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Original Article

A study on effects of backrest thickness on the upper arm and trunk muscle load during wheelchair propulsion

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Abstract. [Purpose] The purpose of this study was to investigate the effects of the thickness of a wheelchair backrest provided for support and comfort on upper arm and trunk muscle load during wheelchair propulsion by using accelerometers. [Subjects and Methods] The Fourteen healthy participants were enrolled in this study. The study compared effects of three backrest conditions including no pad, a 3-cm-thick lumbar pad, and a 6-cm-thick lumbar pad. The instruments used for measurement were used two accelerometers. The participants were asked to propel their wheelchairs, which had been equipped with two accelerometers, 30 times. [Results] The intensity of muscle movement with the 3-cm-thick lumbar pad was significantly lower than the intensities with no lumbar pad and the 6-cm-thick lumbar pad. The muscle intensity did not differ significantly between the no pad and 6-cm-thick lumbar pad conditions. [Conclusion] An appropriately thick backrest has good effects on upper arm and trunk muscles during wheelchair propulsion. In the future, we must consider the appropriate backrest thickness for providing wheelchair users with a comfortable wheelchair.

Key words: Accelerometer, Backrest, Wheelchair

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INTRODUCTION

Wheelchairs are important chairs that provide structural support for the trunk, pelvis, and extremities in wheelchair users[1)]. Proper structural support allows them to perform activities of daily living under comfortable conditions[2)]. Of the various support systems, consideration of a suitable backrest thickness is especially crucial for wheelchair users[3)]. An unsuitable backrest thickness increases the load on some shoulder muscles and can lead to shoulder pain during wheelchair propulsion[4)]. Previous studies have indicated that a proper backrest for a wheelchair can help reduce lumbar load and activation of the upper extremity muscles[4, 5)]. These results have important implications for maintain active lifestyles providing function, comfort, and support for manual wheelchair users[6)]. Therefore, the therapist must consider the most suitable backrest when evaluating and recommending a wheelchair for patients.

Previous studies have examined the suitability of a backrest by measuring shoulder or trunk muscles with surface electromyography (sEMG). However, the use of sEMG has the limitations of only providing data for a limited number of channels and only being able to scan the movements of a few muscles groups. Also, only movements made in a certain direction can be analyzed when using EMG[7)]. An accelerometer is a subjective assessment tool that can detect acceleration and deceleration in response to movements in one, two, or three directions (uni-, bi-, or triaxial accelerometers) as well as energy expendixure[8)]. Also, an accelerometer is a valid and reliable tool for monitoring the level of various activities[9)]. Muscle movement changes

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dependent on backrest thickness can be detected by using accelerometers attached to the trunk and arm during arm propulsion[10, 11]. Thus, measurement using accelerometers may allow a selection of a suitable backrest thickness for wheelchair users.

Therefore, the purpose of this study was to investigate the effects of backrest thickness on the trunk and shoulder muscles by assessing acceleration using accelerometers during wheelchair propulsion.

SUBJECTS AND METHODS

Fourteen healthy people participated in this study. Participants with upper extremity pain or neuromuscular disorder were excluded. All participants were informed of the study's purpose and procedures, and all signed informed consent forms voluntarily. We used three backrest thicknesses and two accelerometers. The backrests used in this study had no lumbar pad, a 3-cm-thick lumbar pad, or a 6-cm-thick lumbar, and the density of the lumbar pads was 27 kg/m^3. MMA7260q triaxial accelerometers developed by Freescale Corporation were used. The sensitivity of the accelerometers ranges from −6 to +6 G. Data for measurement and storage in this study were set at 100 Hz. We calibrated the single vector magnitude (SVM) by summing the acceleration of the three axes. The three backrest conditions were tested in random order, and the lumbar pads were positioned such that they were aligned at the mid lumbar level (L3). The two accelerometers were attached along the right upper arm and lateral trunk using Velcro straps. Participants were asked to propel their own manual wheelchairs 30 times under the three backrest conditions. Five minutes of rest was given between measurements.

Using one-way repeated-measures analysis of variance (ANOVA), we compared the differences in the levels of activities of the upper arm and trunk muscles according to lumbar pad thickness. Post hoc analyses were performed using Bonferroni's correction. All data were analyzed with a level of statistical significance of $p<0.05$ using the IBM SPSS Statistics, Version 22.0, software (IBM Corp., Armonk, NY, USA).

RESULTS

The results showed that the SVM for the muscle activities with the 3-cm-thick lumbar pad was significantly lower than that with no lumbar pad (no lumbar pad, 35,350 ± 3,652 cm/s^2; 3-cm-thick lumbar pad, 30,600 ± 3,855 cm/s^2) ($p<0.05$). Also, the SVM for the 6-cm-thick lumbar pad was significantly higher than that for the 3-cm-thick lumbar pad (6-cm-thick lumbar pad, 37,640 ± 3,769 cm/s^2; 3-cm-thick lumbar pad, 30,600 ± 3,855 cm/s^2) ($p<0.05$). On the other hand, there was no significant differences in SVM between no lumbar pad and the 6-cm-thick lumbar pad ($p>0.05$).

DISCUSSION

This study compared the differences in muscle activity of the trunk and upper arm according to backrest thickness during wheelchair propulsion. For measuring muscle movements, we used two accelerometers attached to the trunk and upper arm. The SVM calculated from the accelerometer measurements represented the actual intensity of movement of the trunk and upper arm[12]. The results of this study indicated that among the three types of wheelchair backrest, the intensities of movement of the upper arm and lateral trunk were decreased when participants used a wheelchair equipped with a 3-cm-thick lumbar pad compared with no lumbar pad or a 6-cm-thick lumbar pad. This finding corresponds to the results obtained in a backrest study using EMG[4]. It seems that the intensity of muscle movement assessed by accelerometer is correlated with the EMG amplitude of the proximal and distal muscles[7]. Moreover, this correlation also indicates that the timing variables that are changed are the push time and recovery time, as increases in these times require more energy expenditure[13]. The SVM is used to classify physical activity level. In our study, SVM increases may be due to a less than optimal position during wheelchair propulsion. Consistent with this hypothesis, use of an appropriate backrest enabled less expenditure of energy through effective arm and trunk movement[14]. A previous study also showed that suitable backward thoracic support can help an individual maintain a comfortable wheelchair sitting posture, preventing or reducing the risks of back pain[15]. Also, shoulder muscle loads during manual propulsion by wheelchair users can be decreased by using a suitable or adjustable backrest[16]. These results indicate that an appropriate backward support position can maintain neutral pelvic tit and lumbar lordosis[3] and provide a biomechanical advantage to the shoulder[4]. The use of accelerometers in this study is very significant, especially considering that previous studies have used accelerometers for monitoring physical activity or wheelchair movement[17, 18]. Accelerometers make it easy to measure variables such as movement time and peak velocity, and it is also easy to obtain data such as EMG records[7, 19]. In the future, we must consider the appropriate backrest thickness for wheelchair users, and assessment methods using accelerometers can provide feedback for appropriate wheelchair measurement for wheelchair users.

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