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Original Article

The effects of backrest thickness on the shoulder muscle load during wheelchair propulsion

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Abstract. [Purpose] This study investigated the optimal thickness of the wheelchair backrest for lumbar load and increased comfort. [Subjects] Fifteen healthy people participated. [Methods] The study examined three randomized backrest conditions: no pad; a 3-cm-thick lumbar pad; and a 6-cm-thick lumbar pad. The location of the lumbar pad was standardized at the mid-lumbar level (L3). Participants were instructed to propel the wheelchair using only the handrims. [Results] Activation of the anterior deltoid, upper trapezius, and biceps brachii muscles was significantly reduced when the participants used the 3-cm pad compared to no pad, while it was significantly increased in the anterior deltoid, upper trapezius, posterior deltoid, and biceps brachii when the participants used the 6-cm pad compared to the 3-cm pad. Muscle activation did not differ significantly between the no pad and the 6-cm lumbar pad conditions. [Conclusion] A lumbar pad decreased the activation of the upper extremity muscles. We believe that padding of the appropriate thickness will lead to effective muscle activation while propelling a wheelchair and decrease the risk of musculoskeletal disease.
Key words: Electromyography, Lumbar pad, Wheelchair

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INTRODUCTION

Upper-limb pain and dysfunction are frequent complaints associated with manual wheelchair propulsion, which is physically demanding and involves repetitive movements[1)]. About 73% of wheelchair users suffer from chronic upper-limb pain, which is primarily attributed to two factors: wheelchair propulsion and transfers[2)]. Therefore, selecting the appropriate wheelchair and seating system is one of the most important decisions for those who spend long periods of time in their wheelchairs[3)]. Active wheelchair users report shoulder, elbow, and wrist/hand pain, chiefly shoulder pain[4)]. The chair backrest is designed to decrease the stresses on the vertebral column by: allowing relaxation of the erector spinae muscles, maintaining lumbar lordosis, and improving comfort[5)]. While biomechanical variables are important criteria for wheelchair users, they have not been studied sufficiently. Prevention is the best way to reduce chronic pain, and researchers have suggested various methods of preventing the development of problems during wheelchair propulsion. Ergonomic wheelchair seats provide good support for the user under dynamic conditions. Back belts might have positive effects on sustaining an erect trunk and lumbar lordosis by supporting the force from the knees, but they may secondarily lead to knee discomfort. Another method allows the user to lean backwards[1, 6)]. The backrest thickness may also affect comfort and performance[7)]. Consequently, criteria for the optimal design of backrests need to be established. It is also important to investigate how the backrest thickness affects comfort, especially in a dynamic setting during wheelchair propulsion. Therefore, this study investigated the effects of backrest thickness on the lumbar load and comfort by assessing the surface electromyography (sEMG) activity of the shoulder muscles during wheelchair propulsion with lumbar support.

SUBJECTS AND METHODS

Fifteen healthy people (seven females) participated. All of the subjects were informed of the study purpose and methods before participating, and provided their informed consent according to the principles of the Declaration of Helsinki. None reported any upper extremity pain or neuromuscular disorder. Our study consisted of three randomized backrest conditions: no pad; a 3-cm-thick lumbar pad; and a 6-cm-thick lumbar pad. The lumbar pads of the backrests used in this study had a density of 27 kg/m^3. The location of the lumbar pad was standardized by aligning it at the mid-lumbar level (L3). Participants were instructed to propel the wheelchair using only the handrims. They propelled the wheelchair 30 times with their hands, the upper body in an upright position at an average rate of once per second. For stable propulsion, the wheelchair was raised from ground level. A 5-minute rest was given between measurements. The sEMG activity of the upper extremity muscles was col-

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Table 1. Muscle activations during wheelchair propulsion with the different lumbar pad conditions (n=15)

Muscle	%RVC (mean±SD)		
	None	3-cm pad	6-cm pad
Anterior deltoid*	70.13±22.15	49.81±16.82	66.02±21.72
Upper trapezius*	100.22±18.20	83.82±15.33	110.82±20.53
Posterior deltoid*	105.31±23.71	95.85±16.77	100.18±18.90
Biceps brachii*	110.89±16.35	90.30±15.19	118.70±13.49

*$p<0.05$

lected, amplified, digitized, and analyzed using an ME6000-biosignal monitor (Mega Electronics, Kuopio, Finland). The electrode locations were as follows: anterior deltoid, anterior aspect of the arm, approximately 4 cm below the clavicle; upper trapezius, slightly lateral to and halfway between the cervical spine at C-7 and the acromion; posterior deltoid, 2 cm below the lateral border of the spine of the scapula and angled obliquely to the arm; and biceps brachii, attached at the middle muscle belly over the short and long heads. The EMG data were converted into root mean square (RMS) values in a window comprising 300 ms of data. We obtained the reference voluntary contraction (RVC) using the submaximal normalization method. SPSS 22.0 (SPSS, Chicago, IL, USA) was used to analyze the differences in shoulder muscle activities. The Kolmogorov–Smirnov test was performed to test for a normal distribution before using parametric statistics. The significance of differences among wheelchair propulsion with no lumbar pad, the 3-cm lumbar pad, and the 6-cm lumbar pad was tested using one-way repeated-measures analysis of variance (ANOVA*)*. Values of $p<0.05$ were accepted as significant. For the significant main effect, the Bonferroni correction was used to identify the specific mean differences.

RESULTS

The normalized EMG data obtained while performing the wheelchair propulsion task with no pad, a 3-cm-thick lumbar pad, and a 6-cm-thick lumbar pad revealed significant differences in the activation of the anterior deltoid, upper trapezius, posterior deltoid, and biceps brachii muscles. Muscle activation of the anterior deltoid, upper trapezius, and biceps brachii muscles significantly decreased when the 3-cm pad was used compared to none, and significantly increased in the anterior deltoid, upper trapezius, posterior deltoid, and biceps brachii when the participants used the 6-cm pad compared to the 3-cm pad. There were no significant differences in muscle activation between the no pad and the 6-cm lumbar pad conditions (Table 1).

DISCUSSION

Many studies have indicated that there is a relationship between wheelchair propulsion and upper limb injuries[1, 8]. Previous study has shown that a lumbar support increased (or preserved) the comfort while sitting. Especially, it indicated that a 2–3° change in lumbar posture influences the compressive load at L4–L5 when performing spinal loading work[9]. Our present results show that there was a significant decrease in the activation of the anterior deltoid, upper trapezius, and biceps brachii muscles when the participants used the 3-cm pad compared to no pad, while the activation of the anterior deltoid, upper trapezius, posterior deltoid, and biceps brachii significantly increased when the participants used the 6-cm pad compared to the 3-cm pad. There were no significant between the no pad and the 6-cm lumbar pad conditions. Generally, the push phase mainly uses the anterior deltoid, pectoralis major, and biceps brachii, whereas the recovery phase primarily uses the upper trapezius and middle and posterior deltoid[10, 11]. One possible explanation for our result is the effect of muscle activation on the propulsion efficiency when performing wheelchair propulsion with the 3-cm pad compared with no pad or a 6-cm pad. It has also been reported that an appropriate lumbar pad provides a biomechanical advantage to the shoulder during seated work. A decrease in muscle load might elicit the optimal curvature of the lumbar spine when propelling a wheelchair. This suggests that although users might not benefit from a lumbar pad to improve their temporal muscle load, long-term users develop musculoskeletal shoulder pain. Goosey et al. indicated that a lower propelling frequency could explain the effectiveness of pushing economy. A high frequency is associated with more shifts during the deceleration and acceleration phases, and increased inertial limb moments. As a result, a lower frequency leads to less muscle activity, possibly reducing rotator cuff fatigue, while maintaining the stability of the humeral head[4, 12, 13]. In this study, the backrest was rated as more comfortable, and it had better dampening capability, which allowed leverage in the contact area between the lumbar spine and backrest during wheelchair propulsion. The results of our present study confirm that an appropriate lumbar pad allows more effective coordination of the shoulder muscles and increases comfort during wheelchair propulsion.

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