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Morphometry of the deep muscles of the extensor compartment of the forearm and related variations

Harpreet S. Gulati[1], Biswabina Ray*[,2], Sushma[3], Anthony S. D'Souza[3] and Naveen Kumar[4]

[1]Department of Anatomy, M.M.Medical College & Hospital, Solan, India, [2]Department of Anatomy, ESIC Medical College- PGIMSR, Bengaluru, India, [3]Department of Anatomy, Kasturba Medical College, Manipal, India and [4]Department of Anatomy, Melaka Manipal Medical College, India

SUMMARY

The architecture and dimensions of the muscle-tendon unit has a close relation with muscle performance. The aim of this study was to conduct morphometry and note the variations of the deep muscles of the extensor compartment of the forearm. The origin, insertion, anatomical variations, length of muscle belly and tendon of the deep extensors of the forearm, i.e. abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus and extensor indicis were noted in 38 sides of 19 cadavers. Results were statistically analysed and tabulated. There were no extra bellies of any muscle, but one 60-year-old male cadaver showed a variant muscle extensor digitorum brevis manus with the absence of extensor indicis. The variant muscle did not have any extra tendon or extra muscle belly. It was excluded from statistical analysis. The average muscle length and tendon length of abductor pollicis longus were 15.37 cm & 6.2 cm respectively; those of the extensor pollicis brevis were 15.37cm & 9.07 cm respectively; those of the extensor pollicis longus were 12.47 cm & 12.88 cm respectively; and those of extensor indicis were 10.06 cm & 14.4 cm respectively. Tendons and muscles work together to absorb or generate tension in the system. Muscle and tendon length are involved in the amount of force production.

Key words: Abductor pollicis longus – Extensor pollicis brevis – Extensor pollicis longus – Extensor indicis – Tendon, muscle

Corresponding author: Biswabina Ray. Department of Anatomy, ESIC Medical College- PGIMSR, Bengaluru, India.
E-mail: biswabina.ray@gmail.com

INTRODUCTION

Muscle performance is invariably related to the morphology and dimensions of the muscle-tendon unit, and the effect of maturation on these architectural characteristics in humans is currently unknown. According to Redl et al. (2007) changes in the tendon rest lengths of muscles and changes in the fiber length were most critical to model estimates of muscle force. Zajac et al. (1989) illustrated the integrated ability of muscle and tendon to generate force statically and dynamically by formulating a generic model of the "musculotendon actuator", which has only one parameter: the ratio of tendon length at rest to muscle fiber length at rest. In tendon transfer reconstructions, to have the same capacity for imparting movement to objects and exerting force on them, the donor muscle should have the same tendon length/muscle-fiber length ratio as the replaced muscle (Zajac, 1992). Tendon length is an important parameter for the selection of muscle during tendon transfer procedure. A tendon transfer is that procedure in which the tendon of insertion or of origin of a functioning muscle is mobilized, detached or divided, and reinserted into a bone or a different tendon to supplement or substitute for the action of the recipient tendon. Zajac (1989) suggested that functional effect of a long compliant tendon in series with muscle fibres was to increase the functional operating range of the muscle tendon unit. Thus, in addition to muscle architecture, tendon lengths and tendon properties can also be considered important design criteria which should be considered

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in transfer procedure. Sharma et al., in a morphometric study, showed the ratio between muscle belly length and total length of muscle indicating isokinetic strength of the forearm flexor group of muscles (Sharma et al., 2009). Therefore, the present authors carried out the study on deep extensor muscles of the forearm, which was not studied previously. The aim of the present study was to conduct morphometry on the muscle and tendon lengths, and identify any variations in the deep muscles of the extensor compartment of the forearm. If there are additional muscles or tendons, the kinematics around the joint are certainly altered. These assume significance in surgery, especially related to tendon transfers. Knowledge of potential tendon multiplicity and variations may help in the identification and repair of these structures.

MATERIALS AND METHODS

During routine cadaver dissection 38 formalin-embalmed upper limbs were dissected. The skin, superficial fascia, and antebrachial fascia from the lateral aspect of the forearms were then excised, and the individual deep extensor muscles of the forearm, i.e abductor pollicis longus (APL), extensor polli cis brevis (EPB), extensor pollicis longus (EPL) and extensor indicis (EI) were studied. Unbraided silk thread was placed along the whole length of the fleshy part of the muscle. The most proximal and most distal points were marked. Measurements of the normal muscles and their tendons were done with the help of a digital calliper. Length of tendon and total length of the muscle was also taken in a similar manner. Presence of any additional muscles was noted and photographed. Anatomical description of the variation was achieved by measuring its length and attachment. Variant muscles were excluded from statistical analysis. Muscle belly length and the muscle tendon were separately measured for each of the four muscles. The furthest end of the fleshy fibres on origin and tendon end denoted the length of the muscle belly. The tendon length was measured up to a point where no fleshy attachment was observed and measured till the bony attachment.

RESULTS

In the 38 upper limbs studied, the mean muscle belly length, mean tendon length, ratio of muscle belly length to tendon length and mean muscle length to total length (muscle belly + tendon length) were described (Table 1). In this table we show the parameters of the superficial layer of muscles of the posterior or extensor compartment of the forearm.

One additional muscle was noted with the simultaneous absence of the EI muscle. The muscle belly ‘Extensor digitorum brevis manus’ arises from the posterior surface of the lunate carpal bone. The insertion was along with tendon of extensor digitorum into the proximal phalanx of the index finger leading to dorsal digital expansion of the index finger (Fig. 1). There were no extra tendons or extra muscle bellies of this muscle. This muscle received its nerve supply from the deep branch of the radial nerve.

DISCUSSION

Musculo-tendinous architecture –the arrangement of contractile and connective tissue elements within a muscle– is an important determinant of muscle function. The presence of additional muscles in the forearm extensor compartment is frequently encountered during surgical procedures and anatomical dissections. Some variant muscles on the dorsum of the forearm and hand, such as the extensor indicis proprius (von Schroeder and Botte, 1995; Tan and Smith, 1998), extensor medii proprius (von Schroeder and Botte, 1991; Khaledpour and Schindelmeiser,1993; Cigali et al., 2002), extensor digitorum brevis manus (Ogura et al., 1987; Khaledpour and Schindelmeiser, 1993; Cigali et al., 2002), and extensor pollicis et indicis accessories (Komiyama et al., 1999), have been described in detail by many authors. Several anatomic studies have documented variations in the number of tendons slips, their insertions, and the location of the musculotendinous junction in case of extensor muscles of the forearm (Komiyama, 1999). The EI muscle is one of the known extensor for its variations. It normally arises from the posterior surface of the ulna and the adjoining interosseous membrane, and is inserted into the ulnar aspect of the extensor expansion of the index finger. Extensor indicis (EI) varies in the number of its tendons, in its position relative to the ED tendon to the index finger, and in its connection to the extensor pollicis longus tendon. (Godwin and Ellis, 1992) The presence of two heads or complete duplication of EI, double tendon of the EI has been reported (Bergman et al., 1988). The presence of

Table 1. Length of muscle belly and tendon of deep muscles of extensor compartment of the forearm

Name of the muscle	Mean muscle belly length (in cm)	Mean tendon length (in cm)	Ratio of mean muscle belly length / mean tendon length	Ratio of mean muscle length / total length (muscle belly+ tendon length)
abductor pollicis longus	15.37	6.2	2.47 / 1	0.71 / 1
extensor pollicis brevis	8.97	9.07	0.99 / 1	0.5 / 1
extensor pollicis longus	12.47	12.88	0.97 / 1	0.49 / 1
extensor indicis	10.06	14.4	0.69 / 1	0.41 / 1

the extensor indicis brevis in addition to normal EI and in the absence of the normal EI has also been reported (Badawi et al, 1995; Rao et al., 2006). Extensor indicis brevis –a "short" index extensor originating from the ligament over the scaphoid bone – has also been reported as a rare anatomical variant (Gahhos and Ariyan, 1983) in the form of a tender mass in a patient. In this study, we have also similarly observed a different muscle ‘extensor digitorum brevis manus’, i.e arising from the lunate which is comparable with the extensor indicis brevis. The knowledge of such anatomical variations is important in diagnosing dorsal hand masses and in planning tendon transfers (Gahhos and Ariyan, 1983). Extensor digitorum brevis manus (EDBM) is a supernumerary muscle in the dorsum of the hand frequently misdiagnosed as a dorsal wrist ganglion, exostosis, tendon sheath cyst or synovitis (Rodriguez et al., 2002).

Tendon transfer is commonly advised in cases of tendon rupture with a significant gap. The use of ECRL or of EPB has been described (Goldner, 1974; Magnel et al., 1988), but transfer of the extensor indicis proprius (Mensch, 1925) is the most widely used and reported. The extensor indicis proprius is an important tendon not only for the function of extension, but because it has important uses in surgery of the hand as a graft and for purposes of transplantation (Kaplan, 1981). Extensor indicis proprius transfer causes no functional deficit in the donor index finger; it is a simple and reliable procedure with few complications (Magnussen et al., 1990).

The longer initial muscle-tendon lengths at the beginning of force production contribute to the greater peak joint movement and power (Mero et al., 2006).

The measurements obtained in cadaveric studies are bound to differ from normal MRI or ultrasound measurements, because there is a certain amount of shrinkage factor in the soft tissues after death, especially after embalming (Loren et al., 1995). But at the same time, relative lengths of the tendons can be very well appreciated by cadaveric measurements.

The tendon affects the transmission of muscle force to the skeleton. After a review of the properties of muscle and tendon, their integrated ability to generate force statically and dynamically was studied by Zajac by formulating one parameter, the ratio of tendon length at rest to muscle fiber length at rest. According to him, the human tendon is not very compliant, snapping once stretched to 10% of its resting length. Muscles vary in the length of their external tendon, which means they vary in the extent to which the whole muscle-tendon complex length is influenced by tendon extension. Comparing muscles in terms of the ratio of their external tendon length to muscle fibre length, he demonstrated that tendon compliance had its greatest functional effect in muscle tendon unit with high tendon length to fiber length ratio (Zajac et al., 1989). In other words, the longer the tendon relative to the muscle fibres, the more influence the tendon properties will have. Therefore, increase in tendon length and thus increased tendon extension leads to increase in the operating range of the muscle-tendon length. In the present study we found that the ratio between muscle and tendon length is usually greater than one except in APL, thus indicating that the tendon is longer than the muscle fibres. Peljovich et al. (2010) stated that the length of a tendon is crucial to avoid strength loss with the transfer. If the original length of the tendon transposed is maintained, the resulting strength will be better. Brand et al. (1981) stated that the mass or volume of a muscle is proportional to its work capacity, and the fiber length of a

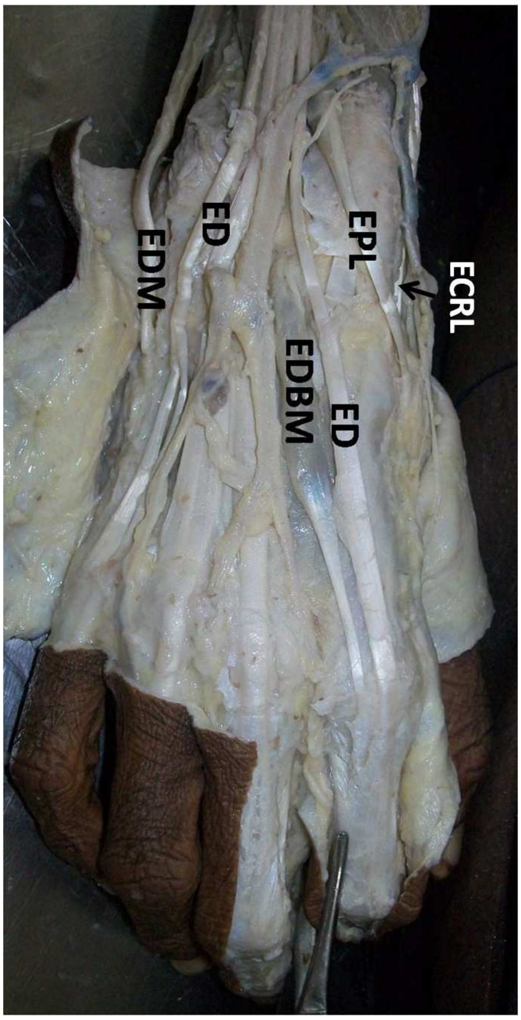

Fig. 1. Photograph showing EDBM (Extensor digitorum brevis manus) taking origin from the posterior surface of lunate. The insertion was along with tendon of extensor digitorum into the proximal phalanx of index finger leading to dorsal digital expansion of the index finger. EPL – Extensor pollicis longus; ED – Extensor digitorum; EDM – Extensor digiti minimi; ECRL – Extensor carpi radialis longus.

muscle is proportional to its potential excursion. They determined the cross-sectional area of the muscle by dividing the fiber length into the volume of each muscle, and a list of relative tension capacities of forearm and hand muscles was prepared. Their data were useful in planning tendon transfer operation.

Behncke (1998), in his study on human dorsal and plantar flexor muscles, showed that increase in gross muscle length, is positively related to maximal isokinetic strength in the lower limb. In a similar study conducted on anterior group of forearm muscles, Sharma et al. (2009) showed isokinetic strength of the forearm flexor group of muscles wherein greater ratio between muscle length and total length indicated greater isokinetic strength. In the present study, the aforementioned ratio was maximum in APL followed by EPB, EPL and EI indicating maximum isokinetic strength in APL.

The variations in the extensor muscles must be borne in mind during surgical procedures. Muscle and tendon length affect the isokinetic strength, and tendon length is an important parameter for determining the usefulness of tendons during tendon transfer procedures.

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