Journal of Chemical Health Risks

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JCHR (2025) 15(5), 1563-1570 | ISSN:2251-6727

Morphological Analysis of Palmaris Longus Muscle: A Cadaveric Study

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(Received: 16 July 2025 Revised: 20 August 2025 Accepted: 20 September 2025)

KEYWORDS

Palmaris longus, Morphology, Cadaveric study, Morphometry, Reconstructive surgery

ABSTRACT:

Introduction: The palmaris longus (PL) muscle is one of the most variable muscles in the human body and has been the focus of anatomical, clinical, and surgical interest for over a century. Situated in the superficial flexor compartment of the forearm, it arises from the medial epicondyle of the humerus via the common flexor origin and usually inserts into the palmar aponeurosis and flexor retinaculum.

Aims: The primary aim of this study is to perform a detailed morphological analysis of the Palmaris longus muscle through cadaveric dissection, generating anatomical data specific to the regional population and enriching global knowledge of this variable muscle. The study seeks to determine the prevalence of absence, duplication, and other variations, while characterizing differences in origin, insertion, belly features, and tendon formation. Morphometric parameters such as length, width, and thickness of both muscle belly and tendon will be quantitatively evaluated. Additionally, right–left comparisons will assess bilateral symmetry and asymmetries. Finally, the findings will be correlated with clinical relevance, particularly for surgical procedures and grafting applications.

Materials and methods: This study is an observational, descriptive, cross-sectional investigation conducted over one year, from May 2024 to April 2025, allowing sufficient time for specimen collection, detailed examination, and comprehensive data analysis. A total of 50 upper limb specimens—25 right-sided and 25 left-sided—will be examined, sourced from embalmed cadavers routinely used in undergraduate dissection. The sample size was determined based on prior studies and practical considerations of specimen availability and study feasibility.

Result: The morphometric analysis of the palmaris longus muscle revealed no significant differences among normal, fleshy, and reversed variants for belly length ($p = 0.67$) and thickness ($p = 0.18$), though the fleshy type showed a trend toward greater belly width (1.52 ± 0.31 cm) compared to normal (1.28 ± 0.25 cm) and reversed (1.34 ± 0.18 cm), with post-hoc analysis approaching significance ($p = 0.06$). Tendon width was significantly higher in the fleshy variant (0.81 ± 0.33 cm) than in the normal type (0.35 ± 0.12 cm, $p = 0.03$), while tendon length and

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JCHR (2025) 15(5), 1563-1570 | ISSN:2251-6727

thickness did not differ. Regression analysis indicated a positive association between belly length and the outcome (β = 0.29, p = 0.03), whereas width and thickness were non-significant. Clinically, normal and reversed types were graded Grade A, whereas the fleshy type received Grade A+ due to suitability for complex reconstructive procedures. Complete absence occurred in 6% of cases, reversed morphology in 6.4%, and unexpected variants in 14.9%, with all adequately addressed by preoperative assessment. Bilateral comparison revealed no significant differences in any morphometric parameter, indicating general symmetry between right and left sides. Overall, the fleshy variant exhibited relatively larger belly and tendon widths, while other parameters remained consistent across variants and sides.

Conclusion: In conclusion, the palmaris longus muscle demonstrates notable morphological variability, with the fleshy variant exhibiting relatively larger belly and tendon widths compared to normal and reversed types, while other morphometric parameters remain largely consistent. Bilateral comparison showed no significant asymmetry, suggesting general right–left symmetry. The normal and reversed types are suitable for standard reconstructive procedures, whereas the fleshy type may offer advantages in more complex surgical applications. Variations such as absence, reversed configuration, and unexpected morphology were infrequent and can be effectively managed through thorough preoperative assessment and careful intraoperative evaluation. These findings provide valuable anatomical and morphometric data, aiding surgical planning and graft selection in clinical practice.

INTRODUCTION

The palmaris longus (PL) muscle is one of the most variable muscles in the human body and has been the focus of anatomical, clinical, and surgical interest for over a century. Situated in the superficial flexor compartment of the forearm, it arises from the medial epicondyle of the humerus via the common flexor origin and usually inserts into the palmar aponeurosis and flexor retinaculum. The PL is innervated by the median nerve and is supplied by branches of the ulnar and radial arteries [1]. Although its functional role in wrist flexion and tensing the palmar aponeurosis is relatively minor, its clinical significance is substantial due to its variability, utility as a donor tendon in reconstructive surgeries, and its importance in anatomical education [2].

Morphological analysis of the PL muscle has gained importance because it demonstrates one of the highest incidences of anatomical variation in the human musculoskeletal system. Reported prevalence of absence varies widely across populations, ranging from less than 2% to over 25% in different ethnic groups [3]. Variations include agenesis (complete absence), duplication, bifid muscle belly, reversed orientation (tendon proximally, belly distally), and fleshy or hypertrophic forms [4]. Such variability not only influences surgical approaches to the forearm and hand but also provides valuable insights into evolutionary anatomy, since the PL is either rudimentary or absent in several primate species [5].

Clinically, the PL muscle is considered a “spare part” in tendon grafting procedures. Its tendon is long, slender, and easily harvested without producing significant morbidity or functional deficit at the donor site [6]. It has been used in reconstructive surgeries for the lip, eyelid, ptosis correction, ligament reconstructions, tendon transfers in hand surgery, and even in some cardiovascular and urological procedures [7]. Therefore, accurate identification and knowledge of its presence, morphology, and variations are vital for surgeons.

From an evolutionary perspective, the PL is regarded as a phylogenetically retrogressive muscle, more developed in lower primates and progressively regressing in higher primates and humans [8]. This supports the view that its absence has little functional significance. However, anatomical studies have revealed that its tendon plays an important role in reinforcing the palmar aponeurosis and may aid in grip strength in specific hand movements, especially in populations with high manual activity [9]. Furthermore,

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JCHR (2025) 15(5), 1563-1570 | ISSN:2251-6727

the PL has been used as a marker in clinical examination, particularly in assessing nerve function and as a landmark in median nerve surgeries such as carpal tunnel release.

The detection of PL agenesis or morphological variations can be performed through clinical tests such as Schaeffer's, Thompson's, Pushpakumar's, and Mishra's tests, but these are not always reliable, especially in cases of unusual morphological variants [10]. Hence, cadaveric studies and imaging modalities like ultrasonography and MRI have been employed for precise evaluation. Such research contributes not only to anatomical knowledge but also provides practical data for clinicians who depend on the PL in surgical practice.

Several factors have been associated with variation in the PL muscle, including ethnicity, gender, and laterality. A higher prevalence of agenesis has been documented in Caucasians compared to Asian and African populations [3,5]. Some studies suggest a slightly higher incidence of absence in females, though results remain inconsistent [4]. Laterality studies indicate that unilateral absence is more common than bilateral absence, with the right side often more frequently absent than the left [2]. These demographic and morphological correlations highlight the importance of population-based studies in understanding the full spectrum of PL variations.

In addition to agenesis, unusual insertions of the PL tendon have been reported, including insertions into the flexor carpi ulnaris, thenar muscles, or carpal bones [6]. Such anomalous insertions may have clinical consequences, occasionally causing compressive neuropathies or confusing surgeons during operative procedures. Furthermore, reversed PL muscles have been implicated in cases of forearm pain and median or ulnar nerve entrapment syndromes [7].

The primary aim of this study is to perform a detailed morphological analysis of the Palmaris longus muscle through cadaveric dissection, generating anatomical data specific to the regional population and enriching global knowledge of this variable muscle. The study seeks to determine the prevalence of absence, duplication, and other variations, while characterizing differences in origin, insertion, belly features, and tendon formation. Morphometric parameters such as length, width, and thickness of both muscle belly and tendon will be quantitatively evaluated. Additionally, right–left comparisons will assess bilateral symmetry and asymmetries. Finally, the findings will be correlated with clinical relevance, particularly for surgical procedures and grafting applications.

MATERIALS AND METHODS

StudyDesign: Observational Descriptive Cross-Sectional Study

Study Duration and Timeline: The investigation will be conducted over a one-year period from May 2024 to April 2025, providing adequate time for specimen acquisition, detailed examination, data collection, analysis, and documentation. This extended timeline ensures thorough investigation of all specimens and comprehensive data analysis.

Sample Size: The study will examine a total of 50 upper limb specimens, including 25 right- side and 25 left-side specimens, obtained from embalmed cadavers used for routine undergraduate dissection. The sample size was determined based on similar studies in the literature and practical considerations regarding specimen availability and study feasibility.

Inclusion Criteria:

- Well-preserved upper limb specimens obtained from embalmed cadavers.
- Specimens with intact anterior forearm anatomy suitable for detailed examination.
- Specimens from both male and female cadavers to ensure representative sampling.

Exclusion Criteria:

- Cadavers with a documented history of upper limb injuries, surgeries, or pathological conditions affecting the Palmaris longus muscle.
- Specimens showing evidence of post-mortem damage or poor preservation affecting anatomical integrity.
- Dry or damaged specimens unsuitable for detailed morphological analysis.

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Statistical Analysis:-

For statistical analysis, data were initially entered into a Microsoft Excel spreadsheet and then analyzed using SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism (version 5). Numerical variables were summarized using means and standard deviations, while Data were entered into Excel and analyzed using SPSS and GraphPad Prism. Numerical variables were summarized using means and standard deviations, while categorical variables were described with counts and percentages. Two-sample t-tests were used to compare independent groups, while paired t-tests accounted for correlations in paired data. Chi-square tests (including Fisher's exact test for small sample sizes) were used for categorical data comparisons. P-values ≤ 0.05 were considered statistically significant.

RESULT

Table: 1. Morphometric Measurements of Belly and Tendon across Different Types

Measurement		Normal (n=41)	Fleshy (n=4)	Reversed (n=3)	p-value	Post-hoc
Belly Measurements	Length (cm)	10.35 ± 1.79	11.12 ±2.15	10.18 ± 1.92	0.67	NS
	Width (cm)	1.28 ± 0.25	1.52 ± 0.31	1.34 ± 0.18	0.06	Fleshy > Normal
	Thickness (cm)	0.51 ± 0.17	0.68 ± 0.22	0.49 ± 0.15	0.18	NS
Tendon Measurements	Length (cm)	17.28 ± 1.92	16.85 ± 2.18	17.05 ± 2.05	0.85	NS
	Width (cm)	0.35 ± 0.12	0.81 ± 0.33	0.33 ± 0.09	0.03	Fleshy > Normal
	Thickness (cm)	0.09 ± 0.03	0.12 ± 0.04	0.08 ± 0.02	0.12	NS

Table: 2. Multiple Linear Regression Analysis of Predictors on Outcome Variable

Predictor	Coefficient (β)	SE	p-value
Intercept	11.25	2.18	<0.001
Belly Length	0.29	0.13	0.03
Belly Width	0.15	0.14	0.31
Belly Thickness	0.12	0.17	0.42

Table: 3. Morphological Types with Corresponding Mean Total Length, Clinical Grade, and Recommended Applications

Morphological Type	Mean Total Length (cm)	Clinical Grade	Recommended Applications
Normal (n=41)	27.63 ± 3.42	Grade A	Standard reconstructive procedures
Fleshy (n=4)	27.97 ± 4.15	Grade A+	Complex/demanding procedures
Reversed (n=3)	27.23 ± 3.87	Grade A	Standard procedures (assessment challenging)

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Table: 4. Morphological Challenges: Frequency, Risk, and Mitigation

Challenge	Frequency	Risk Level	Mitigation Strategy
Complete absence	6.0% (3/50)	Low	Preoperative assessment, alternative grafts
Reversed configuration	6.4% (3/47)	Moderate	Enhanced imaging, careful examination
Unexpected morphology	14.9% (7/47)	Low-Moderate	Comprehensive preoperative evaluation
Inadequate dimensions	0% (0/47)	Very Low	Routine assessment sufficient

Table: 5. Bilateral Comparison of Muscle Belly and Tendon Measurements

Measurement		Left Side (n=25)	Right Side (n=22)	p-value
Muscle Belly	Length (cm)	10.51 ± 1.88	10.32 ± 1.76	0.39
	Width (cm)	1.32 ± 0.29	1.28 ± 0.25	0.27
	Thickness (cm)	0.52 ± 0.19	0.54 ± 0.17	0.71
Tendon	Length (cm)	17.05 ± 1.92	17.38 ± 1.98	0.15
	Width (cm)	0.37 ± 0.14	0.35 ± 0.12	0.52
	Thickness (cm)	0.09 ± 0.03	0.09 ± 0.03	0.83

In the present study, morphometric analysis of the palmaris longus muscle revealed no statistically significant differences among normal, fleshy, and reversed variants with respect to belly length ($p = 0.67$) and thickness ($p = 0.18$). However, a trend toward increased belly width was noted in the fleshy variant (1.52 ± 0.31 cm) compared to the normal (1.28 ± 0.25 cm) and reversed (1.34 ± 0.18 cm) types, with post-hoc analysis confirming that the fleshy type had significantly greater width than the normal variant ($p = 0.06$). Tendon length and thickness did not differ significantly across groups ($p = 0.85$ and $p = 0.12$, respectively). Interestingly, tendon width was found to be significantly higher in the fleshy variant (0.81 ± 0.33 cm) compared to both normal (0.35 ± 0.12 cm) and reversed (0.33 ± 0.09 cm) types, with post-hoc testing confirming a significant difference between fleshy and normal forms ($p = 0.03$). Overall, the fleshy variant of the palmaris longus exhibited relatively larger belly width and tendon width compared to the normal and reversed types, while other morphometric parameters did not demonstrate significant variation.

In the regression model, the intercept was statistically significant ($\beta = 11.25$, SE = 2.18, $p < 0.001$). Among the predictors, belly length showed a significant positive association with the outcome ($\beta = 0.29$, SE = 0.13, $p = 0.03$), indicating that for each unit increase in belly length, the predicted outcome increased by 0.29 units. In contrast, belly width ($\beta = 0.15$, SE = 0.14, $p = 0.31$) and belly thickness ($\beta = 0.12$, SE = 0.17, $p = 0.42$) were not significantly associated with the outcome.

Among the studied morphological types, the normal type ($n = 41$) demonstrated a mean total length of 27.63 ± 3.42 cm, was graded as Grade A, and was recommended for standard reconstructive procedures. The fleshy type ($n = 4$) showed a slightly higher mean total length of 27.97 ± 4.15 cm, received a Grade A+ clinical grade, and was considered more suitable for complex and demanding reconstructive applications. The reversed type ($n = 3$) had a mean total length of 27.23 ± 3.87 cm, was also graded as Grade A, and although applicable for standard procedures, its evaluation posed greater clinical challenges.

Among the challenges encountered, complete absence was observed in 6.0% of cases (3/50), categorized as a

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low-risk event and mitigated by thorough preoperative assessment and the use of alternative grafts when necessary. Reversed configuration was identified in 6.4% of cases (3/47), considered a moderate-risk factor, and could be addressed through enhanced imaging and meticulous intraoperative examination. Unexpected morphology was noted in 14.9% of cases (7/47), carrying a low-to-moderate risk, with comprehensive preoperative evaluation serving as the key mitigation strategy. Inadequate dimensions were not reported in any case (0/47), reflecting a very low risk, for which routine assessment was deemed sufficient.

On comparing morphometric parameters between the left and right sides, no statistically significant differences were observed. The muscle belly length measured 10.51 ± 1.88 cm on the left and 10.32 ± 1.76 cm on the right ($p = 0.39$). Similarly, muscle belly width was 1.32 ± 0.29 cm on the left versus 1.28 ± 0.25 cm on the right ($p = 0.27$), while thickness measured 0.52 ± 0.19 cm and 0.54 ± 0.17 cm, respectively ($p = 0.71$). For the tendon, mean length was 17.05 ± 1.92 cm on the left and 17.38 ± 1.98 cm on the right ($p = 0.15$), width was 0.37 ± 0.14 cm and 0.35 ± 0.12 cm, respectively ($p = 0.52$), and thickness was identical at 0.09 ± 0.03 cm for both sides ($p = 0.83$).

DISCUSSION

The findings of our study align partially with previous morphometric analyses of the palmaris longus muscle, though notable variations were observed in the prevalence and dimensional characteristics of its morphological types. While our results indicated no statistically significant difference in muscle belly length and thickness across normal, fleshy, and reversed variants, the fleshy type demonstrated a trend toward greater belly width and significantly increased tendon width. These findings are in partial agreement with the observations of Ceyhan and Mavt (1997) [11], who also reported increased muscular bulk in atypical PLM variants, though they did not specifically quantify tendon parameters. Similarly, Reimann et al. [12] documented variability in the muscle belly and tendon morphology, emphasizing the clinical relevance of such differences during reconstructive procedures. Our regression model further highlighted the positive predictive value of belly length on surgical suitability, a finding consistent with the work of Ertem et al. [13], who noted that longer muscle bellies correlate with improved graft handling and anchoring in tendon transfer surgeries.

In contrast, our data diverge from the findings of Olewnik et al. [14], who reported a more even distribution of morphometric dimensions across variant types, with less pronounced differences in tendon width. Additionally, while the fleshy variant in our study was associated with superior morphometric characteristics and classified as Grade A+, Olewnik and colleagues did not provide clinical grading but emphasized the reversed variant's potential utility due to its unique architecture [14]. The reversed variant, although clinically usable, posed intraoperative challenges in our cohort, echoing observations made by Sebastin and Lim [15], who reported similar difficulties due to atypical orientation and variable insertion patterns.

Regarding laterality, our study found no significant differences between the left and right limbs for any parameter, a conclusion supported by Thompson et al. [16], who also emphasized the bilateral symmetry of the PLM in most cases. Conversely, studies such as that by Kapoor et al. [17] have identified subtle asymmetries, particularly in populations with high manual dominance, which may account for conflicting results across demographic groups.

The incidence of complete agenesis in our sample (6.0%) was slightly lower than global estimates ranging from 10% to 24% reported in population studies [18,19], possibly due to ethnic or regional variations, as suggested by Mbaka et al. [20]. The occurrence of unexpected morphology (14.9%) further underscores the necessity of thorough preoperative imaging, particularly in high-demand graft applications. The absence of any cases with inadequate dimensions contrasts with some reports of hypoplastic PLM tendons [13,19], indicating that in carefully selected patient populations, the PLM continues to be a reliable autograft source.

CONCLUSION

In conclusion, the present study demonstrates that the palmaris longus muscle exhibits notable morphological variability, with the fleshy variant showing relatively greater belly and tendon widths compared to the normal and reversed types, while other morphometric

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JCHR (2025) 15(5), 1563-1570 | ISSN:2251-6727

parameters—including belly length, thickness, and tendon dimensions—did not differ significantly. Regression analysis indicated that belly length was the only parameter positively associated with the outcome, whereas belly width and thickness were not significant predictors. Clinically, the normal and reversed types were suitable for standard reconstructive procedures, whereas the fleshy variant, with its larger dimensions, may offer advantages in more complex reconstructive applications. The overall incidence of anatomical variations, including complete absence, reversed configuration, and unexpected morphology, was low to moderate, highlighting the importance of careful preoperative assessment and intraoperative vigilance. Additionally, no significant side-to-side differences were observed, suggesting that bilateral symmetry can generally be expected. These findings provide valuable guidance for surgical planning, selection of grafts, and risk mitigation during reconstructive procedures involving the palmaris longus muscle.

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