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Original Article

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The Effects of Various Directions of Handle Grip on the Upper Limb Muscle Activity of Wheelchair Attendants during Ramp Climbing

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| Abstract |

Purpose: This study aimed to determine the effects of various wheelchair handling directions on the upper limb muscle activities of wheelchair attendants while climbing a ramp.

Methods: For the study participants, healthy males over 20 years of age were chosen, and the order of the direction of wheelchair handle grip was determined using a randomized method. The handling directions for pushing the wheelchair up a ramp included a general grip with ulnar deviation, a medial grip with wrist pronation, and a neutral grip with a neutral wrist. The muscle activities in the participants' upper limbs were measured using surface electromyography. For statistical data processing, SPSS 18.0 was used to perform repeated measures ANOVA in order to compare the muscle activity among the intervention groups. A contrast test was also conducted among the participants. The significance level (α) was set to 0.05.

Results: There was a significant difference between groups using a general grip and a medial grip in the biceps brachii, triceps brachii, and flexor carpi radialis muscles ($p<0.05$). There was also a significant difference between using a general grip and a neutral grip in the biceps brachii and flexor carpi radialis muscles ($p<0.05$), and there was a significant difference between using a medial grip and a neutral grip in the biceps brachii and extensor carpi radialis brevis muscles ($p<0.05$).

Conclusion: In this study, the wheelchair assistants' wrist muscle activity was the lowest with a neutral grip while ascending a ramp. Accordingly, this study proposes that wheelchair assistants push wheelchairs up ramps with a neutral grip.

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

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Ⅰ. Introduction

Average life expectancy has recently increased thanks to the advancement of medical science and improvement of medical techniques (Kim, 2017). At the same time, the number of people who suffer from disabilities continues to growth (Kwon & Kong, 2005). Recovery of the quality of life and return to the society of the disabled has become an important social issue where the security of mobility becomes the first requirement (Sie et al., 1992). Wheelchair, which is a representative walking aid for people with disabilities, helps easy mobility of the disabled and induces their social participation through increased social accessibility. Wheelchair also provides convenience of mobility to the elderly people or those who have difficulties in walking (Kim, 2015; Kwon & Kong, 2005). Wheelchair is essential in daily life for vertical movement in spaces that have grounds with different height, such as building entrance (Kim et al., 2010). Stairs and ramp are most frequently observed vertical shift facilities in our daily life. Stairs are difficult to use for mobility devices with wheels, such as wheelchair, stroller, and bicycles, as well as people with reduced mobility. Ramp is indispensable for those who have difficulties in using stairs and installation of ramp is becoming more universal these days (Yoo, 1995). As pushing wheelchair on ramp requires stronger power than pushing it on the ground, pushing wheelchair on ramp or uneven surface is particularly difficult for elderly people or women with weak muscle strength (Jang et al., 2016; Kim, 2012). Wheelchair users with severe disability who are unable to move without help from assistant also have difficulties in using ramp (Lee et al., 2010). Most of the wheelchair users who have severe disability need assistant and they need help from caregiver when moving from wheelchair to restroom or moving from bed to wheelchair (Lee et al., 2011). Caregivers frequently use their body in a repeated way, such as moving patients, lifting patients, or bending lower back, and they are one of the groups that experience high incidence rate of musculoskeletal disease (Collins et al., 1996). Certain musculoskeletal diseases that occur in arm are occupational illness (Yun et al., 2001), which include De Quervain’s tendinitis and carpal tunnel syndrome (Kim et al., 2007). Force, repetition, inappropriate posture, and vibration are some of the risk factors that can occur in case of repeated use of arms (Sanders, 2004). The external force that occurs from inappropriate posture caused by the size of handle or gripping method affects the gripping power and the force on the gripping tool is determined by the intended motion (Buchholz et al., 1988; Kuorinka & Forcier, 1995). Although a few previous studies examined the effects of tool-gripping direction on the muscle activity (Lee et al., 1996; Potvin et al., 2004), most of them focused on certain few muscles (Choi, 2007). This study examines how the muscle activity of wheelchair assistants’ arm changes according to the direction of wheelchair grip when they push wheelchair on ramp with a 60kg sandbag fixed on the wheelchair.

Ⅱ. Methods

1. Participants

Male students over the age of 19 who are enrolled in D University located in Busan City, South Korea were selected as research subject of this study. The subjects had no experience of musculoskeletal disease and neurologic or orthopaedic contracture and pain in their upper arm during the past three months. The subjects received sufficient explanation on the purpose and method of the experiment before the implementation of the experiment. All subjects participated in the experiment

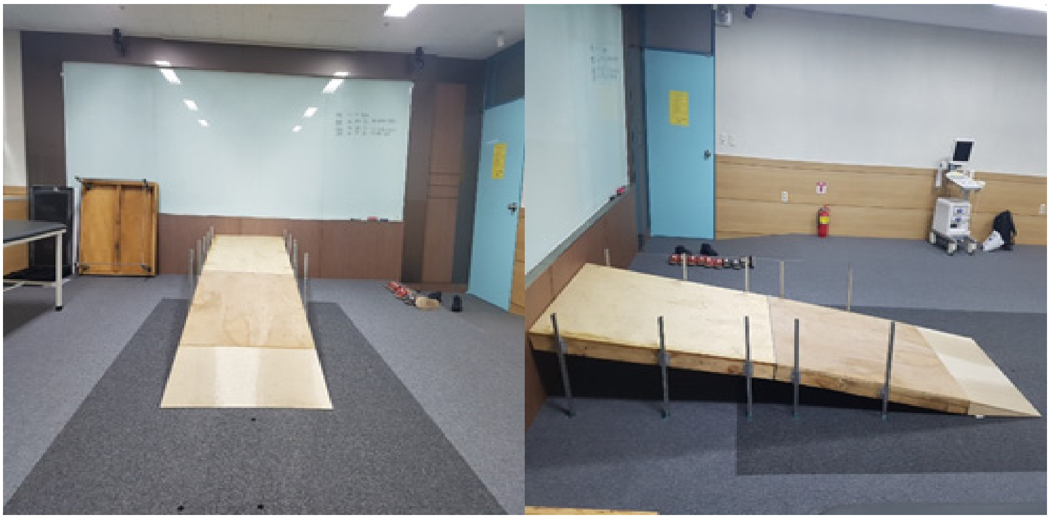

Fig. 1. Ramp design.

voluntarily. After submitting the written consent, the subjects participated in the experiment in random order. This study received approval from the Ethics Committee of Dong-Eui University for the protection of rights and safety of research subjects and obedience of law related to bioethics and safety. The approval number is DIRB-201709-HR-R-026.

2. Measurement tool

1) Design of ramp

The ramp was designed to have a height of 45cm, width of 100cm, and length of 360cm with a slope of 1 : 8(Fig. 1).

2) Design of wheelchair grip

We directly designed three types of wheelchair grips for this study: general grip for ulnar deviation, medial grip for wrist pronation, and neutral grip for wrist neutrality(Fig. 2).

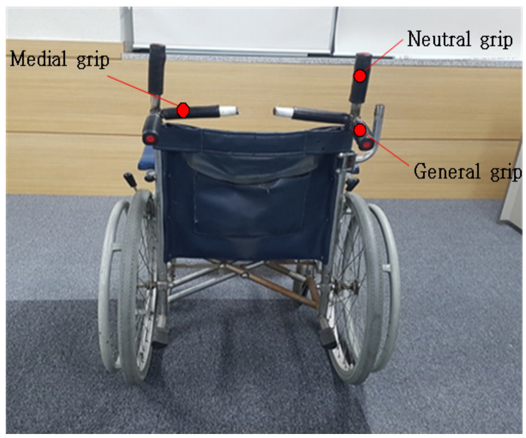

Fig. 2. Wheelchair handle grip.

3) Surface electromyogram

In this study, we used surface electromyogram of Noraxon telemyo 2400system (TM DTS, Noraxon, Scottsdale, USA) to measure the muscle activity of body trunk and arm on the right side when the wheelchair assistant pushes the wheelchair. To decide the location of electrode attachment, the wheelchair assistant took a posture that can give maximum resistance to each muscle and contracted the corresponding muscle as much as possible. Then, the anode electrode was attached to muscle belly, which is the part that is most strongly activated during this posture, and the cathode electrode was attached 2cm apart from the anode electrode in parallel direction to the muscle. The electrode was attached to biceps brachii, triceps brachii, flexor carpi radialis, and extensor carpi radialis brevis. The sampling rate of electromyogram signal was set at 3,000Hz. After removing white noise by using the frequency band of 20-500Hz, we obtained the root mean square (RMS) of the measured electromyogram values. Rectification and smoothing was used for the treatment of other signals. The electromyogram signal was normalized in %RVC (reference voluntary contraction), which is used as a reference value that standardizes the electromyogram signal in certain motion (Cram et al., 1998).

3. Measurement method

In this study, the order of three types of wheelchair grip, which was general grip, medial grip, and neutral grip, was randomly determined. The research subjects pushed wheelchair with a 60kg fixed sandbag on ramp by grabbing the wheelchair grip according to the randomly determined order. The subjects climbed the ramp following the measurer's signal. The muscle activity was measured from the moment the rear wheel of the wheelchair touches the ramp while the front wheel of the wheelchair is completely on the ramp. The muscle activity was repeatedly measured for three times in each grip. To prevent the compensation act, muscle activity in each grip was repeatedly measured for three times, followed by three-minute resting time.

4. Data analysis

In this study, used SPSS version 18.0 for Windows to analyze the data collected in this study. We used repeated measure analysis of variance to compare the muscle activity of the same subject during ramp climbing according to the wheelchair grip direction and conducted within-subject contrast test. Significance level (α) in the statistical treatment was set at 0.05.

Ⅲ. Results

1. General characteristics of the subjects

The research subjects included 20men whose average age was 22.85±2.64years, average height was 175.35±4.50cm, and average weight was 70.80±8.24kg. Table 1 summarizes the general characteristics of the research subjects (Table 1).

Table 1. General characteristics of subjects (n=20)

Characteristics	Mean±SD
Age (years)	22.85±2.64
Height (cm)	175.35±4.50
Weight (kg)	70.80±8.24

2. Comparison of the muscle activity

1) Comparison of muscle activity of the wheelchair grip direction during ramp climbing (Table 2).

3. Comparison of the muscle activity among different intervention methods

1) Comparison of the muscle activity of biceps brachii muscle among differenet intervention methods

A statistically significant difference of the muscle activity of biceps brachii was observed between general

Table 2. Comparison of muscle activity of the wheelchair grip direction during ramp climbing

Muscle	General	Medial	Neutral	F	p
BC	3316.76±498.60	1289.63±182.39	2235.41±291.36	20.86	0.00*
TC	1460.43±193.49	2261.57±253.31	1668.93±205.10	3.57	0.05*
FCR	2623.05±210.98	2485.75±222.50	2159.55±163.23	3.38	0.05*
ECRB	2470.46±188.10	2830.61±221.27	1990.64±192.18	6.01	0.01*

*p<0.05, Mean±SE
BC: biceps brachii muscle, TC: triceps brachii muscle, FCR: flexor carpi radialis muscle, ECRB: extensor carpi radialis brevis muscle
General: general grip, Medial: medial grip, Neutral: neutral grip

Table 3. Comparison of muscle activity of the biceps brachii muscle among the interventions

Period	TypeⅢSS	df	MS	F	p
General vs Medial	88905439.57	1.00	88905439.57	30.72	0.00*
General vs Neutral	27551394.95	1.00	27551394.95	10.64	0.00*
Medial vs Neutral	17473390.26	1.00	17473390.26	18.65	0.00*

*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 4. Comparison of muscle activity of the triceps brachii muscle among the interventions

Period	TypeⅢSS	df	MS	F	p
General vs Medial	3967721.19	1.00	3967721.19	6.55	0.02*
General vs Neutral	782556.14	1.00	782556.14	3.18	0.09
Medial vs Neutral	1226095.39	1.00	1226095.39	1.49	0.24

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

grip and medial grip, between general grip and neutral grip, and between medial grip and neutral grip (p<0.05)(Table 3).

2) Comparison of the muscle activity of triceps brachii muscle among differenet intervention methods

There was a statistically significant difference of the muscle activity of triceps brachii between general grip and medial grip (p<0.05). No statistically significant difference was observed between general grip and neutral grip and between medial grip and neutral grip (Table 4).

3) Comparison of the muscle activity of flexor carpi radialis muscle among differenet intervention methods

A statistically significant difference of the muscle activity of flexor carpi radialis was observed between general grip and medial grip and between general grip and medial grip (p<0.05). There was no statistically significant difference between medial grip and neutral grip (Table 5).

Table 5. Comparison of muscle activity of the flexor carpi radialis muscle among the interventions

Period	TypeⅢSS	df	MS	F	p
General vs Medial	4848564.34	1.00	4848564.34	4.22	0.05*
General vs Neutral	4898747.86	1.00	4898747.86	5.60	0.03*
Medial vs Neutral	129.18	1.00	129.18	0.00	0.99

*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 6. Comparison of muscle activity of the extensor carpi radialis brevis muscle among the interventions

Period	TypeⅢSS	df	MS	F	p
General vs Medial	1660545.06	1.00	1660545.06	1.93	0.18
General vs Neutral	4898747.86	1.00	4898747.86	5.60	0.03*
Medial vs Neutral	11683158.76	1.00	11683158.76	11.79	0.00*

*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 the muscle activity of extensor carpi radialis brevis muscle among differenet intervention methods

There was a statistically significant difference of the muscle activity of extensor carpi radialis brevis between general grip and medial grip and between general grip and medial grip. There was no statistically significant difference between medial grip and neutral grip ($p<0.05$) (Table 6).

Ⅳ. Discussion

Elbow joints of biceps brachii and triceps brachii act as antagonistic muscle for each other and they occasionally work as synergist (Neumann, 2010). These two muscles involve in the flexion and extension of elbow and act as mediator that supports the basic function of lower arm (Shin, 2006). Kim (2014) reported that the muscle activity of biceps brachii and triceps brachii differs according to the types of handles of walker aid. Another previous study reported that the muscle activity of triceps brachii differs according to the form of wrist joint (Kim et al., 2011). It is known that the muscle activity of biceps brachii and triceps brachii when pushing wheelchair depends on the promotion speed and slope of ramp (Kim, 2012; Kong, 2004). In our study, a significant difference between general grip and medial grip was observed in biceps brachii and triceps brachii. Choi (2007) argued that gripping ultrasound applicator increases the muscle activity of flexor carpi ulnaris and decreases the muscle activity of extensor carpi radialis as the wrist is pronated in ulnar deviation. In our study, the muscle activity of biceps brachii was highest in general grip, which is similar to the case of gripping of ultrasound applicator. According to Newsam et al (1990), wrist shows a certain pattern when pushing wheelchair where the wrist becomes flexion and pronation condition in case of ulnar deviation and flexion and supination condition in case of radial deviation. Although wrist becomes extension and pronation condition in ulnar deviation when pushing wheelchair on flat ground, the wrist becomes extension and supination condition in radial deviation when climbing ramp. As a result, biceps brachii that is innervated by flexor and supinator of elbow joint acts most strongly (Neumann, 2010). Triceps brachii minimally acted because of the extension of elbow joint and pronation of wrist (Kim et al., 2011). In case of medial grip, the muscle activity of biceps brachii was lowest and the muscle activity of triceps brachii was highest. As the flexion moment of biceps brachii decreases in pronated wrist, the action of biceps brachii diminished. On the contrary, triceps brachii, which neutralizes the tendency of pronator teres muscle that tries to bend elbow, acted most strongly (Neumann, 2010). Only biceps brachii showed a significant difference between general grip and neutral grip. Previous studies reported that the neutral position of wrist increases the stability of elbow joint and that it induces lower muscle activity of biceps brachii (Barr et al., 2001; Lee, 2008). The movement of elbow joint is restricted during ramp climbing and the action of biceps brachii diminishes, which causes lower muscle activity in case of neutral grip. A significant difference between medial grip and neutral grip was observed only in biceps brachii. Kim (2011) argued that the neutral position of wrist during isometric exercise of elbow joint produces stronger muscle activity of biceps brachii than the case of wrist extension. It is because the movement of wrist is restricted in wrist neutral position in order to increase the stability of lower arm. As a result, the muscle activity of elbow joint, which acts as lever of lower arm, increases due to the compensation act (Kim & Park, 2011). We believe that medial grip produced lower muscle activity than neutral grip during ramp climbing as the former induced extension of wrist.

Wrist joint plays a critical role in wrist movement and it involves in the flexion, extension, ulnar deviation, and radial deviation of wrist (Park, 2012). The activity of wrist muscles changes according to the location of wrist joint (Kim, 2011) and the muscle activity also changes depending on the types of handles (Kim, 2014). In our study, we observed a significant difference of flexor carpi radialis between general grip and medial grip. General grip induces radial deviation of wrist when climbing ramp and the muscle activity of flexor carpi radialis increases because the muscle acts as synergic muscle in case of radial deviation (Neumann, 2010).

Medial grip induces wrist extension when climbing ramp and the muscle activity of wrist flexor, which acts as antagonistic muscle, consequently decreases, producing lower muscle activity of flexor carpi radialis (Kim et al., 2005; Kim, 2011). The neutral position of wrist increases the stability of wrist and hence it is proper to secure appropriate length of wrist muscle. During ramp climbing, wrist movement stabilized and the muscle activity of flexor carpi radialis decreased in case of neutral grip, which induces the neutral position of wrist. As a result, a significant difference was observed between general grip and neutral grip (Fagarasanu et al., 2004; Kwon et al., 2004; Lee et al., 2009; Son et al., 2002). A significant difference of extensor carpi radialis brevis was observed between medial grip and neutral grip. Medial grip produces higher muscle activity of wrist extensor than flexor. As the wrist extensor supports the weight of hand against gravity, medial grip produced the highest muscle activity (Mogk & Keir, 2010). On the contrary, neutral grip produced the lowest muscle activity. Barr et al (2001) argued that the activity of extensor carpi radialis decreases in case of neutral wrist position compared to wrist pronation as the gravitational influence of hand and lower arm relatively decreases (Fujii et al., 2007; Lee et al., 2009). The neutral grip produced the lowest muscle activity as the gravitational influence of hand and lower arm relatively decreased in case of ramp climbing. Summarizing the result of our study, the muscle activity of wrist was lowest in case of neutral grip, compared to general grip and medial grip in a comparison among different grips. Hence, we suggest using neutral grip when climbing ramps.

Ⅴ. Conclusion

In this study result, the muscle activity of biceps brachii and flexor carpi radialis statistically decreased and the muscle activity of triceps brachii statistically increased in case of medial grip in a comparison between general grip and medial grip. In a comparison between general grip and medial grip, the muscle activity of biceps brachii and flexor carpi radialis statistically decreased in neutral grip. In a comparison between medial grip and neutral grip, the muscle activity of biceps brachii statistically increased and the muscle activity of extensor carpi radialis brevis statistically decreased in neutral grip. Summarizing the result of our study, the muscle activity of wrist was lowest in case of neutral grip, compared to general grip and medial grip. We suggest that it is best to use neutral grip when climbing ramps.

Reference

Barr AE, Goldsheyder D, Ozkaya N, et al. Testing apparatus and experimental procedure for position specific normalization of electromyographic measurements of distal upper extremity musculature. *Clinical Biomechanics.* 2001;16(7):576-585.

Buchholz B, Frederick LJ, Armstrong TJ. An investigation of human palmar skin friction and the effects of materials, pinch force and moisture. *Ergonomics.* 1988;31(3):317-325.

Choi SH. The influence of the pattern of gripping the ultrasound head on the activity of upper limb muscles. Yonsei University. Dissertation of Master's Degree. 2007.

Collins JW, Owen BD, NIOSH. Research initiatives to prevent back injuries to nursing assistants, aides, and orderlines in nursing homes. *American Journal of Industrial Medicine.* 1996;29(4):421-424.

Cram JR, Kasman GS, Holtz J. Introduction to surface electromyography. Gaithersburg. Aspen. 1998.

Fagarasanu M, Kumar S, Narayan Y. Measurement of angular wrist neutral zone and foreman muscle activity. *Clinical Biomechanics.* 2004;19(7):671-677.

Fujii H, Kobayashi S, Sato T, et al. Co-contraction of the pronator teres and extensor carpi radialis during wrist extension movements in humans. *Journal of Electromyography and Kinesiology.* 2007;17(1):80-89.

Jang DJ, Kim YC, Hong WP, et al. Study on the measurement of driving torque for power assist wheelchair. *Journal of the Korean Society for Precision Engineering.* 2016;27(5):197-198.

Kim CS, Lee DH, Lee JH, et al. Effects of ramp slope and height on usability and physiology during wheelchair driving. *Journal of the Ergonomics Society of Korea.* 2010;29(4):681-686.

Kim EJ. A study on factors affecting the satisfaction of life of the elderly people with disabilities. Hanshin University. Dissertation of Master's Degree. 2017.

Kim JJ. Control of power assisted wheelchair for rehabilitation and movement. Gachon University. Dissertation of Master's Degree. 2015.

Kim JT, Lim CJ, Hong IK, et al. Implementation of game and interface for improvement of hand-grip strength. *Journal of the Ergonomics Society of Korea.* 2007; 11(32):138-141.

Kim SH, Lee WH, Ha SM, et al. A comparison of EMG activity for long and lateral heads of triceps brachii muscles according to exercise and forearm positions during triceps strengthening exercises. *Physical Therapy Korea.* 2011;18(1):28-36.

Kim SJ. Analysis of muscle activation and motion during wheelchair propulsion in relation to the degree of the ground slope incline in paraplegic patients with spinal cord injury and in non-paraplegic individuals. Daegu University. Dissertation of Doctorate Degree. 2012.

Kim SM. Effect of the shape and height of walker handles on muscle activity in upper and lower extremities during sit-to-stand. Hallym University. Dissertation of Master's Degree. 2014.

Kim TW. The effects of arm muscle activation on wrist joint factors about isometric exercise of elbow joint. *The Korea Journal of Sports Science.* 2011;20(3):1723-1730.

Kim TW, Park BY. The effect of biceps brachii activation on wrist joint factors about hyperextension of elbow joint. *Journal of Wellness.* 2011;6(1):121-128.

Kim YH, Tae KS, Song SJ. Evaluation of upper-limb motor recovery after brain injury: the clinical assessment and electromyographic analysis. *Physical Therapy Korea.* 2005;12(1):91-99.

Kong JY. The effects of fatique on elbow and wrist kinematic characteristics during manual wheelchair propulsion. Daegu University. Dissertation of Doctorate Degree. 2004.

Kuorinka I, Forcier L. Work-related musculoskeletal disorders (WMSDs). London. Taylor & Francis. 1995.

Kwon HC, Jung DH, Kong JY. The effect of standard keyboard and fixed-spilt keyboard on wrist posture during word processing. *Physical Therapy Korea.* 2004;11(1):35-43.

Kwon HC, Kong JY. Characteristics of the buttock interface pressure according to wheelchair propulsion speed and various back reclined seating position. *Physical Therapy Korea.* 2005;12(2):1-10.

Lee CC, Nelson JE, Davis KG, et al. An ergonomic comparison of industrial spray paint guns. *International Journal of Industrial Ergonomics.* 1996;19(6):425-435.

Lee DH, Park DK, Lee HJ, et al. Suggest a ramp design method considering the wheelchair occupant and assistant. *Journal of the Ergonomics Society of Korea.* 2010;15(10):193-198.

Lee HL, Sim HY, Kim JM, et al. Musculoskeletal disorders among non-standard employed caregivers in south korea. *Korean Journal of Clinical Geriatrics.* 2011;12(2):150-160.

Lee KJ. Comparison of upper extremity muscle activity with transverse plane angle changes during vertical keyboard typing. Hanseo University. Dissertation of Master's Degree. 2008.

Lee KJ, Noh JS, Kim TH, et al. Comparison of upper extremity muscle activity with transverse plane angle changes during vertical keyboard typing. *Physical Therapy Korea.* 2009;16(2):67-76.

Mogk J, Keir P. The effects of posture on forearm muscle loading during gripping. *Ergonomics.* 2010;46(9):956-975.

Neumann DA. Kinesiology of the musculoskeletal system: foundations for rehabilitation, 2nd ed. St. Louis, Missouri. Mosby. 2010.

Newsam CJ, Rao SS, Mulroy SJ, et al. Three dimensional upper extremity motion during manual wheelchair propulsion in men with different levels of spinal cord injury. *Gait & Posture.* 1999;10(3):223-232.

Park YH. The carpal bone motion analysis in carpal joint movement. Seoultech University. Dissertation of Master's Degree. 2012.

Potvin JR, Agnew MJ, Woert CV. An ergonomic comparison of pneumatic and electrical pistol grip hand tools. International Journal of Industrial Ergonomics.

2004;34(6):467-478.

Sanders MJ. Ergonomics and the management of musculoskeletal disorder, 2nd ed. St. Louis, Missouri. Butterworth Heinemann. 2004.

Shin SJ. Anatomy and biomechanics of the elbow. *Clinics in Shoulder and Elbow.* 2006;11(11):24-33.

Sie IH, Waters RL, Adkins RH. Upper extremity pain in the postrehabilitation spinal cord injured patient. *Archives of Physical Medicine and Rehabilitation.* 1992;73(1): 44-48.

Son MK, Ahn BH, Yoon YS. Effect of forearm position on the supination and pronation strengths and emg activities of related muscles. *Annals of Rehabilitation Medicine.* 2002;26(4):432-438.

Yoo NH. Walkability on ramps by gait analysis. *Journal of the Korean Institute of Landscape Architecture.* 1995;23(2):157-166.

Yun HY, Lee YG, Eoh HJ, et al. Results of a survey on the awareness and severity assessment of the upper-limb work-related musculoskeletal disorders among female bank tellers in Korea. *International Journal of Industrial Ergonomics.* 2001;27(5):347-357.