Effect of various wheelchair handle grip directions on muscle activities of upper body of assistant during movement on ascending and descending ramps

SANG-YEOL LEE, PT, PhD1), SU-KYOUNG LEE, PT, PhD2)*, SU-HONG AHN, PT, MS3)

1) Department of Physical Therapy, Kyungsung University, Republic of Korea
2) Department of Physical Therapy, College of Nursing, Healthcare Sciences and Human Ecology, Dong-Eui University: 176 Eomgwangno, Busanjin-gu, Busan 47340, Republic of Korea
3) Department of Biomedical Health Science, Dong-Eui University, Republic of Korea

Abstract. [Purpose] This study aims to determine the effects of various wheelchair handle grip directions on the muscle activities of the upper body of an assistant during movement on ascending and descending ramps. [Subjects and Methods] The study subjects were 17 young and healthy participants whose mean age, height, and weight was 23.0 ± 2.7 years, 175.5 ± 4.7 cm, and 70.0 ± 14.2 kg, respectively; all subjects voluntarily consented to participate. Three grip directions were tested: general grip, medial grip, and neutral grip. Muscle activities in the serratus anterior, rhomboid, erector spinae, biceps brachii, triceps brachii, bracioradialis, flexor carpi radialis, and extensor carpi radialis were measured using an electromyograph (EMG). [Results] Significant differences were seen in the muscle activities of the biceps brachii, bracioradialis, and flexor carpi radialis during wheelchair movement on an ascending ramp and in the biceps brachii and triceps brachii during movement on a descending ramp. [Conclusion] Measurement results showed that the general grip resulted in the highest muscle activities in the upper body of assistants during wheelchair movement on both ascending and descending ramps.

Key words: Wheelchair, Handle grip, Ramp

INTRODUCTION

With developments in medicine and improvements in medical technologies, average life spans have increased1). In turn, the number of people with disabilities has increased2). Disabled people and the elderly often use wheelchairs for movement or as a walking aid, thereby improving their quality of life and social accessibility and participation3) 4). Steps have typically been used to enter buildings or facilities; however, disabled people must use ramps. Walking or moving through ramps is now becoming essential for both the general public and disabled people5). Ramps are used to move strollers, wheelchairs, or bicycles vertically in outdoor spaces, because these are otherwise difficult to move through steps6). Although ramp slopes should be less than 1:12 in principle, the slope can be up to 1:8 if the vertical height is less than 100 cm, as specified in regulations7). During wheelchair propulsion on a sloped ramp, different motor patterns or muscle strengths are required. However, the elderly, women with poor muscle strength, or disabled people8) may need the assistance of guardians or caregivers9). Caregivers must perform repetitive actions of the body, such as moving and lifting patients or bending at the waist, that impose high loads on their musculoskeletal systems. Thus, they are one of the most vulnerable groups to occupational musculoskeletal disorders10). In particular, caregivers who use their arms often to push and pull wheelchairs are vulnerable to musculoskeletal...
disorders such as De Quervain’s tendinitis, carpal tunnel syndrome, and elbow pain\textsuperscript{11}. Furthermore, inappropriate postures resulting from the handle size and grip method of wheelchairs can influence the grip force\textsuperscript{12}, and muscle activities may be affected by the type of grip tool\textsuperscript{13, 14}. Thus, the present study aims to determine the effect of various wheelchair handle grip directions on the muscle activities of the upper body of assistants when ascending or descending a ramp.

**SUBJECTS AND METHODS**

The subjects were fully informed of the study purpose beforehand, and all of them voluntarily consented to participate. The subjects were 17 young and healthy participants whose mean age, height, and weight was 23.0 ± 2.7 years, 175.5 ± 4.7 cm, and 70.0 ± 14.2 kg, respectively. The subjects had no neurological and musculoskeletal problems in the last one year as well as no pain or joint movement limits in the upper and lower extremities. The procedures of this study were harmless to the human body. All subjects read and signed a written consent form. They listened to an account of the study’s purpose and methods, understood the study content and consented to participate in this experiment. The ramp used in the experiment had height, width, length, and gradient of 45 cm, 100 cm, 360 cm, and 1.8, respectively. The manual wheelchair (MIRAGE-22, MIKI Korea) had length, width, and height of 100 cm, 62 cm, and 86 cm, respectively. A handle with grips in three directions was manufactured and attached to this wheelchair. A 60 kg weight was placed in the wheelchair to simulate the weight of a person. The TeleMyo 2400T wireless electromyograph (EMG) (Noraxon Co., USA) was used to collect data to measure the muscle activities of the wheelchair assistant during wheelchair movement on ascending and descending ramps; the order of ascending and descending the ramp was randomized. The EMG was attached to the serratus anterior, rhomboid, erector spine, biceps brachii, triceps brachii, bracioradialis, flexor carpi radialis, and extensor carpi radialis\textsuperscript{15}. One-way analysis of variance (ANOVA) was used to determine the muscle activities when ascending and descending ramps according to the grip on the wheelchair handle, and the least significant difference (LSD) was used for a post-hoc test. SPSS version 22.0 was used to conduct statistical data analysis, and the level of significance was set to 0.05.

**RESULTS**

A significant difference was found in the biceps brachii, bracioradialis, and flexor carpi radialis during wheelchair movement on the ascending ramp (p<0.05) (Table 1) and in the biceps brachii and triceps brachii during wheelchair movement on the descending ramp (p<0.05) (Table 2).

**DISCUSSION**

The present study was conducted to determine the muscle activities in the upper body of a wheelchair assistant for various handle grip directions when ascending and descending on a ramp. Three grip directions were tested: general grip, medial grip, and neutral grip. Moon and Kim\textsuperscript{16} reported that in 40.3% of cases, patients used wheelchairs themselves, and in 59.7% of cases, guardians or caregivers moved the wheelchairs. Furthermore, 97.5% of wheelchairs were manual and 2.5% were electric. In their study, 35.3% of wheelchair users found it most inconvenient to move on a ramp slope, and more than half of them required a guardian or caregiver to move their wheelchair.

During wheelchair movement on an ascending ramp, the biceps brachii, bracioradialis, and flexor carpi radialis showed significant muscle activities. Lee et al.\textsuperscript{17} reported that an individual’s maximum voluntary contraction (MVC) was affected by the type of handle bar, movement location, and gender. Another study reported a higher proportion of female caregivers compared to male ones. Another study reported that females exhibited 51.6% of MVC when pushing a wheelchair compared to that of males, and females were more vulnerable to musculoskeletal disorders than males. In fact, Moon and Kim\textsuperscript{18} found that caregivers found it most difficult to go up and down the stairs using manual wheelchairs, and therefore, they recommended wheelchair designs that could facilitate movement on a slope. To move a wheelchair with a person weighing 60 kg on an ascending ramp, the biceps brachii was used to bend the arms, the bracioradialis was placed in a neutral position of the wrist to maintain the general grip, and the flexor carpi radialis was activated to grip the wheelchair handle strongly; therefore, these three muscles were more activated than the other muscles when ascending the ramp. Among the three grips, the general grip showed the highest muscle activity. Moreover, the general grip and medial grip showed a significant difference in muscle activities in the post-hoc test. The general grip handle is used widely because it is convenient for use in foldable wheelchairs, which are easy to carry in a vehicle or to store in a narrow space. However, the general grip results in increased muscle activities in the wrists or upper arms. Furthermore, a significant difference in muscle activity was found in the biceps brachii and triceps brachii during wheelchair movement on a descending ramp. On a descending ramp, most muscles measured in a general grip showed high activities, and the general grip showed higher muscle activities than the other grips in the post-hoc test. This is because the co-contraction of the biceps brachii and triceps brachii was used to maintain the arm’s bending to prevent the wheelchair from sliding downward fast. Because no EMG results for the lower extremity are available in this study, the compensation in the lower extremity to control the wheelchair in other than the handle direction cannot be determined; this is a limitation of this study.
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Table 1. Comparison of muscle activations of uphill ramp (unit: %RVC)

| Muscle | General grip | Medial grip | Neutral grip |
|--------|--------------|-------------|--------------|
| SA     | 242.4 ± 101.4 | 252.4 ± 88.9 | 224.5 ± 66.7 |
| RM     | 891.8 ± 723.4 | 777.4 ± 692.4 | 645.6 ± 446.6 |
| ES     | 582.7 ± 240.5 | 537.0 ± 223.3 | 543.8 ± 231.0 |
| BB*    | 3,430.8 ± 2,012.5† | 1,803.5 ± 1,139.0† | 2,725.5 ± 2,069.2 |
| TB     | 1,252.5 ± 830.5 | 1,611.4 ± 1,089.1 | 1,311.1 ± 794.8 |
| BR*    | 2,088.6 ± 1,068.1†¥ | 1,433.1 ± 763.5† | 1,323.4 ± 943.7† |
| FCR*   | 2,340.4 ± 1,075.2† | 1,311.0 ± 593.1† | 1,905.0 ± 1,005.2 |
| ECRB   | 1,998.3 ± 812.49 | 2,386.1 ± 1,617.8 | 1,813.3 ± 1,230.2 |

* † ‡ ¥ Significant difference between general grip and neutral grip (p<0.05).
† Significant difference between general grip and medial grip (p<0.05).
‡ Significant difference between medial grip and neutral grip (p<0.05).

Table 2. Comparison of muscle activations of downhill ramp (unit: %RVC)

| Muscle | General grip | Medial grip | Neutral grip |
|--------|--------------|-------------|--------------|
| SA     | 177.7 ± 52.3 | 189.7 ± 56.5 | 177.8 ± 57.6 |
| RM     | 551.0 ± 470.8 | 536.5 ± 503.3 | 444.7 ± 407.5 |
| ES     | 301.7 ± 117.4 | 317.5 ± 142.9 | 265.5 ± 83.2 |
| BB*    | 1,237.0 ± 688.8†* | 640.2 ± 370.5† | 664.9 ± 369.7† |
| TB*    | 700.6 ± 290.9† | 1,113.1 ± 458.7† | 701.4 ± 321.2† |
| BR     | 1,720.5 ± 756.3 | 1,622.6 ± 733.7 | 1,408.6 ± 825.6 |
| FCR    | 2,893.8 ± 1472.2 | 2,749.2 ± 1,058.4 | 2,296.7 ± 2,139.1 |
| ECRB   | 1,809.0 ± 1234.2 | 1,582.5 ± 762.2 | 1,484.0 ± 1,140.4 |

* † ¥ Significant difference between general grip and neutral grip (p<0.05).
† Significant difference between general grip and medial grip (p<0.05).
‡ Significant difference between medial grip and neutral grip (p<0.05).
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