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# Morphology and morphometry of the semitendinosus distal tendon in adults and foetuses

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***Background:*** *The distal tendon of the semitendinosus is often used as a graft in orthopedic reconstructive surgery. Knowledge of the exact morphology of this tendon, and also the ability to predict its morphometric data are certainly helpful when planning the procedure of surgery. Comparison of the semitendinosus distal tendon anatomy in adults and foetuses may be scientifically relevant. There are no scientific reports on this tendon anatomy in foetuses.*

***Materials and methods:*** *Seventy semitendinosus muscles from cadavers were obtained using standard dissection techniques (50 muscles were obtained from adults and 20 from foetuses). Moreover, ultrasound examinations of 20 muscles were performed in living individuals.*

***Results:*** *Two main parts of the distal tendon were distinguished — the external part not covered with muscle fibres and the internal part, which is partially or entirely hidden within the muscle belly (venter). The average length of the distal tendon was 32.34 cm, while the average lengths of the external and internal parts were 9.65 cm and 12.59 cm, respectively. The external part was solid and cylindrical. The internal part was flat and rolled like a trough, thus making the tendon a poor transplant material. Similarly, the distal tendon in foetuses consisted of two parts, including the external and internal part.*

***Conclusions:*** *The proportions between the lengths of different muscle parts were very similar in adults and foetuses.* (Folia Morphol 2020; 79, 2: 339–349)

**Key words: hamstring, foetal muscle, tendon**

## INTRODUCTION

The semitendinosus is one of the hamstring muscles. Also, it is one of the longest muscles in the body. It arises from the ischial tuberosity and lies on the semimembranosus throughout its course. Finally, it inserts into the tibia, medial to the tibial tuberosity and within pes anserinus. The main function of semitendinosus is flexing the knee and extending hip joint [5, 10, 14, 21].

The modern name of the semitendinosus comes from its characteristic distal tendon, which has an outstanding elongated, thin and cylindrical shape. Because of the specific characteristics of its tendon, the muscle was previously called 'seminervosus' in the 17$^{th}$ and early 18$^{th}$ century, and the distal tendon structure was described as membranous or nervous [52].

The distal tendon gives rise to additional fibres, which attach to the neighbouring muscles or fascia. Usually, one to three additional fibre bundles have been described. Their origin is located a few centimetres (4–8 cm) apart from the tibial insertion [8, 42, 49, 55].

Within pes anserinus, the semitendinosus tendon is located most deeply. The tendon of gracilis overlays

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it directly, while the tendon of sartorius enfolds both tendons [11, 28, 32].

The length of the distal tendon correlates with the person's height and the lower extremity length. It is longer among Caucasians compared to Asians. This measurement is important, because the semitendinosus tendon can be used for reconstruction of different ligaments. The average lengths of the semitendinosus distal tendon provided by various authors are within the range from 21.88 to 29.94 cm [9, 20, 23, 24, 29, 41, 46, 48–50, 54].

There are reports on the length of the distal tendon dividing it into two parts — one non-covered in muscle fibres also called free or 'clean' part, and the other already containing muscle fibres and forming the musculotendinous junction. The average length of the distal tendon free part is within a wide range from 13.2 to 25.9 cm, while the musculotendinous junction length ranges from 11.4 to 14.0 cm [3, 4, 18, 23, 24, 50, 54].

Because of the characteristic morphology, the semitendinosus distal tendon is often used for reconstructions of damaged ligaments and tendons. The semitendinosus distal tendon is specially prepared and most often used for reconstruction of the anterior cruciate ligament. Arthroscopic reconstruction surgeries are currently becoming very popular [6, 15, 34, 40, 44, 51, 56].

Many other ligament and tendon structures, not only in the leg, are also reconstructed using the semitendinosus distal tendon. Examples include the posterior cruciate ligament [57], fibular collateral ligament [7], tibial collateral ligament [25], medial patellofemoral ligament [31, 38], Achilles tendon [43], extensor hallucis longus muscle tendon [27], patellar ligament [1], as well as the anterior talofibular ligament [45], distal tendon of biceps femoris [30], and common origin of the hamstrings following an avulsion injury [33]; for the upper extremity: rotator cuff [17], distal tendon of biceps brachii [53], ligaments of the acromioclavicular joint [16].

In the literature, correction surgeries for scoliosis of the spine in adults have been described, when the interspinous ligaments were strengthened using the semitendinosus distal tendons harvested from cadavers [39].

The semitendinosus distal tendon shows the ability to regenerate. It 'regrows' within the first weeks after excision in most patients (70–100%). Usually, it attaches to unnatural sites, such as semitendinosus fascia or other facias near the knee joint, rarely to pes anserinus. Thanks to such attachments, it is able to support flexion of the knee [2, 13, 19, 22, 26, 35–37, 47].

The current literature lacks descriptions of the semitendinosus distal tendon morphology and morphometry in foetuses. However, there are publications focusing on a similar tendon in foetuses, namely the distal tendon of gracilis.

## MATERIALS AND METHODS

We examined 50 adult and 20 foetal (12–21 weeks) semitendinosus muscles at the Department of Descriptive and Clinical Anatomy and the Forensic Medicine Department, Medical University of Warsaw. Twenty semitendinosus muscles were examined *in situ* using an ultrasound scanner.

We used a classic set of anatomical dissection tools. For studying foetal muscles, we also used Nikon SM 1500 stereoscopic microscope with reflected and transmitted illumination option, C-W 10X B/22 eyepiece, WD 136 Nikon Japan HR Plan Apo 0.5X objective with magnification 0.75–11.25 as well as NY Dornwell 3.0X surgical magnifying glass.

Three researches were involved in the measurements: one was preparing the specimen for measurement, the second one was taking a measurement, the third one was writing down the results. The particular measurements were taken once. In adults, measurements were taken to nearest 0.1 cm, in foetuses — to 0.1 mm.

Ultrasound examination was performed using USG Philips ClearVue 550 scanner with linear 4–12 mHz transducer.

The following measures were taken in our study:

- muscle length **(M)** — measured from the muscle origin (from the medial part of the ischial tuberosity) to the end of the distal tendon insertion;
- distal tendon length **(T)** — a total length of the tendon, measured from the insertion site to the end of the tendinous fibres dissected from the muscle belly. Additionally, we determined the length of the free part of the tendon:
- **Text** — length of the external part of the distal tendon;
- **Tint** — length of the internal part of the distal tendon;
- **Tim** — length of the intermediate part of the distal tendon;
- **Thid** — length of the hidden part of the distal tendon;

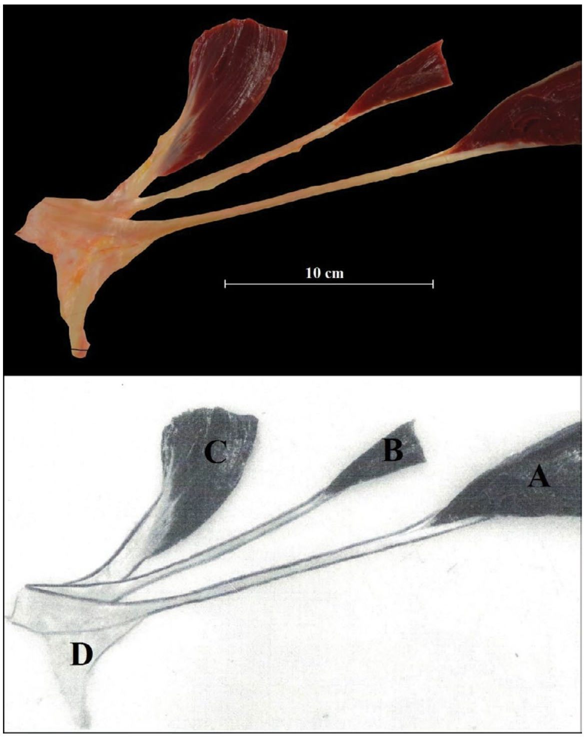


**Figure 1.** Isolated pes anserinus. The view from the inner face; A — semitendinosus muscle; B — gracilis; C — sartorius; D — additional bundle of the semitendinosus tendon.

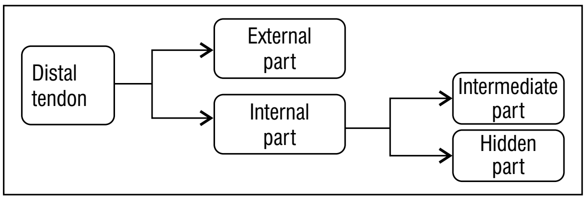


**Figure 2.** Division of the semitendinosus distal tendon.

— **Tvis** — length of the visible part of the distal tendon;
— width of the distal tendinous band **(L)** — maximal width of the band formed by the distal tendon. Because the band creates a sulcus, we also measured the distance between its two margins at the widest point — in the front (L1) and in the back (L2). However, the two measurements were not aligned; the sum of both sulcus margin widths may differ from the total band width.

## RESULTS

The insertion of semitendinosus was located medially to the tibial tuberosity. Together with sartorius and gracilis muscle, it formed pes anserinus, semitendinosus tendon being located most deeply. The gracilis tendon was in the middle, while the distal

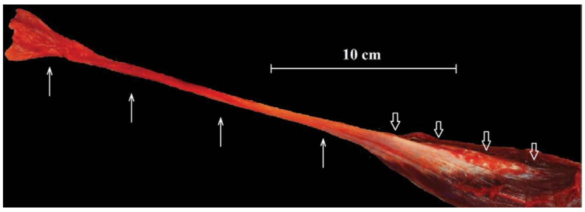


**Figure 3.** Distal tendon of semitendinosus — the external part (thin arrows) and dissected internal part connected to the muscle belly (thick arrows).

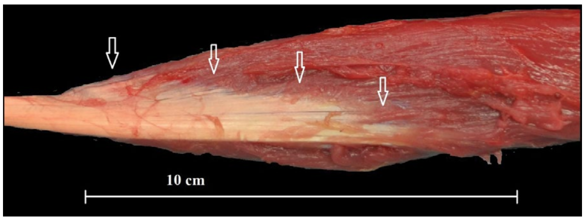


**Figure 4.** Internal part of the distal tendon of semitendinosus (arrows).

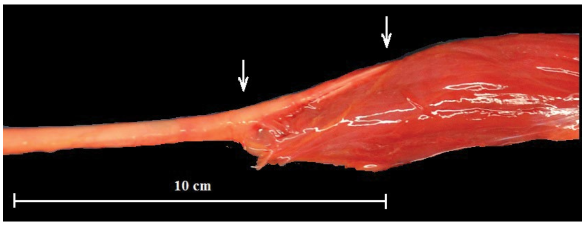


**Figure 5.** Intermediate part of the distal tendon (between arrows).

tendon of sartorius was placed at the top. In each case, the semitendinosus tendon sent an additional bundle connected with the deep fascia of the leg (Fig. 1).

Throughout its course, the distal tendon lied on semimembranosus creating a characteristic impression.

Because of the complex relationships between the distal tendon and the semitendinosus belly, we proposed a division of the tendon into two parts (Fig. 2). We distinguished the external part and the internal part. The external part was outside the muscle belly and was not covered by muscle fibres. The internal part was contained within the muscle belly (Figs. 3, 4). It was further subdivided into the intermediate part (Fig. 5) partially covered with muscle fibres and the hidden part totally hidden within the belly (Fig. 6).

In addition, with this classification, the visible part may be distinguished. It includes the external part and the intermediate part.

The average total length of the distal tendon of the semitendinosus muscle (T) in adults was 32.23 ± 2.23 cm

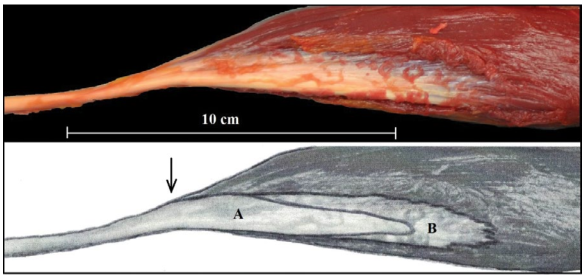


**Figure 6.** Intermediate part of the distal tendon; A — not covered by muscle fibres; external part fragment and the internal part — the intermediate part is marked with the arrow; B — hidden part — traces of muscle fibre dissection.

(24–37); the external part length (Text) was 19.65 ± ± 3.83 cm (11–27.5); the internal part length (Tin) was 12.59 ± 3.58 cm (7.5–21); intermediate part length (Tim) was 7.91 ± 2.90 (3.5–16) and the hidden part length (Thid) was 4.68 ± 2.23 cm (1.5–9.5) (Table 1).

The distal tendon in adults had a cylindrical shape and solid structure. At the point of contact with muscle fibres (proximally), the tendon began to flatten and bend on both sides creating a sulcus. In this trough-shaped part, two bands could be distinguished — the anterior and posterior lamina, which enclosed the belly end in a fan-like manner.

In this guttered, internal part, of the tendon, two laminas connected with each other could be distinguished — frontal and back, which covered distal part of the muscle's belly. The muscle fibres attached between the laminas and partially outside of them (Figs. 7–9).

The average widths of both laminas, measured at their widest points, were as follows: for the anterior lamina (L1) — 1.01 ± 0.46 (0.2–2.0) cm; for the posterior lamina (L2) — 1.63 ± 0.43 (0.8–2.5) cm.

The average length of the intermediate part (Tim) was 7.32 ± 2.72 cm and 4.81 ± 2.82 cm, respectively (Table 1).

In foetuses, the distal tendon of semitendinosus, like in adults, was a part of pes anserinus, located the most deepl.

An additional bundle from the distal tendon was also observed in foetuses. It inserted into the deep fascia of leg like in adults (Fig. 10).

It was difficult to precisely describe the intermediate part in foetuses, and thus we only distinguished two parts — the external and internal part without any further division of the latter (Fig. 11).

The length of the distal tendon in foetuses (fT) was ranging from 9.0 to 53.0 mm (Table 2).

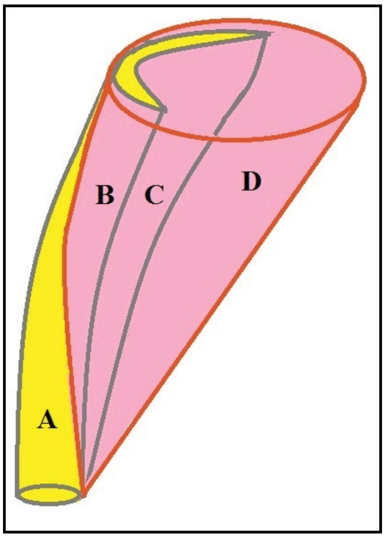


**Figure 7.** Spatial model of semitendinosus — section at the intermediate part of the distal tendon; A, B, C — intermediate part of the distal tendon: A — not covered by muscle fibres; B, C — covered by muscle fibres; B, C — anterior and posterior lamina; D — muscle belly.

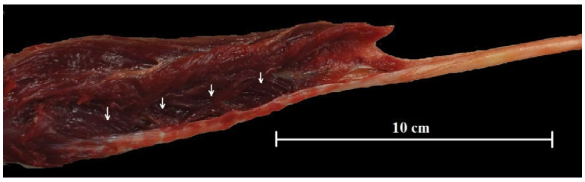


**Figure 8.** Internal part of distal tendon. Muscle fibres attaching to the sulcus (between laminas) can be appreciated (arrows).

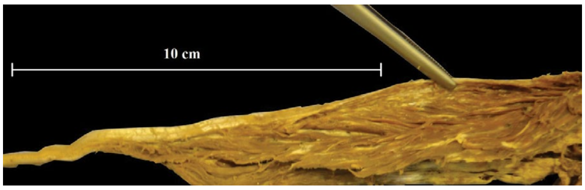


**Figure 9.** The internal part of the distal tendon was grasped with tweezers to better display it and to show muscle fibres running between both laminas.

The scatter plot shows total tendon length relative to age (Fig. 12).

The external part of the distal tendon was easy to visualise on ultrasound. It lied in a sulcus formed by semimembranous (Fig. 12).

The internal part's shape on ultrasound was comparable to autopsy results. Within the muscle belly, the tendon was flattened, extended and U-shaped with different lengths of each arm. It created a nar-

**Table 1.** Descriptive statistics and test of normality for adults

| Variables | N | $\bar{X}$ | SE | Me | Min | Max | Q1 | Q3 | SD | SW-W | P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 35 | 174 | 0.97 | 174.00 | 162 | 187 | 172.00 | 178.00 | 5.74 | 0.9424 | 0.0663 |
| RL | 50 | 88.52 | 0.75 | 89.50 | 75 | 100 | 85.00 | 92.00 | 5.34 | **0.9516** | **0.0398** |
| RLT | 50 | 51.61 | 0.57 | 52.00 | 43 | 61 | 49.00 | 54.00 | 4.02 | 0.9715 | 0.2657 |
| AL | 50 | 80.38 | 0.74 | 81.50 | 65 | 89 | 78.00 | 84.00 | 5.23 | **0.9109** | **0.0011** |
| ALT | 50 | 41.33 | 0.46 | 42.00 | 32 | 49 | 40.00 | 43.00 | 3.27 | **0.9444** | **0.0203** |
| M | 50 | 51.58 | 0.37 | 52.00 | 43 | 56 | 50.00 | 53.00 | 2.61 | **0.9216** | **0.0027** |
| T | 50 | 32.24 | 0.32 | 32.75 | 24 | 37 | 31.50 | 33.50 | 2.23 | **0.889** | **0.0002** |
| Tint | 50 | 12.59 | 0.51 | 11.25 | 7.5 | 21 | 10.50 | 15.00 | 3.58 | **0.9142** | **0.0015** |
| Text | 50 | 19.65 | 0.54 | 20.00 | 11 | 27.5 | 16.50 | 22.50 | 3.83 | 0.9805 | 0.5746 |
| Tvis | 50 | 27.56 | 0.39 | 28.00 | 21 | 32.5 | 26.00 | 29.50 | 2.73 | 0.973 | 0.3051 |
| Tim1 | 50 | 4.81 | 0.40 | 4.50 | 1.5 | 16 | 3.00 | 6.00 | 2.82 | **0.8085** | **0.0000** |
| Tim2 | 50 | 7.32 | 0.39 | 7.25 | 2 | 16 | 5.00 | 9.00 | 2.72 | 0.9599 | 0.0878 |
| Tim | 50 | 7.91 | 0.40 | 7.75 | 3.5 | 16 | 6.00 | 9.00 | 2.90 | **0.9403** | **0.0139** |
| Thid | 50 | 4.68 | 0.32 | 4.50 | 1.5 | 9.5 | 3.00 | 6.00 | 2.23 | **0.9304** | **0.0057** |
| L | 50 | 2.59 | 0.09 | 2.50 | 1.4 | 4.5 | 2.20 | 3.00 | 0.66 | 0.9715 | 0.2651 |
| L1 | 50 | 1.01 | 0.07 | 1.00 | 0.2 | 2.2 | 0.70 | 1.20 | 0.46 | 0.956 | 0.0603 |
| L2 | 50 | 1.63 | 0.06 | 1.65 | 0.8 | 2.5 | 1.20 | 2.00 | 0.43 | 0.9715 | 0.2666 |

N — number of the observations; $\bar{X}$ — arithmetic mean; SE — standard error of the mean; Me — median; Min — minimal value; Max — maximal value; Q1 — first quartile; Q3 — second quartile; SD — standard deviation; SW-W — Shapiro-Wilk test statistic; p — statistical significance; rest abbreviations — see text; results in bold do not meet the criteria of normal distribution

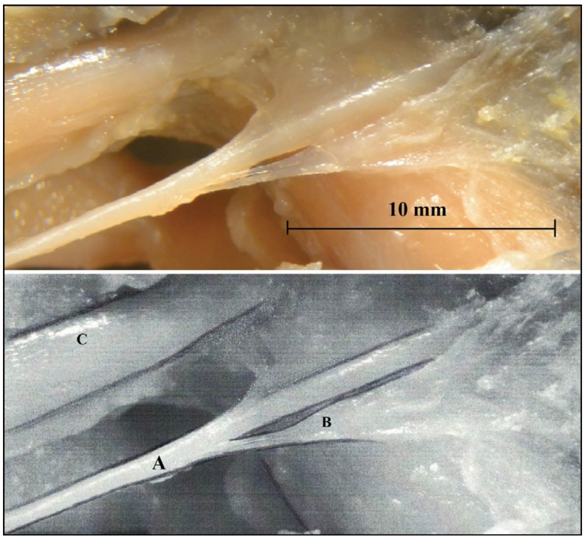


**Figure 10.** Distal tendon of semitendinosus (A) of a foetus (18 weeks) projecting an additional bundle (B) in the direction of the deep fascia of leg. Semimembranosus is visible in the background (C).

row, solid (Fig. 13), or wide fan-shaped (Fig. 14) structure within the belly.

Also, the following anthropometric measurements were obtained:

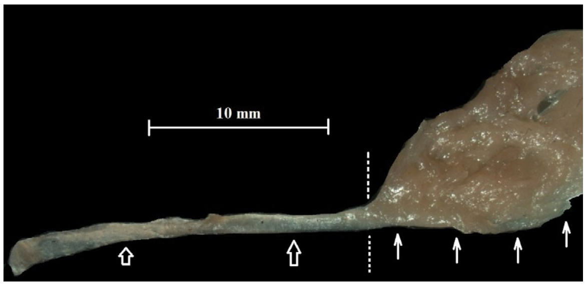


**Figure 11.** Distal tendon in a foetus (17 weeks); external part — thick arrows; internal part — thin arrows; border between them — dotted line.

- **H** — body height;
- **RLT** — relative length of the thigh, measured from the anterior superior iliac spine (most frontal point) to the medial part of the knee (in the middle of the upper edge of the medial condyle of tibia);
- **RL** — relative length of the lower extremity — measured from the anterior superior iliac spine (most frontal point) to the medial malleolus (most medial point);
- **ALT** — absolute length of the thigh — measured from the greater trochanter (most lateral point) to lateral part of the knee (in the middle of the upper edge of the medial condyle of tibia);

**Table 2.** Descriptive statistics and test of normality for foetuses

| Variables | N | X̄ | SE | Me | Min | Max | Q1 | Q3 | SD | SW-W | P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FL | 20 | 21.65 | 1.65 | 22.5 | 9.0 | 34.0 | 18.0 | 26.0 | 7.38 | 0.9395 | 0.2342 |
| HL | 20 | 19.90 | 1.55 | 21.0 | 8.0 | 31.0 | 16.0 | 24.0 | 6.93 | 0.9383 | 0.2222 |
| Age | 20 | 16.45 | 0.59 | 16.5 | 12.0 | 21.0 | 15.0 | 18.0 | 2.63 | 0.9540 | 0.4319 |
| fRL | 20 | 83.9 | 6.37 | 87.5 | 32.0 | 126.0 | 73.5 | 103.0 | 28.48 | 0.9123 | 0.0704 |
| fRLT | 20 | 49.15 | 3.91 | 52.0 | 19.0 | 73.0 | 42.0 | 58.0 | 17.49 | 0.8722 | **0.0129** |
| fAL | 20 | 74.0 | 5.90 | 79.0 | 26.0 | 115.0 | 63.5 | 90.5 | 26.37 | 0.9224 | 0.1101 |
| fALT | 20 | 35.95 | 2.89 | 38.0 | 12.0 | 58.0 | 34.0 | 42.0 | 12.92 | 0.8790 | **0.0170** |
| fM | 20 | 45.95 | 3.79 | 49.0 | 15.0 | 72.0 | 39.5 | 52.0 | 16.94 | 0.9080 | 0.0583 |
| fT | 20 | 31.85 | 2.71 | 35.5 | 9.0 | 53.0 | 26.5 | 36.5 | 12.12 | 0.9258 | 0.1283 |
| fText | 20 | 19.7 | 1.77 | 20.0 | 6.0 | 35.0 | 18.0 | 23.5 | 7.93 | 0.9226 | 0.1112 |
| fTint | 20 | 12.15 | 1.10 | 14.0 | 3.0 | 18.0 | 8.5 | 16.0 | 4.90 | 0.9027 | **0.0461** |

N — number of the observations; X̄ — arithmetic mean; SE — standard error of the mean; Me — median; Min — minimal value; Max — maximal value; Q1 — first quartile; Q3 — second quartile; SD — standard deviation; SW-W — Shapiro-Wilk test statistic; p — statistical significance; rest abbreviations — see text; results in bold do not meet the criteria of normal distribution

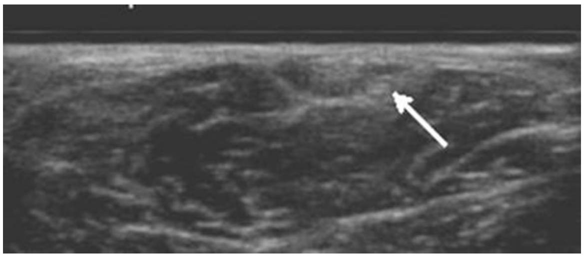

**Figure 12.** Distal tendon (arrow) lies on the semimembranosus belly.

**Figure 13.** Semitendinosus muscle belly with narrow internal part of the distal tendon.

— **AL** — absolute length of the lower extremity — measured from the greater trochanter (most lateral point) to the lateral malleolus (most lateral point).

### Proportions

Pairs of variables, for which proportions were calculated, were chosen in each group.

Statistical comparison between proportions in both groups was conducted. For comparison, we used the same symbols for proportions in foetuses as in adults (we did not use the 'f-' prefix).

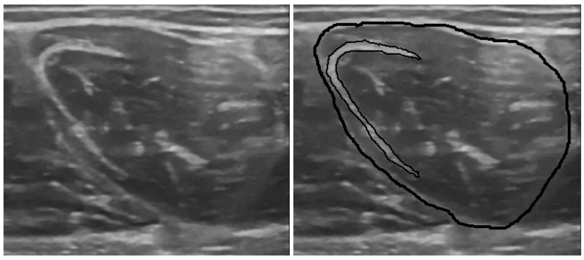

**Figure 14.** Semitendinosus muscle belly with wide internal part of the distal tendon.

The following proportions were calculated and then compared:

— length of the distal tendon — to the length of the muscle (**T/M**);

— length of the internal part of the distal tendon — to the length of the muscle (**Tint/M**);

— length of the external part of the distal tendon — to the length of the muscle (**Text/M**);

— length of the internal part of the distal tendon — to the total length of the distal tendon (**Tint/T**);

— length of the external part of the distal tendon — to the total length of the tendon (**Text/T**).

The Table 3 shows descriptive statistics and proportion analysis between adults and foetuses. To test differences between means in both populations, we used the t-test for independent pairs of variables, or the Mann-Whitney's test if the requirements for parametric tests were not met for at least one variable in a pair (Table 3).

The analysis proved that most proportions were similar in both groups.

The following proportions differed in a statistically significant way:

**Table 3.** Comparison of join proportions in adults and foetuses

| Variable | Foetuses | | | | | Adults | | | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | $\bar{X}$ | Me | Min–Max | SD | N | $\bar{X}$ | Me | Min–Max | SD | t/Z | P |
| T/M | 20 | 0.69 | 0.70 | 0.51–0.68 | 0.04 | 50 | 0.63 | 0.63 | 0.60–0.76 | 0.03 | **4.77** | **0.000*** |
| Tint/M | 20 | 0.26 | 0.26 | 0.14–0.41 | 0.05 | 50 | 0.24 | 0.22 | 0.20–0.35 | 0.07 | 1.48 | 0.140* |
| Text/M | 20 | 0.43 | 0.43 | 0.22–0.51 | 0.04 | 50 | 0.38 | 0.39 | 0.35–0.50 | 0.07 | **2.81** | **0.006** |
| Tint/T | 20 | 0.38 | 0.38 | 0.21–0.65 | 0.06 | 50 | 0.39 | 0.36 | 0.29–0.50 | 0.11 | 0.12 | 0.907* |
| Text/T | 20 | 0.62 | 0.62 | 0.35–0.79 | 0.06 | 50 | 0.61 | 0.64 | 0.50–0.71 | 0.11 | –0.12 | 0.907* |

n — number of the observations; $\bar{X}$ — arithmetic mean; Min — minimal value; Max — maximal value; Q1 — first quartile; Q3 — second quartile; SD — standard deviation; t/Z — t-test statistic for independent samples/*Mann-Whitney test; p — significance level; rest abbreviations — see text; results in bold did not met criteria for normal distribution

**Table 4.** Regression model for H and Text

| N = 34 | Summary of regression of dependent variable: Text<br>R = 0.55981352; $R^2$ = 0.31339117; Adjusted $R^2$ = 0.29193465<br>F(1,32) = 14.606; p < 0.00058; Standard error (SE) of estimation: 2.7133 | | | | | |
|---|---|---|---|---|---|---|
| | b | SE from b | b | SE from b | t(32) | P |
| Intercept parameter | | | –34.0897 | 14.22225 | –2.39693 | 0.022545 |
| H | 0.559814 | 0.146480 | 0.3121 | 0.08167 | 3.82176 | 0.000576 |

— the length of the distal tendon to length of the muscle (T/M) — this parameter was higher in foetuses, which proves that the distal tendon is relatively longer in foetuses;

— the length of the external part of the distal tendon to the length of the muscle (Text/M) — this parameter was higher in foetuses, which proves that the external part of the distal tendon is relatively longer in foetuses.

Nevertheless, the observed differences were minor — no more than 0.05 of the proportion mean. It shows that proportions of semitendinosus muscle parts are comparable in foetuses and adults.

**Regression models**

The morphology characteristics of the external part of the distal tendon make it a good material for transplantation. Because of it, further analysis was conducted, the aim of which was to make a prediction model for the length of the external part based on anthropometric measurements.

The lengths of other parts (including the total length) were not suitable for a regression model (their distribution was not normal and they showed no statistically significant correlations).

Among anthropometric data, only the height and relative length of the thigh had normal distribution and were correlated with the length of the external part of the distal tendon in a statistically significant way.

The first part of analysis we estimated the correlation between height and the length of the external part of the distal tendon (Text) (Table 4).

The analysis of regression allowed us to make an assumption that an increase in height by 1 cm causes an increase in length of the distal tendon external part (Text) by 0.31 cm. Moreover, by slope estimation, the mean error is 0.08. The significance of the results (p = 0.0006) proved that the model is well-fitted. The correlation of two variables was R = 0.56, and the entire regression model explained about 31% of the distal tendon external part length variance ($R^2$ = 0.3134).

In our model, we excluded one case with outliers underestimating the regression values.

Predicted values of external part length of the distal tendon for given body heights have been estimated and presented in Table 5 and Figure 15.

On further regression analysis, we estimated the correlation between relative length of the tight (RLT) and external part of the distal tendon (Text) (Table 6).

The analysis of the regression allowed us to assume that increasing relative length of the tight by 1 cm causes a small increase in length of the external part of the distal tendon (Text) by 0.41 cm. Moreo-

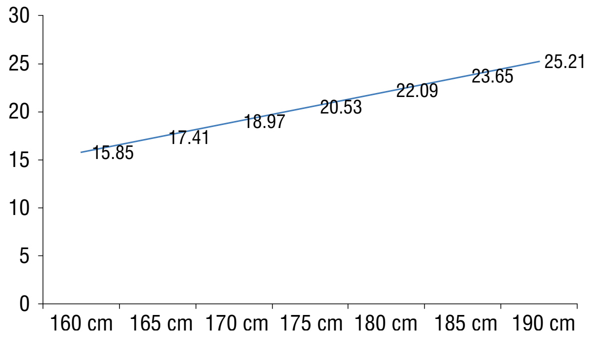


**Figure 15.** Predicted values of Text for selected body heights H.

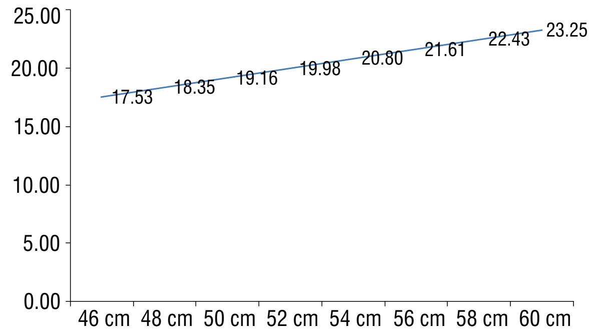


**Figure 16.** Predicted values of Text for selected relative lengths of the tight.

**Table 5.** Predicted values of Text for selected body heights H

| | H | 165 | 170 | 175 | 180 | 185 | 190 |
|---|---|---|---|---|---|---|---|
| Text | 15.85 | 17.41 | 18.97 | 20.53 | 22.09 | 23.65 | 25.21 |
| Confidence interval | 13.32–18.37 | 15.62–19.19 | 17.80–20.13 | 19.57–21.49 | 20.72–23.46 | 21.60–25.70 | 22.39–28.03 |

**Table 6.** Regression model for the tight relative length of the thigh (RLT) and Text

| N = 34 | Summary of regression of the dependent variable: Text<br>R = 0.45346567; $R^2$ = 0.20563111; Adjusted $R^2$ = 0.18872965<br>F(1.47) = 12.166; p < 0.00107; Standard error (SE) of estimation: 3.2909 | | | | | |
|---|---|---|---|---|---|---|
| | b | SE from b | b | SE from b | t(32) | p |
| Intercept parameter | | | –1.24578 | 6.059558 | –0.205589 | 0.838000 |
| RLT | 0.453466 | 0.130006 | 0.40820 | 0.117028 | 3.488046 | 0.001067 |

**Table 7.** Predicted values of the Text for selected relative lengths of the tight (RLT)

| RLT | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 |
|---|---|---|---|---|---|---|---|---|
| Text | 17.53 | 18.35 | 19.16 | 19.98 | 20.80 | 21.61 | 22.43 | 23.25 |
| Confidence interval | 15.90–19.16 | 17.07–19.62 | 18.14–20.18 | 19.03–20.93 | 19.70–21.90 | 20.21–23.01 | 20.66–24.20 | 21.06–25.43 |

ver, for slope estimation, the mean error is 0.12. The significance of results (p = 0.0011) proved that the model is well-fitted. The correlation of two variables was R = 0.45, and the whole regression model explained about 21% of the distal tendon external part length variance ($R^2$ = 0.2056).

In this model, we excluded one case with outliers underestimating the regression values.

Predicted values of the external part length of the distal tendon for selected relative lengths of the tight are given in Table 7 and Figure 16.

## DISCUSSION

The distal tendon is long and strong, and therefore constitutes a good material for transplant in orthopaedic reconstructive surgery of ligaments and tendons. It is worth noting, that there is a part coalescing with muscle belly, so-called musculotendinous junction. However, there are some discrepancies in its description. It results from a lack of precise model of tendon morphology [3, 4, 9, 18, 20, 23, 24, 29, 41, 46, 48, 49, 50, 54].

In this study, two main parts of the distal tendon were distinguished: the internal and external parts.

The internal part of semitendinosus distal tendon contains a fragment that is totally enclosed within the muscle belly — the hidden part, as well as a part covered only partially by muscle fibres — the intermediate part. The intermediate part has not been described in the literature. Therefore, data on musculotendinous junction length may include the entire internal part, or only its fragment, e.g. the hidden or intermediate part.

The internal part, when joining with muscle fibres, flattens and bends on the edges, forming a trough-shaped sulcus surrounded by muscle fibres on both sides. It also becomes fragile and prone to damage during dissection.

In the literature, there is no precise description of morphology of this tendon part. Differences, however, are significant, because the fragile internal part is a poor transplant material.

We also confirmed the presence of an additional bundle from distal tendon to deep fascia of leg [8, 42, 49, 55].

The bundle was also observed in foetuses.

In this study, we also investigated the morphometry of semitendinosus tendon in foetuses. Proportions of selected lengths were compared between two groups. The ratio of the length of the distal tendon to the length of the muscle was slightly higher in foetuses than in adults (0.63 and 0.57, respectively). It might indicate that the tendon is relatively longer in early ontogenesis. Furthermore, the proportions of selected muscle and tendon parts are very similar in both adults and foetuses. In most cases, correlations between lengths of individual muscle parts in foetuses are very strong.

The literature lacks data about semitendinosus muscle morphometry in foetuses, and hence there are no reference sources for comparison of the results with adults.

Interestingly, the analysis of length proportion in a very similar muscle (gracilis), the reciprocal relationship was observed, namely the proportion of the distal tendon to total muscle length was higher in adults [12].

Precise interpretation of such data requires comparison with data obtained from a larger number of muscles. In the literature, there are very few morphometric studies dedicated to foetal muscles. This is a branch of anatomy, which certainly is worth giving attention to.

## CONCLUSIONS

The distal tendon of semitendinosus has two main parts: the internal part (partially or totally covered by muscle fibres) and the external part (without muscle fibres). Only the external part of the tendon seems to be suitable for a transplant. It is cylindrical and solid. The internal part, on the other hand, when joining the muscle belly, begins to flatten and forms a trough, which makes it unsuitable for transplant.

Muscles in adults and foetuses have very similar morphology. Even the proportions between individual parts of the muscle are very similar. It may indicate that final form of the muscle develops very early, and later it only increases its size while the body grows.

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