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Effect of Wheelchair Seat Height on Shoulder and Forearm Muscle Activities during Wheelchair Propulsion on a Ramp

Sang-Yeol Lee, PhD, PT[1)], Seon-Chill Kim, PhD, RT[2)], Myoung-Hee Lee, PhD, PT[3)]

[1)] *Department of Physical Therapy, College of Science, Kyungsung University*
[2)] *Department Radiologic Technology, Daegu Health College: Taejun-dong, Bukgu, Daegu, 702-722 Republic of Korea, TEL: +82 53-320-1458, FAX: +82 53-320-1449*
[3)] *Department of Physical Therapy, Daegu Health College*

Abstract. [Purpose] The purpose of this study was to suggest the proper seat height for wheelchair propulsion on a slope. [Subjects] Participants who met the criteria for this study (n=20). [Methods] Muscular activity was measured while propelling the wheelchair using the chairs of heights corresponding to elbow flexion angles of 0, 30, 60 and 90 degrees. To eliminate the effect of muscular fatigue that might have been caused, wheelchair propulsion with the four elbow joint angles was randomly performed. EMG electrodes to the attached were pectoralis major, flex carpi radialis, extensor carpi radialis, serratus anterior, anterior deltoid, biceps brachi, triceps and lattisimus dorsi. [Results] The anterior deltoid, pectoralis major, triceps, extensor carpi radialis and flexor carpi radialis muscle activations showed significant differences between each groups. [Conclusion] This study investigated propulsion on a slope, not flat ground, where propulsion force is offset by potential energy. Thus, unlike flat ground, where small muscle activity is sufficient for propulsion, much muscle activation is necessary to stably go up a ramp.Our results show that in climbing a ramp, user stability is likely to be compromised at wheelchair seat heights eliciting elbow flexion of less/greater than 60 degrees.

Key words: Muscle activation, Slope way, Wheelchair propulsion

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INTRODUCTION

In order to improve the quality of life of the disabled, their accessibility to society should be guaranteed, for which their mobility in necessary[1)]. For the disabled, a wheelchair is essential for daily life. Use of a wheelchair necessarily results in inconvenient situations. For instance, a ramp is essential at a building entrance to allow wheelchair access. To accommodate this situation, the Welfare Act for the disabled, elderly, and pregnant women (the Ministry of Health, Welfare and Family Affairs, 1997) suggests a 1:12 slope for a ramp. The low suggests a ramp slope, but there is no legal requirement for the structure of a wheelchair.

Lee et al.[3)] suggested a wheelchair seat height suitable for mobility on flat ground. Applying this methodology we investigated the ideal wheelchair height for propulsion on a ramp with a 1:12 slope.

SUBJECTS AND METHODS

The subjects of this study were 20 healthy adults in their twenties who had normal range of motion (ROM) and no musculoskeletal disease. A sufficient explanation of the experimental procedures was provided to the subjects who provided their written consent to voluntary participation.

To limit the difficulty of the wheelchair propulsion in each condition, measurements were performed while propelling the wheelchair over a distance of 3 m on a ramp at maximum speed and the mean measurement values were used in the analysis. To evaluate the muscular activity while propelling the wheelchair at different chair heights, the chair height was adjusted with reference to the elbow joint flexion angle with the user sitting on the chair holding the highest part of the wheelchair wheels. Muscular activity was measured while propelling the wheelchair using chair heights corresponding to elbow flexion angles of 0°, 30°, 60° and 90°. To eliminate the effect of muscular fatigue, that might have occurred during wheelchair propulsion, chair heights corresponding to the four elbow joint angles were randomly used in the experiment. The slope of the ramp was 1:12, as mandated by the Ministry of Health, Welfare and Family Affairs in Korea[2)].

To collect accurate electromyographic data, epilation was carried out with a razor on the parts of the skin to which the electrodes were attached, horny substance was removed with sandpaper, and the parts were cleansed with an alcohol swab. The chosen parts to which the electrodes were the attached were pectoralis major, serratus anterior, extensor carpi radialis, flexor carpi radialis, anterior deltoid, biceps brachi, triceps and lattisimus dorsi.

ProComp InfinitiTM (Thought Technology Ltd., Canada) was employed for the measurement of the muscle

Table 1. Comparison of muscle activaties according to elbow flexion angle when using wheelchair on a ramp

	0°	30°	60°	90°
AD*	18172.8 ± 935.8[a]	17683.2 ± 1119.8[a]	17227.8 ± 937.5[a]	11792.3 ± 750.5[b]
PM*	5330.9 ± 601.1[a]	5893.7 ± 322.3[a]	6245.52 ± 289.0[a]	7707.5 ± 357.5[b]
SA	5174.1 ± 875.1	4881.5 ± 799.9	5414.6 ± 1102.0	4612.9 ± 933.1
BB	9848.4 ± 1151.6	9735.2 ± 1878.6	8295.4 ± 1459.7	7224.0 ± 1465.1
FCR*	5826.8 ± 268.3[a]	6426.1 ± 192.8[a]	6590.7 ± 536.8[a]	7568.1 ± 474.3[b]
LD	2254.4 ± 360.3	2523.9 ± 365.3	3216.6 ± 705.4	1750.3 ± 312.1
ECR*	5392.8 ± 328.7[a]	5813.0 ± 399.2[a]	5971.1 ± 455.6[a]	7152.7 ± 394.3[b]
Tri*	4390.9 ± 524.4[a]	4983.1 ± 614.1[a]	6347.0 ± 668.8[b]	6725.5 ± 726.7[b]

unit : %RVC. mean ± SE.
AD : anterior deltoid; PM : pectoralis major; SA : serratus anterior; BB : biceps brachi; FCR : flexor carpi radialis; LD : latissimus dorsi; ECR : extensor carpi radialis; Tri : triceps brachii
NOTE. Each value represents the mean ± SE. The values with different superscripts in the same row are significantly different ($p<0.05$) by Tukey's measure. * : statistically significant with $p<0.05$.

activity of each muscle. A surface electrode (Triode surface electrode, Thought Technology Ltd., Canada) consisting of a tripolar electrode (positive-ground-negative) was used. The frequency range of the electromyograms was chosen as 20 to 500 Hz, and the sampling frequency was selected as 1024 Hz.

The root mean square of each muscle was measured for five seconds in the anatomical position. Relative muscle contraction was calculated referring to the mean of the electromyogram signal measured for the three seconds in the middle of 5 seconds of data, excluding the data of the first one second and the last one second, and expressed as the muscle activation in % RVC for 10 m performance of wheelchair propulsion.

The measured data were analyzed processed by one-way ANOVA using with SPSS (version 12.0) for Windows to compare the muscle activaties among the wheelchair chair heights. The level of significance was chosen of 0.05.

RESULTS

The anterior deltoid muscle activities were 18172.85 at 0°, 17683.26 at 30°, 17227.89 at 60°, and 11792.31 at 90° with significant differences ($p<0.05$). The pectoralis major muscle activations were 5330.98 at 0°, 5893.74 at 30°, 6245.52 at 60 ° and 7707.50 at 90°, with significant differences ($p<0.05$). Posthoc test found statistically significant differences between 30° and 90°, 60° and 90°, 0° and 90° for the anterior deltoid and pectoralis major muscles ($p<0.05$) (Table 1).

The flexor carpi radialis muscle activities were 5826.85 at 0°, 6426.19 at 30°, 7590.74 at 60°, and 7568.12 at 90° with significant differences ($p<0.05$). The extensor carpi radialis muscle activities were 5392.89 at 0°, 5813.03 at 30°, 6971.15 at 60°, and 7152.77 at 90° with significant differences ($p<0.05$). The triceps muscle activities were 4390.99 at 0°, 4983.12 at 30°, 9347.00 at 60°, and 6725.57 at 90° with significant differences ($p<0.05$). Tukey's posthoc test found statistically significant differences between 0° and 60°, 0° and 90°, 30° and 60°, and 30° and 90° at flexor carpi radialis, extensor carpi rasialis, triceps muscle ($p<0.05$)(Table 1).

DISCUSSION

Using the method of Lee et al.[3)], we analyzed muscular activaties with respect to wheelchair seat height during wheelchair propulsion on a ramp to investigate the ideal wheelchair seat height for propulsion on a ramp.

There have been a variety of studies of joint movements during wheelchair propulsion[4, 5)] and suitable wheelchair structure for wheelchair propulsion[3)], but there have not been many studies of wheelchair propulsion on a ramp, a frequent situation confronting disabled people in their daily lives. Most studies have investigated propulsion on flat ground.

On a ramp, unlike flat ground, due to the angle, the trunk flexors are used to place the center of gravity in front to prevent the wheelchair from going backwards. To accommodate this change, the lower the height of a wheelchair is, the more the pectoralis major muscle is activated to increase the propulsion force to supplement trunk flexion while the hip joint is flexed. This is different from the result of Lee et al.[3)] for propulsion on flat ground with wheelchair seat heights, probably because of the posture which change occurs in propulsion on a ramp.

Hyperextension occurs due to relatively greater shoulder extension occurring as a result of trunk flexion at a wheelchair height of 90° elbow flexion, and shoulder extension occurring as the wheelchair height increases. This appears to be because the length of anterior deltoid fibers become too long/short to generate sufficient force as described by the length-tension curve of the muscle[6)].

Besides, triceps muscle activation increases as the wheelchair height decreases and this seems to be because as the height decreases, the range of triceps activity becomes wider.

Lee et al.[3)] noted that during wheelchair propulsion on flat ground, elbow joint flexion of 30° provides propulsion force using the least muscular activation. However, unlike flat ground on a ramp, propulsion is offset by potential energy. Thus, unlike the flat ground where muscular activity is only required for propulsion, climbing a ramp requires muscular activity to maintain stability and climb the ramp at the same time.

Our results indicate that on a ramp, a wheelchair height eliciting an elbow joint of less/greater than 60° flexion interferes with user stability. Besides, inappropriate activity in a wheelchair may cause radial deviation of the wrist and carpal tunnel syndrome[7]. The result of this study shows that a wheelchair seat height eliciting an elbow joint of 90° flexion may cause carpal tunnel syndrome due to excessive use of the extensor carpi radialis and flexor carpi radialis muscle to improve stability.

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REFERENCES

1) Rodgers MM, McQuade KJ, Rasch EK, et al.: Upper-limb fatique-related joint power shifts in experienced wheelchair users and nonwheelchair users. J Rehabil Res Dev, 2003, 40: 27–37. [Medline] [CrossRef]
2) Ministry for Health, Welfare and Family Affairs (Korea): The law about Disabled people, elderly people, pregnant woman's convenience enhancement guarantee. 2010.
3) Lee SY, Kim SC, Lee MH, et al.: Effect of the height of wheelchair on the shoulder and forearm muscular activation during wheelchair propulsion. J Phys Ther Sci, 2012, 24: 51–53. [CrossRef]
4) DiGiovine CP, Cooper RA, Boninger ML: Dynamic calibration of a wheelchair dynamometer. J Rehabil Res Dev, 2001, 38: 41–55. [Medline]
5) Boninger ML, Cooper RA, Shimada SA, et al.: Shoulder and elbow motion during two speeds of wheelchair propulsion: a description using a local coordination system. Spinal Cord, 1998, 36: 418–426. [Medline] [CrossRef]
6) Neuman DA: Kinesiology of the musculaoskeletal system. Singapore: Elsevier, 2004.
7) Veeger HE, Meershoek LS, van der Woude LH, et al.: Wrist motion in handrim wheelchair propulsion. J Rehabil Res Dev, 1998, 35: 305–313. [Medline]