# Correspondence

## Incidence and morphology of accessory heads of flexor pollicis longus and flexor digitorum profundus (Gantzer's muscles)

In 1813 Gantzer described 2 accessory muscles in the human forearm which bear his name (Wood, 1868; Macalister, 1875; Testut, 1884; Le Double, 1897). The more frequent of the 2 accessory muscles or 'accessorius ad pollicem' was found to arise from the coronoid process of the ulna, coursing distally to attach into the flexor pollicis longus muscle (flexor pollicis longus accessory head, FPLah). The less frequently observed or 'accessorius ad flexorem profundum digitorum' was again found to arise from the coronoid process and course to join into the flexor digitorum profundus (flexor digitorum profundus accessory head, FDPah). Since their initial description, they have been examined in further detail by a number of authors (Wood, 1868; Macalister, 1875; Le Double, 1897; Dykes & Anson, 1944; Mangini, 1960; Malhotra et al. 1982; Dellon & McKinnon, 1987; Kida, 1988). These studies, most of them focusing on the FPLah, all show different results of prevalence, origin, insertion, relations and nerve supply. We undertook this study with the aim of providing a more accurate account of the detailed morphology of both accessory muscles because of the above-mentioned inconsistent anatomical descriptions and the lack of information as to important aspects such as vascular supply, morphology (shape and length) and the coexistence of both accessory heads.

A total of 40 embalmed cadavers (80 arms with equal left/right distribution) were examined in this study. They had been partly dissected by Cambridge preclinical medical students in the autumn of 1994. We then further dissected them using magnification. We examined the arms to check for the existence of FPLah and FDPah respectively in order to document as many morphological aspects as possible including several parameters that had not been addressed before. The sex distribution was 22 male to 18 female cadavers. The age of death ranged from 65 to 94 y with a mean of 83. Categorical data were compared by $\chi^2$ or Fisher's exact test and, when appropriate, comparisons between continuous data (expressed as means ± S.D.) were performed using Student's unpaired $t$ test. $P < 0.05$ was regarded as statistically significant.

The accessory muscles were found in 24 (60%) cadavers (15 male, 9 female). No statistically significant differences were found either for bilateral (right, left) presentations or sexual differences (Table 1). The total number of muscles in the sample was 51 (36 FPLah and 15 FDPah) which appeared in the 40 cadavers in 8 combinations or varieties (Table 2). The accessory muscles appeared in 9 of the 24 cadavers only unilaterally (25% right FPLah, 8.4% left FPLah, 25% right FDPah and 4.2% left FDPah). In the remaining cadavers one or both of the accessory muscles appeared bilaterally. The FPLah appeared bilaterally in 14 cadavers (in 16.7% combined with 1 right FDPah, in 12.5% combined with a bilateral FDPah and in 4.2% combined with 1 left FDPah). The FDPah appeared bilaterally in 4 cadavers (combined with a bilateral FPLah in 12.5% and combined with a left FPLah in 4.2%). The distribution of FPLah and FDPah by sex and side did not show any statistically significant differences.

To our knowledge, there are no previous observations on accessory muscle measurements. The measurements of FPLah and FDPah for sex and side do not show any statistically significant difference. The average overall total length of FPLah was 80.0 ± 16 mm, the tendon of which averaged 11.7 ± 13 mm and the muscle belly 68.0 ± 17 mm. The overall length of FDPah was 161.5 ± 55 mm, the tendon average was 107.4 ± 52 mm and the average length of the muscle belly was 67.0 mm ± 16 mm. The overall difference in length between these 2 accessory muscles appears to be a result of their different tendon lengths as their muscle belly lengths are comparable. This is due to the fact that the FDPah inserts into the FDP tendon/s at wrist level while the FPLah inserts mainly into the FPL tendon in the upper and middle third of the forearm.

For the sake of clarity we will separate the discussion for FPLah and FDPah.

*Flexor pollicis longus accessory head.* This was found in 13

Table 1. *Distribution of accessory muscles found in right and left upper limbs in males, females and in the total sample*

| | FPLah | | FDPah | |
|---|---|---|---|---|
| | Right | Left | Right | Left |
| Male ($n = 22$) | 12 (54.5%) | 9 (41%) | 4 (18.2%) | 2 (9%) |
| Female ($n = 18$) | 8 (44.4%) | 7 (38.9%) | 6 (33.3%) | 3 (16.7%) |
| Total ($n = 40$) | 20 (50%) | 16 (40%) | 10 (25%) | 5 (12.5%) |

Table 2. *Classification of the varieties of presentation of accessory muscles in the sample in order of frequency*

| Variation of presentation | Number of cadavers |
|---|---|
| FPLah (r) | 6 (25%) |
| FPLah (r & l) | 6 (25%) |
| FPLah (r & l) and FDPah (r) | 4 (16.7%) |
| FPLah (r & l) and FDPah (r & l) | 3 (12.5%) |
| FDPah (r) | 2 (8.3%) |
| FPLah (l) | 1 (4.2%) |
| FPLah (r & l) and FDPah (l) | 1 (4.2%) |
| FPLah (l) and FDPah (r & l) | 1 (4.2%) |

r, right side; l, left side.

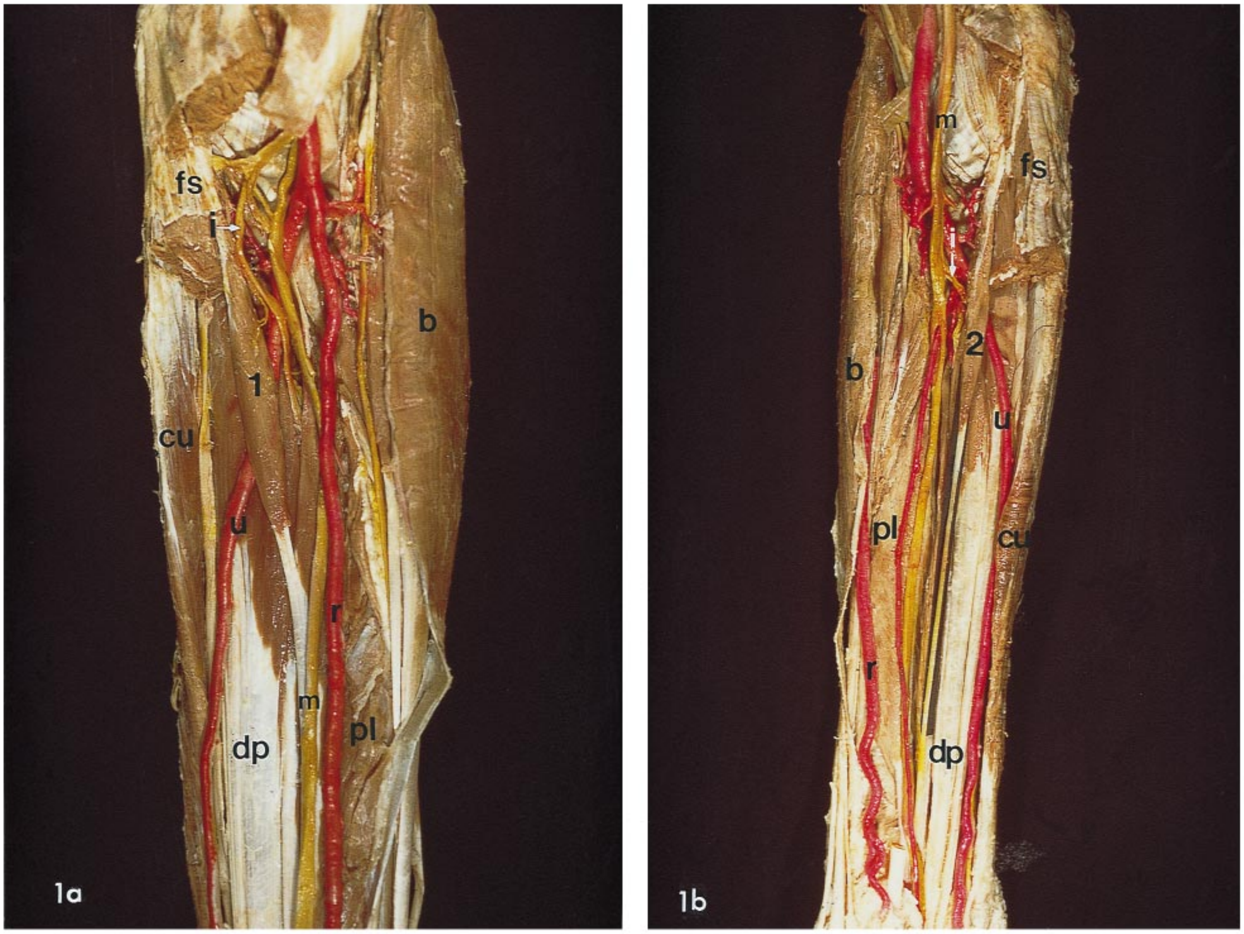


Fig. 1. Anterior views of the forearm after removal of the superficial forearm musculature that show the flexor pollicis longus (pl) and flexor digitorum profundus (dp). (*a*) Left forearm. One flexor pollicis longus accessory head (1) arises from the under surface of flexor digitorum superficialis (fs) and inserts into the upper third of the flexor pollicis longus. (*b*) Right forearm. A flexor digitorum profundus accessory head (2) arises from the under surface of flexor digitorum superficialis and inserts into the index digit tendon. b, brachioradialis; cu, flexor carpi ulnaris; i, anterior interosseous nerve; m, median nerve; r, radial artery; u, ulnar artery.

males and 9 females. The FPLah has been described by a number of authors, all with varying prevalence rates, ranging from 33% (Le Double, 1897) to 75% (Wood, 1868). Our study shows a prevalence of 55%. This is in accordance with the results provided by Dykes & Anson (1944) at 53.3% and Malhotra et al. (1982) at 54.2%. Wood (1868) offered the only previous description in which the prevalence of the muscle is given according to sex (36%, male, 39% female). In our sample, the muscle was present in 32.5% of males and only in 22.5% of females. The only 2 previous studies that have further separated the data according to left or right distribution showed the following prevalences: 28% right, 25% left and 18% bilateral (Dykes & Anson, 1944) and 31.2% right, 15.8% left and 11.3% bilateral (Malhotra et al. 1982). However, our results show that the FPLah more frequently appears bilaterally (58.4%) than unilaterally (25% right, 8.4% left).

The shape of the accessory muscle has been described as a pear-shaped slip (Macalister, 1867), fleshy and fusiform (Wood, 1868) or either fusiform (50%) or a flat slip (50%) (Martin, 1958). We found that it had no single morphology. Indeed, 4 descriptive characteristics in terms of volume or shape were seen: slender (42.9%), voluminous (28.6%) triangular (14.3%) or fusiform (14.3%) (Figs 1*a*, 2*a*, *b*).

The origin of these accessory muscles varies and has been described mainly from the coronoid process or medial epicondyle, via fibres of the flexor digitorum superficialis (FDS) or a combination of both (Wood, 1868; Macalister, 1875; Testut, 1884; Dykes & Anson, 1944; Martin, 1958; Mangini, 1960; Malhotra et al. 1982; Kida, 1988). The most common singular point of origin we found was under the surface of the FDS (Fig. 1*a*), followed by the coronoid process and finally the medial epicondyle (Fig. 2*a*) (Table 3). In none of our cases did it arise from the coronoid process alone as described by previous authors: 4.8% (Dykes & Anson, 1944), 22% (Mangini, 1960) and 3% (Malhotra et al. 1982). When the muscle arose from the coronoid process it was always involved either with the underside of FDS or the medial epicondyle. We did not find any muscle arising from other minor attachments: brachialis muscle, oblique cord or pronator teres muscle, intermuscular flexor fascia (Dykes & Anson, 1944; Mangini, 1960). However, we observed a double-headed FPL accessory muscle in 2 forearms, both in the left arm.

The only references in the literature consulted regarding the insertion of FPLah suggest that it is the continuation of the FPL tendon (Mangini, 1960) or that the insertion takes place at varying levels along the FPL tendon (Testut, 1884).

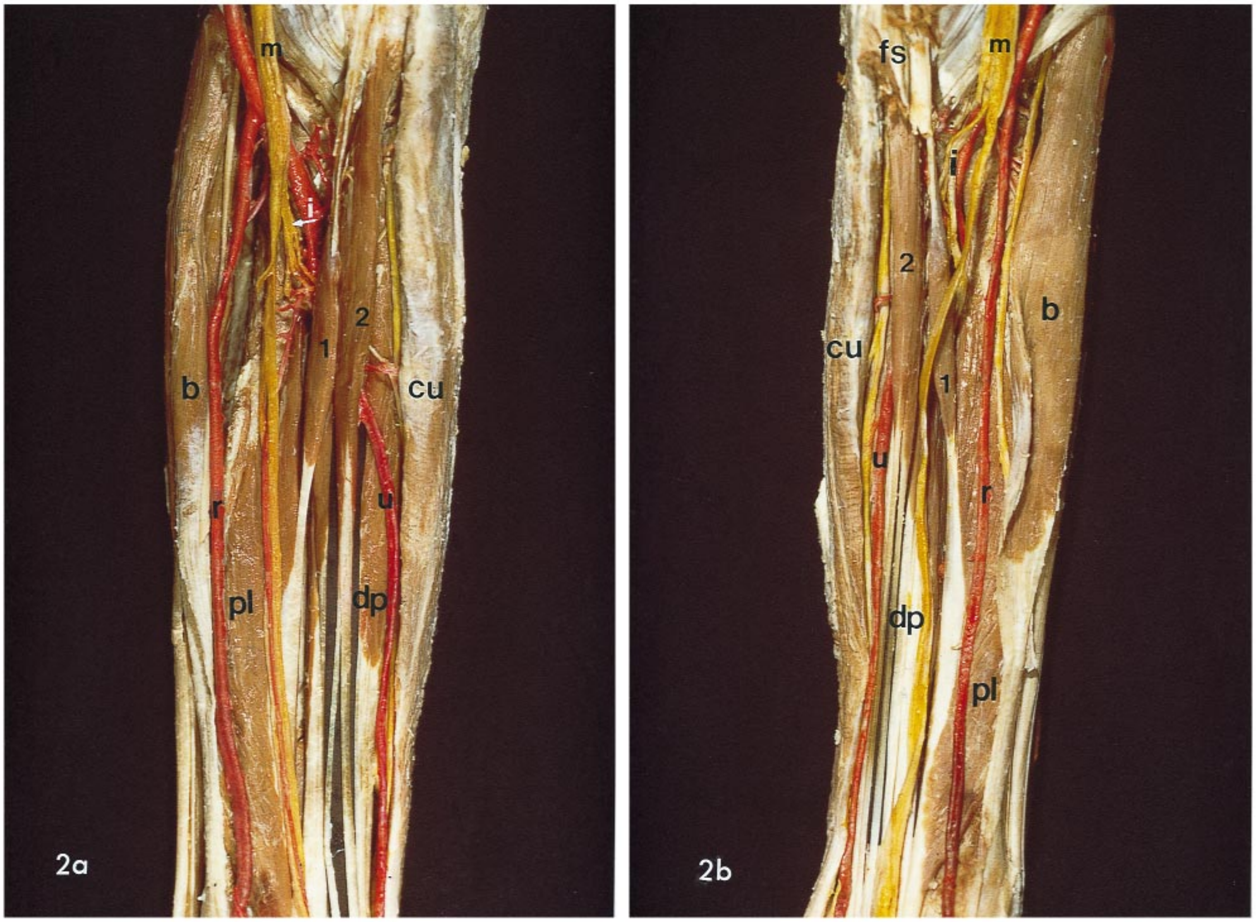


Fig. 2. Anterior views of the forearm after removal of the superficial forearm musculature that show the flexor pollicis longus (pl) and flexor digitorum profundus (dp). (*a*) Right forearm containing both accessory muscles. The flexor pollicis longus accessory head (1) arises from the medial epcondyle and inserts into the upper third of flexor pollicis longus. The flexor digitorum profundus accessory head (2) arises from the medial epicondyle and inserts into the middle, ring and little fingers. (*b*) Left forearm containing both accessory muscles shows the muscles' relations with the median nerve (m) and interosseous nerve (i). The flexor digitorum profundus accessory head (2) inserts into digits 3 and 4. b, brachioradialis; cu, flexor carpi ulnaris; r, radial artery; u, ulnar artery.

We observed that the FPLah in the great majority of cases (Table 3) inserted into the upper third of the FPL tendon (Figs 1*a*, 2*a*) and thus seemed to be the continuation of the main tendon (Mangini, 1960). However, in 22.2% of cases the insertion was into the middle third and in 2.8% into the lower third of the medial side of the FPL tendon. In 1 forearm a common accessory muscle belly was found to arise from the under surface of FDS. It ended in 3 tendinous slips, 2 of which connected to the FPL muscle and the third coursed to join the tendon of FDP to the middle finger.

In relation to blood supply there are no previous studies. During the dissections it was apparent that the blood supply came from muscular branch of vessels nearest to the muscle belly (Figs 1*a*, 2*a*). The most consistent supply was a direct branch from the ulnar artery, recurrent ulnar artery (Fig. 1*a*), median artery or anterior interosseous artery (Table 3). In 4 muscles (11.6%) the blood supply came from a combination of arteries: anterior interosseous and ulnar arteries; median and ulnar arteries; ulnar, anterior interosseous and recurrent ulnar arteries and recurrent radial and ulnar arteries.

Most authors have found the nerve supply to come only from the anterior interosseous nerve (Dellon & McKinnon, 1987; Malhotra et al. 1982) or in 7% of cases from the median nerve (Mangini, 1960; Kida, 1988). In our study, the nerve supply in the majority of cases came from the anterior interosseous nerve (Fig. 1*a*) and less frequently from the median nerve (Table 3). But in contrast to previous authors we found that in 8.8% of muscles the accessory belly received a dual innervation from both nerves.

*Flexor digitorum profundus accessory head*. It was found in 5 males and 6 females. The accessory head has been described with varying prevalence: 2.9% (Mangini, 1960), 18.6% (Wood, 1868) and 35.2% (Kida, 1988). Once again, Wood (1868) is the only previous author to have examined sex differences for this accessory head in which the muscle was seen in 11% of males and 16.7% of females. Our results show a prevalence of 27.5% (12.5% males and 15% females) which, in relation to sex, is close to Wood's figures. No previous studies have taken side into account. The bilateral prevalence was 16.7% and the unilateral 29.2% (25% right, 4.2% left). When $\chi^2$ analysis was performed, the accessory head was found to be independent of side and sex.

The origin has been described as arising from the deep surface of the FDS (Wood, 1868; Macalister, 1875; Le

Table 3. *Origin, insertion, nerve and blood supply of the accessory muscles*

| | FPLah | FDPah |
|---|---|---|
| Origin | | |
| Flexor digitorum superficialis | 29 (80.6%) | 9 (60%) |
| Coronoid process | 11 (30.6%) | 2 (13.3%) |
| Medial epicondyle | 13 (36.1%) | 2 (13.3%) |
| Pronator teres | 0 | 1 (10%) |
| Insertion | | |
| Upper third | 27 (75%) | — |
| Middle third | 8 (22.2%) | — |
| Lower third | 1 (2.8%) | — |
| Tendon to the index finger | — | 4 (26.7%) |
| Tendon to the middle finger | — | 6 (40%) |
| Tendon to the little finger | — | 3 (20%) |
| Tendon to middle and ring fingers | — | 1 (6.7%) |
| Tendon to middle, ring and little fingers | — | 1 (6.7%) |
| Nerve supply | | |
| Median nerve | 2 (5.9%) | 4 (44.4%) |
| Anterior interosseous nerve | 29 (85.3%) | 5 (55.6%) |
| Blood supply | | |
| Ulnar artery | 19 (55.9%) | 8 (61.5%) |
| Anterior recurrent ulnar artery | 6 (17.6%) | 2 (15.4%) |
| Anterior interosseous artery | 2 (11.8%) | 0 |
| Median artery | 1 (2.8%) | 0 |

Double, 1897; Parsons, 1898): coronoid process (25%) or a combination of both (17%) (Kida, 1988). Our findings show, as do Kida's (1988), that it arose mostly from the deep surface of the FDS (Fig. 1*b*) but also from other points: coronoid process, the medial epicondyle (Fig. 2*a*) and pronator teres (Table 3).

The shape of this particular muscle has previously been described as a slim tendon (Macalister, 1867), a rounded tapering muscular slip (Wood, 1868), a slender long tendon (Testut, 1884), and a musculotendinous fascicle (Le Double, 1897). The shape of the actual belly (Figs 1*a*, 2*a*, *b*) has not previously been documented. We found that it was slender (54.5%), triangular (36.4%) or voluminous (9.1%).

Macalister (1875) reviewed the existing literature of Wood (1868) and Turner (1876) and described the insertion into the main muscle in 9 different possible ways: (1) into the index tendon; (2) into the middle tendon; (3) into the ring tendon; (4) into the 5th finger tendon; (5) into the ring and 5th finger tendons; (6) into the index and ring tendons; (7) into the index and 5th finger tendons; (8) into the middle, ring and 5th finger tendons; (9) into the index, middle and ring tendons. No frequencies were specified in this paper. We found a less variable pattern (Table 3) which thus seemed to be random. The tendon coursed almost vertically to the middle third of the forearm where it turned into a slender tendon that ended near the level of the wrist, joining with one or several tendons of the FDP (Figs 1*b*, 2*a*, *b*).

As with the FPLah there are no previous studies regarding the blood supply of FDPah. The blood supply appeared to arise from a muscular branch of the nearest artery (Fig. 1*b*). The most consistent supply is a direct branch from the ulnar artery or recurrent ulnar artery (Table 2). In 3 muscles the blood supply came from a combination of the above-mentioned arteries.

The nerve supply has been described as originating from the median nerve (Kida, 1988) whereas our study shows that this is true in 44.4% of muscles, whilst in the remainder supply is from the anterior interosseous nerve (Table 3).

During its course the FDPah crossed over the ulnar artery and on the ulnar side of the anterior interosseous nerve, without any direct contact (Figs 1*b*, 2*a*, *b*). However, the FPLah was always found to lie anterior to the anterior interosseous nerve and ulnar artery and posterior to the median nerve (Fig. 2*b*). The relations of the FPLah have been described as lying posterior both to the median nerve and the anterior interosseous nerve (Dellon & McKinnon, 1987). However, our findings are in agreement with Mangini (1960) in that it always lies between the median nerve anteriorly and the anterior interosseous nerve posteriorly (Mangini, 1960). This fact may have clinical relevance in relation to the development of anterior interosseous syndrome (Spinner et al. 1987; Dellon & MacKinnon, 1987) or as a cause of restricted movement of the main muscle causing pain via a muscle-tendon shearing action (Ryu & Watson, 1987). In addition, the FDPah was found to lie on the ulnar side of the anterior interosseous nerve, thus making compression of the nerve from this muscle extremely unlikely.

The accessory heads of the flexor muscles have been described in primates and other mammals (pigs, foxes and marmots) as a muscle belly that connects the medial epicondyle origin of the FDS with the more or less differentiated deep flexors muscle (Testut, 1984; Le Double, 1897; Parsons, 1898). The flexor muscles of the forearm that develop from the flexor mass divide into 2 layers, superficial and deep. The FDS, FDP and FPL originate from the deep layer (Lewis, 1910). The existence of accessory muscles connecting the flexor muscles could be explained by the incomplete cleavage of the deep layer of the flexor mass during development, which represents an 'atavistic' character.

M. JONES, P. H. ABRAHAMS
*Department of Anatomy,*
*University of Cambridge, UK*
J. R. SAÑUDO*
*Unit of Anatomy and Embryology,*
*Department of Morphological Science,*
*Faculty of Medicine,*
*Autonomous University of Barcelona,*
*Bellaterra, 018193 Barcelona, Spain*
M. CAMPILLO
*Laboratory of Computational Medicine,*
*Unit of Biostatistics,*
*Autonomous University of Barcelona, Spain*

* Corresponding author.

## ACKNOWLEDGEMENTS

We gratefully thank Bari Logan, Prosector, Cambridge University and his technical team of Martin Watson, Lynette Nearn and Carmen Bester for their help and collaboration to enable the study of the specimens. The study of the Cambridge sample by the Spanish anatomist was made possible by a grant from the Catalan Government.

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