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Palmaris Longus Muscle Variations: Clinical Significance and **Proposal of New Classifications**

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BACKGROUND

The palmaris longus muscle (PLM) is classically described as a slender, fusiform muscle situated medially to the flexor carpi radialis. It originates from the medial epicondyle of the humerus and from the adjacent intermuscular septa and deep fascia. It prolongs into a long tendon, which passes anteriorly to the flexor retinaculum. A few fibres separate from the tendon and interweave with the transverse fibres of the retinaculum, but the largest portion of the tendon passes distally. As the tendon crosses the retinaculum, it broadens out and turns into a flat sheath which then becomes incorporated into the palmar aponeurosis. PLM is a weak accessory flexor of the wrist which tenses the palmar aponeurosis.¹ PLM could also contribute to thumb

Background: The palmaris longus muscle is one of the most variable muscles in the human body and there have been numerous variations reported. The different palmaris longus variations are interesting not only from an anatomical point of view, but they could also have definite clinical significance.

Aim: The aim of this study was to examine the different types of variations of palmaris longus muscle in the Bulgarian population.

Materials and methods: Over a period of 15 years, 56 formol-carbol fixed human cadavers were studied to investigate the different variations of palmaris longus muscle (PLM).

Results: Various anatomical variations of PLM have been reported: absence (2.68%); reversed palmaris longus coexisting with an additional abductor digiti minimi muscle (0.89%); digastric (0.89%); palmaris longus with intermediate muscle belly (1.79%) and duplication (1.79%).

Conclusions: To reveal the wide variety of the types of palmaris longus muscle and their importance for clinical practice, we make a brief literature review concerning the different types of variations, their role in the median and ulnar neuropathy in the wrist or as structures simulating a soft tissue tumour and the application of palmaris longus tendon in plastic and reconstructive surgery as grafting material. We also present new systematic anatomical and clinical classifications of palmaris longus variations by dividing them into two simple groups.

> abduction, when a slip extending from it attaches to the superficial surface of the abductor pollicis brevis muscle.²

The palmaris longus muscle is one of the most variable muscles in the human body and numerous anatomical variations have been reported.^{1,3-6} The PLM may be agenetic, double, split, tendinous, digastric and may have various insertions. It may be inserted on the flexor retinaculum, the fascia of the forearm, the fascia and the muscles of the hypothenar, the short abductor of the thumb, near the metacarpophalangeal joints, the tendon of the flexor carpi ulnaris muscle, the pisiform bone or the scaphoid bone.⁷ Due to its limited action in carpal flexion and the fact that there is no functional loss in the forearm and hand after its removal, it is an ideal donor for plastic and reconstructive surgery.⁸ However, this muscle can also be responsible for median and/or ulnar nerve compression syndromes.⁹⁻¹¹ It may also simulate a tumour in the region of the antebrachium.⁹

In this report we present the occurrence of PLM variations in the Bulgarian population for the first time and also review the existing information on different PLM variations and their possible clinical significance. The new point of our study is presenting simple and systematic anatomical and clinical classifications of the many PLM variations by dividing them into two simple groups.

MATERIALS AND METHODS

Over a period of 15 years, 56 formol–carbol fixed human cadavers were studied to investigate the different variations of PLM. Of these 56 cadavers, 24 were male in the age range of 53-85 yrs; 32 were female in the age range of 61-88 yrs. Dissections were approved by the Medical Legal Office and Local Ethics Committee.

Skin and superficial antebrachial fascia were dissected layer-by-layer and lifted to expose the underlying superficial flexor muscles of the forearm. The subcutaneous veins and nerves were observed. The deep forearm (antebrachial) fascia were dissected and removed. The origin, course and insertion of PLM were observed and the different variations were reported. Photographs were taken to document the observed variations.

RESULTS

Of the 112 dissected and thoroughly observed upper limbs, we found variations of the PLM only in 9 cases. The percentages of occurrence of these variations were: absence (2.68%); reversed palmaris longus coexisting with an additional abductor digiti minimi muscle (0.89%); digastric (0.89%); palmaris longus with intermediate muscle belly (1.79%) and duplication (1.79%). In the remaining 103 upper limbs we discovered a structure and position of the superficial muscles of the forearm conforming to normal morphology, without any anatomical variations. The documented variations were observed both in right and left forearms but only unilaterally in each of the 9 cadavers. There was no evidence of previous injury, surgical interventions or any sort of anomalies and diseases involving the musculoskeletal system.

Complete agenesis of the PLM (Fig. 1a) was observed in 3 upper limbs, two male (a right upper

limb from a 69-year-old and a left upper limb from an 85-year-old formol-carbol fixed Caucasian males cadaver) and one female (a right upper limb from a 77-year-old formol-carbol fixed Caucasian cadaver).

Reversed PLM (Fig. 1b) was seen in one left forearm of a 73-year-old formol-carbol fixed Caucasian female cadaver. The muscle had a long, thin tendon, originating from the medial epicondyle of the humerus, which prolonged into a slightly elongated, elliptical muscle body in the distal third of the forearm. The length of the tendon was 13.6 cm and its width was 0.5 cm. The length of the muscle belly alone was 8.9 cm and it measured 2.6 cm at its widest part. We also noted a coexistence of the reversed PLM with an additional abductor digiti minimi muscle (ADM) (Fig. 1b). In its distal end, the reversed PLM passed superficially above the flexor retinaculum and inserted into the palmar aponeurosis by means of a short, slender tendon. Several tendinous slips inserted into the proximal part of the additional ADM. The median nerve gave off several branches to the reversed PLM before entering the carpal tunnel.

A digastric PLM (Fig. 1c) was observed in one left forearm from a 69-year-old formol-carbol fixed Caucasian male cadaver. It originated in a usual way through a short, flat tendon from the medial epicondyle of the humerus which then prolonged into a fusiform muscle belly. Approximately halfway through the forearm, this muscle belly sharply transformed into a wide tendon, situated superficially along the midline of the forearm. In the distal fourth of the forearm, this tendon gradually prolonged into a second muscle belly with a thinner proximal end and wider distal portion, which resembled a teardrop. This muscle belly arched over the flexor retinaculum and inserted into the palmar aponeurosis. The dimensions of the described structures were as follows: proximal muscle belly - length 9.4 cm, size at widest point 1.5 cm; intermediate tendon length 6.3 cm, size at widest point 0.8 cm; distal muscle belly - length 4.8 cm, size at widest point 1.6 cm. The innervation of the two muscle bellies was provided by multiple branches extending from the median nerve.

PLM with an intermediate muscle belly was discovered in two upper limbs (a 53-year-old formolcarbol fixed Caucasian male cadaver and a 63-yearold formol-carbol fixed Caucasian female cadaver) (Figs 1 d,e). In the left limb the PLM originated with a long, wide tendon from the medial epicondyle of the humerus. This variant of tendon was posi-

tioned along the midline of the forearm and gradually prolonged into an elliptical, slightly elongated muscle belly in the middle third of the forearm. Slightly above the level of the wrist, this muscle belly sharply prolonged into a short, thick and wide tendon, which arched above the flexor retinaculum and inserted into the palmar aponeurosis through a wide insertion. In the middle part of the forearm, the median nerve gave off several branches to the belly of the variant of PLM. The proximal tendon of the PLM had a length of 8.9 cm and measured 0.7 cm at its widest point. The intermediate muscle belly had a length of 6.0 cm and measured 1.3 cm at its widest point. The distal tendon was 3.3 cm long and 0.8 cm at its widest point. In the right forearm, the origin, course, insertion and innervation of the variant PLM were identical. However, the proximal and distal tendons were much thinner and the muscle belly had the shape of a spindle. The dimensions of these structures were as follows: proximal tendon – length 9.1 cm, width 0.3 cm; intermediate muscle belly - length 7.4 cm, size at

its widest point 1.0 cm; distal tendon - length 3.6

cm; width 0.5 cm. Duplication of the PLM was discovered in two upper limbs (63 and 75-year-old formol-carbol fixed Caucasian female cadavers). After removing the fascia and exposing the superficial flexor muscles of the forearm in the left limb (Fig. 1f), we discovered the presence of two muscles with the characteristic features of the palmaris longus muscle. The first muscle was located on the lateral side and originated from the medial epicondyle of the humerus with a small, thin muscle belly, which prolonged into a long tendon midway through the forearm. This tendon then inserted into the palmar aponeurosis. The length of the muscular belly was 9.7 cm and its size at its widest point measured 1.2 cm. The distal tendon of this PLM was 8.6 cm long and 0.4 cm wide. The second PLM was located medially and was partially covered by the distal tendon of the lateral PLM. It originated with a long, thick tendon from the medial epicondyle of the humerus which prolonged into a thick, spindleshaped muscle belly, located in the middle third of the forearm. The muscle belly gradually prolonged into the distal tendon, which was short, thick and broad and separated into several bundles. Some of these bundles were attached to the flexor retinaculum, while others inserted into the proximal points of origin of the muscles of the thenar and hypothenar. These tendinous slips arched over the

median nerve and the ulnar artery and nerve at the canal of Guyon. The length of the proximal tendon of this medial PLM was 7.8 cm and its width was 0.6 cm; the muscle belly measured 6.5 cm in length and 1.7 cm at its widest point; finally, the distal tendon measured 2.4 cm in length and 0.6 cm in width. Both variants of PLM were innervated by short branches from the median nerve. In the right forearm, the two PLM muscles were identical with the previously described, however, they differed in size. The length of the muscular belly of the lateral PLM was 8.8 cm and its size at its widest point measured 0.9 cm. The distal tendon was 7.5 cm long and 0.3 cm wide. As for the medial PLM, the length of its proximal tendon was 6.3 cm and its width was 0.4 cm; the length of the muscular



Figure 1. Photographs of PLM variations: a) absence; b) reversed PLM (asterisk) and ADM (small asterisk) (published in Rom J Morphol Embryol 2009, 50(4):725–727); c) digastric PLM (asterisks); d and e) PLM with intermediate muscle belly (asterisk); f) duplication of PLM (asterisks).

belly was 6.9 cm and its size at the widest point measured 0.8 cm; the distal tendon was 2.7 cm long and 0.3 cm wide.

DISCUSSION

PLM is a phylogenetically retrogressive muscle whose presence is restricted only to mammals and especially to those that use load to walk, such as the orangutan.¹² According to Keith¹³, the PLM shows a higher degree of degeneration in apes and monkeys than in man and is present only in 25% of gorillas. Furthermore, the functions of the PLM are different among various animals. In some animals it participates in the exposure of their claws. Numerous animals that we share a common ancestor with (such as the orangutan) still actively use the muscle to grab things while climbing. Other primate relatives (such as the chimpanzee and gorilla), like humans, do not actively employ the muscle, which is why numerous variants can be observed.¹⁴ With time, the thumb apparatus in primates began to evolve (especially the muscles of the thenar) and consequently the PLM became vestigial.¹⁵ PLM, as a skeletal muscle, originates from the mesoderm of the myotomes of the somites. Hypaxial myoblasts fuse to form multi-nucleated myotubes, which migrate to the periphery and form the cells of the striated skeletal muscle tissue, which form the appendicular muscles (muscles of the limbs). Although the precursors follow an intrinsic program which allows them to differentiate into muscle cells, this process is controlled by environmental signals. During the early embryogenesis the absence of such signals in the ectoderm leads to premature differentiation of the precursors, which in turn may cause agenesis or incomplete genesis of the respective muscles.¹⁶

The PLM is the most variable muscle in the human arm and one of the most variable muscles in the human body.⁴⁻⁶ In the literature there are also reports of an aberrant palmaris longus coexisting with other anatomical variations, such as persistent median artery and flexor carpi ulnaris muscle.¹⁷

Numerous reports of the variations of this muscle could be found in literature (Table 1).

Reimann et al.¹⁸ classified the different PLM variations in the following way: complete agenesis, variation in the location and shape of the fleshly portion, aberrancy in the attachment in either extremity, duplication or triplication, accessory slips, or substitutions of similar shape or position.

As seen from the presented literature review (Table 1), there are numerous data concerning the

different anatomical variations of PLM. In order to present simple and systematic anatomical and clinical classifications of these variations we divide them into two simple groups. The anatomical classification includes: variations concerning an additional muscle belly and variations of the PLM tendon or fibrotendinous slip and accessory muscles. The clinical classification divides the PLM variations into such related to compression syndromes or simulating a soft tissue mass and variations significant for plastic and reconstructive surgery of the hand.

ANATOMICAL CLASSIFICATION

PLM variations with changes in the normal anatomical position and/or accessory muscle bellies (Fig. 2):
1) Reversed PLM (RPL), bifid or trifid reversed and RPL coexisting with an additional ADM;
2) Digastric PLM;

3) PLM with intermediate muscle belly.

Variations of the PLM tendon and/or accessory muscles (**Fig. 3**):

1) Absence;

2) Duplication of PLM;

3) Triplication;

4) Accessory slips to the hypothenar muscles;

5) PLM profundus.

CLINICAL CLASSIFICATION

PLM variations related to median/ulnar nerve compression or simulating a soft tissue mass:

1) Reversed PLM (RPL), bifid or trifid reversed and RPL coexisting with an additional ADM (possible median/ulnar nerve compression or simulating a soft tissue mass);

2) Digastric PLM (possible median nerve compression or simulating a soft tissue mass);

3) Accessory slips (possible median/ulnar nerve compression);

4) PLM profundus (possible median nerve compression in the carpal tunnel);

5) PLM with centrally placed muscle belly (simulating a soft tissue mass);

PLM variations related to reconstructive surgery: 1) Absence (lack of tendon grafts);

2) Duplication or triplication of PLM (additional tendon grafts)

Of all these variations, PLM agenesis is the most frequent variation.^{18,19} Reimann et al.¹⁸ reported the absence of PLM in 12.9%. According to other literature data, there is prevalence of the absence of around 15%, although it is well known that there are differences in the occurrence of PLM absence

between different ethnic groups.²⁰ These differences are presented in **Table 2**. In our study the absence of PLM was reported in only 2.68% of Bulgarians – data which correspond to the aforementioned study of Troha et al.²² in Caucasians. The basis for these racial differences is not yet clear. However, the current predominant hypothesis is that early modern humans have a single origin from East Africa, where the rate of PLM agenesis is the lowest.²⁵ Whether the phylogenetic degeneration of PLM occurred after Homo sapiens migrated out of Africa into new geographic areas is a question still to be fully studied. Another hypothesis associates the low rate of absence of PLM in Africans with the high prevalence of manual labour.²⁶

Literature data contradict with regard to the symmetry of absence of PLM and the gender prevalence.^{20,21,24} In our study, 67% of the reported cases of absence were male and 33% female. Most studies point out that the absence of PLM is most commonly encountered in women and in left arms.^{18,27} Our findings, though, suggest that in the Bulgarian population, the absence of PLM is most commonly discovered in men and on the right side. It has been proven that the absence of PLM is hereditary and the gene responsible for the regulation of its morphological development is the HOX gene.^{12,28} Moreover, a possible dominant expression of genes responsible for PLM variations in family members has also been proposed.⁵

The reported frequency of other variations of this muscle, with the exclusion of its absence, was 9.0%. Among the reported variations are: duplication or bifid PLM, triple-headed PLM, accessory PLM, palmaris profundus and reversed PLM.²⁹ In our study different PLM variations, with the exclusion of its absence, were 5.36%: RPL coexisting with an additional ADM (0.89%); digastric PLM (0.89%); PLM with an intermediate muscle belly (1.79%) and duplication (1.79%). Most of these aberrations have little clinical significance with the exception of the reversed PLM, which may lead to a symptomatic compression of the median and/or ulnar nerve.³⁰

Compression neuropathies in the wrist are frequent and have been well described. They can be provoked by ganglia, neoplastic masses, vascular abnormalities, ligamentous attachments, and also different anomalous muscles.⁶ Anatomic anomalies of the upper limbs and particularly of the PLM are frequent and may lead to serious complaints in certain professional groups.³¹ Variations of this muscle could cause nerve compression with slow progressive

symptoms such as carpal tunnel syndrome more frequently than acute nerve compression.³² These symptoms include oedema on the palmar surface of the wrist, weakness and reduction of muscular strength, pain and numbress in the area innervated by the median and/or ulnar nerve. According to Depuydt et al.³³ in cases when median nerve symptoms are effort-related or when there is a relapse after an adequate release of the carpal tunnel, the possibility of an anomalous muscle must be considered. There are many reports in literature of median and/ or ulnar nerve compression due to the existence of a variant PLM.^{9,11,32,33} In all cases of entrapment by a variant PLM, the excision of this muscle is curative. Moreover, in clinical practice, the variant PLM could be incidentally found during clinical examination without provoking clinical symptoms and may simulate a soft tissue tumor.9 In cases of nerve and artery compression by anomalous muscles, ultrasound imaging and/or MRI could be used as imaging modalities that could help in determining muscle variations.34

The PLM is often considered to be an ideal donor in reconstructive and plastic surgery.³⁵ This is accounted for by the fact that this muscle has sufficient length and diameter and could be used as harvest material without donor site morbidity in various reconstruction interventions.³⁵ Knowledge of different PLM variations is important to provide safe and successful surgical procedures.⁸ The PLM could be used for tendon grafts in the replacement of long flexors of the fingers, the flexor pollicis longus tendon, dorsal finger injuries involving both soft tissue loss and extensor tendon defects.⁸ It is also utilized as a simple static support in the treatment of facial paralysis, in digital pulley reconstruction, lip augmentation, and in various nerve palsies as tendon transfer.8,23,24

CONCLUSION

PLM variations are described as one of the most common muscular variations in the human body, and, as we have discussed in detail, their presence has specific clinical significance. Therefore, the possible presence of PLM variations must be considered by clinicians during clinical examination of the forearm, during surgical interventions in that region, or while searching for an entrapment site of the median and/or ulnar nerve. We believe that the two new anatomical and clinical classifications presented will add to the literature data and will give a better insight into PLM variations.

Variations of the PL	Reference
Absence	Reimann et al. (1944) ¹⁸ ; Troha et al. (1990) ²² ; Ceyhan and Mavt (1997) ²¹ ; Sebastin et al. (2005) ²⁰ ; Kapoor et al. (2008) ²⁷ ; Kigera and Mukwaya (2011) ²⁶ ; Yammine (2013) ²⁵
Duplication or triplication	Macalister (1875) ³ ; Reimann et al. (1944) ¹⁸ ; Mori (1964) ⁴ ; Georgiev et al. (2009) ¹⁷
Digastric muscle (with proximal and distal bellies)	Macalister (1875) ³
Reversed muscle (muscle belly reaching the palmar aponeurosis, with tendon located proximally)	Macalister $(1875)^3$; Meyer and Pflaum $(1987)^{10}$; Giunta et al. $(1993)^{11}$; Ninkovic et al. $(1995)^{32}$; Depuydt et al. $(1998)^{33}$; Georgiev et al. $(2009)^5$
Bifid or trifid reversed variation (proximal tendon and distal bifid/trifid muscle belly)	Natsis et al. (2007) ¹⁹
Reversed muscle coexisting with ADM	Georgiev and Jelev (2009) ⁶
PLM with intermediate muscle belly	Kachlik et al. (2016) ²³
'Palmaris accessorius'originating from the flexor carpi radialis, the biceps brachii, the flexor carpi ulnaris or the flexor digitorum superficialis	Macalister (1875) ³ ; Mori (1964) ⁴
'Palmaris accessorius' inserting into the middle third of the antebrachial fascia, the thenar fascia, the ab- ductor digiti minimi or the carpal bones as separate partitions	Macalister (1875) ³ ; Mori (1964) ⁴
PLM profundus	Dyreby et al. (1982) ²⁴

Table 1. Reported variations of the PL muscle

 Table 2. PLM agenesis among different ethnic groups and populations

Ethnic group or population	Occurrence (%)
Asians	4.8% for in vivo studies (Sebastin et al. 2005) ²⁰ 4.3% for cadaveric studies (Sebastin et al. 2005) ²⁰
Native Americans (Red Indian and Amazonian)	7.1% for in vivo studies (Sebastin et al. $2005)^{20}$
Africans	11.3% (Sebastin et al. 2005) ²⁰
Turkish	64% (Ceyhan and Mavt, 1997) ²¹
North American Caucasians	5.5% (Troha et al. 1990) ²²

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Figure 2. PLM variations with changes in the normal anatomical position and/or accessory muscle bellies: **a)** RPL; **b)** bifid reversed; **c)** RPL coexisting with ADM; **d)** digastric PLM; **e)** PLM with intermediate muscle belly.



Figure 3. Variations of the PLM tendon and/or accessory muscles:a) Absence; b) Duplication of PLM; c) Triplication; d) Accessory slips; e) PLM profundus.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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Вариации мышцы palmaris longus: клиническое значение и предложение новой классификации

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Folia Medica 2017;59(3):289-297. doi: 10.1515/folmed-2017-0035 **Введение:** Мышца palmaris longus является одной из самых вариабельных мышц в теле человека и сообщается о её многочисленных вариациях. Различные вариации palmaris longus представляют собой интерес не только с анатомической точки зрения, но могут иметь и определённое клиническое значение.

Цель: Целью данной работы является исследование различных вариаций мышцы palmaris longus среди болгарского населения.

Материалы и методы: В течение 15-летнего периода были исследованы 56 человеческих трупов, зафиксированных в формалин-карболе, с целью установления различных вариаций ПЛ.

Результаты: Были установлены различные вариации palmaris longus: отсутствие (2.68%); обратный палмарис лонгус, сосуществующий с дополнительным m. abductor digiti minimi (0.89%); двубрюшная мышца (0.89%); palmaris longus с промежуточным мышечным животом (1.79%) и парная (1.79%).

Заключение: С целью установления большого разнообразия разновидностей palmaris longus и их значения в клинической практике, нами был составлен краткий обзор литературы, связанной с разновидностями вариаций, их ролью в медианной и локтевой невропатии запястья или в качестве структур, симулирующих опухоль мягких тканей, и применение сухожилия palmaris longus в пластической и реконструктивной хирургии в качестве трансплантационного материала. Нами также представлены новые системные анатомические и клинические классификации вариаций palmaris longus, распределённые в две обыкновенные группы.