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ORIGINAL ARTICLE

# Musculus peroneus longus in foetal period

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*Background:* The lateral compartment of the leg, due to its distal and concurrent superficial positioning, is a multiple trauma site. Detailed knowledge of compartimentum lateralis cruris (CLC) structure is crucial for physicians. Musculus peroneus longus (MPL) is located within the structures of the CLC most superficially. There is a lot of data on the morphology of the MPL but there is no publication analysing in detail its anatomy in the foetal period. The aim of the study was to determine the variability of metric and morphological parameters of MPL in a studied period of prenatal ontogenesis.

*Materials and methods:* The analysis included 207 human foetuses (101 males and 106 females) at calendar age from 113 to 222 days. The analysed material comes from the local anatomy collection. Foetuses were stored in typical preservation solutions. Access to the muscle was obtained on the basis of standard preparation techniques. The authors evaluated the metric parameters of the muscle showing the presence of variable dynamics of metric increments of the examined muscle in particular age classes.

*Results:* In the studied period of prenatal ontogenesis, MPLs of the foetuses increased by about 60% in the length and width dimension and by about 100% in the thickness dimension. The topography of the initial and final muscle attachment was also evaluated. Statistically significant dimorphic differences were found in some aspects of muscle attachment topography.

*Conclusions:* The analysis of the place of the origin and insertion of MPL showed a relatively large variety of these features. (Folia Morphol 2022; 81, 1: 124–133)

**Key words: foetus, lateral compartment of the leg, dissection, fibularis longus muscle**

## INTRODUCTION

The lateral compartment of the leg (*compartimentum lateralis cruris*) is bounded by two fibrous intermuscular septa, which are attached to the crural fascia [3, 30]. It contains several important anatomical structures, which are of great importance for the mechanics of the foot [25]. The following muscles: *Musculus peroneus longus* and *Musculus peroneus brevis*, filling the compartment, are not only responsible for the pronation and plantar flexion of the foot, but they also stabilize the first ray of the foot in the toe-off phase of gait [4]. The lateral compartment of the leg,

**Table 1.** Basic metric data of the examined group of foetuses

| Age class | Number of foeti | Age [g] | $M\bar{x}m$ [g] | $M\bar{x}f$ [mm] | $L\bar{x}m$ [mm] | $L\bar{x}f$ [mm] | $Vtub\bar{x}m$ [mm] | $Vtub\bar{x}f$ [mm] | $C\bar{x}m$ [mm] | $C\bar{x}f$ [mm] |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 69 | 18.80 | 211.47 | 255.77 | 212.56 | 219.94 | 182.08 | 188.38 | 182.08 | 188.38 |
| 6 | 78 | 22.49 | 397.28 | 429.64 | 263.21 | 263.82 | 185.15 | 189.06 | 185.15 | 189.06 |
| 7 | 40 | 25.83 | 580.50 | 524.95 | 300.61 | 292.50 | 208.83 | 207.50 | 208.83 | 207.50 |
| 8 | 13 | 30.62 | 615.13 | 712.00 | 322.25 | 335.00 | 217.00 | 229.60 | 217.00 | 229.60 |

M — body mass; L — body length; Vtub — vertex-tuberale length; C = CRL — crown-rump length; $\bar{x}$ — mean value interpolated at the centre of age class; f — female; m — male; age — average calendar age in weeks

due to its distal and concurrent superficial positioning, is a multiple trauma site, which may contribute to the occurrence of various clinical pathologies [17]. It is subject to a high risk of fractures of bones, which constitute its scaffolding, bruises, lacerations or stab wounds. One of the most serious consequences leg injuries is the compartment syndrome, which can be the result of injuries as well as of intensive physical activity. If untreated, it can lead to irreversible disturbances in the innervation and blood supply of the foot and leg. This may cause tissue necrosis [23, 27–29]. Detailed knowledge of *compartimentum lateralis cruris* structure is therefore significant not only for an anatomist but also for surgeons and traumatologists. Peroneus longus muscle (MPL) is located within the structures of the lateral compartment of the lower leg most superficially [21]. The proximal muscle attachment is wide, as fibres branch off in two groups: the proximal one, from the lateral condyle of the shin, capsule of tibiofibular joint and head of the fibula, and the distal one begins on the shaft of the fibula and the crural fascia. Proximal part of the muscle is divided into two compartments by the common fibular nerve (*nervus fibularis communis*), running in this area. In many anatomical publications, the more superficially positioned compartment is referred to as a superficial head, while the deeper part is defined as a deep head [3, 4]. The terminal tendon of the nerve lies in a gutter formed by the peroneus brevis muscle (*musculus fibularis brevis*), and just above the lateral malleolus of the tendon of both muscles they pass under the fibular retinaculum and penetrate the fibro-osseous canal, which allows the tendon to pass from the leg to the foot [21]. This is where the tendons cross. In the plantar region of foot the MPL is attached to the base of the first metatarsus and medial cuneiform bone. The terminal section of the muscle plays an extremely important role in supporting the plantar arch of foot [34]. There is a lot of data on the morphology of the described muscle in the available literature [3, 4, 30], but there is no publication analysing in detail the anatomy of the MPL in the foetal period. The aim of the study was to determine the variability of metric and morphological parameters of *musculus peroneus longus* in a studied period of prenatal ontogenesis. In addition, the authors of the paper will determine the presence of possible dimorphic and bilateral differences.

## MATERIALS AND METHODS

The analysis included 207 human foeti (101 males and 106 females) at calendar age from 113 to 222 days of foetal life. Only four foetuses of both sexes were analysed in the fourth month, and three foetuses in the ninth month. Due to the insufficient number in these classes, the mentioned foetuses were excluded from the metric analysis. The analysed foetal material is derived from the collection of the Department of Anatomy, Medicine Faculty, Wroclaw Medical University. The material was obtained from the maternity wards of local clinics as a result of preterm births and miscarriages in the years 1960–1996. Before conservation, the calendar and morphological age of each foetus were determined individually for each of them. To assess the morphological age of foeti, a multi-characteristic assessment method for the foetus age, was used [15, 16, 35]. If the difference between morphological and calendar age was more than 2 weeks, the foeti were determined as dysmorphic and excluded from the analysis. The foetuses are stored in an appropriate solid preservative solution containing ethanol, glycerol and formaldehyde in constant proportions in a room at a stable temperature. The way of storing foetuses did not change during the whole period of storage. The study excluded foetuses with visible developmental malformations and those that did not have complete clinical documentation. The reliability and scientific value of the collection used for research have been confirmed in many previously published studies [8, 10–12, 15, 20, 31, 32]. Basic data of the studied foetus population have been presented in Table 1.

Access to the muscle was obtained on the basis of standard preparation techniques. In the first stage, the skin and subcutaneous tissue were removed. Then the fascia was cut and the structures of *compartimentum lateralis cruris* were shown. MPL was cleaned from its top, at the head of the fibula up to the lateral malleolus canal. In the second stage, the terminal tendon of the studied muscle was prepared by removing the surface structures within the plantar region of foot. The morphological features of the examined muscle were evaluated after final visualisation of its whole structure. The data collected during the morphological evaluation were recorded in the form of schematic drawings. Photographs, which documented the research, were taken. The length and thickness of the muscle belly and the length of the muscle tendon were measured using digital calliper Mitutoyo – Absolute Digimatic 573-125-10, Mitutoyo Corp, Kawasaki, Japan. Each measurement was performed 3 times and the average value was taken into account for statistical analysis. All measurements were carried out with a foetus being positioned in a fixed, uniform manner on the measuring table. The obtained data was routed to MS Excel 2010, Microsoft Corp., Redmond, WA, USA. The obtained digital data were then statistically analysed using the Statistica PL, Tibco Software Inc., USA statistical package. The average values were adjusted to the middle of the age class according to the Legrange interpolation formula [5]. Aim of this statistical procedure was to achieve equal time intervals between successive age classes. This made it possible to precisely determine the growth rate of each of the analysed features. Two-factor ANOVA variance analysis was used to assess bilateral and dimorphic differences. In order to examine the differences between the quality features, the chi-square test of independence was used. For the analysed metric features, the rate of their growth was calculated using the formula: $\frac{b-a}{a} \times 100$, where 'a' is average value of the characteristic in the month of development, 'b' — average value of this characteristic in the following month of development. Work has a local bioethical commission acceptance KB-708/2017.

## RESULTS

### Metric evaluation

Length of the muscular belly and the length of terminal tendon of MPL (Table 2) were determined on the basis of preparation studies. In the case of the assessment of the length of the MPL belly, statistical analysis (t-Student test) did not reveal any statistically significant bilateral differences in both the male (p = 0.416) and female (p = 0.337) genders. Additionally, ANOVA's two-factor analysis showed that among the analysed parameters only age, regardless of gender, significantly differentiated the MPL length (p < 0.001). At the same time, Tukey's post hoc test revealed the presence of a statistically significant difference between the MPL length in 5-month-old foetuses and foetuses in the remaining age classes for both male and female sex. The test did not reveal differences between foetuses of different sexes in the same age class. However, a statistically significant difference was found between 6- and 8-month foetuses in both sexes (Table 3).

The Student's t-test for the two dependent variables showed no statistically significant bilateral differences between male (p = 0.41) and female (p = 0.09) foetuses while evaluating the length of the final MPL tendon. The analysis of the relationship between sex and age of foetuses (ANOVA) and the dynamics of growth of the tendon length showed that only age significantly differentiated the length of the tendon (p < 0.001) regardless of the examined side. Additionally, the post hoc test revealed that there is a statistically significant difference between the length of the MPL tendon in 5-month-old foetuses and foetuses in other age classes. A difference was also observed between 6- and 8-month-old foetuses but only the male gender (Table 4).

The most intensive increase in the length of this muscle (belly and tendon) is characteristic for the period between 5 and 6 months of age. Period between 6 and 7 month of the intrauterine development demonstrates a decrease in the rate of growth by 70–80%. Re-acceleration of the growth rate takes place in the 8 month and it is about 1/3 of the value when compared to the first observed period.

The data on the thickness of the MPL belly are presented in Table 5. Statistical analysis carried out with the Student's t-test for the two dependent variables confirmed the absence of bilateral differences in the male sex (p = 0.70) and the presence of borderline statistical differences in the female sex (p = 0.049). Similarly to muscle length and tendon length of the MPL, its thickness varies only by age of the individuals regardless of body side (ANOVA; p = 0.000). Analysis of the maximum thickness of the MPL indicates that the most intensive growth rate is observed between 5 and 6 month of the foetal life and this is visible for

**Table 2.** Basic metric characteristics of *musculus peroneus longus* (MPL) in examined population

| Age class | N | MPLL | | MPLT | |
|---|---|---|---|---|---|
| | | Right (SD) | Left (SD) | Right (SD) | Left (SD) |
| **Male** | | | | | |
| 5 | 34 | 39.57 (6.12) | 39.21 (1.33) | 27.67 (0.99) | 27.94 (5.73) |
| 6 | 39 | 54.56 (7.34) | 54.83 (1.24) | 37.45 (0.93) | 37.30 (5.21) |
| 7 | 18 | 59.36 (7.26) | 59.07 (1.83) | 38.81 (1.37) | 40.23 (5.67) |
| 8 | 8 | 66.68 (5.42) | 65.68 (2.75) | 44.58 (2.05) | 46.04 (6.41) |
| **Female** | | | | | |
| 5 | 35 | 42.31 (8.31) | 41.80 (1.32) | 28.59 (0.98) | 28.85 (6.31) |
| 6 | 39 | 56.00 (7.70) | 55.69 (1.24) | 38.49 (0.93) | 39.12 (6.02) |
| 7 | 22 | 59.91 (9.96) | 59.96 (1.83) | 40.19 (1.24) | 41.04 (6.37) |
| 8 | 5 | 65.82 (7.67) | 67.26 (2.75) | 44.72 (2.60) | 45.40 (5.01) |

L — belly length; T — tendon length; SD — standard deviation

**Table 3.** Results of the post-hoc test (Tukey's test) for two-way ANOVA age to sex in the range of *musculus peroneus longus* belly length in the examined foetal group. The red numbers indicate statistically significant result.

| Sex | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Right side** | | 39.574 | 54.651 | 59.361 | 66.675 | 42.314 | 56.000 | 59.914 | 65.820 |
| Male | 5 | | 0.000032 | 0.000032 | 0.000032 | 0.816700 | 0.000032 | 0.000032 | 0.000032 |
| Male | 6 | 0.000032 | | 0.380128 | 0.041410 | 0.000032 | 0,994324 | 0,166184 | 0.045341 |
| Male | 7 | 0.000032 | 0.380128 | | 0.325851 | 0.000032 | 0.787345 | 0.999998 | 0.710049 |
| Male | 8 | 0.000032 | 0.041410 | 0.325851 | | 0.000032 | 0.048131 | 0.392693 | 0.999999 |
| Female | 5 | 0.816700 | 0.000032 | 0.000032 | 0.000032 | | 0.000032 | 0.000032 | 0.000032 |
| Female | 6 | 0.000032 | 0.994324 | 0.787345 | 0.008131 | 0.000032 | | 0.542008 | 0.046946 |
| Female | 7 | 0.000032 | 0.166184 | 0.999998 | 0.392693 | 0.000032 | 0,542008 | | 0.777974 |
| Female | 8 | 0.000032 | 0.045341 | 0.710049 | 0.999999 | 0.000032 | 0.046946 | 0.777974 | |
| **Left side** | | 39.209 | 54.828 | 59.067 | 65.675 | 41.803 | 55.687 | 59.964 | 67.260 |
| Male | 5 | | 0.000032 | 0.000032 | 0.000032 | 0.864503 | 0.000032 | 0.000032 | 0.000032 |
| Male | 6 | 0.000032 | | 0.542445 | 0.007889 | 0.000032 | 0.999716 | 0.205708 | 0.017520 |
| Male | 7 | 0.000032 | 0.542445 | | 0.482301 | 0.000032 | 0.794361 | 0.999961 | 0.425621 |
| Male | 8 | 0.000032 | 0.007889 | 0.482301 | | 0.000032 | 0.021118 | 0.634922 | 0.999965 |
| Female | 5 | 0.864503 | 0.000032 | 0.000032 | 0.000032 | | 0.000032 | 0.000032 | 0.000032 |
| Female | 6 | 0.000032 | 0.999716 | 0.794361 | 0.021118 | 0.000032 | | 0.440039 | 0.036944 |
| Female | 7 | 0.000032 | 0.205708 | 0.999961 | 0.634922 | 0.000032 | 0.440039 | | 0.555593 |
| Female | 8 | 0.000032 | 0.017520 | 0.425621 | 0.999965 | 0.000032 | 0.036944 | 0.555593 | |

both sexes. Period between 6 and 7 month of a foetal development reveals the reduction of the growth rate by 50% to 75%. Between 7 and 8 month of the pre-natal period development, the rate of growth of the characteristics decreases very rapidly. The decrease ranges from as much as up to 98%. It was only in the case of the right MPL in male foetus that growth rate remained at the same level as in the previous period. Detailed statistics (Tukey's post hoc test) are shown in Table 6.

**Morphological evaluation**
*Proximal attachment*

According to data from the previously published studies, based on an evaluation of the dissection materials, the proximal attachment of the MPL is located

**Table 4.** Results of the post-hoc test (Tukey's test) on *musculus peroneus longus* tendon length for the examined group. Results in red are statistically significant

| Sex | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Right side** | | 27.67 | 37.45 | 39.81 | 44.58 | 28.59 | 38.49 | 40.19 | 44.72 |
| Male | 5 | | 0.000032 | 0.000032 | 0.000032 | 0.997982 | 0.000032 | 0.000032 | 0.000032 |
| Male | 6 | 0.000032 | | 0.844296 | 0.033750 | 0.000032 | 0.993613 | 0.641422 | 0.143218 |
| Male | 7 | 0.000032 | 0.844296 | | 0.530317 | 0.000032 | 0.993183 | 0.999999 | 0.706019 |
| Male | 8 | 0.000032 | 0.033750 | 0.530317 | | 0.000032 | 0.122558 | 0.599782 | 1.000000 |
| Female | 5 | 0.997982 | 0.000032 | 0.000032 | 0.000032 | | 0.000032 | 0.000032 | 0.000032 |
| Female | 6 | 0.000032 | 0.993613 | 0.993183 | 0.122558 | 0.000032 | | 0.957691 | 0.316984 |
| Female | 7 | 0.000032 | 0.641422 | 0.999999 | 0.599782 | 0.000032 | 0.957691 | | 0.765517 |
| Female | 8 | 0.000032 | 0.143218 | 0.706019 | 1.000000 | 0.000032 | 0.316984 | 0.765517 | |
| **Left side** | | 27.94 | 37.30 | 40.23 | 46.04 | 28.85 | 39.12 | 41.04 | 45.40 |
| Male | 5 | | 0.000032 | 0.000032 | 0.000032 | 0.998262 | 0.000032 | 0.000032 | 0.000032 |
| Male | 6 | 0.000032 | | 0.654295 | 0.003243 | 0.000032 | 0.872867 | 0.247059 | 0.072549 |
| Male | 7 | 0.000032 | 0.654295 | | 0.280427 | 0.000032 | 0.997859 | 0.999868 | 0.661700 |
| Male | 8 | 0.000032 | 0.003243 | 0.280427 | | 0.000032 | 0.049874 | 0.443223 | 1.000000 |
| Female | 5 | 0.998262 | 0.000032 | 0.000032 | 0.000032 | | 0.000032 | 0.000032 | 0.000032 |
| Female | 6 | 0.000032 | 0.872867 | 0.997859 | 0.049874 | 0.000032 | | 0.923765 | 0.322431 |
| Female | 7 | 0.000032 | 0.247059 | 0.999868 | 0.443223 | 0.000032 | 0.923765 | | 0.810350 |
| Female | 8 | 0.000032 | 0.072549 | 0.661700 | 1.000000 | 0.000032 | 0.322431 | 0.810350 | |

**Table 5.** Basic statistical data of *musculus peroneus longus* belly thickness

| Age | N | Mean value (standard deviation) |
|---|---|---|
| **Male, right** | | |
| 5 | 34 | 1.31 (0.38) |
| 6 | 39 | 2.09 (0.68) |
| 7 | 18 | 2.41 (0.74) |
| 8 | 8 | 2.81 (0.58) |
| **Male, left** | | |
| 5 | 34 | 1.35 (0.35) |
| 6 | 39 | 2.02 (0.52) |
| 7 | 18 | 2.52 (0.82) |
| 8 | 8 | 2.51 (0.56) |
| **Female, right** | | |
| 5 | 35 | 1.50 (0.58) |
| 6 | 39 | 2.14 (0.53) |
| 7 | 22 | 2.57 (0.79) |
| 8 | 5 | 2.60 (0.56) |
| **Female, left** | | |
| 5 | 35 | 1.53 (0.52) |
| 6 | 39 | 2.03 (0.52) |
| 7 | 22 | 2.36 (0.75) |
| 8 | 5 | 2.38 (0.41) |

on the lateral surface of the knee region. The original attachment of the muscle was being observed between the proximal part of the fibula and the proximal part of the tibia due to the course of the common fibular nerve in majority of the examined specimens. The site of the original attachment was found to be either very large, including the head of fibula, part of the shaft of fibula as well as the lateral condyle of tibia or very narrow, including only the fibula head. Based on anatomical observations, six basic types of primary muscle attachments were determined (Fig. 1):

— type I — head of the fibula, 1/2 superior of the shaft of the fibula, lateral condyle of the tibia;
— type II — head of the fibula, 1/2 superior of the shaft of the fibula;
— type III — head of the fibula, lateral tibia, superior 1/3 of the body of fibula
— type IV — head of the fibula, lateral tibia, superior 2/3 of the body of fibula;
— type V — head of the fibula, lateral condyle of the tibia;
— type VI — other locations not included within the aforementioned and remaining types of the original attachment.

**Table 6.** Results of the post-hoc test (Tukey's test) on *musculus peroneus longus* belly thickness for the examined group. Results in red are statistically significant

| Sex | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Right side** | | 1.31 | 2.09 | 2.41 | 2.81 | 1.50 | 2.14 | 2.57 | 2.60 |
| Male | 5 | | 0.000033 | 0.000032 | 0.000032 | 0.894120 | 0.000032 | 0.000032 | 0.000243 |
| Male | 6 | 0.000033 | | 0.607280 | 0.044574 | 0.000692 | 0.999977 | 0.062652 | 0.641840 |
| Male | 7 | 0.000032 | 0.607280 | | 0.759939 | 0.000038 | 0.779637 | 0.990376 | 0.998376 |
| Male | 8 | 0.000032 | 0.044574 | 0.759939 | | 0.000033 | 0.078102 | 0.977459 | 0.998673 |
| Female | 5 | 0.894120 | 0.000692 | 0.000038 | 0.000033 | | 0.000178 | 0.000032 | 0.003537 |
| Female | 6 | 0.000032 | 0.999977 | 0.779637 | 0.078102 | 0.000178 | | 0.133019 | 0.746058 |
| Female | 7 | 0.000032 | 0.062652 | 0.990376 | 0.977459 | 0.000032 | 0.133019 | | 1.000000 |
| Female | 8 | 0.000243 | 0.641840 | 0.998376 | 0.998673 | 0.003537 | 0.746058 | 1.000000 | |
| **Left side** | | 1.35 | 2.02 | 2.52 | 2.51 | 1.53 | 2.03 | 2.36 | 2.38 |
| Male | 5 | | 0.000041 | 0.000032 | 0.000035 | 0.890278 | 0.000039 | 0.000032 | 0.003249 |
| Male | 6 | 0.000041 | | 0.035664 | 0.314252 | 0.004389 | 1.000000 | 0.311993 | 0.879043 |
| Male | 7 | 0.000032 | 0.035664 | | 1.000000 | 0.000032 | 0.039344 | 0.984605 | 0.999654 |
| Male | 8 | 0.000035 | 0.314252 | 1.000000 | | 0.000233 | 0.327963 | 0.997880 | 0.999904 |
| Female | 5 | 0.890278 | 0.004389 | 0.000032 | 0.000233 | | 0.003775 | 0.000033 | 0.032970 |
| Female | 6 | 0.000039 | 1.000000 | 0.039344 | 0.327963 | 0.003775 | | 0.331978 | 0.886912 |
| Female | 7 | 0.000032 | 0.311993 | 0.984605 | 0.997880 | 0.000033 | 0.331978 | | 1.000000 |
| Female | 8 | 0.003249 | 0.879043 | 0.999654 | 0.999904 | 0.032970 | 0.886912 | 1.000000 | |
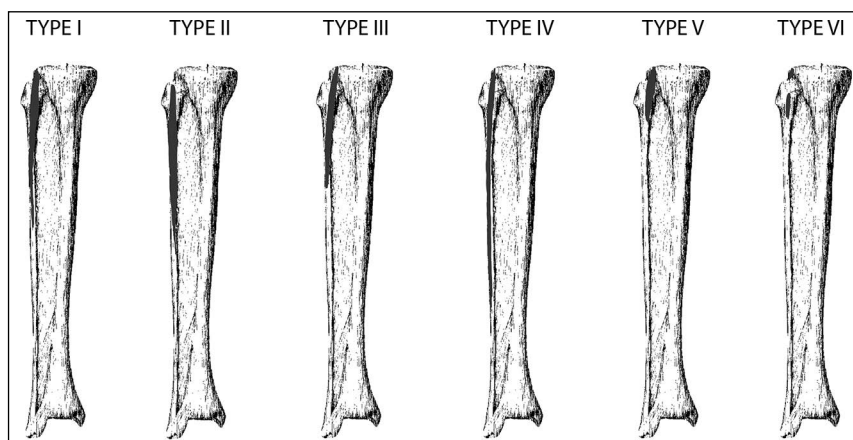


**Figure 1.** The main six types of fibularis longus muscle proximal attachments.

Statistical analysis (test for two structure parameters) did not reveal statistically significant dimorphic differences in the frequency of individual types of MPL proximal attachments on the right and left side ($p \geq 0.05$).

### *Distal attachment*

Analysis of the distal part of the MPL has shown that in about 90% of cases the terminal attachments are located on the medial cuneiform bone and on the base of the first metatarsal bone. Three basic types of this attachment have been distinguished:

— type 1 — medial cuneiform bone with the base of the first metatarsal bone (Fig. 2);
— type 2 — base of the first metatarsal bone (Fig. 3);
— type 3 — medial cuneiform bone (Fig. 4).

The remaining 10% of the population was characterised by a very variable terminal attachment including the surface of medial cuneiform bone, shaft

**Figure 2.** Type 1 of the distal attachment of the musculus fibularis longus; A — the base of the first metatarsal bone; B — medial cuneiform bone, female, right, 7 month.



**Figure 3.** Type 2 of the distal attachment of the musculus fibularis longus; female, right, 7 month.
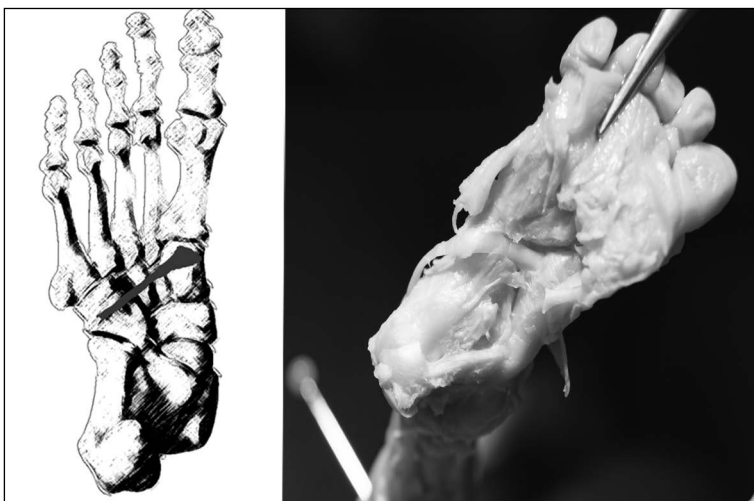


**Figure 4.** Type 3 distal attachment of the musculus peroneus longus; male, right, 7 month.

**Table 7.** Distal attachment of the *musculus fibularis longus* typology. Type 4 constitutes a group of single unrelated attachment types

| Distal attachment type | Right | | | | Left | | | |
|---|---|---|---|---|---|---|---|---|
| | Male | Female | Total | | Male | Female | Total | |
| | | | N | P | | | N | P |
| Type 1 | 77 (74.76%) | 76 (73.08%) | 153 | 0.34 | 70 (67.96%) | 77 (74.04%) | 147 | 0.51 |
| Type 2 | 7 (6.80%) | 10 (9.62%) | 17 | 0.52 | 10 (9.71%) | 18 (17.31%) | 28 | 0.1259 |
| Type 3 | 10 (9.71%) | 14 (13.46%) | 24 | 0.46 | 15 (14.56%) | 5 (5.77%) | 20 | 0.01 |
| Type 4 | 9 (8.73%) | 4 (3.84%) | 13 | 0.31 | 8 (7.77%) | 4 (3.85%) | 12 | 0.02 |
| All | 103 (100%) | 104 (100%) | 207 | – | 103 (100%) | 104 (100%) | 207 | – |

of the first metatarsal bone and the navicular bone. For statistical purposes, this differentiated group was defined as type 4 of the terminal attachment of the MPL. The analysis did not reveal the presence of statistically significant differences in the location of terminal attachment of the MPL in the right limb. Analysis of the left lower limb revealed a significantly statistical difference in the occurrence of type 3 terminal attachment of the MPL — was more common in male foetuses (14.56%) than in female foetuses (5.77%). Statistically significant differences in type 4 were also found (Table 7).

## DISCUSSION AND CONCLUSIONS

*Musculus peroneus longus* is of great clinical importance. Cases of its damage accompanied by the occurrence of the inter-fascial tightness syndrome have been frequently described [1, 18, 27, 29]. First of all, peroneus longus tendon autografts are commonly used in many orthopaedic procedures like deltoid ligament reconstruction [13] and medial patellofemoral ligament reconstruction [14] and anterior cruciate ligament reconstruction [24] (anterior half of the peroneus longus tendon). One of the reasons associated with clinical usefulness of the tendon is its length and its stable, unchangeable course, which has been shown in our study. Additionally, its attractiveness in terms of surgical procedures results from synergistic function of the MPL and peroneus brevis muscle.

When analysing the proximal part of the MPL, the most frequently pointed are the lateral condyle of the tibia and the head of fibula [7] as the site of the original attachment. According to Davda et al. [6] its origin is on the proximal 2/3 lateral side of fibula, anterior intermuscular septum and the lateral condyle of the tibia. The results obtained in this study also indicated that the site of the original attachment of

this muscle is quite varied. The original attachment was usually located on the head and the closer half of the fibula and on the lateral condyle of the tibia. This applies to the whole examined foetus cohort, which may imply that this feature does not show any significant dimorphic and bilateral differences. Evaluating the dynamics of the belly and MPL tendon development, the authors, who describe the leg muscles in the foetal period, present very diverse and contradictory data. For example Domagala et al. [9] when analysing the peroneus tertius, proved that as the foetus age increase, an increasingly longer belly and proportionally shorter tendon are being observed. According to the authors of the paper this is to be a result of physical activity of the foetus, which increases in utero with age. It must be emphasised that the study of Domagala et al. [9] includes the analysis of an atypical muscle within the anterior compartment of the leg and relatively large foetal material is examined by the authors. Within the MPL analysis, Albay and Candan [2] proves that the length of tendon increases rapidly in the third trimester. This work, however, is based on a much smaller study group and the material is divided into only three age classes (second trimester, third trimester, full time newborns). On the other hand, the results of our work indicate that the growth rate of both the belly and the MPL tendon is similar, the highest in the fifth to sixth month of life, whereupon it drops sharply to slightly increase in the last age class. It has not been proved that the dynamics of an increase in the tendon length has significantly changed in relation to the length of the belly.

From 5 month of the foetal life the MPL tendon in the examined foetuses proved to be very long. Its length is close to the length of the entire muscle. It was observed that the tendon begins deeply between the muscle fibre bundles, which has been confirmed

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by the research of Bogacka et al. [4] carried out on adults. This tendon subsequently runs along the plantar region of foot and is usually attached to the base of the first metatarsal bone [24]. Shyamsundar et al. [26] suggest that the MPL attachment to the first metatarsal bone is most commonly observed and typical muscle termination. The authors claim that the connection observed between the tendon and the medial cuneiform bone is only a weak slip. According to our observations, the dominating attachment was the one connected within the medial cuneiform bone and the first metatarsal bone, but the distribution of fibres between the bones was either proportional or the majority of fibres were directed towards the plantar surface of the medial cuneiform bone. Similarly to our observations, Davda et al. [6] indicate the site of the muscle attachment on the closer part of the plantar surface of the medial cuneiform bone and on the base of the first metatarsal bone in a more precise manner. Despite the fact, the authors emphasize a relatively high variability of the terminal attachment. Moreover, a major interpersonal differentiation of this trait has been revealed by the foetal studies. In more than 70% of all examined individuals, the site of terminal attachment of the MPL was shown to be on the medial cuneiform bone and on the base of the first metatarsal bone. The remaining types are present in 30% of cases, so it may be concluded that the encountering any of them in practice is less likely.

Analysis of differences between average values of length, breadth and thickness of both muscles in successive age classes has shown that the growth rate of both muscles is very similar to that of the scapula [19]. The authors indicate a negative correlation with the length-width index of the scapula in foetuses, observed with age. This study has revealed that thickness increases most intensely, then as in the case of the scapula, it is followed by the width and finally the length.

The authors have described a great number of anomalies and variations within the peroneal muscles region. Example: a low-located muscle tummy, presence of a bone spur of the fibula penetrating into the muscles, a very extended peroneal trochlea, a very slack inferior peroneal retinaculum and many others [3, 22, 33]. However, in the examined sample, no aforementioned varieties or abnormalities in the course of peroneal muscles were found. It should therefore be concluded that the anomalies and varieties mentioned within the peroneal muscles, are

secondary. They do not result from developmental errors in the embryonic period, but suggest that they occur along with the motility of the lower limbs. Thus, they are rather the result of paragenetic or epigenetic and environmental factors.

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# REFERENCES

1. Aigner F, Longato S, Gardetto A, et al. Anatomic survey of the common fibular nerve and its branching pattern with regard to the intermuscular septa of the leg. Clin Anat. 2004; 17(6): 503–512, doi: 10.1002/ca.20007, indexed in Pubmed: 15300871.

2. Albay S, Candan B. Evaluation of fibular muscles and prevalence of accessory fibular muscles on fetal cadavers. Surg Radiol Anat. 2017; 39(12): 1337–1341, doi: 10.1007/s00276-017-1887-y, indexed in Pubmed: 28608130.

3. Bakkum BW, Russell K, Adamcryck T, et al. Gross anatomic evidence of partitioning in the human fibularis longus and brevis muscles. Clin Anat. 1996; 9(6): 381–385, doi: 10.1002/(SICI)1098-2353(1996)9:6<381::AID-CA4>3.0.CO;2-E, indexed in Pubmed: 8915617.

4. Bogacka U, Dziedzic D, Komarnitki I, et al. Anatomy of the long peroneal muscle of the leg. Folia Morphol. 2017; 76(2): 284–288, doi: 10.5603/FM.a2016.0054, indexed in Pubmed: 27714727.

5. Bożiłow W, Sawicki K. Metody badań zmienności cech anatomicznych człowieka podczas rozwoju prenatalnego i okołoporodowego. Akademia Medyczna, Wrocław 1980: 52–85.

6. Davda K, Malhotra K, O'Donnell P, et al. Peroneal tendon disorders. EFORT Open Rev. 2017; 2(6): 281–292, doi: 10.1302/2058-5241.2.160047, indexed in Pubmed: 28736620.

7. Didomenico LA, Cross DJ, Giagnacova A. Technique for utilization of an interference screw for split peroneus brevis tendon transfer in lateral ankle stabilization. J Foot Ankle Surg. 2014; 53(1): 114–116, doi: 10.1053/j.jfas.2013.09.016, indexed in Pubmed: 24239429.

8. Domagała Z, Domański J, Zimmer A, et al. Methodology of preparation of corrosive specimens from human placenta: A technical note. Ann Anat. 2020; 228: 151436, doi: 10.1016/j.aanat.2019.151436, indexed in Pubmed: 31704147.

9. Domagała Z, Gworys B, Kreczyńska B, et al. contribution to the discussion concerning the variability of the third peroneal muscle: An anatomical analysis on the basis of foetal material. Folia Morphol. 2006; 65(4): 329–36, indexed in Pubmed: 17171612.

10. Domagała Z, Gworys B, Porwolik K. Preliminary assessment of anatomical variability of nervus peroneus superficialis in the foetal period. Folia Morphol. 2003; 62(4): 401–403, indexed in Pubmed: 14655126.

11. Dudek K, Kędzia W, Kędzia E, et al. Mathematical modelling of the growth of human fetus anatomical structures. Anat Sci Int. 2017; 92(4): 521–529, doi: 10.1007/s12565-016-0353-y, indexed in Pubmed: 27393150.

12. Dudek K, Nowakowska-Kotas M, Kędzia A. Mathematical models of human cerebellar development in the fetal period. J Anat. 2018; 232(4): 596–603, doi: 10.1111/joa.12767, indexed in Pubmed: 29315634.

13. Ellis SJ, Williams BR, Wagshul AD, et al. Deltoid ligament reconstruction with peroneus longus autograft in flatfoot deformity. Foot Ankle Int. 2010; 31(9): 781–789, doi: 10.3113/FAI.2010.0781, indexed in Pubmed: 20880481.

14. Grunfeld R, Oh I, Flemister S, et al. Reconstruction of the deltoid-spring ligament. Tech Foot Ankle Surg. 2016; 15(1): 39–46, doi: 10.1097/btf.0000000000000108.

15. Gworys B, Domagała Z, Markocka-Maczka K. Development of the descending colon during the human foetal period. Folia Morphol. 2004; 63(2): 173–178, indexed in Pubmed: 15232772.

16. Gworys B, Domagala Z. The typology of the human fetal lanugo on the thorax. Ann Anat. 2003; 185(4): 383–386, doi: 10.1016/S0940-9602(03)80066-3, indexed in Pubmed: 12924478.

17. Herzog GA, Serrano-Riera R, Sagi HC. Traumatic proximal tibiofibular dislocation: a marker of severely traumatized extremities. J Orthop Trauma. 2015; 29(10): 456–459, doi: 10.1097/BOT.0000000000000348, indexed in Pubmed: 26397776.

18. Hiramatsu K, Yonetani Y, Kinugasa K, et al. Deep peroneal nerve palsy with isolated lateral compartment syndrome secondary to peroneus longus tear: a report of two cases and a review of the literature. J Orthop Traumatol. 2016; 17(2): 181–185, doi: 10.1007/s10195-015-0373-8, indexed in Pubmed: 26362782.

19. Kedzia A, Andrzejak R, Dudek K, et al. Analysis of human scapula morphometry in the fetal period. Adv Clin Exp Med. 2009; 18(3): 197–204.

20. Kędzia A, Ziajkiewicz M, Seredyn A, et al. Computer morphometric analysis of the palmaris longus muscle in the fetal period. Adv Clin Exp Med. 2009; 18(5): 437–47.

21. Olewnik Ł. Is there a relationship between the occurrence of frenular ligaments and the type of fibularis longus tendon insertion? Ann Anat. 2019; 224: 47–53, doi: 10.1016/j.aanat.2019.03.002, indexed in Pubmed: 30930196.

22. Patil V, Frisch NC, Ebraheim NA. Anatomical variations in the insertion of the peroneus (fibularis) longus tendon. Foot Ankle Int. 2007; 28(11): 1179–1182, doi: 10.3113/FAI.2007.1179, indexed in Pubmed: 18021587.

23. Rajasekaran S, Hall MM. Nonoerative management of chronic exertional comartment syndrome: a systematic review. Curr Sports Med Rep. 2016; 15: 191–198.

24. Rhatomy S, Asikin AI, Wardani AE, et al. Peroneus longus autograft can be recommended as a superior graft to hamstring tendon in single-bundle ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2019; 27(11): 3552–3559, doi: 10.1007/s00167-019-05455-w, indexed in Pubmed: 30877316.

25. Sarig-Bahat H, Krasovsky A, Sprecher E. Evaluation of clinical methods for peroneal muscle testing. Physiother Res Int. 2013; 18(1): 55–62, doi: 10.1002/pri.1534, indexed in Pubmed: 22911954.

26. Shyamsundar S, Wazir A, Allen PE. Variations in the insertion of peroneus longus tendon-a cadaver study. Foot Ankle Surg. 2012; 18(4): 293–295, doi: 10.1016/j.fas.2012.05.003, indexed in Pubmed: 23093127.

27. Slabaugh M, Oldham J, Krause J. Acute isolated lateral leg compartment syndrome following a peroneus longus muscle tear. Orthopedics. 2008; 31(3): 272, doi: 10.3928/01477447-20080301-37, indexed in Pubmed: 19292237.

28. Imade S, Takao M, Miyamoto W, et al. Leg anterior compartment syndrome following ankle arthroscopy after maisonneuve fracture. J Arthrosc relat Surg. 2009; 25(2): 215–218, doi: 10.1016/j.arthro.2007.08.027, indexed in Pubmed: 19171284.

29. van Zantvoort APM, de Bruijn JA, Winkes MB, et al. Isolated chronic exertional compartment syndrome of the lateral lower leg: a case series. Orthop J Sports Med. 2015; 3(11): 2325967115617728, doi: 10.1177/2325967115617728, indexed in Pubmed: 26740955.

30. Wilke J, Engeroff T, Nürnberger F, et al. Anatomical study of the morphological continuity between iliotibial tract and the fibularis longus fascia. Surg Radiol Anat. 2016; 38(3): 349–352, doi: 10.1007/s00276-015-1585-6, indexed in Pubmed: 26522465.

31. Woźniak J, Kędzia A, Dudek K. Brachial plexus variations during the fetal period. Anat Sci Int. 2012; 87(4): 223–233, doi: 10.1007/s12565-012-0150-1, indexed in Pubmed: 22945314.

32. Wozniak S, Pytrus T, Kobierzycki C, et al. The large intestine from fetal period to adulthood and its impact on the course of colonoscopy. Ann Anat. 2019; 224: 17–22, doi: 10.1016/j.aanat.2019.02.004, indexed in Pubmed: 30914345.

33. Yammine K. The accessory peroneal (fibular) muscles: peroneus quartus and peroneus digiti quinti. A systematic review and meta-analysis. Surg Radiol Anat. 2015; 37(6): 617–627, doi: 10.1007/s00276-015-1438-3, indexed in Pubmed: 25638531.

34. Zanetti M, Pfirrmann CWA, Saupe N, et al. Anatomic variants associated with peroneal tendon disorders: MR imaging findings in volunteers with asymptomatic ankles. Radiology. 2007; 242(2): 509–517, doi: 10.1148/radiol.2422051993, indexed in Pubmed: 17255421.

35. Ziółkowski M, Gworys B, Kurlej W. Estimation of fetal age on the basis of certain measurements and ossification of the sternum. Folia Morphol. 1988; 47(1-4): 145–151, indexed in Pubmed: 3267621.