Introduction

Gantzer’s muscle refers to a group of accessory muscles of the flexor compartment of the forearm. It descends beneath with flexor digitorum superficialis (FDS) up to mid-forearm. It takes origin from at the medial epicondyle of humerus (ME) (common flexor origin) or coronoid process of the ulna or fascial sheath of FDS or pronator teres. It inserts onto the deep flexors, i.e., flexor pollicis longus (FPL) and flexor digitorum profundus (FDP) [1]. This muscle was first reported by Albinus in the 18th century and described by Gantzer [2], a German anatomist, in 1813. Based on initial observations, the authors identified two main variants of Gantzer’s muscle, i.e., accessory head of FPL (ahFPL) and accessory head of FDP (ahFDP) [3]. Underneath the FDS, Gantzer’s muscle follows an oblique path from the medial to the lateral aspect of the forearm before joining the FPL [4]. Furthermore, the Gantzer’s muscle can contribute to the FDP muscle through a second tendon. The presence of ahFPL and ahFDP could

The prevalence and distribution of the variants of Gantzer’s muscle: a meta-analysis of cadaveric studies

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Abstract: The Gantzer’s muscle is often present in the flexor compartment of the forearm. It lies underneath flexor digitorum superficialis and compresses the anterior interosseous nerve. Furthermore, this muscle frequently bestows an accessory muscle of flexor pollicis longus or flexor digitorum profundus, or sometimes together. The current meta-analysis aims to compute the prevalence of subtypes of Gantzer’s muscle. Major electronic databases (PubMed, Scopus, Google Scholar, etc.) were searched for title and abstract. After removing the duplicate citations, the titles/abstracts were shortlisted with the help of inclusion and exclusion criteria. The shortlisted titles/abstracts were downloaded or collected from the library. The data of all subtypes of Gantzer’s muscle were pooled from shortlisted published manuscripts for meta-analysis. The pooled estimate of other anatomical characteristics was also observed. A total of 59 cadaveric studies of sample size 5,903 were evaluated for pooled prevalence of flexor pollicis longus (accessory head). Similarly, the authors evaluated 14 studies of 1,627 upper limbs for flexor digitorum profundus (accessory head). The unit of analysis was per 100 upper limbs. The Pooled prevalence of accessory muscle of flexor pollicis longus and flexor digitorum profundus were 48% (95% CI, 44%–52%) and 17% (95% CI, 13%–21%), respectively. The Gantzer’s muscle is present in 2/3rd of the upper limbs. Accessory head of flexor pollicis longus is almost three times more common than the accessory head of flexor digitorum profundus. A classification of Gantzer’s muscle is needed to reduce the ignorance of these variants.

Keywords: Forearm, Prevalence, Hand, Skeletal muscle, Cadaver

Received July 9, 2021; Revised September 7, 2021; Accepted September 17, 2021
be explained by the embryological events of the common flexor muscle mass, which splits into two strata: deep and superficial during differentiation [1]. The FPL, FDP, and pronator quadratus muscles are all derived from the deep layer. Gantzer's muscle is the product of an imperfect cleavage of the deep layer [4]. The human gained the FPL during its evolution. The introduction of FPL into the flexor compartment allowed the thumb to move independently in three different planes [5]. A detailed meta-analysis was conducted by Roy et al. (2015) [6] on the ahFPL variant of Gantzer's muscle. The authors did not include ahFDP. There was at least a dozen of the manuscript which dealt with ahFDP. So, the pooled prevalence of Gantzer's muscle in the previous meta-analysis may be considered inaccurate. Finding such deficiency in the previous meta-analysis forced us to conduct the current study to elucidate the pooled estimate of both variants (ahFPL and ahFDP) and unfold the more comprehensive picture. This research aimed to determine the pooled prevalence of these accessory muscles in various populations and their morphometry and relation to the anterior interosseous nerve (AIN). It will be helpful in clinical diagnosis and surgical approaches to the forearm.

Materials and Methods

Search strategy
The authors have conducted a thorough search of the electronic databases PubMed, Google Scholar, Scopus, ScienceDirect, and EMBASE to find papers suitable for inclusion in the meta-analysis. Gantzer's muscle or accessory head of FPL or ahFPL and accessory head of FDP or ahFDP were among the keywords used in the quest. There were no time or language limitations. We thoroughly reviewed relevant studies or publications to identify potentially qualified articles for the meta-analysis.

Inclusion and exclusion criteria
Studies with extractable data on the occurrence of Gantzer's muscle in the upper limbs were deemed suitable for inclusion in the meta-analysis. The meta-analysis excluded publications that were case reports, letters to the editor, or conference abstracts, original articles which had insufficient data. During the eligibility appraisal, any disputes among the reviewers are resolved by consensus among all reviewers. The appraisal of quality of each study was conducted with the help of the Anatomy Quality Assessment tool [7].

Data extraction
The authors have collected information on the prevalence of ahFPL or ahFDP, origin, insertion, nerve supply, laterality, relation with nerves of the forearm, and morphological variation from included studies. In addition, we contacted the manuscript authors for more information via email if necessary information was missing.

Statistical analysis
Statistical analysis was performed by R statistical package 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria). The Higgin's I^2 test was used to determine study heterogeneity. A fixed-effects model was used if heterogeneity (Higgin’s I^2 statistics) was less than 50%. A random-effects model was used if the heterogeneity (I^2 statistics) was greater than 50%. To investigate the causes of heterogeneity, subgroup analysis, sensitivity, and cumulative analysis were used when needed. The unit of analysis was per 100 upper limbs examined.

Results

Characteristics of included studies
Fifty-eight studies in the current review have been undertaken to explore the prevalence of Gantzer's muscle (Fig. 1) [4, 8-55]. These studies examined 5,903 upper limbs for ahFPL variant (Table 1). Only 14 studies have been explored for the prevalence of ahFDP, including the data of 1,627 limbs (Table 1) [3, 8-14, 54]. A total of 5,903 limbs were included in the meta-analysis, which has data from 1868 to 2021. The data of Wagenseil (1936) [54] was bifurcated according to the population because they estimated the prevalence of Gantzer's muscle in Mongoloid and European populations. These data were collected from June 2020 to February 2021. The study population was predominantly adult cadavers, except for one study, i.e., Kara et al. (2012) [32]. The majority of manuscripts included in the review had wide geographical distribution, and it included data from all subcontinents except Australia.

Prevalence
The pooled prevalence of Gantzer's muscle (ahFPL and ahFDP) was found to be 65% (95% confidence interval [CI], 57%–73%) in 5,903 upper limbs. Fifty-eight cadaveric studies (n=5,903 upper limbs) reported the pooled prevalence of only ahFPL to be 48% (95% CI, 44%–52%) (Fig. 2).
sensitivity analysis was conducted to capture the fluctuation in the prevalence after excluding each study. The range of variability of prevalence was 1% (47%–48%). The cumulative analysis was executed to examine the maximum variations in the prevalence estimates by adding each study.

The pooled estimate of the only ahFDP in 1,627 limbs from 14 studies was 17% (95% CI, 13%–21%) (Fig. 3). The variability of the pooled estimate was 2% in sensitivity analysis and 8% in cumulative analysis. Thus, the heterogeneity of the estimate was 74.3%.

Ethnic and geographical distribution

African studies have demonstrated the highest prevalence, 73% (95% CI, 53%–87%) of ahFPL in 157 limbs with nil heterogeneity. The Mongoloid population 56%, (95% CI, 47%–65%) in 2,532 limbs and North American population 51%, (95% CI, 40%–61%) in 589 limbs have similar prevalence. South American studies, including 521 limbs, have a prevalence of 44% (95% CI, 29%–60%). The Caucasian population (Asian 41% in 1,447 limbs and European 39 % in 657 limbs) has a lower prevalence of ahFPL than the ethnicities mentioned earlier. No studies were reported from the Australian population. The heterogeneity among studies of other ethnic groups varied from 76% to 94%.

The prevalence of ahFDP was 24% (95% CI, 22%–27%) in Mongoloid population without any heterogeneity of estimate. The same prevalence in African, Caucasian of Asian and European origin were 9% (95% CI, 3%–23%), 17% (95% CI, 11%–26%) and 11% (95% CI, 7%–18%), respectively. The prevalence in North and South American populations were based on only a single study, and they were 3% (95% CI, 0.7%–10%) and 3% (95% CI, 0.41%–18%), respectively. Most of the estimates have wider confidence intervals due to the low sample size.

Laterality and sex distribution

The laterality of ahFPL was examined in 1,275 limbs (Table 2). The occurrence of ahFPL was more frequent in right side (49%) (95% CI, 46%–53%) than left side (45%) (95% CI, 42%–49%) with rate difference of 5% (95% CI, 0.2%–11%, \(P=0.043\)). Almost, similar occurrences of ahFDP were in right and left upper limbs, i.e., 9% (95% CI, 5%–14%) and 10% (95% CI, 6%–15%), respectively. The unilateral occurrence of ahFDP was 8%, and bilateral occurrence was slightly higher, i.e., 10%. The data on sex distribution was inadequate. The prevalence of ahFPL was 38% in males and 13% in females in 402 limbs which would be misleading. The distribution of ahFDP in males and females was 12% and 23%, respectively. So, females have a double prevalence rate of ahFDP.

Anatomical distribution

The origin of ahFPL was evaluated in 1,283 limbs (Table 2). The commonest site of its origin was ME in 37% (95% CI, 35%–40%) followed by coronoid process of ulna (CP) in 24% (95% CI, 22%–26%), and muscle sheath of FDS in 15% (95% CI, 13%–17%). The dual origin from ME and CP has been observed in 8% (95% CI, 7%–10%). Antebrachial fascia also
Table 1. Study characteristics of Gantzer’s muscle

| Reference                  | Year | Prevalence (%) | 95% confidence interval | ahFPL/ahFDP | No. and ethnicity of sample | Risk of bias |
|----------------------------|------|----------------|--------------------------|-------------|----------------------------|--------------|
| Adachi [53]\textsuperscript{a} | 1910 | 63             | 54–70                    | 84          | 134 Asian Mongoloid        | Unclear      |
| Afroze et al. [18]         | 2020 | 24             | 14–38                    | 12          | 50 Asian Caucasian         | High         |
| al-Qattan [15]             | 1996 | 52             | 33–70                    | 13          | 25 Asian Caucasian         | Low          |
| Bagoji et al. [16]         | 2017 | 29             | 19–42                    | 17          | 58 Asian Caucasian         | Moderate     |
| Bajpe et al. [17]          | 2015 | 24             | 14–38                    | 12          | 50 Asian Caucasian         | High         |
| Ballesteros et al. [19]    | 2019 | 32             | 24–42                    | 34          | 106 South American         | Low          |
| Rando [53]\textsuperscript{a} | 1956 | 64             | 59–69                    | 217         | 340 Asian Mongoloid        | Unclear      |
| Bangarayya et al. [20]     | 2018 | 40             | 24–58                    | 12          | 30 Asian Caucasian         | Moderate     |
| Bilecenoglu et al. [21]    | 2005 | 20             | 9–38                     | 6           | 30 Asian Caucasian         | Low          |
| Burute and VatsalaSwamy [22]| 2017 | 36             | 29–44                    | 56          | 156 Asian Caucasian        | High         |
| Caetano et al. [23]        | 2015 | 68             | 57–77                    | 54          | 80 South American          | Low          |
| Chakravartith et al. [24]  | 2014 | 72             | 59–83                    | 39          | 54 Asian Caucasian         | Moderate     |
| Dubois de Monte-Marin et al. [55] | 2021 | 11             | 4–26                     | 4           | 36 European Caucasian      | Moderate     |
| Dellon and Mackinnon [25]  | 1987 | 33             | 20–48                    | 14          | 43 North American          | Low          |
| Desai et al. [26]          | 2017 | 58             | 46–70                    | 35          | 60 Asian Caucasian         | High         |
| Dolderer et al. [27]       | 2011 | 26             | 11–50                    | 5           | 19 European Caucasian      | Low          |
| Dykes and Anson [28]       | 1944 | 53             | 45–61                    | 80          | 150 North American         | Moderate     |
| El Domiaty et al. [8]      | 2008 | 62             | 47–75                    | 26          | 42 African                 | Low          |
| Gunmal et al. [29]         | 2013 | 51             | 44–58                    | 92          | 180 Asian Caucasian        | Moderate     |
| Hemmady et al. [30]        | 1993 | 67             | 53–78                    | 36          | 54 Asian Caucasian         | Low          |
| Herrold et al. [31]        | 2020 | 55             | 49–60                    | 148         | 271 South American         | High         |
| Inoue [53]\textsuperscript{a} | 1934 | 71             | 61–79                    | 71          | 100 Asian Mongoloid        | Unclear      |
| Jones et al. [3]           | 1997 | 45             | 34–56                    | 36          | 80 European Caucasian      | Low          |
| Kara et al. [32] (adult)   | 2012 | 38             | 26–52                    | 20          | 52 Asian Caucasian         | Low          |
| Kara et al. [32] (fetal)   | 2012 | 32             | 23–43                    | 29          | 90 Asian Caucasian         | Low          |
| Khade et al. [33]          | 2020 | 53             | 36–70                    | 16          | 30 Asian Caucasian         | Moderate     |
| Kida [34]                  | 1988 | 62             | 54–70                    | 82          | 132 Asian Mongoloid        | Low          |
| Kudo and Obata [53]        | 1957 | 55             | 48–61                    | 118         | 216 Asian Mongoloid        | Low          |
| Kumari et al. [35]         | 2017 | 42             | 29–56                    | 20          | 48 Asian Caucasian         | Moderate     |
| Le Double and Berry [36]   | 1897 | 33             | 28–39                    | 100         | 300 European Caucasian     | Moderate     |
| Loth [53]\textsuperscript{a} | 1912 | 89             | 78–95                    | 50          | 56 African                 | Low          |
| Mahakkanukrauh et al. [37] | 2004 | 62             | 56–68                    | 149         | 240 Asian Mongoloid        | Moderate     |
| Malhotra et al. [38]       | 1982 | 54             | 48–60                    | 130         | 240 North American         | Moderate     |
| Manginii [10]              | 1960 | 74             | 63–82                    | 56          | 76 North American          | Low          |
| Matsunaga et al. [39]      | 2000 | 35             | 27–43                    | 50          | 144 Asian Mongoloid        | Low          |
| Mohammed [9]               | 2018 | 64             | 52–76                    | 38          | 59 African                 | Low          |
| Mori [41]                  | 1964 | 50             | 43–57                    | 103         | 205 Asian Mongoloid        | Low          |
| Mustafa et al. [40]        | 2016 | 45             | 25–66                    | 9           | 20 Asian Caucasian         | Moderate     |
| Oh et al. [51]             | 2000 | 67             | 55–77                    | 48          | 72 Asian Mongoloid         | Moderate     |
| Oliveira et al. [11]       | 2021 | 50             | 34–66                    | 17          | 34 South American          | Low          |
| Pai et al. [12]            | 2008 | 46             | 38–55                    | 58          | 126 Asian Caucasian        | Low          |
| Philip and Dakshayani [13] | 2018 | 22             | 13–36                    | 11          | 50 Asian Caucasian         | Moderate     |
| Ravi Prasanna et al. [42]  | 2019 | 36             | 24–50                    | 18          | 50 Asian Caucasian         | High         |
| Riveros et al. [43]        | 2015 | 10             | 3–27                     | 3           | 30 South American          | Moderate     |
| Sano [53] Pan et al. [53]  | 1931 | 70             | 38–90                    | 7           | 10 Asian Mongoloid         | Unclear      |
| Sato [44]                  | 1969 | 25             | 22–29                    | 151         | 604 Asian Mongoloid        | Moderate     |
| Sekizawa [53]\textsuperscript{a} | 1960 | 54             | 43–64                    | 45          | 84 Asian Mongoloid         | Unclear      |
| Sharma et al. [45]         | 2008 | 40             | 28–53                    | 24          | 60 Asian Caucasian         | Moderate     |
| Shoyo et al. [46]          | 2015 | 42             | 30–54                    | 26          | 62 Asian Caucasian         | Low          |
| Shirali et al. [47]        | 1998 | 55             | 42–67                    | 33          | 60 North American          | Moderate     |
| Tamang et al. [48]         | 2013 | 25             | 16–37                    | 15          | 60 Asian Caucasian         | High         |
| Tomizawa [53]              | 1986 | 54             | 35–73                    | 13          | 24 Asian Mongoloid         | Moderate     |
| Tubbs et al. [49]          | 2006 | 20             | 8–43                     | 4           | 20 North American          | Low          |
| Uyarogh et al. [50]        | 2006 | 52             | 39–65                    | 27          | 52 Asian Caucasian         | Moderate     |
| Wagenseil [54]             | 1936 | 73             | 65–79                    | 103         | 142 Asian Mongoloid        | Moderate     |
| Wagenseil [54] Pan et al.  | 1936 | 55             | 47–62                    | 82          | 150 European Caucasian     | Moderate     |
gave origin to ahFPL in 4% (95% CI, 3%–5%). The fascial sheath of FDS was the predominant site of origin for ahFDP, which was 74% (95% CI, 65%–82%). The origin ahFDP from ME, CP, and pronator teres were 15% (95% CI, 9%–23%), 6% (95% CI, 3%–13%) and 4% (95% CI, 2%–10%), respectively in 214 samples.

Gantzer’s muscle was inserted either in the muscle belly or tendon of FPL and FDP. The insertion of ahFPL was examined in 345 limbs (Table 3). The ahFPL was inserted in the muscle belly of FPL in 1/2nd to 2/3rd of the sample, and remaining samples were inserted on the tendinous part of FPL. The extent of ahFPL in the upper 1/3rd of the forearm was observed in 71% of the sample, followed by 23% in the middle 1/3rd and the remaining 6% extended up to the lower 1/3rd of the forearm. The insertion of ahFDP was predominantly on the tendon of the index finger, i.e., 47% (95% CI, 37%–57%), followed by the tendon of middle finger, i.e., 20% (95% CI, 13%–29%) (Table 3).

The innervation of ahFPL was examined in 1,237 limbs (Table 2). AIN was the predominant supply of ahFPL in 2/3rd of samples (95% CI, 64.1%–69.3%). The median nerve supplied ahFPL in 1/3rd samples (95% CI, 30.6%–35.9%). Ulnar nerve innervated it in 0.1% samples (95% CI, 0%–4%). The innervation of ahFDP was AIN in 55.6% and medial nerve (MN) in 44.4% (Table 1).

### Table 1. Continued

| Reference | Year | Prevalence (%) | 95% confidence interval | ahFPL/ahFDP | No. and ethnicity of sample | Risk of bias |
|-----------|------|----------------|-------------------------|------------|-----------------------------|--------------|
| Wood [14] | 1868 | 61             | 49–72                   | 44         | 72 European Caucasian       | Low          |
| Yang et al. [4] | 2017 | 48             | 37–59                   | 35         | 73 Asian Mongoloid          | Moderate     |
| Yu et al. [52] | 2018 | 58             | 31–82                   | 7          | 12 Asian Mongoloid          | Moderate     |
| Pooled weighted prevalence | 48 | 44–52 | 2,844 | 5,903 random effect model |
| Bando [53] | 1956 | 25             | 21–30                   | 86         | 340 Asian Mongoloid         | Moderate     |
| El Domiaty et al. [8] | 2008 | 14             | 7–28                    | 6          | 42 African                  | Unclear      |
| Inoue [53] | 1934 | 29             | 21–39                   | 29         | 100 Asian Mongoloid         | Unclear      |
| Jones et al. [3] | 1997 | 18             | 11–27                   | 14         | 80 European Caucasian      | Low          |
| Kudo and Obata [53] | 1957 | 20             | 16–26                   | 44         | 216 Asian Mongoloid         | Low          |
| Mohamed [9] | 2018 | 5              | 2–15                    | 3          | 59 African                  | Low          |
| Mangini [10] | 1960 | 3              | 1–10                    | 2          | 76 North American           | Low          |
| Oliveira et al. [11] | 2021 | 3              | 0–18                    | 1          | 34 South American           | Low          |
| Pai et al. [12] | 2008 | 14             | 9–22                    | 18         | 126 Asian Caucasians        | Low          |
| Philip and Dakshayani [13] | 2018 | 22             | 13–36                   | 11         | 50 Asian Caucasians         | Moderate     |
| Sano [53] | 1930 | 23             | 14–36                   | 13         | 56 Asian Mongoloid          | Unclear      |
| Sekizawa [53]| 1960 | 21             | 14–31                   | 18         | 84 Asian Mongoloid          | Unclear      |
| Wagenseil [54] | 1936 | 26             | 20–34                   | 37         | 142 Asian Mongoloid         | Moderate     |
| Wagenseil [54] | 1936 | 10             | 6–16                    | 15         | 150 European Caucasian      | Moderate     |
| Wood [14] | 1868 | 7              | 3–16                    | 5          | 72 European Caucasian       | Low          |
| Pooled weighted prevalence | 17  | 13–21 | 302 | 1,627 random effect model |

ahFPL, accessory head of flexor pollicis longus; ahFDP, accessory head of flexor digitorum profundus. *Secondary reference was used because the data collected from secondary reference due to inaccessibility of original manuscript.* ahFDP.

### Morphological distribution

The morphology of ahFPL was examined in a sample of 655 limbs (Table 2). The fusiform shape was the predominant shape of muscle which was observed in almost 3/4th of samples. The length of ahFPL varied from 6.9 to 12 cm, and width varied from 0.3 to 0.7 cm. The adequate data was unavailable to estimate the morphological distribution of ahFDP. However, the Fusiform shape was predominant in ahFDP.

### Risk of bias

Most of the studies did not provide adequate information about sex distribution. The studies may have a high risk of bias (ROB) because the authors did not report adequate anatomical and morphological details [16, 17, 20, 25, 30, 41, 47]. The studies with a higher ROB reported less prevalence of ahFPL, i.e., 37% (95% CI, 27%–48%) than moderate and low ROB studies, i.e., 47% and 52%. The prevalence of ahFDP was similar in both moderate and low risk. None of the studies was categorized into a high ROB for ahFDP.

### Publication bias

The funnel plot of the current meta-analysis was symmetrical. Egger’s linear regression test for publication bias was conducted, refuting the possibility of publication bias.
was similar to the estimated pooled prevalence. (P-value=0.858). Trim and fill analysis was undertaken to estimate pooled prevalence. The observed pooled prevalence was similar to the estimated pooled prevalence.

Discussion

Summary of findings

In the current meta-analysis, the prevalence of Gantzer’s muscle was 65% in 5,903 upper limbs, which is inconsistent with the results of the prior meta-analysis. The pooled prevalences of ahFPL and ahFDP variants were 48% and 17%, re-
Variants of Gantzer’s muscle

Characteristics of variants of Gantzer’s muscle: laterality, sex, morphological distribution

| Characteristic          | ahFPL | ahFDP |
|-------------------------|-------|-------|
| Laterality              |       |       |
| Right                   | 49    | 9     |
| Left                    | 45    | 10    |
| Unilateral              | 47    | 8     |
| Bilateral               | 53    | 10    |
| Sex                     |       |       |
| Male                    | 38    | 12    |
| Female                  | 13    | 23    |
| Origin                  |       |       |
| Flexor digitorum supercilis | 15  | 74    |
| CP                      | 24    | 74    |
| ME                      | 37    | 15    |
| Antebrachial fascia     | 4     | NA    |
| Dual origin (CP & ME)   | 8     | NA    |
| Pronator teres          | NA    | 4     |
| Innervation             |       |       |
| Anterior interosseous nerve | 66.7 | 55.6  |
| Median nerve            | 33.2  | 44.4  |
| Ulnar nerve             | 0.1   | 0.1   |
| Morphology              |       |       |
| Fusiform                | 72    | NA    |
| Voluminous              | 2     | NA    |
| Slender                 | 10    | NA    |
| Voluminous & fusiform   | 1     | NA    |
| Triangular              | 5     | NA    |
| Strap-like              | 4     | NA    |
| Papillary like          | 6     | NA    |

ahFPL, accessory head of flexor pollicis longus; ahFDP, accessory head of flexor digitorum profundus; P, prevalence; CI, confidence interval; CP, coronoid process of ulna; ME, medial epicondyle of humerus; NA, not applicable.

Table 2. Characteristics of variants of Gantzer’s muscle: laterality, sex, anatomical and morphological distribution

| Characteristic          | ahFPL   | ahFDP   |
|-------------------------|---------|---------|
| Laterality              | P (%)   | 95% CI (%) |
| Right                   | 49      | 46–53   |
| Left                    | 45      | 42–49   |
| Unilateral              | 47      | 43–51   |
| Bilateral               | 53      | 49–57   |
| Sex                     | P (%)   | 95% CI (%) |
| Male                    | 38      | 32–44   |
| Female                  | 13      | 8–18    |
| Origin                  | P (%)   | 95% CI (%) |
| Flexor digitorum supercilis | 15  | 13–17   |
| CP                      | 24      | 22–26   |
| ME                      | 37      | 35–40   |
| Antebrachial fascia     | 4       | 3–5     |
| Dual origin (CP & ME)   | 8       | 7–10    |
| Pronator teres          | NA      | NA      |
| Innervation             | P (%)   | 95% CI (%) |
| Anterior interosseous nerve | 66.7 | 64.1–69.3 |
| Median nerve            | 33.2    | 30.6–35.9 |
| Ulnar nerve             | 0.1     | 0.1–0.2 |
| Morphology              | P (%)   | 95% CI (%) |
| Fusiform                | 72      | 69–75   |
| Voluminous              | 2       | 1–4     |
| Slender                 | 10      | 8–13    |
| Voluminous & fusiform   | 1       | 0–1     |
| Triangular              | 5       | 3–6     |
| Strap-like              | 4       | 3–6     |
| Papillary like          | 6       | 4–8     |

The prevalence of Gantzer’s muscle has been shown to be 44.2%, with a 95% confidence interval of 34.7% to 54% in a previous meta-analysis conducted by Roy et al. (2015) [6]. The authors have computed only the prevalence of the ahFPL variant in 2,358 upper limbs. We considered both variants for pooled estimation. The prevalence of ahFPL in the present meta-analysis was 48% (95% CI, 44%–52%) in 5,903 upper limbs. The difference in prevalence between both meta-

**Agreement or disagreement with other studies**

The prevalence of Gantzer’s muscle has been shown to be 44.2%, with a 95% confidence interval of 34.7% to 54% in a previous meta-analysis conducted by Roy et al. (2015) [6]. The authors have computed only the prevalence of the ahFPL variant in 2,358 upper limbs. We considered both variants for pooled estimation. The prevalence of ahFPL in the present meta-analysis was 48% (95% CI, 44%–52%) in 5,903 upper limbs. The difference in prevalence between both meta-

https://doi.org/10.5115/acb.21.141

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Fig. 3. Pooled weighted prevalence of accessory head of flexor digitorum profundus variant. ES, effect size (log-odds ratio); CI, confidence interval; W, weight of study (inverse variance); N, sample size. Secondary reference was used because the data collected from secondary reference due to inaccessibility of original manuscript.
analyses is attributed to higher sample size. The present
meta-analysis examined more than double the sample size
of the previous meta-analysis. The authors [3, 12, 37, 53] re-
ported Gantzer’s muscle prevalence, which varied from 60%
to 71%. These authors reported both variants. The studies [14,
15, 25, 28, 38, 41, 47] reported lower prevalence (39%–55%)
and they only included ahFPL variant. The second variant,
*i.e.*, ahFDP, might have been missed due to ignorance. Such
ignorance may be dealt with in the classification of these
variants. The variants of Gantzer’s muscle may be classified
as per its morphology and attachment (Fig. 4). They were
classified into three types. The suggested classification is
as follows, based on the review of various literatures, which
could be helpful in the future to study the relationship with
the nearby structure.

Type I: ahFPL
  Type Ia: Insertion into the belly of FPL
  Type Ib: Insertion into the tendon of FPL
Type II: ahFDP
  Type IIa: Insertion into the first tendon of FDP (index fin-
ger)
  Type IIb: Insertion into the second tendon of FDP (middle
finger)
Type IIc: Insertion into the third tendon of FDP (ring fin-
ger)
Type IId: Insertion into the fourth tendon of FDP (little
finger)
Combination of any of two or more may be denoted as
IIbcd or IIab, etc.
Type III: ahFPL and ahFDP
The sub-category of type III will be developed in the fu-
ture with the availability of adequate data.

Type III is rare, and this subtype was not included for the
pooled prevalence of variants of Gantzer’s muscle due to in-
adequate description and data. The forearm muscle blastema
develops from Interzone blastema over cartilage of develop-
ing radius and ulna at the 4th week of intrauterine life [6, 8].
The superficial muscle blastema migrates earlier than the
blastema of the deeper muscle. FDS, FDP, and FPL are phy-
logenetically newer muscles that develop from volar hand
blastema, and they ascend upwards to reach the definitive
origin [12]. The fascial sheath of superficial muscles like FDS
or pronator teres a guide for deeper FPL and FDP. The vari-
ants of Gantzer’s muscle might be developmental errors [3,
12]. The FPL is the newer muscle (phylogenetically) among
the forearm flexors, which could be the reason for the higher
prevalence of ahFPL.

**Clinical implications**

These muscles generally lie deep to MN and are innervat-
ed by AIN [56]. The Gantzer’s muscle has long been debated
as a cause of neurological compression of AIN or MN. Tabib
et al. [57] documented AIN syndrome caused by Gantzer’s
muscle. The patient had isolated weakness of the FPL and
was unable to pinch between thumb and index finger. The
pronated and extended elbow may cause characteristic pain
in front of the mid-forearm. Electrodiagnostic investigation
revealed moderate slowing of conduction velocity. On surgical
exploration, Gantzer’s muscle along with swollen AIN.

|       | ahFPL |       | ahFDP |
|-------|-------|-------|-------|
| Insertion | P (%) | 95% CI (%) | Insertion | P (%) | 95% CI (%) |
| Muscle | 61 | 52–70 | Index finger tendon | 47 | 37–57 |
| Tendon | 13 | 7–20 | Middle tendon | 20 | 13–29 |
| Proximal third of forearm | 71 | 66–76 | Ring finger tendon | 0 | 0–7 |
| Middle third of forearm | 23 | 18–27 | Little finger tendon | 10 | 5–18 |
| Lower third of forearm | 6 | 3–8 | Middle & ring finger tendon | 20 | 13–29 |
|       |       |       | Middle, ring & little finger tendon | 3 | 1–9 |

ahFPL, accessory head of flexor pollicis longus; ahFDP, accessory head of flexor digitorum profundus; P, prevalence; CI, confidence interval.
The surgical removal led to the resolution of pain within a month. Similar reports were also noted in many other literatures [57-60]. Such syndrome was named as Kiloh–Nevin syndrome or AIN syndrome. This disorder also often leads to loss of pinching [12, 56].

**Limitation & potential bias**

The high heterogeneity of pooled prevalence and inadequate data of sex distribution were the significant limitations. The high heterogeneity was mainly attributed to the variable population of studies. Most old studies lack sex-based data, and retrieving such data from the author’s communication was impossible. It is the scope of further research. The strength of the current meta-analysis is that the present study has a double sample size than the previous one.

**Conclusion**

The prevalence of Gantzer’s muscle is 65%. It has two major variants: ahFPL and ahFDP. Both variants have population and sex variations. The origin of both variants is almost similar, but their insertions vary. Accessory head of FPL inserts on belly or tendon of FPL. Still, the other variant (ahFDP) inserts on the tendon of the FDP for the index and middle finger.

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Conceptualization: AA, RKJ. Data acquisition: AA, RKJ, BC. Data analysis or interpretation: AA, AP. Drafting of the manuscript: AA, RKJ, BC. Critical revision of the manuscript: AP, BC. Approval of the final version of the manuscript: all authors.

**Conflicts of Interest**

No potential conflict of interest relevant to this article was reported.

**References**

1. Zdilla MJ, Paucaruri P, Celuck TJ, Andrews RC, Lambert HW. A Gantzer muscle arising from the brachialis and flexor digitorum superficialis: embryological considerations and implications for median nerve entrapment. Anat Sci Int 2019;94:150-3.
2. Gantzer KFL. [Dissertation on the anatomical variations of the muscular structure: with the consent of the highly esteemed medical class chaired by Charles Asmund Rudolph]. Berolini: Typis Ioannis Friderici Starckii; 1813. Latin.
3. Jones M, Abrahams PH, Sañudo JR, Campillo M. Incidence and morphology of accessory heads of flexor pollicis longus and flexor digitorum profundus (Gantzer’s muscles). J Anat 1997;191(Pt 3):451-5.
4. Yang K, Jung SJ, Lee H, Choi IJ, Lee JH. Topographical relations between the Gantzer’s muscle and neurovascular structures. Surg Radiol Anat 2017;39:843-8.
5. Gyambibi A, Lemelin P. Comparative and quantitative myology of the forearm and hand of prosimian primates. Anat Rec (Hoboken) 2013;296:1196-206.
6. Roy J, Henry BM, Pękala PA, Vikse J, Ramakrishnan PK, Walocha JA, Tomaszewski KA. The prevalence and anatomical characteristics of the accessory head of the flexor pollicis longus muscle: a meta-analysis. PeerJ 2015;3:e1255.
7. Henry BM, Tomaszewski KA, Ramakrishnan PK, Roy J, Vikse J, Loukas M, Tubbs RS, Walocha JA. Development of the anatomical quality assessment (AQUA) tool for the quality assessment of anatomical studies included in meta-analyses and systematic reviews. Clin Anat 2017;30:6-13.
8. El Domiaty MA, Zoair MM, Sheta AA. The prevalence of accessory heads of the flexor pollicis longus and the flexor digitorum profundus muscles in Egyptians and their relations to median and anterior interosseous nerves. Folia Morphol (Warsz) 2008;67:63-71.
9. Mohammed WHE. Prevalence and morphology of Gantzer’s muscle: a cadaveric based study [theses]. Omdurman: Omdurman Islamic University; 2018.
10. Mangini U. Flexor pollicis longus muscle. Its morphology and clinical significance. J Bone Joint Surg Am 1960;42:467-70.
11. Oliveira KM, Breder CB, Ponte EF, Cordeiro AF, Oliveira MFS, Gomes WAPR, Gonçalves MF, Gonçalves GR, Grecco LH, Meggiolaro EDA, Silva JGBPCP, López CAC. The accessory heads of the muscles flexor pollicis longus and flexor digitorum profundus (Gantzer muscle) - an anatomical study in Brazilian cadavers. Morphologie 2021 Mar 17 [Epub]. https://doi.org/10.1016/j.morpho.2021.02.010.
12. Pai MM, Nayak SR, Krishnamurthy A, Vadaonkar R, Prabhu LV, Ranade AV, Janardhan JP, Rai R. The accessory heads of flexor pollicis longus and flexor digitorum profundus: incidence and morphology. Clin Anat 2008;21:252-8.
13. Philip SE, Dakshayani KR. A morphological study of a rare
variant of Gantzer’s muscle. Int J Anat Res 2018;6:4811-4.
14. Wood J. XVII. Variations in human myology observed during the winter session of 1867-68 at King’s College, London. Proc Royal Soc London 1868;16:483-525.
15. al-Qattan MM. Gantzer’s muscle. An anatomical study of the accessory head of the flexor pollicis longus muscle. J Hand Surg Br 1996;21:269-70.
16. Bagoji IB, Doshi MA, Hadimani GA, Bannur BM, Patil BG, Patil BS, Das KK. Incidence and morphology of the accessory head of the flexor pollicis longus muscle (Gantzer’s muscle) in South Indian population. J Anat Soc India 2017;66(Suppl 1):S50.
17. Bajpe R, Tarakeshwari R, Shubha R. Gantzer muscles: a study on 50 cadaveric upper limbs. Nat J Clin Anat 2015;4:179-85.
18. Afroze MKH, Umesh SN, Sangeeta M, Varalakshmi KL, Tiwari S. An anatomical and morphological study on accessory head of flexor pollicis longus (Gantzer’s muscles) and its clinical emphasis. Int J Anat Res 2020;8:7568-71.
19. Ballesteros DR, Forero PL, Ballesteros LE. Accessory head of the flexor pollicis longus muscle: anatomical study and clinical significance. Folia Morphol (Warsz) 2019;78:394-400.
20. Bangarayya V, Narayana P, Pillai T, Priyanka K. A study on accessory muscle of flexor compartment of forearm. IOSR J Dent Med Sci 2018;17:18-21.
21. Bilecenoglu B, Uz A, Karalezli N. Possible anatomical structures causing entrapment neuropathies of the median nerve: an anatomi
22. Burute P, Vatsalasawamy P. Accessory heads of forearm flexors and flexor carpi radialis brevis: a cadaveric study with clinical significance. Int J Anat Res 2017;5:3698-703.
23. Caetano EB, Sabongi JJ, Vieira LÁ, Caetano MF, Moraes DV. Gantzer muscle. An anatomical study. Acta Ortop Bras 2015;23:72-5.
24. Chakravarthi KK, Ss, Venumadhav N, Sharma A, Kumar N. Anatomical variations of brachial artery - its morphology, embryogenesis and clinical implications. J Clin Diagn Res 2014;8:AC17-20.
25. Dellow AL, Mackinnon SE. Musculosponeurotatic variations along the course of the median nerve in the proximal forearm. J Hand Surg Br 1987;12:359-63.
26. Desai RR, Desai AR, Ambali MP. Incidence of accessory head of flexor pollicis longus (only in males) and its clinical significance. Nat J Integr Res Med 2017;8:88-91.
27. Dolderer JH, Prandl EC, Kehrer A, Beham A, Schaller HE, Briggs C, Kelly JL. Solitary paralysis of the flexor pollicis longus muscle and its nerve supply. Anat Anz 1996;21:269-70.
28. Dykes J, Anson BJ. The accessory tendon of the flexor pollicis longus muscle. Anat Rec 1944;90:83-7.
29. Gunal S, Siddiqui A, Daimi S, Farooqui M, Wabale R. A study on the accessory head of the flexor pollicis longus muscle (Gantzer’s muscle). J Clin Diagn Res 2013;7:418-21.
30. Hemmady MV, Subramanya AV, Mehta IM. Occasional head of flexor pollicis longus muscle: a study of its morphology and clinical significance. J Postgrad Med 1993;39:14-6.
31. Herrold CB, Cook RL, Burkett JT, Hobekia NA, Zdilla MJ, Lambert HW. The Gantzer muscle: an expanded study of this variant forearm muscle. FASEB J 2020;34:1-1.
32. Kara A, Elvan O, Yildiz S, Ozturk H. Accessory head of flexor pollicis longus muscle in fetuses and adult cadavers and its relation to anterior interosseous nerve. Clin Anat 2012;25:601-8.
33. Khade B, Chaudhari G, Yadav N, Mangalagiri A. Anatomical study of accessory head of flexor pollicis longus and its clinical significance. Natl J Clin Anat 2020;9:151-4.
34. Kida M. [The morphology of Gantzer’s muscle, with special reference to the morphogenesis of the flexor digitorum superficialis]. Kaibogaku Zasshi 1988;63:539-46. Japanese.
35. Kumar A, Kumar S, Akhtar MJ, Ratnesh R, Kumar V. Morphological study of accessory heads of deep flexor muscle of forearm. J Med Sci Clin Res 2017;5:24172-6.
36. Le Double AF, Berry RJ. [Treatise on variations of the muscular system of man: and their significance from the point of view of zoological anthropology]. Paris: Schleicher frères; 1897. French.
37. Mahakkanukrau P, Surin P, Ongkana N, Sethadavit M, Vaidhayakarn P. Prevalence of accessory head of flexor pollicis longus muscle and its relation to anterior interosseous nerve in Thai population. Clin Anz 2004;176:631-5.
38. Malhotra VK, Sing NP, Tewari SP. The accessory head of the flexor pollicis longus muscle and its nerve supply. Anatom Anz 1982;151:503-5.
39. Matsunaga K, Matsuzaki A, Miyachuchi R. Relationship of Gantzer’s muscle (accessory head of flexor pollicis longus) with median and anterior interosseous nerves. Orthop Traumatol 2000;49:165-9.
40. Mustafa AYAE, Alkushi AG, Alasmari WAM, Ali Sakran AME, Elamin AM. Anatomical study of theaccessory heads of the deep flexor muscles of the forearm (Gantzer muscles). Int J Anat Res 2016;4:2984-7.
41. Mori M. Statistics on the musculature of the Japanese. Okajimas Folia Anat Jpn 1964;40:195-300.
42. Prasanna KH, Das AK, Kulkarni AL. Study of morphology of Gantzer muscle in forearm and its clinical significance. Sch Int J Anat Physiol 2019;2:261-4.
43. Riveros A, Olave E, Sousa-Rodrigues C. Anatomical study of the accessory head of the flexor pollicis longus muscle and its relationship to the anterior interosseous nerve in Brazilian individuals. Int J Morphol 2015;33:31-5.
44. Sato S. Statistical studies on the anomalous muscles of the Kyushu-Japanese. 4. The muscles of the upper limb. Kurume Med J 1969;16:69-81.
45. Sharma M, Chabbra U, Kaushal S, Patnaik VVG, Prashar R. Accessory head of flexor pollicis longus muscle. J Exerc Sci Physiother 2008;4:15-8.
46. Shayo J, Pokhojaev A, Medlej B. The Gantzer’s muscle: an anatomical and US study [Internet]. Princeton, NJ: Labome. Org-Research; 2015 [cited 2021 May 27]. Available from: http://www.labome.org/research/The-Gantzer-s-muscle-an-anatom-
47. Shirali S, Hanson M, Branovacki G, Gonzalez M. The flexor pollicis longus and its relation to the anterior and posterior interosseous nerves. J Hand Surg Br 1998;23:170-2.
48. Tamang BK, Sinha P, Sarda RK, Shilal P, Murlimanju BV. Incidence and morphology of accessory head of Flexor pollicis longus muscle—an anatomical study. J Evol Med Dent Sci 2013;2:6800.
49. Tubbs RS, Custis JW, Salter EG, Wellons JC 3rd, Blount JP, Oakes WJ. Quantitation of and superficial surgical landmarks for the anterior interosseous nerve. J Neurosurg 2006;104:787-91.
50. Uyaroglu FG, Kayalioglu G, Erturk M. Incidence and morphology of the accessory head of the flexor pollicis longus muscle (Gantzer's muscle) in a Turkish population. Neurosciences (Riyadh) 2006;11:171-4.
51. Oh CS, Chung IH, Koh KS. Anatomical study of the accessory head of the flexor pollicis longus and the anterior interosseous nerve in Asians. Clin Anat 2000;13:434-8.
52. Yu JM, Yoon SP, Kim J. Accessory head of flexor pollicis longus in Jeju islander cadavers. J Med Life Sci 2018;15:16-8.
53. Tomizawa I. Arthropological studies on variation of the muscles of upper extremity of the Ainu. Sapporo Med J 1986;55:101-23.
54. Wagenstein F. [Investigations into the musculature of the Chinese]. Z Für Morphol Anthropol 1936;36:39-150. German.
55. Dubois de Mont-Marin G, Laulan J, Le Nen D, Bacle G. Topographic anatomy of structures liable to compress the median nerve at the elbow and proximal forearm. Orthop Traumatol Surg Res 2021;107:1028-13.
56. Çiftçioglu E, Kopuz C, Corumlu U, Demir MT. Accessory muscle in the forearm: a clinical and embryological approach. Anat Cell Biol 2011;44:160-3.
57. Tabib W, Aboufarah F, Asselineau A. [Compression of the anterior interosseous nerve by Gantzer's muscle]. Chir Main 2001;20:241-6. French.
58. Degreef I, De Smet L. Anterior interosseous nerve paralysis due to Gantzer's muscle. Acta Orthop Belg 2004;70:482-4.
59. Nakano KK, Lundergran C, Okihiro MM. Anterior interosseous nerve syndromes. Diagnostic methods and alternative treatments. Arch Neurol 1977;34:477-80.
60. Rodner CM, Tinsley BA, O’Malley MP. Pronator syndrome and anterior interosseous nerve syndrome. J Am Acad Orthop Surg 2013;21:268-75.