Palmaris Longus Agenesis Variation & Evolution:

Adventures at the anthropology-anatomy interface

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Abstract

Prior to the coalescence of four-field anthropology in the USA during the early 1900s, physical anthropologists frequently found employ in anatomy departments. Today, fewer physical anthropologists work as allied health science educators and researchers. Consequently, most contemporary research on soft-tissue human anatomical variation is conducted from clinical rather than evolutionary perspectives. Here we explore how muscle variation data derived from cadaveric collections, along with comparative and functional data, can inform evolutionary hypotheses.

We review both antique physical anthropology and modern clinical literature on the frequency of palmaris longus agenesis (PLA), and present novel data from LMU-DCOM's cadaver laboratory: 9% of our European-descent population exhibited either bi- or unilateral PLA, consistent with previous studies on other European populations (e.g., Thompson 1921, Thompson 2001), and in contrast to the low frequency of PLA reported in African (e.g., Adejuwon 2012), Asian (e.g., Roohi 2007), and Native American (e.g., Machado 1967) populations. Interestingly, both reverse and double-bellied palmaris longus were observed. No correlation of PLA was found with plantaris agenesis; this is unsurprising given the small sample size but is consistent with Vanderhoft's (1996) report with a sample size of 22, suggesting genetic and/or developmental decoupling of palmaris longus and plantaris.

We discuss possible evolutionary mechanisms for this curiously common and remarkable anatomical variant's inconsistent presentation within and between populations, as well as directions for future research, such as the potential for conducting anatomical variation GWAS and establishing an online anatomical variant database.

Background

Musculus palmaris longus, or simply palmaris longus, is one of the superficial flexor muscles in the antebrachium. It is the most variable muscle in the human body, both in its specific form as well as its total agenesis. This muscle usually arises from the medial epicondyle of the humerus and passes distally lying medial to the flexor carpi radialis muscle. It continues on to the wrist, usually inserting into the flexor retinaculum, and sometimes sending tendinous fibers to the palmar aponeurosis proper. More common variants of palmaris longus include:

- Belly reversal (reverse palmaris longus): the muscle belly is located distally rather than proximally (see Fig. 3)
- Double-belly: both a proximal and a distal muscle belly are present, with an intermediate tendon
- Duplication or triplication: two or three palmaris longus muscles present in one antebrachium
- Accessory tendinous slips: one palmaris longus muscle that has multiple origins and/or insertions (see Fig. 4)
- Agenesis: the palmaris longus muscle is simply absent from the antebrachium (this can occur uni- or bilaterally)

These different variations can be of clinical importance as they may cause compartment syndrome (abnormally high pressure in the anterior antebrachial muscle compartment), carpal tunnel syndrome, or Guyon's syndrome (entrapment of the ulnar nerve in Guyon's canal, the space between the pisiform and the hamate's hook).

Clinical Considerations

Absence of the palmaris longus muscle has not been shown to significantly affect grip or pinch strength (Sebastin *et al*. 2005). Therefore, its absence likely does not affect fitness. Because it is apparently superfluous, its tendon is often harvested for grafts, usually for replacement of the flexor pollicis longus tendon (Unglaub *et al*. 2006) . Its use has also been documented in the reconstruction of the lower lip in patients with cancer of the lip or gums (Jeng *et al*. 2004). In these surgeries, a composite radial forearm-palmaris longus tendon flap is created to reconstruct the intraoral lining. Other clinical uses of its tendon include formation of a sling to correct ptotic (drooping) eyelids instead of using the tensor fasciae latae tendon (Lam *et al*. 1996), and in the repair of chronic, incomplete tears to the ipsilateral triceps tendon (Scolaro *et al*. 2013). Surgeons will frequently utilize the superficiality of the palmaris longus as an anatomical landmark before commencing procedures.

Comparative Anatomy

Palmaris longus is a primitive muscle in the sense that it is widely distributed amongst tetrapods in general and mammals in particular. It is present in mammals as diverse as Tasmanian devils, camels, seals, hyraxes, beavers, and bats – at least in the relatively few dissected specimens from these less well-studied species recorded in the literature (Macalister 1878, Huxley 1872). Though patterns of PLA in other animals are not well-studied, it appears *Hippopotamus amphibius* develops palmaris longus while its pygmy relative *Choeropsis liberiensis* exhibits variable PLA (Fisher *et al.* 2007). The function of palmaris longus is chiefly as a weak wrist flexor, though in cats, it is involved in claw retraction.

In primates, palmaris longus is present in prosimians and monkeys. Hominoid palmaris longus muscles are variable: apparently always present in orangutans, very rarely absent in gorillas, sometimes absent in chimpanzees, and sometimes absent in humans. See Table 1 for a detailed survey of chimpanzee PLA reported in the literature. Unfortunately, provenience of dissected non-human primates is almost never reported in the literature; therefore, it is at present impossible to describe any potential population pattern of PLA in any primate other than humans. As in humans and most other mammals, palmaris longus acts as a weak wrist flexor in our ape cousins.

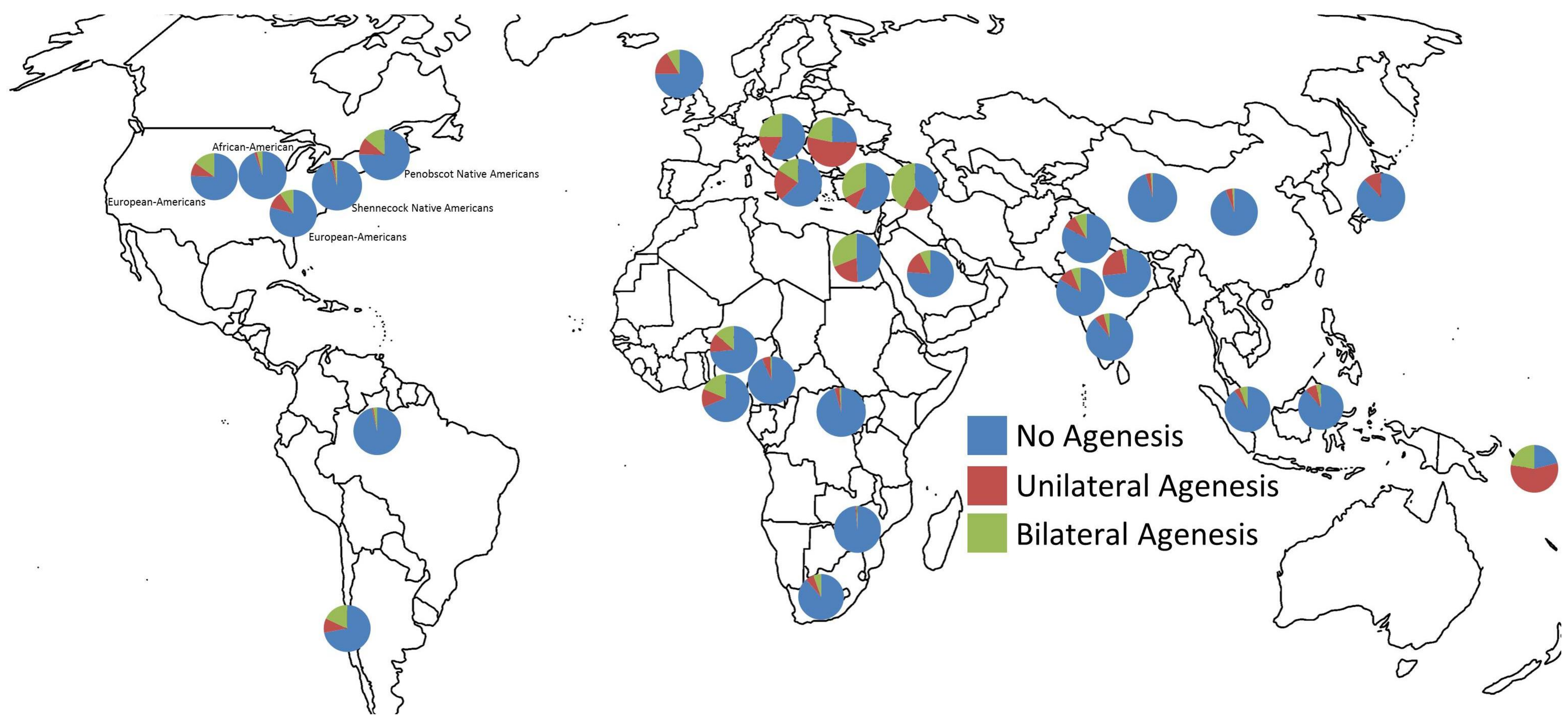

Figure 1. Global pattern of palmaris longus agenesis (PLA). European descent Americans depicted from LMU-DCOM's anatomy lab. Other studies listed in the reference page.

Figure 3. Right antebrachium exhibiting muscular belly reversal of palmaris longus. Note the belly is distal rather than proximal. According to our research, this variant is present in about 5% of Europeans who have a palmaris longus.

Figure 4. Left antebrachium exhibiting accessory tendinous slips. Note the palmaris longus both inserts onto the flexor retinaculum and the fifth metacarpal. Variants similar to this appear to occur at a rate of about 1-2% in Europeans.

Reference	Sample Size	% Unilateral Agenesis	% Bilateral Agenesis
Tyson 1699	1	0%	0%
Vrolik 1841	1	0%	0%
Wilder 1862	1	0%	0%
Gratiolet & Alix 1866	1	0%	0%
Humphry 1867	2	0%	0%
Macalister 1871	1	0%	0%
Champneys 1972	1	0%	0%
Chapman 1879	1	0%	0%
Hepburn 1892	1	0%	0%
Beddard 1893	1	0%	0%
Dwight 1895	1	0%	0%
Keith 1899	6	8%	8%

Reference	Sample Size	% Unilateral Agenesis	% Bilateral Agenesis
MacDowell 1910	1	0%	0%
Ribbing 1912	1	0%	0%
Sonntag 1923	1	0%	0%
Sonntag 1924	3	0%	33%
Loth 1931	10	5%	0%
Miller 1952	1	0%	0%
Ziegler 1964	1	0%	0%
Swindler & Wood 1973	1	0%	0%
Sarmiento 1994	9	10%	10%
Gibbs 1999	14	21%	21%
Carlson 2006	2	25%	0%

Table 1. List of chimpanzee PLA studies in the literature. Note that we were able to generate a larger sample size in one year at one medical school anatomy lab than apparently has been generated for chimpanzees since science started. This highlights the need to acquire more soft tissue anatomical data from the non-human primates.

Figure 2. Right antebrachium exhibiting typical palmaris longus morphology.

Agenesis Variation

Figure 1 illustrates the global pattern of human PLA. Importantly, no study of PLA, including our own conducted at LMU-DCOM, reports statistically significant differences between rates of PLA in males vs females. PLA is rare in north Asians (approaching 0% in Chinese), and most common in island southeast Asia (more than 75% in the Solomon Islands).

Interestingly, both South and North American Natives exhibit low rates of PLA, perhaps owing to their north Asian ancestry. Though few studies have surveyed South Americans, PLA is more common in mixed-ancestry university students than in less-integrated natives – perhaps reflecting the higher frequency of PLA observed in Europeans than north Asians. The same pattern applies to South Africa, where mixed-ancestry university students also exhibit higher frequency of PLA than native Africans.

Nigerians exhibit marked variation in that some surveyed populations exhibit low rates of PLA while others are much higher. This variation seems unlikely to have been caused by population admixture given the people studied. Perhaps this variation is instead due simply to Nigeria's relatively large population size and long-standing genetic heterogeneity. Interestingly, the variation observed in Nigeria is in stark contrast to the relative homogeneity of other surveyed sub-Saharan African populations. The relative lack of African anatomical variation data undermines anatomy teaching in not only Africa, but also in the Americas – an issue of growing importance as immigration from Africa increases.

Agenesis Evolution

Though described in human anatomy textbooks as a weak wrist flexor, this muscle is apparently less than important given that many otherwise normal humans lack it either uni- or bilaterally. There is no evidence indicating humans exhibiting PLA (either congenitally or as a result of surgical intervention) suffer from reduced survivorship or reproductive success. Thus, palmaris longus is likely not undergoing adaptive evolution.

That chimpanzees also exhibit PLA at rates comparable to many human subpopulations suggests this muscle has been undergoing evolutionary stasis since the time of our last common ancestor. However, because orangutans apparently rarely (if ever) exhibit PLA, it is possible this muscle has adaptive value in the more arboreal apes. Therefore, we suggest PLA likely began increasing in frequency sometime between our last common ancestor with chimpanzees and our last common ancestor with orangutans. Its future in human subpopulations is likely determined by stochasticity and gene flow.

Future Work

Testing the hypothesis that palmaris longus transitioned from experiencing adaptive evolution (as it likely is in orangutans) to drift (as it appears to be in humans and chimpanzees) sometime between ~15mya and ~5mya is difficult because muscles typically do not fossilize. Neither the origin nor insertion of palmaris longus are particularly notable bony landmarks. However, further elucidation of *Pan* PLA patterns, and potentially contrasting PLA patterns in the more arboreal lowland gorilla with the more terrestrial mountain gorilla could be informative. Unfortunately, it is difficult to administer non-invasive tests of PLA to chimpanzees and gorillas; acquisition of this information requires cadaveric dissection (or expensive and impractical imaging of sedated apes).

While PLA's evolutionary origins might never be entirely resolved, our study does highlight the potential for creating systematically and rigorously acquired data sets of soft tissue variation in humans. LMU-DCOM's Department of Anatomy has begun cataloging muscular variants of its cadaver anatomy donors towards the end of producing an open-access database useful to both researchers and clinicians. The evolution of soft tissue anatomy remains understudied in physical anthropology, and we hope to stimulate future research in this area.

Unfortunately, GWAS utilizing cadavers aimed at uncovering genetic etiology of soft tissue variation remains a distant prospect given the requisite sample sizes, though concerted efforts by many anatomy labs could eventually produce useful results.

Acknowledgments

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References: **PDF:**