Motor impairment in the human hand following eccentric exercise

Abstract Motor impairment was induced by having subjects perform two sets of 50 maximal contractions, using the first dorsal interosseus (FDI) muscle to abduct the index finger, while the muscle was being stretched. Tests were conducted prior to the exercise (pre-exercise) and 24 h following the exercise (post-exercise). There were declines of 19% in maximal abduction torque and 15% in maximal flexion torque at the metacarpophalangeal joint, during isometric contraction post-exercise compared to pre-exercise. The ability to stabilize the metacarpophalangeal joint about the abduction/adduction axis was reduced by 14% post-exercise, and the variability in tracking an isometric torque target increased by 30%. There was a decrement of 7%–10% in the median frequency of the power density spectrum of FDI electromyogram (EMG) throughout a 60 s maintained abduction at 50% maximal voluntary contraction. The mean rectified EMG, on the other hand, increased by 100%–175% for torque levels below 40% of maximal voluntary contraction, post-exercise. The results were consistent with preferential injury of type II muscle fibres in FDI. Although non-exercised synergist muscles appeared to be inhibited during maximal voluntary flexion, there was evidence that they compensated for injured FDI muscle fibres during maintained contraction at sub-maximal flexion torque.

Key words Muscle injury · Movement · Stability · Finger

Introduction

Lengthening of active muscle, often referred to as eccentric contraction, occurs commonly in normal activities, for example, when slowly lowering an object held in the hand. Active muscle can develop much larger forces during lengthening, than during isometric or shortening contraction (Katz 1939). While this is advantageous for controlling the motion of objects which are being lowered under the influence of gravity, it creates greater risk of injury to muscle or tendon than activities which involve only isometric or concentric contraction (Newham et al. 1983; Clarkson et al. 1986; Berry et al. 1990; Faulkner et al. 1993). A number of studies have shown that indicators of injury, induced by eccentric loading of muscle, occur more frequently in large, fast-twitch (type II) muscle fibres than in the smaller, slow-twitch (type I) fibres (Fridén et al. 1983; Lieber and Fridén 1988).

While the selectivity of injury to type II muscle fibres has received considerable attention, investigation of functional impairment, following eccentric exercise, has been limited. It is clear that eccentric exercise affects maximal force. Following a period of eccentric exercise, maximal isometric force has been found to decrease by as much as 50% (Clarkson et al. 1992) before recovering gradually over a period of days to weeks (Newham et al. 1987; Ebbeling and Clarkson 1989; Howell et al. 1993). However, most activities of daily living require sub-maximal muscle forces. Studies examining the effects of eccentric exercise on sub-maximal muscle forces have focused almost entirely on static tasks (Komi and Viitasalo 1977; Newham et al. 1983; Berry et al. 1990; Kroon and Naeije 1991). Our first objective was to obtain a clear picture of motor impairment, following eccentric exercise, by examining dynamic tasks.

While changes to the pattern of activation of synergist muscles have been reported following eccentric exercise (Hasson et al. 1993), previous protocols only
examined synergist muscles which had all been eccentrically exercised. No study has been designed to exercise a single muscle and then investigate activities in which both exercised and non-exercised muscles participate synergistically. Such situations may occur in activities such as weight training. For example, the anterior deltoid muscle is a prime mover during the bench press, as well as being activated eccentrically each time the weight is lowered. The posterior deltoid muscle, on the other hand, is relatively inactive during this manoeuvre. However, during other movements, such as shoulder abduction, the two muscles act as synergists. Thus, the two muscles may be used synergistically after only one of them has been eccentrically exercised. Our second objective was to provide a more comprehensive description of motor impairment by investigating the effects of eccentric exercise of one muscle on the function of a non-exercised synergist muscle.

To achieve the first objective, we examined the effects of eccentric exercise on the ability to perform activities such as ballistic movement, postural stabilization and force tracking. Subjects performed a period of strenuous eccentric exercise, during which the first dorsal interosseus (FDI) muscle was stretched while attempting to abduct the metacarpophalangeal (MP) joint of the index finger. Because FDI contributes to both abduction and flexion of the MP joint, we were able to quantify motor impairment for the two actions. This allowed us to achieve our second objective by examining tasks involving finger flexion. In this way, we were able to determine whether eccentric exercise of FDI, in abduction, affected synergist flexor muscles, which did not contribute to abduction.

**Methods**

Subjects

Ten healthy male subjects, with no history of neuromuscular disease or injury involving the index finger, participated in this study (age range 22–31 years). Nine of the subjects were right-handed, the other left-handed. Each gave written informed consent to participate prior to the experiment. None had previously participated in any studies involving eccentric exercise. The subjects were asked not to participate in any weight-training activities, specifically for the upper extremities, for the duration of the study. The experiment was approved by the University Research Ethics Review Committee at Simon Fraser University. All experiments were conducted in compliance with Canadian Research Council guidelines for experimentation using human subjects.

General design

The subjects were tested on two separate occasions, prior to eccentric exercise (pre-exercise), and 24 h later (post-exercise). To ensure reproducible placement of electromyogram (EMG) electrodes on both days, indelible ink was used to mark the skin. To ensure accurate positioning in the test apparatus, the subject’s forearm and hand were supported and strapped in a stiff elastoplast splint, moulded to the shape of the hand (Figs. 1 and 2). All tests were performed on the left hand.

![Fig. 1 Diagram of apparatus used for metacarpophalangeal joint abduction of the index finger](image1)

![Fig. 2 Diagram of apparatus used for metacarpophalangeal joint flexion of the index finger. EMG (FDS) Electromyogram (flexor digitorum superficialis muscle)](image2)

Apparatus

A torque motor (PMI U16M4) was used to generate loads, which were computer controlled. The maximal torque that could be produced by the motor was 5 N·m. Position and velocity were measured by a potentiometer and tachometer, respectively. The torque was measured by a linear strain gauge mounted on a cylinder, coupling the motor shaft to a lever arm. The resolution of the torque sensor was 0.004 N·m.

Recording

Surface EMG was recorded from the FDI, flexor digitorum superficialis (FDS) and extensor digitorum communis (EDC) muscles. The FDS is an extrinsic flexor and EDC an extrinsic extensor of the MP joint. The electrode was initially positioned over the centre of the muscle in alignment with the muscle fibres, approximately midway between origin and insertion. It was then moved incrementally in different directions to obtain the largest signal while the subject performed brisk test movements of the index finger. The final placement varied from subject to subject, depending on where the largest signal was obtained. Test movements comprised isolated MP abduction, flexion and extension.