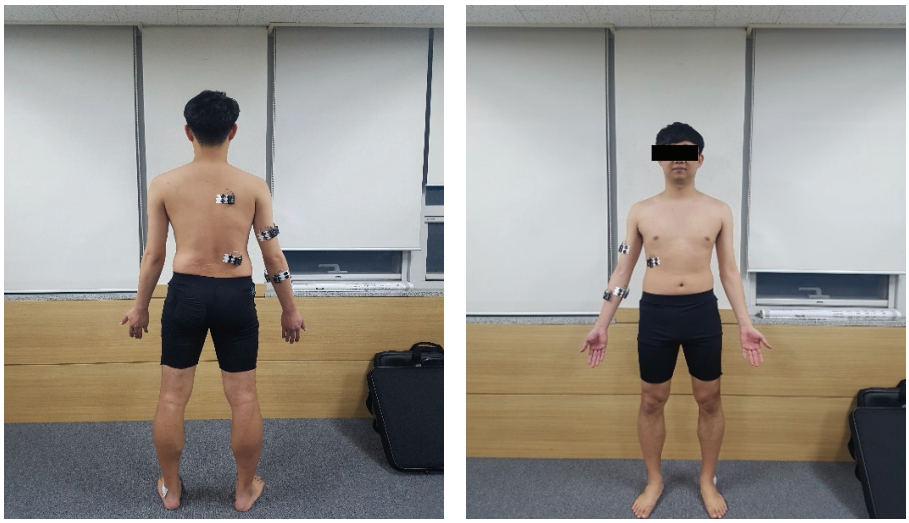

Fig. 2. Adhesive positions of surface EMG electrodes.

Noraxon, Scottsdale, USA). The EMG frequency was sampled at 2000Hz for recording, and the band pass filter was processed at 20-450Hz, and the root mean square (RMS) value was obtained. Other signal processing was processed by rectification and smoothing. To normalize the measured muscular activities, the EMG signals were standardized at certain actions as reference voluntary contraction, or %RVC, for reference values. The measurement posture for RVC value acquisition was maintained in an upright posture for 5 seconds in an anatomical posture. To measurement, the subjects removed their shirts, and medical alcohol cotton was wiped on their skin before the electrodes were attached.

4) Borg's CR-10 Scale

The Borg's CR-10 Scale, which is used in this study, is a subjective method of evaluating the physical discomfort of the work by dividing the physical discomfort into 0~10. Borg's CR-10 Rating Scale is "0" means "no intensity" It means the feeling when sitting comfortably or lying down, and "10" means strong strength that is unbearable (Woo, 2001)(Table 1).

Table 1. Borg's CR-10 Scale

Rating	Exertion scale
10	Extremely strong
9	
8	
7	Very strong
6	
5	Strong
4	
3	Moderate
2	Weak
1	Very weak
0	Nothing at all

3. Measurement method

After providing instruction methods for the subjects, we applied a randomized controlled trial approach to determine the order of using the three wheelchair grips (general, medial, and neutral). According to the procedures, a subject climbed the uphill ramp by pushing

Fig. 3. Ramp ascent.

a wheelchair to which a 60kg sandbag had been attached (Fig. 3). Muscular activities were measured until the chair's front wheel had gained the summit of the ramp and the rear wheel touched the ramp, while the subjective inconvenience was measured with the Borg CR10 Scale, one of the evaluation methods for rating of perceived exertion, to determine how the participant subjectively assessed his physical inconvenience during ramp climbing. This measurement was repeated three times for each grip direction. To prevent substitution, a three-minute rest period was provided after the three repetitive measurements for each grip.

4. Statistical analyses

To map the general characteristics of the subjects, the mean and standard deviations of their ages, heights, and weights were obtained by descriptive statistics. A repeated measure using ANOVA compared the EMG and the subjective assessment of physical inconvenience of the same subject during wheelchair propulsion on the ramp according to the three grip directions. The subjects were selected by applying power (80%) and effect side (1.0) using the G-power 3.1 program and 18 players were selected for each group (Cohen, 1988). A total of 20 subjects were selected considering the dropouts. A contrast test within subjects was performed. SPSS 18.0 (version 18.0 for Windows, IBM, USA) was used to process the data statistically. The significance level (p) was set at 0.05.

Ⅲ. Result

1. General characteristics of the research subjects

Table 2 shows the general characteristics of the subjects. The subjects consisted of 20 men who were 22.85±2.64 years of age, 175.35±4.50cm in height, and weighing 70.80±8.24kg.

2. Comparison of trunks muscle activity

Comparison of trunks muscle activity of the wheelchair handle grip direction when climbing the ramp (Table 3).

Table 2. General characteristics of subjects (n=20)

Sex (gender)	Male (20)/Female (0)
Age (years)	22.85±2.64
Height (cm)	175.35±4.50
Weight (kg)	70.80±8.24

Mean±SD

3. Comparison of muscular activities of the serratus anterior during each intervention method

There were no statistically significant differences in the muscular activities of the serratus anterior between use of the general grip and the medial grip, the general grip and the neutral grip, or the medial grip and the neutral grip ($p>0.05$)(Table 4).

Table 3. Comparison of trunks muscle activity of the wheelchair handle grip direction when climbing the ramp

Muscle	General	Meidal	Neutral	F	p
SA	267.81±26.24	261.80±21.55	232.11±18.45	0.73	0.49
RM	825.11±170.34	685.62±140.89	581.09±121.80	0.71	0.50
ES	492.51±50.62	465.86±45.44	402.23±38.92	1.05	0.36

*p<0.05, Mean±SE
SA: serratus anterior muscle, RM: rhomboid major muscle, ES: erector spinae muscle
General: general grip, Medial: medial grip, Neutral: neutral grip

Table 4. Comparison of muscular activities of the serratus anterior during each intervention method

Period	TypeⅢSS	df	MS	F	p
Period × group	15860.21	1.50	10564.06	1.38	0.26
General vs Medial	19727.99	1.00	19727.99	1.24	0.28
General vs Neutral	27246.92	1.00	27246.92	1.88	0.19
Medial vs Neutral	605.66	1.00	605.66	0.14	0.71

*p<0.05, TypeⅢSS: typeⅢ sum of squares, df: degree of freedom, MS: mean squares, General: general grip, Medial: medial grip, Neutral: neutral grip

Table 5. Comparison of muscular activities of the rhomboid major during each intervention method

Period	TypeⅢSS	df	MS	F	*p*
Period × group	1048235.71	1.14	916876.40	7.66	0.01*
General vs Medial	1334646.45	1.00	1334646.45	7.12	0.02*
General vs Neutral	1778285.89	1.00	1778285.89	8.58	0.01*
Medial vs Neutral	31774.80	1.00	31774.80	1.95	0.18

*p<0.05, TypeⅢSS: typeⅢ sum of squares, df: degree of freedom, MS: mean squares, General: general grip, Medial: medial grip, Neutral: neutral grip

4. Comparison of muscular activities of the rhomboid major during each intervention method

The muscle activity of rhomboid major was statistically significantly increased in general grip compared to general grip and medial grip, and between general and neutral grip ($p<0.05$), but not between the medial grip and the neutral grip ($p>0.05$)(Table 5).

5. Comparison of muscular activities of the lumbar erector spinae during each intervention method

The muscle activity of erector spinae was statistically significantly increased in general grip compared to general grip and medial grip, and between general and neutral grip ($p<0.05$), but not between the medial grip and the neutral grip ($p>0.05$)(Table 6).

6. Comparison of subjective discomfort during each intervention method

The significant differences in the subjective discomfort was statistically significantly increased in general grip compared to general grip and medial grip ($p<0.05$), but not between the general grip and the medial grip and between the medial grip and the neutral grip ($p>0.05$) (Table 7).

Ⅳ. Discussion

Wheelchair propulsion can activate the muscles of the trunk (Lee et al., 2014), including the rhomboid major and the lumbar erector spinae. These two are important components of the trunk muscles (Seo et al., 2015) that balance the body against external loads, such as gravity or lifting of heavy objects (Choi et al., 2005). When resistance rises against weight, the trunk muscles show

Table 6. Comparison of muscular activities of the lumbar erector spinae during each intervention method

Period	TypeⅢSS	df	MS	F	*p*
Period × group	91569.77	1.98	46369.67	4.33	0.02*
General vs Medial	71718.28	1.00	71718.28	4.78	0.04*
General vs Neutral	178911.31	1.00	178911.31	6.56	0.02*
Medial vs Neutral	24079.72	1.00	24079.72	1.15	0.30

*p<0.05, TypeⅢSS: typeⅢ sum of squares, df: degree of freedom, MS: mean squares, General: general grip, Medial: medial grip, Neutral: neutral grip

Table 7. Comparison of subjective discomfort during each intervention method

Period	TypeⅢSS	df	MS	F	*p*
Period × group	4.72	2.00	2.36	3.48	0.04*
General vs Medial	5.35	1.00	5.35	4.00	0.06
General vs Neutral	8.46	1.00	8.46	5.69	0.03*
Medial vs Neutral	0.36	1.00	0.36	0.29	0.60

*p<0.05, TypeⅢSS: typeⅢ sum of squares, df: degree of freedom, MS: mean squares, General: general grip, Medial: medial grip, Neutral: neutral grip

a high activity level by strongly contracting, followed by increased body extension (Lee & Kwon, 2013). The more the muscular activities of the trunk increase, the greater the force applied to both hands (Cha, 2008), while, at the same time, the activities of the wrist muscles increase (Jang et al., 2013). Heo et al. (2014) reported that the muscle activity of the trunk muscle varies according to the shape of the walker and the shape of the handle. And Choi (2012) reported that the activity of the trunk muscle varies with the height of the handle of the walker.

In this study, there was a significant difference in the activities of the rhomboid major and the lumbar erector spinae between use of the general and medial grip wheelchair handles. The general grip requires more muscular strength in the wrists to generate the same power, because the wrists are ulnarly deviated (Yang et al., 2006). The medial grip, which pronates the wrists, requires minimum grasping power (Razza et al., 2010). When grasping power weakens, the muscular activities of the wrists also decrease (Park & Kim, 2012). Thus, the general grip put more load on the wrists because of its ulnar deviation, resulting in an increase in the muscular activities of the trunk, while the medial grip decreased the muscular activities of the wrists due to wrist pronation, decreasing the muscular activities of the trunk. In addition, significant differences were noted between use of the general grip and the neutral grip because the neutral grip put the wrists in a neutral position, which stabilized the trunk muscles (Lee, 2008). Similarly, Ahn (2018) reported that the wrist neutral grip showed lower muscle activity than the general grip posture.

At the same time, the rhomboid major and the erector spinae, which contribute to trunk stabilization, showed a lower level of activity. In this study, serratus anterior there was no significant difference between the three grips. Because the serratus anterior contributed to the balance of the body and stability of the scapula during wheelchair propulsion regardless of the handle direction (Kim et al., 2013).

The Borg CR10 Scale, as a subjective measure, is used to investigate subjective inconvenience, such as pain or suffering, by measuring body parts (Kim, 2013). Although subjective scales are easier to use than other quantitative measurements and provide valid and reliable data on physical efforts included in job performance, they are affected by the efforts of experimenters, thus requiring particular attention to using or analyzing subjective measurements and sometimes combination with other quantitative techniques (Woo, 2001). Moreover, the subjective inconvenience can be different based on the position of the wrists during job performance (Choi et al., 2005) or the angles of ramps in wheelchair propulsion (Kim, 2012). In the study, significant differences were noted between the use of the general and medial grips. The ulnar deviation of the wrists could increase the load on the wrists, inducing musculoskeletal disorders in the region (Armstrong et al., 1987; Xu & Tang, 2009).

On the other hand, the neutral position of the wrists was most ideal for performing jobs with the wrists or rehabilitation of the wrists, reducing the muscular activities of the wrist-related muscles (Lee et al., 2009; Li et al., 2005). And the neutral position also enabled the wrists to produce maximal isometric force (Kreulen & Smeulders, 2008). Werner et al. (1997) reported that the pressure in the wrists was highest (19.8mmHg) when the wrists were ulnarly deviated and lowest (8.3mmHg) when the wrists were neutral. As the result of the previous study, as the general grip was located on the ulnar deviation wrist, the wrist muscle activity increased with the increase in the pressure in the wrist, so that the trunk muscle activity increased and the subjective discomfort increased due to the relatively greater force. Neutral grip is a neutral position of the wrist. As the activity of the

wrist is lowered, the activity of the trunk of the wrist is lowered, and the subjective discomfort is decreased because the effect is relatively small.

The results of this study showed that the subjective evaluation of the rhomboid major, erector spinae and the subjective discomfort during the operation were the least in neutral grip. According to neutral grips will help improve the function of the muscular skeleton system and reducing subjective discomfort because ramp climbing can reduce the load on the trunk muscles and maximize efficiency with less force.

Ⅴ. Conclusion

The results of this study showed that the subjective evaluation of the rhomboid major, lumbar erector spinae muscle activity and the physical discomfort during the operation were the least in neutral grip. According to neutral grips will help improve the function of the muscular skeleton system, because ramp climbing takes less strain on the trunk muscles and reduces subjective discomfort. The limit of this research is also not being studied for occupational groups engaged in wheelchair assistance work, and the number of subjects to generalize the results of this research is insufficient. Therefore, in future research, we hope that the research will be carried out on occupational groups related to wheelchair assistance and the results of this research will be reflected.

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