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Effect of wrist position on thumb flexor and adductor torques in paralysed hands of people with tetraplegia

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ABSTRACT

Background: People with tetraplegia often have extensive paralysis of the hand yet retain crude hand function. Their hand function is dependent on manipulating wrist position with the neurally-intact wrist extensor muscles to change the passive tension in paralysed thumb muscles. This moves the thumb in relation to the paralysed index finger enabling basic grasp. The aim of this study was to quantify the effect of wrist position on thumb flexor and adductor torques generated in paralysed hands of people with tetraplegia.

Methods: Thumb flexor and adductor torques were measured as the wrist was passively moved from a fully flexed to a fully extended position in 10 people with tetraplegia who had paralysis of all thumb muscles. The relationships between thumb torques and wrist angles were quantified with torque–angle curves.

Findings: There was a consistent curvilinear relationship between wrist angle and both thumb flexor and thumb adductor torques. Thumb flexor torques were greatest and thumb adductor torques were smallest when the wrist was fully extended.

Interpretation: Wrist position influences the thumb flexor and adductor torques generated in the paralysed hand. This is probably due to the effect of wrist position on the passive tension of the thumb muscles spanning the wrist. These findings have implications for people with C6 and C7 tetraplegia who rely on the passive torques generated by the paralysed thumb muscles for hand function.

1. Introduction

People with complete C6 and C7 tetraplegia have paralysis of finger and thumb flexor muscles. Nonetheless they retain some ability to grasp objects through the use of a tenodesis grip. A tenodesis grip is achieved by actively manipulating wrist position with the neurally-intact wrist extensor muscles. Changes in wrist position modify the passive tension in the paralysed extrinsic finger and thumb muscles. For example, wrist extension places a stretch on the extrinsic thumb and finger flexor muscles, generating passive thumb and finger flexor torques which pull the thumb and fingers together. Objects can then be held between the thumb and first finger (Curtin, 1999; Harvey, 1996; Harvey et al., 2001; Johanson and Murray, 2002).

There are different types of tenodesis grips but the two most widely used are the lateral key grip and pincer grip (Harvey, 2008). In the lateral key grip the thumb contacts the side of the first (index) finger and in the pincer grip the thumb contacts the tip of the first finger. Patients cannot elect which grip they use. Instead, the type of grip is determined by the passive adductor torque generated about the thumb joints. This torque determines the point of contact between the thumb and the index finger. The thumb flexor torque then determines the "tightness" of the grip. Together the passive thumb flexor and adductor torques are major determinants of the effectiveness and type of tenodesis grip attained by people with C6 and C7 tetraplegia (Harvey, 1996).

Despite the importance of passive thumb flexor and adductor torques to the hand function of people with tetraplegia, surprisingly little research has been directed at understanding the relationship between wrist angle and thumb torques (Johanson and Murray, 2002). This information is important for clinicians and basic scientists interested in improving the hand function of people with tetraplegia. It is also important for quantifying the effectiveness of different interventions, such as stretching, splinting or surgery, aimed at changing the passive extensibility of the extrinsic thumb muscles. Data on the effect of wrist position on thumb torques could also be used in computer models to predict the effect of electrical stimulation on thumb movement. The purpose of this study was therefore to determine the influence of wrist position on the thumb flexor and adductor torques generated in people with paralysis of all thumb muscles.

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2. Methods

2.1. Subjects

Ten inpatients and outpatients from a Sydney spinal injury unit were invited to participate in the study. To be eligible for inclusion, subjects had to have sustained a C7 or above motor complete spinal cord injury on at least one side of the body according to the International Standards for Neurological Classification of Spinal Cord Injury (also referred to as ASIA; American Spinal Injury Association, 2003). Potential subjects were only included if they also had total paralysis of all thumb muscles, and they were excluded if they had a history of surgery or trauma to the thumb, hand or wrist, or had marked spasticity in the hand or contractures of the wrist or thumb.

The left hand was tested in all but two subjects in whom the left hand did not meet the inclusion criteria. The ASIA motor levels for the tested hands were C4 (one hand), C5 (two hands) and C6 (seven hands). The median (interquartile) time since injury and age of subjects was 15 years (6–20) and 47 years (43–58), respectively. All but one subject were male.

The study received ethical approval from the appropriate institutions. Informed consent was obtained from all subjects. The authors certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

2.2. Experimental protocol

Testing always followed the same format. Subjects were tested in their wheelchairs with their forearms and hands fixed in a custom-built testing device supported on a table. The device was used to manipulate wrist and thumb position while measuring thumb flexor and adductor torques (Li et al., 2004).

The device (Fig. 1) consisted of a forearm component and a hand component. The forearm component fixed the forearm in a mid-pronated position to the table. The hand component fixed the hand so that the metacarpophalangeal joints of the fingers were in approximately 70° of flexion. The interphalangeal joints of the fingers were not secured but rather free to rest in a neutral position. The hand component sat on rollers and rotated about the wrist joint on the table. It was connected to the forearm component by a joint fitted with a potentiometer. The axis of the joint and potentiometer was aligned with the axis of the wrist so that the potentiometer provided a measure of wrist angle. A force transducer was positioned under the pad of the thumb to measure thumb flexor torques, or along the medial border of the distal phalanx to measure thumb adductor torques. The force transducer produced an extensor moment on the IP joint of the thumb, stabilizing the thumb into extension. The thumb was loosely taped to the force transducer to prevent the thumb sliding. The tape was not used to pull the thumb against the force transducer. While it is possible that the tape might have had a small effect on the measured torques, its effect would have been to produce a constant offset in torque. Any torque due to taping would not have changed as a function of wrist angle. The carpometacarpal (CMC) joint was positioned in extension and halfway between the extremes of abduction and adduction when measuring the flexor torque, and in abduction and half way between the extremes of flexion and extension when measuring the adductor torque. These two testing positions were chosen to mimic the position adopted by the thumb when manipulating large objects. Data from the potentiometer and force transducer were simultaneously collected at 115 Hz onto a laptop computer using Matlab software. The measured force was multiplied by the distance between the force transducer and the CMC joint to derive thumb torques. The distance was measured with electronic calipers at the commencement of each testing session.

The wrist was manually moved cyclically by the assessor from a fully flexed to a fully extended position. The mean (SD) angular velocity was 12.5 (2.9) degrees s^{-1}. The small variations in velocity would not have affected the torques because, while the passive torque–angle properties of joints are velocity-dependent, large changes in velocity are required to produce very small changes in torque (Nordez et al., 2008). The tests were repeated six times to obtain three sets of measures of thumb flexor torques and three sets of measures of thumb adductor torques. Data were collected after one slow preconditioning cycle. Each time the wrist was moved into maximal wrist flexion and extension. The maximal available range varied between subjects.

2.3. Data analysis

Torque–angle curves were constructed for each trial for wrist angles between 42° flexion and 58° extension. These angles represented the maximal wrist flexion and extension attained by all subjects. Wilcoxon rank sum tests were used to compare the thumb flexor and thumb adductors torques generated with the wrist at 42° flexion and 58° extension. A P value of less than 0.05 was considered statistically significant.

3. Results

The relationships between the thumb adductor and flexor torques and wrist angles for each of the 10 subjects are shown in Figs. 2 and 3. The median (interquartile) thumb flexor and adductor torques with the wrist at 42° flexion, neutral and 58° extension are shown in Table 1. A consistent finding was that the thumb adductor torque was greatest when the wrist was flexed and least when the wrist was extended. The relationship between the thumb flexor torque and wrist angle was less consistent between individuals although the thumb flexor torque was always least when the wrist was in a neutral position. The thumb flexor torque increased when the wrist was extended but sometimes also increased when the wrist was flexed (see Fig. 3, subject no. 7).

4. Discussion

This study quantifies the effect of wrist position on the flexor and adductor torques generated in people with paralysis of all thumb muscles. Thumb flexor and adductor torques are an important determinant of hand function in individuals with C6 and C7 tetraplegia.

In most subjects thumb flexor torques increase as the wrist is moved from a neutral to an extended position (see Fig. 3) while the thumb adductor torques do the opposite (see Fig. 2); that is, they increase as the wrist is moved from a neutral to a flexed position. In some subjects the thumb flexor torque increases both as the wrist is moved from a neutral to an extended position and as the wrist is moved from a neutral to a flexed position.

The change in thumb flexor and adductor torques with wrist position is probably due to a change in passive tension in the paralysed thumb muscles that span the wrist and thumb joints: the flexor pollicis longus, abductor pollicis longus, extensor pollicis longus and extensor pollicis brevis muscles (Smutz et al., 1998). Anatomical studies suggest that wrist extension increases passive tension in the flexor pollicis longus muscle but decreases the tension in the extensor pollicis longus and extensor pollicis brevis muscles. In contrast, wrist flexion increases the passive tension in the extensor pollicis longus and extensor pollicis brevis muscles but decreases