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Original Article

A study of the extensor tendons of the hand from point of view of evolution

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ABSTRACT

Introduction: Both anatomists and the surgeons need to have knowledge of anatomy of extensor muscles and their variations but the analysis of characteristics of each of these muscles can also improve our understanding of evolution of modern human beings.
Methods: 100 upper limbs preserved in 10% formalin were dissected to study the extensor muscles on the dorsum of forearm and hand.
Results: 28% incidence of variation was observed. Variant muscles such as extensor carpi radialis tertius (4%), extensor digitorum brevis manus (2%) and extensor medii proprius(4%) were observed. Duplication and triplication of extensor digitorum communis tendons to the 2 nd, 3 rd and 4 th digits was noted. A 28% incidence of absence of extensor digitorum communis tendon to the little finger was observed.
Discussion: Present study attempted to explain the presence of these extra muscles on the basis of their actions. Increased supination and pronation movements have been associated with more number of muscles/tendons in the extensor carpi radialis muscle and could explain the formation of extensor carpi radialis tertius muscle observed in the present study. The need to extend wrist and throw an object in a precise direction which was the need of the primate evolving to be the human being, could explain the extra extensors seen over the wrist and digits. A very well developed extensor mechanism is needed for precise functioning of the hand. The present study attempts to link together the functioning of individual extensor muscles to the trajectory of events involved in evolution of primates.

1. Introduction

It is known that the knowledge of anatomy of extensor muscles and their variations on the dorsum of the hand is necessary for the anatomists and the surgeons.[4] But the analysis of characteristics of each muscle can also improve our understanding of the evolution of modern human beings.[5]

Extensor muscles of the forearm and hand and their detailed anatomy is studied by medical students during cadaveric dissection. During this period they learn to identify the muscles of this region on the basis of their origin and tendons of insertion. At times the medical students may find themselves confused due to the existence of more tendons and muscles than are described in the standard textbooks of anatomy.

The present study was undertaken to study the extensor muscles of the forearm and hand and to note the variations therein. The study then attempts to explain the existence of these variations on the basis of their function and its place in evolution of human beings.

2. Materials and methods

110 upper limbs of adult cadavers, of unknown sex, preserved in 11% formalin were selected for present study which was carried out in the dissection hall of our Medical College. The limbs that were mutilated or otherwise damaged were excluded from the study. The limbs were tagged from 1 to 110.

Skin and superficial fascia from the back of forearm and hand were reflected. The extensor retinaculum was dissected and divided longitudinally to completely expose the extensor tendons lying in the underlying compartments. Each tendon was traced proximally to its muscle and distally to its insertion. Any additional bellies of muscle and additional tendons of insertion or splitting of

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the tendons was noted. Variations in tendons or presence of accessory muscles in this region were noted.

3. Results

Overall incidence of variation among the extensors was observed to be 28%.

The tendons of extensor carpi radialis longus and brevis(ECRL, ECRB) muscles lie in the 2 nd osseo-fascial compartment. The muscles were seen taking origin from the lateral supracondylar ridge and common extensor origin and were inserted into the dorsal surface of base of 2 nd and 2 nd and 3 rd metacarpal bones respectively. A 4% incidence of variation was observed in these muscles. In 4 hands, an extensor carpi radialis tertius(ECRT) was observed. In 3% of hands the additional belly of ECRT was found taking origin from posterolateral surface of radius lying deep to ECRB muscle, and was inserted via a thin long tendon into dorsal surface of 3 rd metacarpal bone. In 1% of the hands the additional muscle ECRT was found lying deep to ECRB muscle and its tendon was observed to split into two before getting inserted into the dorsal surface of the 3 rd metacarpal bone (Fig. 1).

The four tendons of extensor digitorum communis (EDC) and the extensor indicis proprius (EIP) muscle were placed in the 4 th osseofascial compartment deep to the extensor retinaculum. The EDC muscle arose from the common extensor origin, formed 4 tendons to the medial 4 digits in the middle of the forearm. The tendons passed deep to the extensor retinaculum passing on the dorsal surface of the corresponding metacarpal and proximal phalange to be inserted into the corresponding dorsal digital expansion and the dorsal surface of the middle and distal phalange. 28% of the EDC muscles showed variations. Details of the variations of both the above muscles are given in Table 1 (Figs. 2–5).

Placed deep to the four tendons of EDC in the same 4 th osseofascial compartment was the EIP muscle. The muscle took origin from the posterior surface of ulna and adjacent interosseous membrane. Its tendon joined the tendon of EDC to the index finger on its ulnar side and contributed to the formation of the corresponding dorsal digital expansion. In one hand the tendon of EIP was found to be duplicated. Both muscles arose from posterior surface of shaft of ulna and adjacent interrosseous membrane. The muscle attached proximally formed a tendon and was attached to the EDC tendon to index finger from the medial side, while the additional muscle formed a thin long tendon that joined the EDC tendon to index finger from the lateral side.

2% of the limbs showed presence of extensor digitorum brevis manus (EDBM) muscle. The muscle took origin from the lower end of radius and adjacent carpal bones and from capsule of wrist joint.

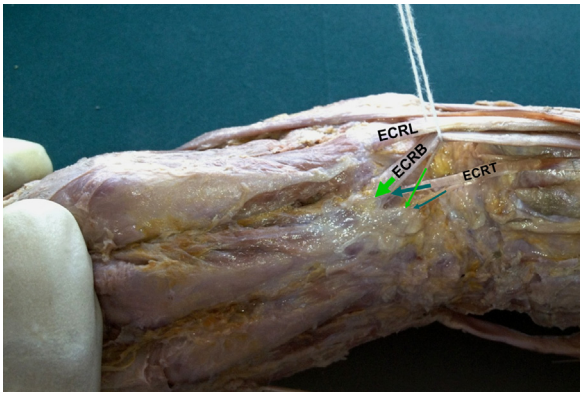

Fig. 1. The photograph shows ECRL, ECRB (tendon splitting into two) and ECRT (tendon splitting into two) lying deep to ECRB.

Table 1
Details of the variations observed in the Extensor Digitorum Communis and Extensor indicis proprius muscles along with the percentage of incidence of each variation in present study.

	Name of the Variation	Incidence of the variation
1	Absence of tendon to little finger	28% (Fig. 2A)
2	Absence of Extensor indicis proprius muscle	2%
3	Duplication of extensor indicis proprius muscle	1% (Fig. 2B)
4	3 tendons to middle and ring finger	2%
5	Duplication of tendon to	
	Index finger	1%
	Middle finger	1% (Fig. 3B)
	Ring finger	12% (Fig. 3A)
	Little finger	2% (Fig. 3A)
6	Triplication of tendon to ring finger	5% (Fig. 3B)
7	Triplication of tendon to middle finger	1%
8	Extensor medii proprius: Single	3% (Fig. 4A)
	Double	1% (Fig. 4B)

It formed a muscle belly lying deep to the EDC tendons, the tendon being attached to the extensor expansion over the 3 rd digit (Fig. 5A).

Placed medial to the above muscles, in the 5 th osseofascial compartment beneath the extensor retinaculum, was the extensor digiti minimi (EDiMi) muscle. It was also seen to arise from the common extensor tendon, passed deep to the extensor retinaculum, receiving the attachment of the EDC muscle to the 5 th digit, and finally getting attached to the dorsal digital expansion of the 5 th digit. 20% incidence of variation in the EDiMi muscles was observed.

16% of the muscles showed the tendon of insertion splitting into 2 and both getting attached to the little finger (Fig. 2A). In 3% of the muscles, three tendons were formed, two tendons being inserted into little finger and lateral one tendon into the ring finger by joining the EDC tendon to the ring finger (Fig. 5B).

The extensor carpi ulnaris was observed most medially. The muscle was observed taking origin from the common extensor tendon and posterior border of ulna, passing in the groove between the head and styloid process of ulna, through the 6 th compartment beneath the extensor retinaculum and attaching distally to the tubercle on the medial side of 5 th metacarpal bone. No variations were observed in this muscle.

All the muscles were supplied by the posterior interosseous nerve.

4. Discussion

The present study involved dissection of hundred upper limbs to study the extensor tendons on the dorsum of the hand.

The ECRL and ECRB muscles showed a 4% incidence of variation. In 4 hands, an ECRT was observed. Thus in these four hands the 2 nd compartment below the extensor retinaculum had 3 muscles in it instead of the usual two with the ECRT lying deep to the ECRB. Nayak et al. have also reported finding of the ECRT muscle which took origin from the common extensor origin and was attached distally to the bases of 2 nd and 3 rd metacarpal bones.[12] Bergman et al. have reported an *extensor carpi radialis intermedius* which took origin from the lateral epicondyle of humerus and was inserted similar to above muscle.[1] However the additional muscle reported in this study was found to lie between ECRL and ECRB muscles. Similar additional bellies have also been reported by Srimani et al. and Shetty and Nayak.[17,16] In both cases the muscle had its proximal attachment to the ECRL muscle and formed a separate tendon distally. In the present study all 4 additional muscles took origin separately from the proximal end of radius. None of the earlier studies report a split tendon of the additional muscle.

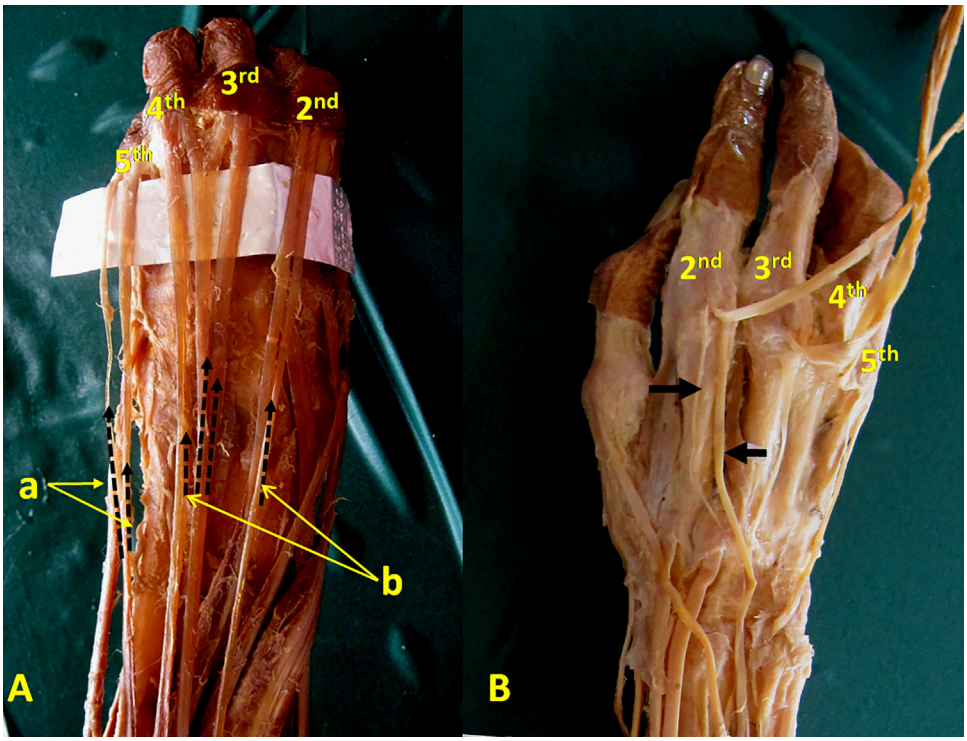

Fig. 2. The photograph "A" shows absence of EDC tendon to the little finger. Also seen are (a) Duplicated tendons of EDiMi (b) Tendons of EDC to 2 nd, 3 rd and 4 th digits (tendon to 4 th digit is duplicated). Photograph "B" shows duplicated tendon of EIP as depicted by 2 black arrows.

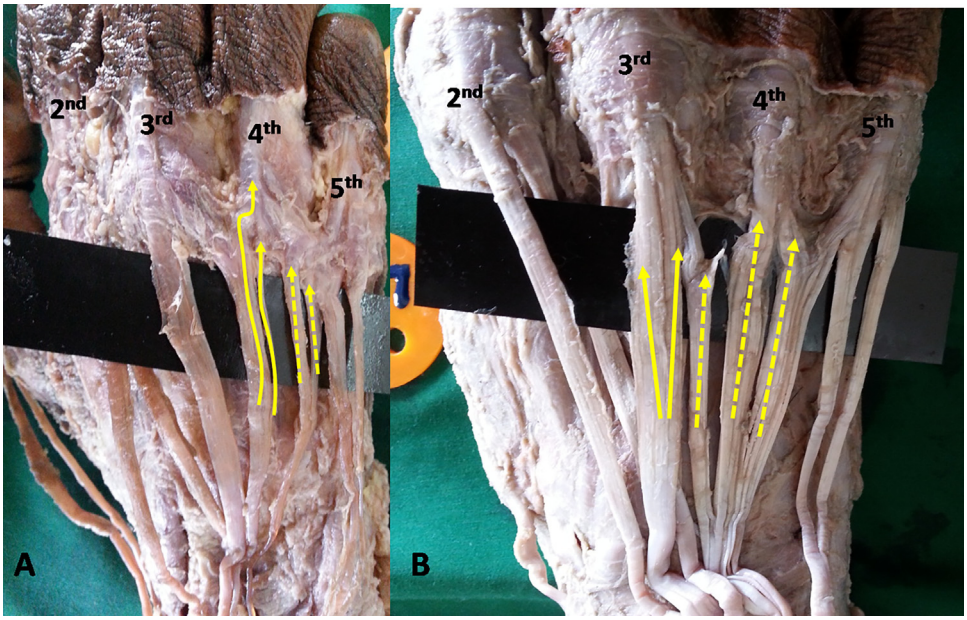

Fig. 3. The photograph "A" shows duplication of tendon of EDC to the 4 th (straight lines) and 5 th (dotted lines) digits. Photograph "B" shows duplication of tendon of EDC to the 3 rd (straight lines) and triplication of tendon to 4 th (dotted lines) digits.

A study by Guintard and Cossu compared the ECRL and ECRB in man to those in several domestic animals and concluded that the adaptation of a species to certain way of life and type of locomotion can bring significant morphological variations.[7] The extensor carpi radialis (ECR) muscle can be single in those animals where there is loss of supination and pronation movement. They noted three broad morphological types in the structure of ECR muscle namely one single muscle as seen in sheep, an intermediate type as seen in some carnivores wherein the fleshy part appears divided into two in the distal third of forearm and ends in two tendons and two muscles with two tendons as seen in man (Fig. 6). If lack of pronation and supination can be a reason for there being a single muscle belly of ECR, can an increase in this function explain the incidence of additional bellies in the ECR muscle? It is interesting to note that both ECRL and ECRB are ascribed the movements of extension and radial rotation of the wrist joint by standard texts of

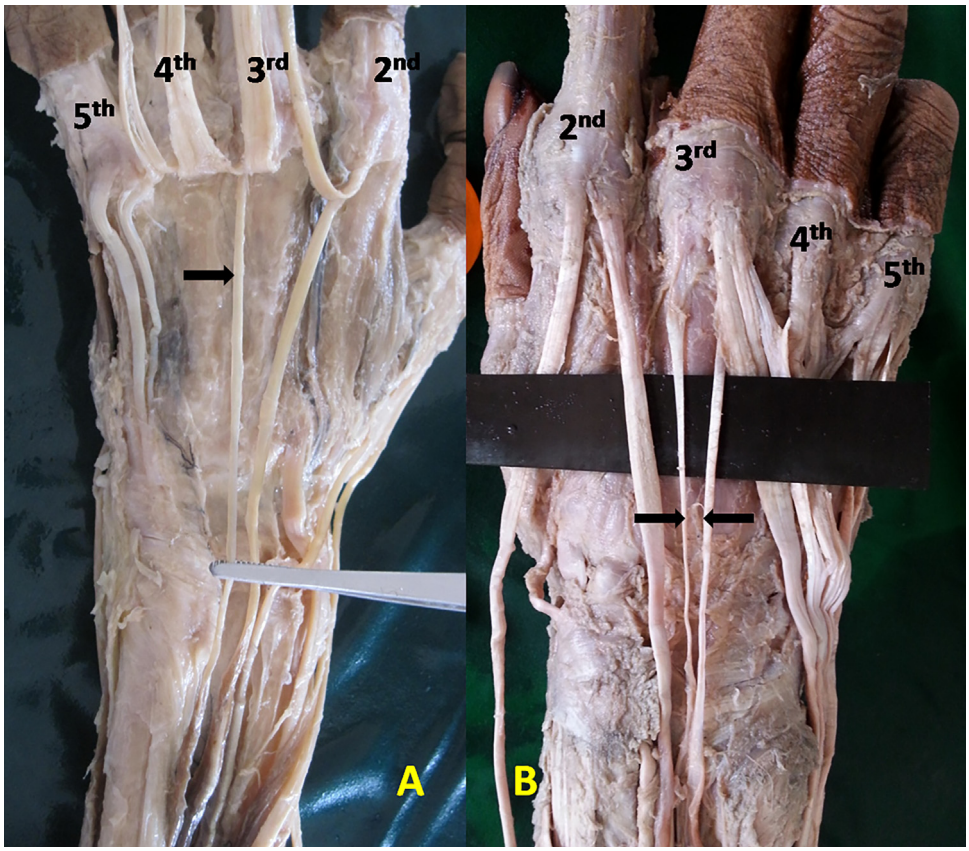

Fig. 4. The photograph "A" shows a single Extensor medii proprius and photograph "B" shows double Extensor medii proprius muscle.

Fig. 5. The photograph "A" shows EDBM muscle (black arrow) lying deep to the EDC tendons and photograph "B" shows the extensor digit minimi muscle splitting to form three tendons, two of which went to little finger (straight black arrows) while a thin third medially placed slip (dotted arrow) got attached to the EDC tendon to the ring finger.

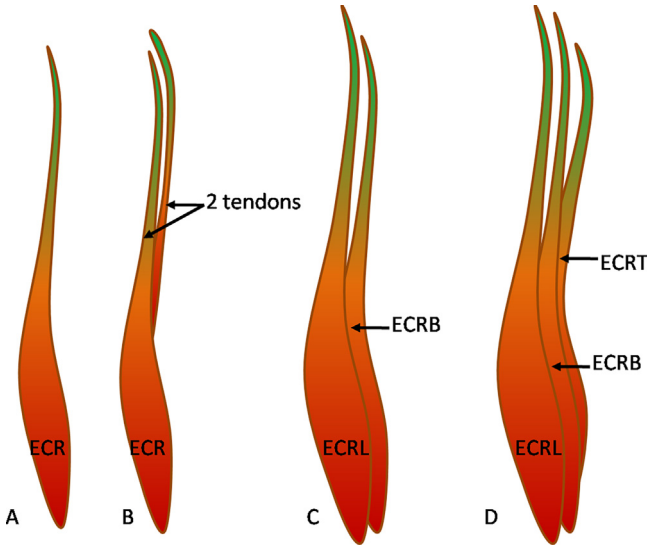

Fig. 6. Diagrams showing the extensor carpi radialis muscles as discussed by Guintard. A. Single ECR. B. One muscle and 2 tendons as seen in carnivores. C. 2 muscles (ECRL, ECRB) and 2 tendons as seen in man. D. 3 muscles (ECRL, ECRB, ECRT) and 3 tendons as seen in variation observed in present study.

anatomy while the study by Guintard and Cossu found changes in these muscles according to ability of the animal to supinate and pronate the limb.[18,7]

The ECRL and ECRB are important wrist extensors. Any additional muscle in this group would aid in the important wrist extension action which enhances the functioning of the hand.

The EDC and the EIP pass through the 4th osseofascial compartment. Present study reports multiple variations here such as increase in number of tendons to the 2nd, 3rd and 4th digits and 28% incidence of absence of the EDC tendon to the 5th digit. Duplication of EIP and EDiMi muscle was also observed. Similar variations have also been reported by other authors.[4,2]

A study by Dass et al. reported a 2% incidence of two tendons of EIP, one was on the ulnar side of corresponding EDC tendon and other on its radial side.[4] Present study also reports finding of duplication of EIP muscle and a 4% incidence of extensor medii proprius. A double extensor medii proprius was reported by Bharambe et al.[2] A bilateral extensor medii proprius with a split tendon of EIP was reported by Li and Ren.[10]Wilkinson et al. studied the functioning of hand in order to create a robot hand and found that the EIP muscle which is attached to EDC tendon to index finger is an additional muscle to that digit and its existence gives the index finger a certain independence of movement compared to the 3rd, 4th and 5th digits.[20] Additional tendons of EIP could further increase this independence of the index finger. Additional muscle to the middle finger, i.e. extensor medii proprius could similarly provide independent movement to the middle finger.

Nayak et al. reported extra tendon lying between EDC tendons to 4th and 5th digits which split into two and contributed to both these tendons.[11] Present study also reports a similar variation. Multiple tendons in form of duplication and triplication of EDC to middle and to ring finger have been reported by Dass et al.[4] Paul and Das reported a case where EDC tendons to both the ring and the little finger were duplicated.[14] Kocabiyik et al. reported a case where there were three tendons of EDC to middle finger and two to the ring finger.[9] Present study also reports similar formation of EDC tendons. Dass et al. reported a 66% incidence of absence of the EDC to little finger.[4] Present study reports a 28% incidence of absence of EDC to little finger.

The present study reports finding of 2% incidence of EDBM. This muscle has also been reported by other authors.[3,6,15,8,13] The EDBM reported by Bolla, Jadhav and Zambare and Ranade et al. was attached to the extensor expansion over the index finger while that reported by Dixit et al. was attached distally to that of the middle finger. Ogura et al. in their study of EDBM muscles found that the EDBM is a variant of the EIP muscle and often found attached to it.[13] However both the EDBM muscles being reported by present study were not having any attachment to the EIP muscle. There have been reports of EDBM in gorillas, also associated with either digit 2 or digit 3 though it is not regularly observed.[20]

Young in a study of evolution of human hand compared the present human hand to the hand of the chimpanzee.[21] While the chimpanzee has elongated fingers, the thumb is small and relatively immobile. Their grip is a “hook grip” and is primarily due to the four flexed digits. The weak and short thumb is not opposable to the index finger and not adapted to the “throwing movement”.

Young says that as the human hand evolved, the balance of strength shifted radially to the thumb, 2nd and 3rd digits. The thumb finger elongated. With this the human hand gained a unique grip, namely the “precision grip”. The precision grip was used for grasping an object and then throwing it with force. The grasping of an object needed the long opposable thumb which could grasp the object from one side while the fingers with their fingertip pads grasped it from the other. When the object was released the extension of the fingers controlled the release of the object in the precise direction. Thus enhanced control in these actions is a key element in the accuracy needed in the throwing movement.

Thus during throwing movement, an object gets picked up by the “precision grip”, followed by extension at the wrist to move the object to an advantageous position. This is followed by flexion at the wrist for the actual throwing of the object. Thus the wrist moves from extension to flexion. The increased range of extension in the human wrist increases the acceleration of throwing of an object. The flexed wrist with its short flexor muscles prevents the chimpanzee therefore from using the hand for throwing and could be the reason for its adaptation of a quadrupedal mode of locomotion.[21]

The kinetic energy needed to propel the object forward in a precise direction is channeled through the index and middle fingers of the throwing hand which extend and their tips provide the “final thrust” to the object being thrown. The extra wrist and finger extension ability needed for throwing with precision using the precision grip, could explain increase in number and also the spread of the extensor muscles and tendons in the forearm and hand.

Wilkinson et al. attempted to create an anatomical robot hand.[20] They found that most similar researchers did not create the extensor mechanism of the hand due to its complexity. However they found that many finger postures of the robot hand were impossible without creation of the artificial extensor mechanism. Can increasing use of hand by the humans necessitating extension movement at the wrist and hand, explain the high percentage of incidence of extra extensor muscles and tendons as observed in present study? The presence of multiple tendons may also alter the kinematics around the site of attachment to the phalanx. Knowledge of normal and variant anatomy of the extensor tendons, may be helpful while performing graft and tendon transfer operations. [19]

5. Conclusion

110 upper limbs were dissected to study the extensor muscles on the dorsum of forearm and hand. 28% incidence of variation was

observed. Variant muscles such as ECRT, EDBM and extensor medii proprius were observed. Duplication and triplication of EDC tendons to the 2 nd, 3 rd and 4 th digits was noted. A 28% incidence of absence of EDC tendon to the little finger was observed.

Present study attempted to explain the presence of these extra muscles on the basis of their action. The study attempts to correlate the formation of ECRT muscle to the supination and pronation movements as well as to it being an extensor of wrist joint. The need to extend wrist and throw an object in a precise direction which was the need of the primate evolving to be the human being, could explain the extra extensors seen over the wrist and digits. The present study attempts to link together the function of individual muscles to the trajectory of events involved in evolution of primates.

Conflicts of interest

None.

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None.

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