Clinical Biomechanics 26 (2011) 725–728

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Flexor carpi ulnaris tenotomy alone does not eliminate its contribution to wrist torque

Marije de Bruin [a,*], Mark J.C. Smeulders [a], Michiel Kreulen [a,b]

[a] Department of Plastic, Reconstructive and Hand Surgery, Academic Medical Center, Postbox 22660, 1100 DD Amsterdam, The Netherlands
[b] Department of Plastic Reconstructive and Hand Surgery, Red Cross Hospital, Postbox 1074, 1940 EB Beverwijk, The Netherlands

ARTICLE INFO

Article history:
Received 15 December 2010
Accepted 10 March 2011

Keywords:
Cerebral palsy
Spastic muscle
Myofascial force transmission

ABSTRACT

Background: Flexor carpi ulnaris muscle tenotomy and transfer to the extensor side of the wrist are common procedures used to improve wrist position and dexterity in patients with cerebral palsy. Our aim was to determine whether this muscle still influences wrist torque even after tenotomy of its distal tendon.

Methods: Intra-operatively, we determined in vivo maximal wrist torque in hemiplegic cerebral palsy patients ($n = 15$, mean age 17 years) in three conditions: 1) with the arm and the muscle intact; 2) after tenotomy of the flexor carpi ulnaris just proximal to the pisiform bone, with complete release from its insertion; and 3) after careful dissection of the belly of the muscle from its fascial surroundings up until approximately halfway its length.

Findings: After tenotomy of the flexor carpi ulnaris muscle, the maximal wrist torque decreased 18% whereas dissection of the muscle resulted in an additional decrease of 18%.

Interpretation: We conclude that despite the tenotomy of its distal tendon, the flexor carpi ulnaris still contributes to the flexion torque at the wrist through myofascial force transmission. Quantification of this phenomenon will help in the study of the effects of fascial dissection on the functional results of tendon transfer surgery.

1. Introduction

The flexor carpi ulnaris muscle (FCU) is one of the strongest forearm muscles and is presumed to be largely responsible for a flexion and ulnar deviation deformity of the wrist in patients with cerebral palsy (CP). To improve dexterity, the prime goal of upper extremity surgery in patients with wrist flexion deformity is to rebalance forces around the wrist such that a work trajectory around a neutral position is achieved. Distal FCU tenotomy and transfer of its distal tendon to the extensor side of the wrist are common procedures performed to reach this new balance (Beach et al., 1991; Green and Banks, 1962). For the purpose of FCU transfer, the adjacent connective tissues are dissected up until approximately halfway of the muscle belly until a straight line of pull to the receptor tendon can be achieved (Kreulen et al., 2003). Such dissection is commonly not considered to affect muscle function, and in most biomechanical models muscles are considered independent actuators (Delp and Loan, 2000). However, the connective tissue envelope of the human FCU has shown to be stiff enough to transmit force and strong enough to withstand the total amount of force that is exerted by the FCU (Kreulen et al., 2003). Moreover, fascia has been increasingly acknowledged as a secondary pathway of force transmission that affects muscle performance (Maas et al., 2005; Smeulders and Kreulen, 2007; Yucesoy et al., 2006). We hypothesize that sole tenotomy of the distal tendon of the FCU only limitedly decreases wrist flexion torque, because the intact fascial connections to the FCU will still remain to transmit force onto the wrist. Hence, subsequent dissection of the fascial connections will result in a further decrease of the wrist torque. To test this hypothesis, we measured maximal wrist flexion torque intraoperatively during upper extremity surgery in cerebral palsy patients. Wrist torque before tenotomy of the FCU (1) was compared to wrist torque after sole tenotomy, leaving the myofascial connections intact (2), and after subsequent dissection of the FCU to its adjacent connective tissue up until approximately halfway the muscle belly, leaving both innervation, and vascularization intact (3).

2. Methods

2.1. Subjects

Fifteen patients that were planned for a FCU procedure with distal tendon and muscle dissection were included after having given informed consent. Patients had a type Zancolli IIa or IIb grasp and release pattern, which means active finger extension is accompanied by a wrist flexion angle greater than 20°. Furthermore, in the type Zancolli IIa pattern the wrist can be actively extended with flexed fingers whereas in the type Zancolli IIb pattern there is no active wrist extension (Zancolli et al., 1987). The Manual Ability Classification

* Corresponding author at: Department of Plastic, Reconstructive and Hand Surgery, Academic Medical Center, Postbox 22660 Suite G4-226, 1100 DD Amsterdam, The Netherlands.
E-mail address: m.debruin@amc.uva.nl (M. de Bruin).

0268-0033/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.clinbiomech.2011.03.007

System (MACS; Eliasson et al., 2006) was used to record bilateral upper-limb motor function. During surgery, force measurements were performed at the operated extremity of the patient. The study was approved by the medical ethical committee of the Academic Medical Center (AMC) and adhered to the ethical guidelines of the 1975 Declaration of Helsinki.

2.2. Experimental setup

Previous to surgery, the palmar side of the head of the third metacarpal bone and the distal palmar crease of the wrist were marked. For this setup, the distal palmar crease of the wrist was assumed to be the palmar projection of the wrist flexion axis. Surgery was done under general anesthesia without administration of muscle relaxants and measurements were performed without a tourniquet.

Two gel-filled skin electrodes (Red Dot 2560, 3M Inc., Minneapolis, Minnesota, USA) were placed on the skin over the cubital tunnel of the elbow and connected to a custom-built, constant current peripheral nerve stimulator. For safety, the stimulator was isolated from the electric mains using an isolation transformer. The electrodes were covered with plastic foil to allow for a sterile surgical field. To provoke wrist flexion, the ulnar nerve was supramaximally stimulated provoking FCU and the flexor digitorum profundus (FDP) of the 4th and 5th digit to maximally contract. It should be noted that the ulnar nerve also activates intrinsic muscles in the hand that do not contribute to wrist torque. The palmar side of the head of the third metacarpal bone was marked and an S-shaped strain gauge connected to a computer for data registration (Epel Industrial S.A., Barcelona, Spain) was used as a hand-held dynamometer and placed at this point while the surgeon manually fixated the forearm in neutral position. The distal part of the forearm was placed on a solid cylinder to assure that the hand was not blocked dorsally (Fig. 1). Furthermore, care was taken not to move the strain gauge laterally during contractions. The force at the impact point was measured during supramaximal electrical stimulation (140 mA, 50 Hz, 0.1 ms pulse duration, 1000 ms stimulation duration). Measurements were done with intervals of 1 min to allow for recuperation of the muscle.

2.3. Wrist torque determination

Force at the impact point was measured in three conditions: 1) with the arm and the FCU intact; 2) after tenotomy of the FCU just proximal to the pisiform bone, with complete release from its insertion; and 3) after careful dissection of the belly of the FCU from its fascial surroundings up until approximately halfway its length. Care was taken that the innervation and vascularization was kept intact. Each condition was repeated three times. One surgeon (MK) performed all measurements. Wrist torque (*T* in Nm) was calculated using the following formula:

$$T = F{*}a$$

In this formula, *F* represents measured force at the impact point (in N) and *a* represents the moment arm, which is defined as the distance (in m) of the impact point of the force transducer to the wrist crease (Fig. 2). Maximal passive wrist extension (°) was measured in each condition.

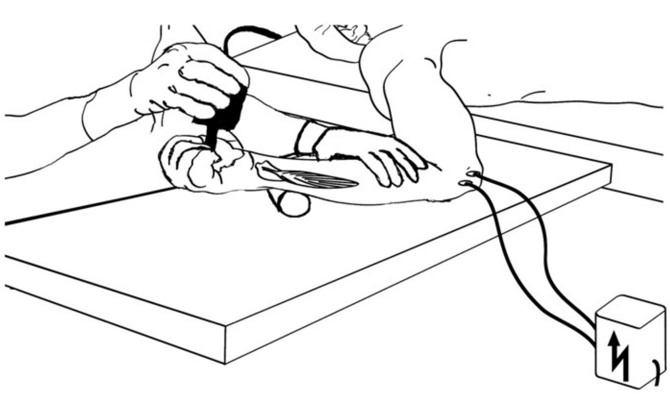

Fig. 1. Schematic drawing of the intraoperative experimental setup. The surgeon fixates the forearm in neutral position. The forearm is positioned so that the hand is not blocked dorsally. The ulnar nerve is stimulated supramaximal.

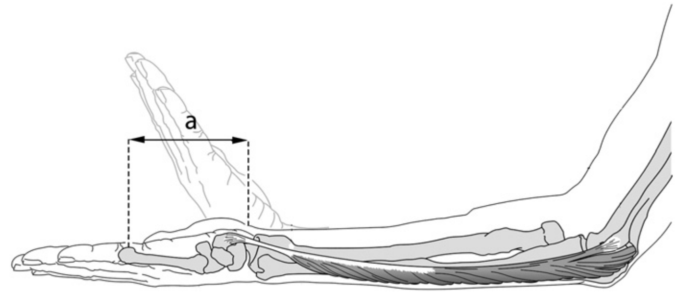

Fig. 2. Schematic drawing of the forearm with moment arm (a) between impact point on the head of the third metacarpal bone and the distal palmar crease which is taken as the palmar projection of the wrist flexion axis.

2.4. Data analysis

Raw signals were forward filtered and maximal force was determined for every signal (Fig. 3). Statistical analysis was performed using SPSS (SPSS Statistics 17.0). To determine reliability of measurements, Cronbach's α was calculated for each condition. The maximum torque was calculated and averaged over all three trials in each condition. Change of torque was expressed as a percentage relative to the torque before tenotomy. Percentages were compared using a Student *t*-test.

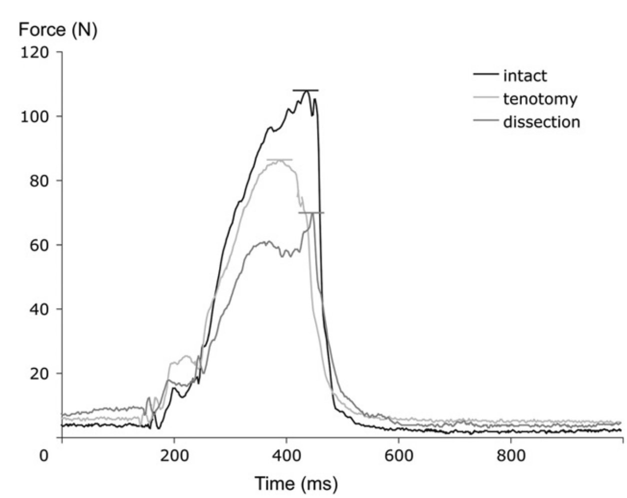

Fig. 3. Typical example of the measured signals after forward filtering in the intact, tenotomy and dissection condition. The horizontal lines at the peak of the signals represent the maximal force. These maxima were averaged over three trials per condition.