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Comparison of Shoulder and Back Muscle Activation in Caregivers According to Various Handle Heights

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Abstract. [Purpose] This study aims to improve the safety for caregivers and avoid musculoskeletal diseases by examining the shoulder and trunk muscle activity depending on wheelchair handle height as the caregiver provides propulsion to a wheelchair for wheelchair-bound patients. [Subjects] The participants were caregivers who met the criteria for this study (n=30). [Methods] To determine the activity of the shoulder and trunk muscles of caregivers depending on the handle height, the muscle activity was measured as a wheelchair was being pushed under three height conditions. [Results] According to the study results, the deltoid middle fiber, serratus anterior muscle, rhomboid muscle, and erector spinalis of lumbar part showed significantly low muscle activity at a height that produced an elbow joint flexion angle of 30°. Caregivers are highly likely to develop musculoskeletal disease if the handle height is excessively low. In addition, the burden on the shoulder and back muscles can be reduced at heights that lead to flexion of 30°. [Conclusions] As a caregiver pushes a wheelchair, the handle height has a close relationship with the burden on the shoulder and back muscles. If the handle height is excessively low, the caregiver is highly likely to develop musculoskeletal disease.
Key words: Caregiver, Muscle activation, Wheelchair handle height

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INTRODUCTION

Increasing attention has been paid to the mobility of the handicapped to improve their quality of life and secure their accessibility to society[1)]. A major means of securing mobility is self-propulsion using a manual wheelchair[2)]. On the other hand, there are many cases in which the handicapped or elderly who are incapable of self-propulsion cannot move around without help of a caregiver.

The elderly population has increased due to the recent increase in average life span, which has resulted in growing interest in products for aged people. Such products have been developed to satisfy the needs of convenience for product users. Recent studies have assessed a variety of ways of resolving the problems that users can encounter[2, 3)]. Many books on wheelchairs have been published that suggest a variety of sizes and heights of wheelchair for users[4)]. On the other hand, in some cases, a user cannot operate products for the elderly directly, such as a wheelchair. The increase in the elderly population leads to an increase in the number of caregivers. In general, caregivers take care of patients when the patient is unable to express his or her intention and experiences difficulties in the performance of various physical functions[5)]. When a patient experiences difficulties in movement, the caregiver uses a wheelchair to help the patient move around. The caregiver tends to be exposed to a range of musculoskeletal diseases, as the caregiver uses a wheelchair to help the patient move and takes care of the patient. The population of caregivers has increased with the increasing population in need of their help. On the other hand, few studies of this subject have been conducted. Consequently, it is essential to examine ways of improving the convenience and safety of caregivers who use wheelchairs. Against this backdrop, this study suggests the most efficient handle height for task performance by measuring the shoulder and trunk muscle activity depending on the handle height as the caregiver pushes a wheelchair by its handles.

SUBJECTS AND METHODS

Thirty men and women (8 men and 22 women) with no musculoskeletal diseases and whose jobs were to provide care to patients were enrolled in this study, which was performed suggest the correct height for a wheelchair handle. The study subjects were given a sufficient explanation of the experimental procedures and asked to submit a written consent form to express their intention to voluntarily participatie.

The mean age, height and weight of the study subjects

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were 45.67 years old, 163.6 cm and 60.9 kg, respectively.

To restrict the level of difficulty when pushing a wheelchair, measurements of muscle activity were conducted at the point where the wheelchair began to move on a flat surface or where the static friction was the highest. In addition, a weight of 70 kg was placed on the wheelchair to generate constant static friction.

The elbow angle when the user was holding the handle while standing perpendicular to it was used to set the handle height according to the physical conditions of the user. The measurements were conducted with the angle of the elbow joint set to 0°, 15° and 30° (Fig. 1).

A ProComp Infiniti^{TM} (Thought Technology Ltd., Montreal West, Quedec, Canada) was used, and a surface electrode (Triode surface electrode, Thought Technology Ltd., Montreal West, Quedec, Canada), consisting of three electrodes (positive, ground, negative), was used to measure the activation of each muscle. The frequency of the electromyograph signal was set to 20–500 Hz and the sampling frequency was 1,024 Hz.

Depilation of electrode attachment sites was performed with a razor; the horny layer of the skin was removed with sandpaper. The electrodes were attached after cleaning the sites with an alcohol swab to gather accurate electromyogram data.

The selected muscles around the shoulder were the serratus anterior muscle, upper trapezius, deltoid middle fiber, and rhomboid muscle, and the selected muscle around the trunk were the cervical part, thoracic part and lumbar part of the elector spinae muscle.

The root mean square data for each muscle were measured for five seconds in the anatomical position. The level of muscle activation during exercise was expressed as % RVC by calculating the relative muscle contraction of the 100% average muscle contraction in the middle one second of a three-second measurement, i.e. by ignoring the first and last second of the measurement.

The measured data were analyzed using commercial software, PASW 18.0. One-way ANOVA was performed to compare the three conditions. A post hoc test was performed using Tukey' test. The significance level, α, was set to 0.05.

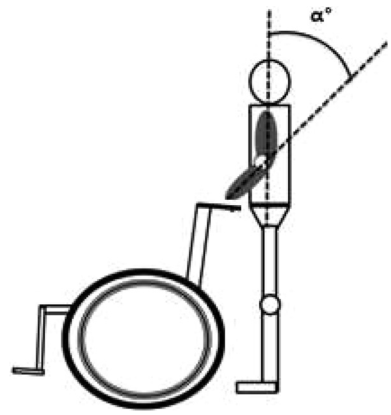

Fig. 1. Method of handle height measurement in this study

RESULTS

The muscle activation of the deltoid middle fiber were 525.12, 376.62 and 229.55 at the elbow flexion angles of 0, 15 and 30°, respectively. The muscle activity showed a significant decrease with increasing flexion angle ($p<0.05$). Post hoc analysis demonstrated that the muscle activity decreased at a wheelchair height with a flexion angle of 15° or higher ($p<0.05$).

The muscle activation of the serratus anterior muscle were 226.03, 177.79 and 151.46 under the three height conditions. These results were similar to those of the deltoid middle fiber. The post hoc analysis results were also identical to those of the deltoid middle fiber ($p<0.05$).

The muscle activation of the rhomboid muscle were 441.94, 448.76 and 290.01 at the elbow flexion angles of 0, 15 and 30°, respectively. The muscle activity showed a significant decrease with increasing flexion angle ($p<0.05$). Post hoc analysis demonstrated that the muscle activity decreased significantly with a wheelchair height that had a flexion angle of 30° or more ($p<0.05$).

The muscle activation of the lumbar part of the erector spinae muscle were 415.63, 392.25 and 212.26 at the three heights, respectively. The muscle activity showed a significant decrease with increasing flexion angle ($p<0.05$).

Post hoc analysis demonstrated a significant decrease in muscle activity at a wheelchair height with a flexion angle of 30° or higher ($p<0.05$).

The supraspinatus muscle, upper trapezius, and cervical and thoracic parts of the erector spinae muscles did not show any significant difference under the three conditions ($p>0.05$) (Table 1).

DISCUSSION

A wheelchair is an auxiliary equipment that helps a patient with difficulty in walking and move around. In addition, there is a wide selection of wheelchairs, and wheelchairs have been manufactured in a range of forms according to the physical impairments and operational skills of patients[4)].

Recently, many studies have analyzed the effects on the bodypatients propel a wheelchair on their own and the diverse characteristics of the wheelchair[2, 6, 7)].

On the other hand, the elderly, whose bodies are weak, have difficulties in propeling a wheelchair on their own. To compensate for this weakness, the caregiver helps a patient propel their wheelchair. Although the caregiver' role has increased, few studies have examined the caregiver' use of a wheelchair.

These results of the present study demonstrated that the activity of the deltoid middle fiber, serratus anterior muscle, rhomboid muscle, and lumbar part of the erector decreased with increase wheelchair height when the caregiver propelled the wheelchair at each height. As a result, the lowest muscle activity when propelling a drive wheelchair was observed at an elbow flexion angle of 30°. The use of low

Table 1. Comparison of muscle activation at various wheelchair handle heights

	0° flexion of the elbow	15° flexion of the elbow	30° flexion of the elbow
DM	525.1±84.1†	376.6±51.1‡	229.5±21.6‡
SA	226.0±20.8†	177.7±10.8‡	151.4±10.5‡
SS	559.2±84.7	442.0±55.2	357.7±56.0
UT	487.7±80.5	544.0±111.2	412.9±84.8
RH	441.9±38.2†	448.7±44.2†	290.0±35.6‡
C-ES	274.6±44.3	255.4±35.7	200.1±19.8
T-ES	324.7±29.4	315.9±30.7	245.5±25.7
L-ES	415.6±54.4†	392.2±54.0†	212.2±16.3‡

C-ES, cervical of the elector spinaemuscle; T-ES, thoracic of the elector spinae muscle; L-ES, lumbar of the elector spinae muscle; DM, deltoid middle fiber; SA, serratus anterior; SS, supra spinatus; UT, upper trapezius; RH, rhomboid, Each value represents the mean±SD. The values with different superscripts (†, ‡) in the same column are significantly different ($p<0.05$, Tukey' post hoc test)

muscle activity to propel a wheelchair under the same conditions leads to low levels of fatigue for caregivers when propelling a wheelchair and prevention of musculoskeletal diseases in the shoulder and back muscles despite long hours of wheelchair propelling.

The activities of all eight muscles measured in this experiment were highest when the wheelchair had a height that led to an elbow flexion angle of 0°. Force from the pectoralis major is needed to provide propulsion as in the case in which the patient propels their own wheelchair. On the other hand, if the elbow joint angle is 0°, the muscle is in a position in which it has difficulties in contraction, which prevents the pectoralis major from generating the appropriate contraction force. This can be found in the results when an actual patient propels a wheelchair[8–10].

As reported by Lee et al.[4], if a caregiver has an elbow joint that is in extension, the pectoralis major that provides propulsion is unable to play a role. Therefore, other muscles are used excessively. This means that a wheelchair handle with an excessively low height can impose excessive burdens on the shoulder and back muscles of the caregiver, thereby increasing the risk of injury.

In this study, the height of the wheelchair handle was measured at a flexion angle of up to 30°. Therefore, it is necessary to consider various heights in a future study. In addition, it is also believed to be necessary to conduct a study on wheelchairs with various designs to ensure the safety of the caregiver.

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