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# A study of extensor pollicis longus and brevis and abductor pollicis longus from the perspective of evolution

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## Abstract

**Background:** The Extensor pollicis longus and brevis and abductor pollicis longus muscles have evolved progressively in different primates according to the function expected from the pollux finger. Analysis of individual muscles in different primates can help our understanding of evolution. **Aims and objective:** The present study was undertaken to study these three muscles and to note the variations therein and to attempt to explain the existence of these variations on the probable basis of their evolutionary history. **Methodology:** The extensor pollicis longus, brevis and abductor pollicis longus muscles were dissected meticulously in 100 upper limbs of adult cadavers. **Results:** In case of extensor pollicis longus and extensor pollicis brevis, 2% incidence of duplication of muscle and 1% of duplication of tendon and 1% incidence of duplication of muscle and 2% of duplication of tendon was observed respectively. In case of abductor pollicis longus 23% incidence of variation was observed. The muscle was observed to split into multiple tendons of muscles to have widespread attachment beyond the 1st metacarpal bone. **Conclusion:** The extensor pollicis longus with minimum variation seems to have settled in its evolutionary trajectory. In 8% of abductor pollicis longus studied, superficial and deep heads were observed. Oudenaarde states that the superficial head is used for range of movement and the deep set of fibers are used for strength of contraction. Elliot observes that the wide attachment of the abductor pollicis longus on the muscles abductor pollicis brevis and the opponens pollicis, the 1st carpometacarpal joint capsule and trapezium bone could be for better anchorage for radial deviation at the wrist joint. The extensor pollicis brevis muscle is seen as a separate muscle only in humans, hylobatids and gorillas whereas in all other primates. The chimpanzee hand seems to have evolved one step further with two extensor pollicis brveis muscles.

**Keywords:** Extensor pollicis longus, Extensor pollicis brevis, Abductor pollicis longus, Primates, Hylobatids, Evolution.

## INTRODUCTION

The extensor pollicis longus and brevis (EPL, EPB) and abductor pollicis longus (APL) are three muscles belonging to the dorsal group of forearm muscles which are separately attached to the pollux finger and involved in its independent manipulation compared to rest of the four digits.

Each of the muscles has evolved progressively in different primates according to the function expected from the thumb finger. Study of the comparative anatomy of the thumb among the primates is crucial to help us understand the functional morphology, behaviour and the phylogeny of the mammals [1]. Analysis of the muscle characters can help our understanding of evolution and homologies of the forearm and hand muscles of modern humans [2].

The present study was undertaken to study these three muscles and to note the variations therein. The study attempts to explain the existence of these variations on the probable basis of their evolutionary history.

## METHODOLOGY

100 upper limbs of adult cadavers, of unknown sex, preserved in 10% formalin were selected for present study which was carried out in the dissection hall of our Dept of Anatomy. The limbs that were mutilated or otherwise damaged were excluded from the study. The limbs were tagged from 1 to 100.

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Skin and superficial fascia from the back of forearm and hand was reflected. The extensor retinaculum was dissected and divided longitudinally to completely expose the EPL, EPB and APL 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 the tendons was observed. Variations in tendons or presence of accessory muscles in this region were noted.

**RESULTS**

Overall incidence of variation was observed to be 23%.

**Extensor Pollicis Longus**

The EPL muscle was placed in the 3rd osseo-fascial compartment just medial to the dorsal tubercle. The muscle arose from the posterior surface of shaft of ulna and adjacent interosseous membrane and formed an elongated tendon that passed superficial to the extensor carpi radialis longus and brevis muscles and was inserted into the dorsal surface of base of distal phalange of the thumb. 2% of the EPL muscles showed duplication of muscle while 1% showed duplication of the tendon. In all cases both the muscles or the duplicate tendons passed through the same extensor compartment. (Fig 1A,B)

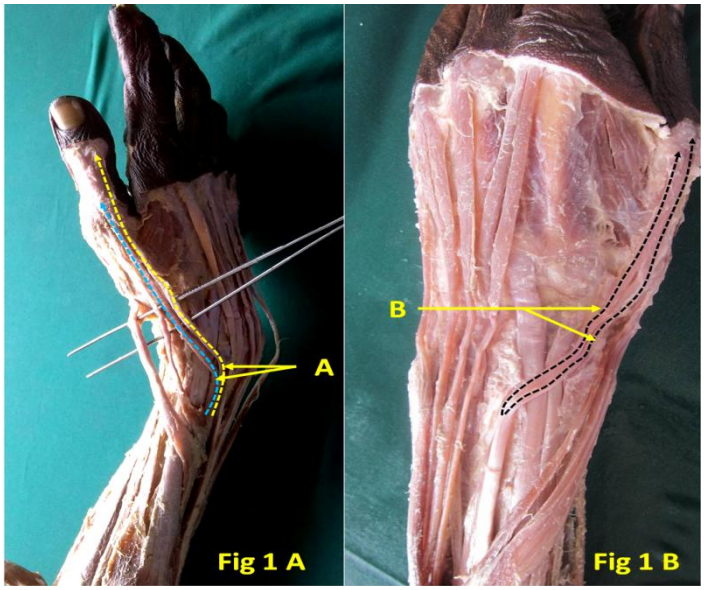


**Figure 1:** Fig 1A. The photograph shows shows duplication of the EPL muscle marked by blue and yellow dotted lines (A) Fig 1B shows duplication of the tendon of EPL muscle marked by black dotted lines (B).

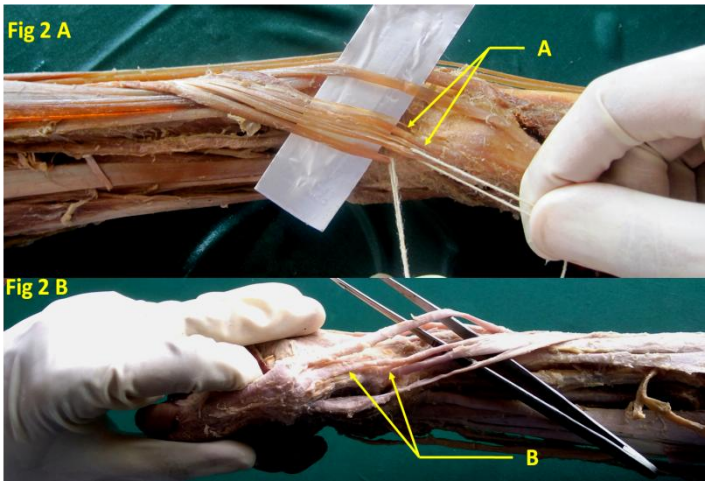


**Figure 2:** Fig 2 A. The photograph shows duplication of the EPB muscle (A). Fig 2 B. The photograph shows splitting of EPB muscle into two tendons (B).

**Extensor pollicis brevis**

In three hands (3%) the EPB showed variation. In one hand there was duplication of the muscle and in the other two hands there were two tendons observed emerging from a single EPB muscle. The laterally placed tendon in both cases was thin and inserted proximally into the lateral aspect of 1st metacarpal bone, and the thicker tendon, was medially placed and inserted more distally into the proximal phalange of the same finger. (Fig 2A, B)

**Abductor pollicis longus**

A 23% incidence of variation was observed in the APL muscle.

In 10%, the APL muscle, besides attachment to the base of 1st metacarpal bone, also showed attachment to abductor pollicis brevis (APB) through a separate slip of attachment or through two separate tendons. (Fig 3 A)

In one of the hands the muscle formed showed formation of 2 tendons. The medial tendon was inserted on the base of 1st

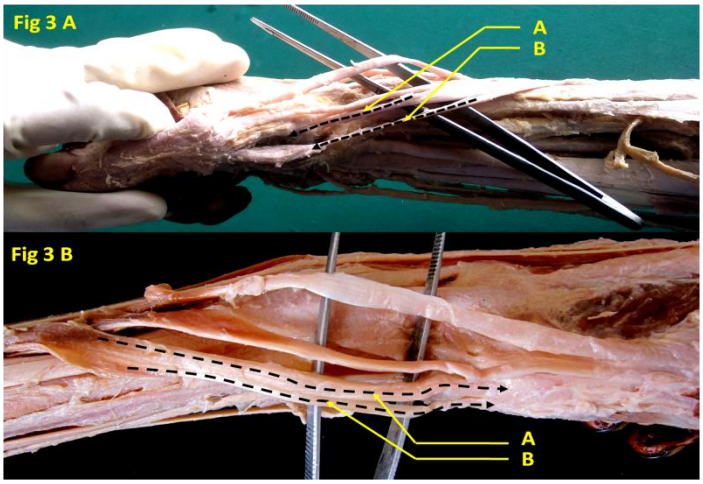


**Figure 2:** Fig 3 A. The APL muscle formed two tendons. One of the tendons can be seen attached to the 1st metacarpal bone (A) and the other slip attached to APB muscle (B). Fig 3 B The photograph shows APL muscle forming 2 tendons, one placed medially(A) and the other laterally (B). In both Fig A and B the tendons have been marked by dotted black lines (B).

metacarpal bone on the dorsal surface and lateral tendon was also attached to the APB muscle. (Fig 3 B)

In another hand the APL formed 2 bellies of muscle. The medial belly split into 4 tendons which were inserted into dorsal surface of base of 1st metacarpal bone (2 slips attached here), into the joint capsule, and into APB muscle. The lateral muscle formed one tendon which was inserted deeper to the rest of the tendons into the APB. (Fig 4 A)

In one hand 2 muscle bellies and 5 tendons were observed. 2 were medial and inserted into base of 1st metacarpal bone on the dorsal surface of hand and into APB and the lateral muscle split into 3 tendons that were inserted into the APB and opponens pollicis muscles and into the 1st carpometacarpal joint capsule. (Fig 4 B)

One of the APL muscles formed 2 muscle bellies which formed 5 tendons. 3 tendons were medial, 2 of which were inserted into base of 1st metacarpal and 3rd deeply placed tendon was inserted into the APB muscle. The lateral muscle split into 2 tendons that were inserted into the APB muscle and into the 1st carpometacarpal joint capsule. (Fig 4 C)

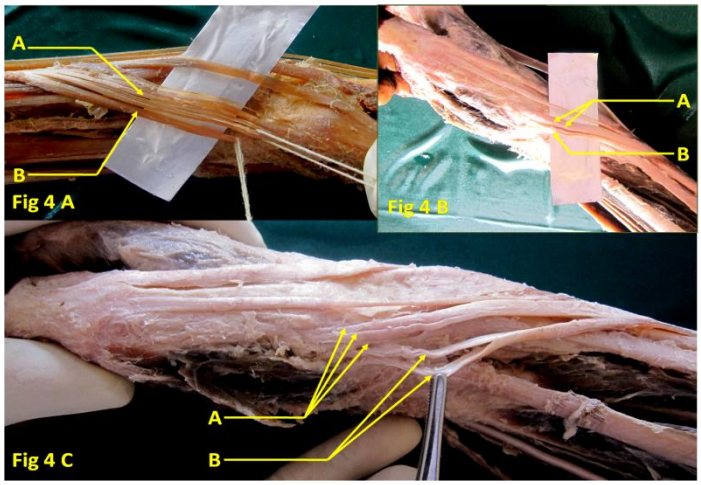


**Figure 4:** Fig 4 A. The photograph shows the APL muscle forming 2 muscles. The medial belly can be seen splitting into 4 tendons (A) and the lateral muscle (B) formed one tendon which was inserted deeper to the rest of the tendons into the APB muscle. Fig 4 B. The photograph shows APL muscle forming 2 muscle bellies. The medial muscle formed 2 tendons and the lateral muscle split into 3 tendons. Fig 4 C. The APL muscles formed 2 muscle bellies. The medial muscle formed 3 tendons (A), and the lateral muscle split into 2 tendons (B).

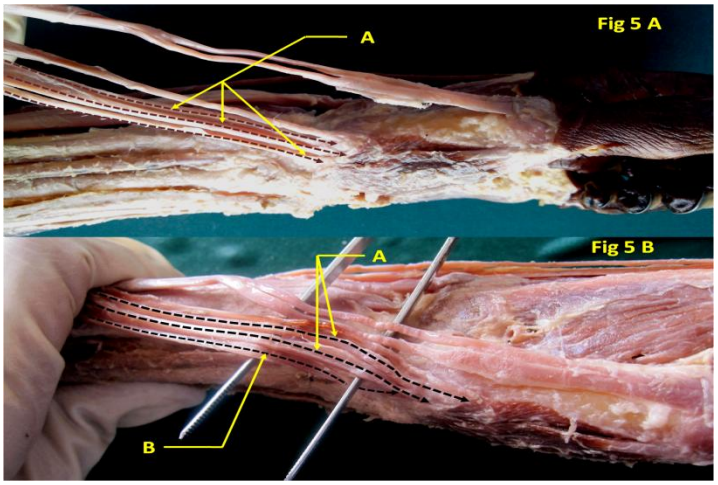


**Figure 5:** Fig 5 A. The photograph shows APL muscle forming 3 tendons (A). Fig 5 B. The APL muscle in this photograph can be seen forming 3 tendons. 2 tendons were placed medially and superficially (A) while the 3rd tendon passed deeper and more laterally to the other 2 and was inserted into the APB muscle (B).

In 8%, the number of muscle bellies and /or tendons of APL were increased to three.

In one case the APL had 3 tendons. One was inserted into base of 1st metacarpal, 2nd into APB and 3rd partly into the 1st carpometacarpal joint capsule and partly into APB. (Fig 5 A)

In another hand, the APL muscle formed 3 tendons. 2 were medial and superficial and inserted into base of 1st metacarpal bone on the dorsal surface of hand and into APB muscle and the deeper tendon passed more laterally deep to the other 2 tendons and was also inserted into the APB muscle. (Fig 5 B)

In one hand the muscle showed formation of 3 tendons, two of which were superficial and the third was deeply placed in comparison. The medial and intermediate tendons were superficially placed. Medial tendon was inserted on the base of 1st metacarpal bone on the dorsal surface, intermediate tendon was also attached to the APB muscle. The lateral tendon passed deep to both these tendons and was attached to the base of 1st metacarpal bone on the dorsal surface and to the 1st carpometacarpal joint capsule and also gave few fibers to the APB muscle.

The division of muscle fibers into superficial and deep was seen in 8% of the hands and into medial and lateral heads in 4% of the hands. Table 1 shows the summary of various attachments of APL muscle along with their percentage of incidence.

**Table 1:** The table shows the various attachments of APL muscle with the percentage of incidence of each attachment

| | | |
|---|---|---|
| 1 | 1st metacarpal bone | 100% |
| 2 | Abductor pollicis brevis muscle | 23% |
| 3 | Opponens pollicis muscle | 9% |
| 4 | Trapezium Bone | 6% |
| 5 | Capsule of 1st carpometacarpal joint | 6% |

**DISCUSSION**

The present study involved dissection of hundred upper limbs to study the EPL, EPB and APL muscles.

The EPL muscle lies in the 3rd compartment beneath the extensor retinaculum. Present study reports 3% incidence of variation in this muscle. Thus the 3rd extensor compartment had two tendons passing through it instead of one. Such a double tendon was also reported by Sevivas et al which was detected during dorsal approach to the wrist for rheumatoid arthritis. However each tendon of EPL had its own independent extensor compartment [3]. Nishijo et al reported a case of duplication of the EPL tendon wherein the both the tendons passed radial to the Lister's tubercle and there was an associated absence of EPB tendon [4.] This placement of the tendons resulted in tenosynovitis which was the presenting complaint of the patient.

Aversi-ferreira found that in cebus monkeys the EPL muscle's tendon bifurcated to get attached to both proximal and distal phalanges of the thumb similar to the variation observed in present study [1]. Diogo et al studied the EPL muscle in man and other primates such as gorilla and chimpanzee and found them to be very similar [5]. The EPL muscle seems to have settled in its evolutionary trajectory among the primates and shows few variations.

Komiyana M *et al.* have studied the extensor indicis proprius muscle in 164 hands and reported the finding of extensor indicis radialis or extensor pollicis et indicis accessories muscle. Here a slip of the extensor indicis muscle was attached also to the pollux finger [6]. Such muscles have also been reported in new world monkeys [7]. Aversi-Ferreira states that this could point to a developmental relationship between these two neighbouring muscles that control the thumb and index finger, both of which are crucial for the precision grip [1].

However present study did not report any finding of attachment between the EPL and extensor indicis proprius muscles. Aversi-Ferreira et al compared the EPL muscle in cebus monkeys and with that of other primates and found that in cebus monkeys, and in chimpanzees and humans the EPL in not deeply blended with the extensor indicis whereas such deep blending has been observed in many other primates[1]. Diogo *et al*. state that both these muscles phylogenetically originate from the extensors digitorum breves of other terapods.[5]

A 23% incidence of variation was observed in the APL muscle in the present study. The types of attachments of APL have been depicted in Table 1. It was observed that the APL besides getting attached to the radial side of the base of 1st metacarpal bone also gave variable slips of attachments to the joint capsule of 1st carpometacarpal joint, the

trapezium bone and to the APB and opponens pollicis muscles. Thus APL tended to have wide attachment. This was achieved by either having a single muscle that formed multiple tendons of attachment or by forming 2 muscles that later had multiple tendons of attachment. (Fig 6A, B) The muscle also seemed to be forming 2 sets of fibers, superficial and deep set (8%) or at times medial and lateral set (4%) of fibers.

In a study by Nayak et al, an APL with 6 slips of insertion was observed. This muscle also had an additional slip of muscle from the brachioradialis muscle. The muscle was found attached to the palmar aspect of 1st metacarpal bone, to the trapezium and to the thenar muscles through these tendons [8].

Oudenaarde stated that the APL, on dissection can be said to have superficial and deep heads. The deep part originates from the ulna, interosseous membrane and the radius. This forms a central tendon and close to insertion, it can form several branches that get attached to trapezium, APB or fascia covering it, opponens pollicis and to capsule and anterior oblique ligament of 1st carpometacarpal joint [9]. There are two superficial heads, one originating from ulna and interosseous membrane and other from the radius and terminate in a tendon to the 1st metacarpal bone. This tendon too can divide into multiple smaller tendons. The author states that while the deep fibers are short and obliquely placed, the superficial fibers are long and arranged in a parallel manner. It appears that the superficial fibers can shorten to a great extent but do not have much strength while deep fibers are arranged for strength but lack range of shortening. In the present study also in 8% hands, the APL muscle was found to be divided into superficial and deep parts close to the distal end of forearm. As per Oudenaarde, deep fibers are short and meant for strength of contraction and in present study besides being attached to 1st carpometacarpal joint, its capsule and ligaments, the deep fibers were always attached to the APB muscle. The authors would like to suggest that possibly the deep fibers of APL are utilized for strong abduction of the pollux finger which is carried out in conjunction with the APB muscle. The widespread attachments could also ensure good stability during movements of the 1st carpometacarpal joint [9]. A study by El-Beshbishy and Abdel-Hamid, involving dissection of 50 APL muscles reported no single tendon of APL. The APL exhibited 2-6 tendons which were classified into medial and lateral. On studying the thickness of these tendons, the lateral was found to be thicker and was verified to be the main tendon, while the medial tendons were the accessory tendons [10]. In 4% of the hands in the present study, the APL muscle was observed to be divided into medial and lateral heads. In each of these hands, the laterally placed head was found to be attached to the APB muscle while the medial was attached to the 1st metacarpal bone. The standard texts of anatomy state the distal attachment of the APL muscle to be 1st metacarpal bone making it the main tendon [11]. Thus the finding by the present study seems opposite of the finding by El-Beshbishy and Abdel-Hamid [10].

Elliot states that instead of considering the APL as the abductor of the thumb finger, it should be considered as radial deviator of the wrist as a whole [12]. As a radial deviator of the wrist it is possible that APL muscle may need wider spread of attachment besides that to the 1st metacarpal bone. This could explain the widespread attachment of the APL muscle. Slips of attachment to the trapezium bone, 1st carpometacarpal joint capsule, APB and opponens pollicis muscles could provide the extra anchorage needed for the difficult and minuscule radial deviation movement seen at the wrist joint.

The EPB muscles showed 3% incidence of variation wherein there was formation of two muscles or 2 tendons. While the lateral tendon was thin and inserted on the lateral aspect of 1st metacarpal bone, the medial tendon was thick and was inserted on the proximal phalange of the same digit. In the study by Nayak et al, 17 out of 156 upper limbs studied showed presence of double tendon and 6 showed occurrence of triple tendon [13]. No such triple tendon formation was observed in present study. In 100% of the limbs dissected the muscle belly of EPB was separate from that of APL which is a finding similar to that reported by Nayak *et al.* Bagoji *et al*. reported a single muscle with three tendons of insertion [14]. Two of these were distally attached to the 1st metacarpal and one to the proximal phalange.

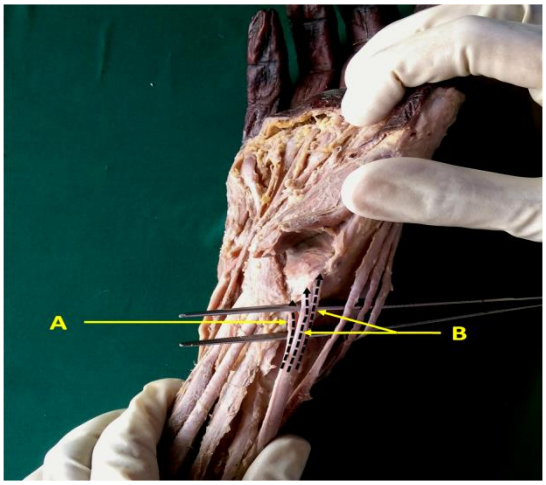


**Figure 6:** In this photograph the APL muscle formed 3 tendons, two of which were superficial (B) and the third was deeply placed in comparison (A).

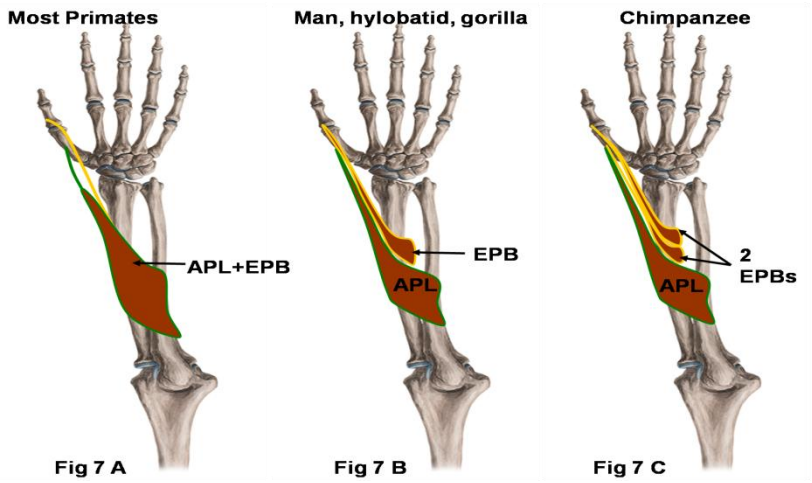


**Figure 7:** Fig 7 A. The diagram shows the single abductor pollicis muscle seen in most primates. 2 tendon can be seen emerging from it, one (green) going to base of 1st metacarpal and other (yellow) to base of proximal phalange. Fig 7 B. The diagram shows separate APL and EPB muscles with one tendon each as seen in man, hylobatids and gorillas. Fig 7 C. This diagram shows 1 APL muscle and 2 EPB muscles as seen in chimpanzees.

Phylogenetically, the APL and the EPB are said to have differentiated from the same muscle mass. Diogo *et al.* found that the "abductor pollicis" in most primates is a muscle having two tendons but one muscle belly [5]. In man, hylobatid and to some extent the gorilla, the "abductor pollicis" and its two tendons separate out to form two muscles namely the APL and EPB muscles [1,5]. Balter M states that humans have more primitive hands than the chimpanzees [15]. The hand of the chimpanzees has one extra muscle in this group i.e. it has one APL and two EPB muscles. (Fig 7 A,B,C) The double tendon of EPB as seen in present study and also reported by Nayak et al is similar to that observed in the chimpanzees where the distal attachments are also on the lateral aspect of 1st metacarpal bone and on the proximal

phalange [13]. It is said that the EPB is phylogenetically a young muscle and its absence does not limit movement of the thumb. In fact its surgical removal makes no functional difference to the thumb finger movements. Nayak et al state that this muscle could be in the infancy of evolution which could be the reason why we are unable to understand how it contributes to the thumb function [13].

Aversi-Ferreira noted that humans were remarkable in movements of their thumb because the EPL in many primates is blended with extensor indicis (and through it with the other digits because it gives attachments to them) but not so in man, uncoupling the action of these two muscles [1]. Essentially this uncouples the extension of thumb from extension of rest of the digits giving them independence of movement. The APL in primates has attachment to 1st metacarpal and adjacent carpal bones linking their action together. In humans the APL is separately attached to the 1st metacarpal bone thus its action gets uncoupled form that involving the carpal bones. Humans are also unique because they have three separate dorsal muscles of forearm namely APL, EPB and EPL attached to three different parts of the pollux finger namely 1st metacarpal, proximal phalange and distal phalange respectively.

Marzke studied the percentage of weight of thumb musculature in the total musculature of the hand in various animals also participating in the evolutionary process comparable to man such as gorilla and pan [16]. It was found that the human thumb has the highest percentage of comparative muscle weight. Can this also explain increase in number of the muscles involved in manipulation of the pollux finger such as duplication of EPL, EPB and the APL?

**Conflict of Interest**

The authors have no conflict of interest.

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Nil.

**Authors' contribution:**

Each author has made substantial contributions to each of the three components mentioned below:

- Concept and design of study or acquisition of data or analysis and interpretation of data;
- Drafting the article or revising it critically for important intellectual content; and
- Final approval of the version to be published.
- Each contributor has participated sufficiently in the work to take public responsibility for appropriate portions of the content of the manuscript.
- The order of naming the contributors has been based on the relative contribution of the contributor towards the study and writing the manuscript.

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