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Reflex control of posterior shoulder muscles from arm afferents in healthy people

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ABSTRACT

In order to position the hand during functional tasks, control of the shoulder is required. Heteronymous reflexes from the upper limb to shoulder muscles are used to assist in this control. To investigate this further, the radial and ulnar nerves were stimulated at elbow level whilst surface electromyographic activity of posterior deltoid, infraspinatus and latissimus dorsi muscles were recorded. In addition, the cutaneous branch of the radial nerve and the skin of the fifth digit were stimulated in order to investigate any cutaneous contribution to reflex activity. Reflexes were evoked in all three of these shoulder muscles from hand and/or forearm afferents. However, the reflexes differed; whereas both excitatory and inhibitory reflexes were evoked in posterior deltoid and infraspinatus, the reflexes in latissimus dorsi were mainly excitatory. Cutaneomuscular reflexes were seldom evoked here, but when they were present they were generally evoked at longer latencies than the reflexes evoked by mixed nerve stimulation. The results suggest a role for reflexes originating from the forearm and/or hand in the control of the shoulder.

1. Introduction

Accurate positioning of the wrist and hand during functional movements requires precise positioning of the shoulder (Levin, 1996). In order to efficiently position the hand during a task, it seems likely that afferents originating from the hand or forearm would feedback to shoulder muscles to assist with positioning of the arm. Therefore, it is unsurprising that reflex connections have been demonstrated in healthy human subjects from muscle afferents originating from the hand and forearm to scapulothoracic and glenohumeral muscles such as trapezius, serratus anterior, anterior deltoid and pectoralis major (Alexander and Harrison, 2003; Creange et al., 1992; Marsden et al., 1981). In addition, cutaneomuscular reflexes (CMRs) originating from the hand have also been evoked in trapezius, serratus anterior, anterior and posterior deltoid and infraspinatus (Hundza and Zehr, 2007; Zehr and Kido, 2001). However, this pattern of heteronymous reflexes remains incomplete as although these muscles are important in positioning the hand in front of the body, there has been limited investigation of reflexes in posterior shoulder muscles evoked with stimulation of mixed nerves. This is a surprise as the shoulder requires a balanced level of control of anterior and posterior muscles to achieve optimal function and feedback from the periphery is likely to originate from non cutaneous afferents as well as afferents of cutaneous origin. Deltoid, infraspinatus and latissimus dorsi are particularly important muscles to investigate as infraspinatus stabilizes the head of the humerus in its socket and all three muscles move the arm. Posterior deltoid abducts, extends and horizontally extends the shoulder (Donatelli, 1997; Williams et al., 1989), infraspinatus stabilizes and externally rotates the shoulder (Donatelli, 1997), and the large latissimus dorsi helps to stabilize the shoulder during flexion (Kronberg et al., 1990) and medially rotates and extends the arm (Williams et al., 1989). Due to their extensive role, an understanding of the healthy control of these muscles is relevant to clinicians treating patients with shoulder pathologies (Ainsworth, 2006; Hundza and Zehr, 2007).

Therefore, the aim of this study was to investigate whether reflexes could be evoked from forearm and/or hand afferents to posterior muscles controlling the shoulder such as posterior deltoid, infraspinatus and latissimus dorsi by stimulating mixed nerves.

2. Methodology

With ethical approval from Hammersmith and Queen Charlotte's and Chelsea Research Ethics Committees (reference number 04-Q0406-150) and informed, written consent, a sample of convenience of 22 healthy people was recruited. People who had previous shoulder or neck pain, diabetes, rheumatological or neurological disease and who were pregnant were excluded.

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2.1. Recording electromyographic (EMG) activity

Surface electrodes (Ambu, Blue sensor) were positioned 3 cm apart on the belly of each of the shoulder muscles (posterior deltoid, infraspinatus and latissimus dorsi) and on the belly of a distal muscle supplied by the nerve being stimulated (usually flexor digiti minimi brevis for the ulnar nerve and extensor carpi radialis brevis for the radial nerve). Accurate electrode positioning was tested by appropriate manual resistance of the arm by the researcher, activating each muscle in turn. EMG activity was amplified (Digitimer NL844), isolated (Digitimer, NL820), and filtered between 30 Hz and 6 kHz (Digitimer, NL125). The data was then digitised at a sampling frequency of 4 kHz (CED 1401) and stored for later analysis using Signal software version 3.10.

2.2. Electrical stimulation

Electrical stimulation of the ulnar and radial nerves (22 subjects), and the skin of the fifth digit and the cutaneous branch of the radial nerve (9 subjects) were carried out in a varied order using a 1 ms square wave pulse delivered percutaneously every 3 s (Digitimer DS7A stimulator). To stimulate the radial nerve, an anode (a gel covered metal plate) was secured over the posterior/lateral aspect of the upper arm along the path of the radial nerve in the spiral groove. A cathode was positioned over the nerve just distal to the elbow at the point where it passes between the two heads of supinator (Alexander and Harrison, 2003; Alexander et al., 2005). This was located using a hand held, button electrode until a motor response was evoked in extensor carpi radialis brevis. This location was marked and then an adhesive electrode (a Blue sensor electrode) was applied at this point and the location tested once more. To stimulate the cutaneous afferents of the radial nerve the button electrode was first used to find the cutaneous branch supplying the back of the lateral side of the hand. This was stimulated at the point where the nerve crosses the lateral border of the radius. Appropriate location was confirmed by the pattern of sensation experienced by the subject. Once this was found an adhesive electrode was positioned in its place.

To stimulate the ulnar nerve, the anode was secured to the medial aspect of the upper arm in the groove made between the biceps and triceps muscles. A cathode (a Blue sensor electrode) was secured over the ulnar nerve as it runs within the ulnar groove. The appropriate location was tested by ensuring that a motor response could be evoked in flexor digiti minimi brevis. To stimulate the cutaneous afferents of the ulnar nerve to the hand, ring electrodes were sited over the proximal and middle phalanges of the fifth finger.

Motor threshold (MT) was determined whilst stimulating the mixed nerves. This was defined as the stimulus intensity at which the motor response was just evoked in a muscle supplied by the nerve being stimulated. The accuracy of determining motor threshold was checked by changing the stimulus intensity above and below motor threshold several times. The nerve was then stimulated at intensities greater than 1.3MT as this is known to activate a fuller range of muscle afferents than stimulation below this intensity (Gracies et al., 1994; Lourenco et al., 2006; Simonetta-Moreau et al., 1999). Sixty stimuli were delivered at 1.5–2MT. This stimulation intensity was sufficient to activate groups I and II muscle afferents (Gracies et al., 1994; Lourenco et al., 2006) as well as joint afferents (Marchand-Pauvert et al., 2002) without causing discomfort to the subjects.

Perception threshold, whilst stimulating cutaneous afferents, was determined as the intensity at which the subject begins to perceive a prickling sensation. The accuracy of determining perception threshold was checked by changing the stimulus intensity above and below perception threshold several times. Sixty stimuli were then delivered at twice the perception threshold. This was sufficient intensity to stimulate the cutaneous afferents without any discomfort.

2.3. Task

The arm was positioned in approximately 90° abduction and 90° external rotation. The position of the arm and the level of muscle activity were monitored during testing and verbal feedback was given to the subject to maintain muscle activity at 20–30% maximum voluntary contraction (MVC). This level of background activity causes some of the motoneurones to fire, and brings others closer to firing threshold than if they were simply held at rest, but it is not too high a level of activity so as to risk obscuring reflexes due to high levels of background EMG (Pierrot-Deseilligny and Mazevet, 2000; Schieppati and Nardone, 1997). The subject was helped to maintain this level of activity by verbal feedback from the researchers who monitored the muscles activity using a light biofeedback device calibrated to the muscle's MVC. Frequent rests were taken during testing (usually after every 20–30 stimuli) and subjects were informed about the importance of avoiding fatigue. In addition, the subjects were asked to visualise a writing task without initiating any movement. Our previous investigations have demonstrated that visualising such a complex task increases the amplitude of a similar reflex (Alexander et al., 2004). Therefore it was hoped that this imagery might increase the amplitude of any evoked response making it easier to visualise above the background EMG. Total time for testing each subject including rest periods was approximately 60–90 minutes.

2.4. Data analysis

The EMG from 60 stimuli were rectified and averaged, then visually inspected for presence of reflexes by two researchers independently. As in other studies measuring reflexes, only reflexes exceeding two standard deviations above or below the pre-stimulus mean EMG were recorded as present (Wohlert, 1996). This may under-represent the frequency of occurrence of the reflexes, but smaller reflexes that may have been present were challenging to identify. The onset latency of the reflex was then measured from the first clear deflection from the pre-stimulus mean (Alexander and Harrison, 2003). After a visual inspection of the rectified and averaged EMG, it was noted that short and longer latency reflexes were evoked in a consistent manner across the different subjects; therefore they were grouped for analysis into these different epochs of latency.

3. Results

Both excitatory and inhibitory reflexes were evoked over a wide range of latencies in deltoid, infraspinatus and latissimus dorsi in response to stimulation of the radial and ulnar nerves.

Examples of these reflexes can be seen in Fig. 1. Table 1 and 2 detail the sign, latency and frequency of occurrence of the reflexes. Stimulation of the radial and ulnar nerves evoked reflexes in posterior deltoid which were, in the main, an inhibition followed by a late excitation. Radial and ulnar nerve stimulation also evoked reflexes in infraspinatus that had a similar pattern of an inhibition followed by a late excitation. However, in contrast to the reflexes evoked by ulnar nerve stimulation, radial nerve stimulation evoked an additional early excitation. The latissimus dorsi reflexes were, in the main, excitatory and were at a long latency. To summarise, this varying pattern of reflexes evoked by radial and ulnar nerve stimulation were inhibitory and excitatory and had a large range of latencies which are illustrated by Fig. 2.