Comparison of neck and upper-limb muscle activities between able-bodied and paraplegic individuals during wheelchair propulsion on the ground

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Abstract. [Purpose] This study compared the muscle activities of the neck and upper-limb muscles between able-bodied individuals and persons with paraplegia during wheelchair propulsion on the ground. [Subjects and Methods] The muscle activities of the neck and upper-limb muscles of 8 normal individuals and 8 individuals with paraplegia were analyzed during wheelchair propulsion. The activities of the latissimus dorsi, pectoralis major, anterior/posterior deltoids, triceps brachii, extensor carpi radialis, and sternocleidomastoid muscles were assessed. [Results] The paraplegic group showed significantly higher sternocleidomastoid activity than the normal group. Latissimus dorsi activity was also higher in the paraplegia group than in the normal group, but the difference was not significant. There were no significant differences in the other muscle activities between groups. [Conclusion] Paraplegic patients tend to use the sternocleidomastoid and latissimus dorsi muscles with greater degrees of activity. Therefore, physiotherapists should not overlook the treatment of these muscles for paraplegic patients who are long-term wheelchair users.

Key words: Wheelchair propulsion, Muscle activities, Upper-limb muscle

INTRODUCTION

Wheelchair propulsion is essential for ambulation in people with paraplegia. In particular, people with paraplegia due to spinal cord injuries have many upper-limb problems owing to trunk instability and repetitive wheelchair propulsion. Trunk impairments due to manual wheelchair propulsion cause an unstable sitting posture, which decreases the person's abilities to perform wheelchair activities during daily living1). Manual wheelchair users must repetitively use limited upper-limb muscles against a high mechanical load2). Manual wheelchair users have many opportunities to overload the trunk, neck, and upper extremities during wheelchair propulsion, which incur a risk of overuse disease and chronic pain in contrast with normal people3, 4). Therefore, it is important to understand the differences in the muscle activities between normal and paraplegic people during wheelchair propulsion in order to help prevent overuse disease.

However, previous studies mainly involved subjects who were all normal individuals5) or all paraplegia patients6) and investigated the muscle activities of the upper-limb and trunk muscles7). Thus, there is a deficiency of studies comparing able-bodied individuals and people with paraplegia with respect to the muscle activities of the neck and upper limbs during wheelchair propulsion.

Therefore, this study compared the muscle activities of the neck and upper-limb muscles between able-bodied individuals and people with paraplegia during wheelchair propulsion on the ground.

SUBJECTS AND METHODS

The subjects were 8 able-bodied individuals and 8 people with paraplegia. The subjects were informed of the purpose and methods of the study before the experiment. The subjects provided informed consent before participating in the study. The 8 able-bodied individuals had never used a wheelchair and had not experienced any upper-limb disorders during the past year. Meanwhile, the 8 people with paraplegia were full-time wheelchair users, had thoracic spinal cord (i.e., T1–T12) injuries, and had no history of persistent joint pain or musculoskeletal deformities in their upper limbs.

To create homogeneity in the wheelchair propulsion
skills between the people with paraplegia and able-bodied individuals, we trained all subjects to perform ground wheelchair propulsion such that it took from 1.5 to 3 minutes to cover 200 m\(^{36}\). The people with paraplegia used their own wheelchairs, while able-bodied individuals used the activity wheelchair AS model (Nissin, Kitamagoya, Aichi, Japan), which is usually used for individuals with paraplegia.

All subjects performed wheelchair propulsion three times at a comfortable speed on the ground. The wheelchair propulsion tasks were intended to measure muscle activity during the midpoint of the push phase of a stroke on the ground. A surface electromyograph (Telemyo 2400T G2, Noraxon, Scottsdale, AZ, USA) was used to measure muscle activity. We collected electromyogram signals during the push phase of wheelchair propulsion and processed the root mean square and normalization by maximum voluntary isometric contraction. The activity of the latissimus dorsi (LSD), pectoralis major (PCM), anterior/posterior deltoids (AD/PD), triceps brachii (TRB), extensor carpi radialis (ECR), and sternocleidomastoid (SCM) muscles were measured. Electrodes were placed as described previously\(^9\).

Statistical analysis was performed using SPSS version 21.0 (SPSS, Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test and Shapiro-Wilk test were performed first to confirm data normality. An independent t-test was performed to test for significant differences in muscle activation between the two groups. The level of significance was set at \(p < 0.05\).

### RESULTS

A total of 16 male subjects were enrolled. The normal group, which comprised normal able-bodied individuals, had a mean ± SD age, weight, and height of 22.75 ± 1.04 years, 68.00 ± 4.11 kg, and 175.38 ± 3.11 cm, respectively; these values for those in the paraplegic group were 37.00 ± 8.47 years, 71.25 ± 8.05 kg, and 170.75 ± 1.04 cm, respectively. Respect to weight and height, there were no significant differences between two groups (\(p > 0.05\)) but respect to age, there was a significant difference between two groups (\(p < 0.05\)) (Table 1).

| Muscles               | Normal group | Paraplegic group |
|-----------------------|--------------|------------------|
|                       | Mean±SD      | Mean±SD          |
| LSD†                  | 3.14 ± 1.35% | 5.82 ± 2.27%     |
| PCM                   | 23.65 ± 13.08% | 25.67 ± 15.41%  |
| SCM†                  | 4.36 ± 0.87% | 10.44 ± 7.98%   |
| AD                    | 16.41 ± 6.20% | 22.39 ± 17.71%  |
| PD                    | 6.02 ± 1.84%  | 6.60 ± 3.02%    |
| TRB                   | 8.71 ± 5.23%  | 17.42 ± 14.13%  |
| ECR                   | 23.70 ± 9.09% | 23.82 ± 9.84%   |

*\(p < 0.05\) between groups. †0.1 between groups. LSD: latissimus dorsi; PCM: pectoralis major; SCM: sternocleidomastoid; AD: anterior deltoids; PD: posterior deltoids; TRB: triceps brachii; ECR: extensor carpi radialis

### DISCUSSION

This study compared the upper-limb and neck muscle activities during wheelchair propulsion between healthy people and people with paraplegia.

SCM muscle activity was higher in the paraplegia group than the normal group. Recent increases in sitting time as a result of work in front of computer monitors have increased the tendency of the SCM to be overloaded, which causes many pathologies collectively termed “visual display terminal syndrome”\(^{10}\). Muscles can influence the brachial plexus nerve, internal and external carotid arteries, and cervical lymph nodes below them\(^{11}\). Therefore, dysfunction of the SCM muscle can cause head and face pain, nausea, dizziness, cornea, and lacrimation\(^{12}\). In people with paraplegia complaining of shortness of breath, the SCM acts as an accessory inspiratory muscle\(^{13}\). In this situation, people with paraplegia can overactivate the SCM during wheelchair propulsion, which may lead to visual display terminal syndrome as mentioned above. Therefore, physical therapy should include posture education such as maintaining a chin-in position when the trunk or neck is in flexion in order to prevent excessive use of the SCM as well as provide treatment to stretch the SCM for people with paraplegia who use a manual wheelchair\(^{14}\).

The LSD muscle tended to exhibit relatively higher muscle activity in the paraplegia group than the normal group, although the difference was not significant. The LSD plays many roles including extension, adduction, flexion from an extended position, and internal rotation of the shoulder joint\(^{15}\). Future studies should aim to clarify the shoulder motion angle during wheelchair propulsion in order to explain why the LSD muscle exhibits higher activity in paraplegia.

The major limitations of this study are the lack of motion analysis of the shoulder and neck joints for explicating the muscle activity pattern and the small sample size.

In conclusion, during wheelchair propulsion, patients with paraplegia tend to use the SCM and LSD muscles more than normal subjects. Therefore, physiotherapists should not overlook the treatment of these muscles for patients with paraplegia who are long-term wheelchair users.

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