

Anatomy and morphometry of the distal gracilis muscle tendon in adults and fetuses

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Ten human gracilis muscles obtained from adults and ten gracilis muscles collected from human fetuses between the 15th and 21st week of gestation were examined. The results of this preparatory study show that the gracilis muscle in adults is narrow and long — 482 mm on average. The distal tendon of gracilis muscle is long, 294 mm on average. It can be divided into two sections — external part, outside the muscle belly, and internal, intramuscular, part. The latter one is partially covered by muscle fibres and some of it is completely hidden inside the muscle belly, which is on average 76 mm long. Presence of an intramuscular part of the distal tendon was also demonstrated in the foetal material. Moreover, very strong correlations between particular muscle lengths were noted in fetuses. (Folia Morphol 2018; 77, 1: 138–143)

Key words: gracilis, pes anserinus, foetal muscle, tendon

INTRODUCTION

The gracilis muscle is located on the medial side of the thigh. In humans, it is long, often longer than 40 cm, narrow, and weighs about 100 g [22, 28, 33]. Fibres of such long muscles do not always run throughout the entire length of the muscle belly. It is believed that 30–50% of fibres at the most run from one tendon to another, while the remaining fibres terminate intrafascicularly [13, 15].

Gracilis belongs to a group of adductor muscles. It is the only one of them to extend between both joints — the hip and the knee. Its proximal attachment is located on medial margin of inferior pubic ramus and the ramus of the ischium. It begins with a broad, thin tendon. Its long, flat muscle belly runs down along the thigh. It subsequently passes around the medial epicondyle of the tibia and inserts into the superior medial surface of the tibia, medially to the tibial tuberosity [20, 26].

Several accessory bundles, usually 3–5, may emerge from the tendon at the distal end. They may run toward adjacent muscles or fascia [7, 39].

Distal insertion is a part of a structure known as pes anserinus. It is a plate formed by the distal parts of sartorius and semitendinosus muscle tendons, which are also attached to the crural fascia. For that reason pes anserinus (“goose foot”) together with a group of muscles that form it are also sometimes known as tensor fasciae cruris [18, 24, 27, 41].

Gracilis muscle is innervated by the anterior branch of the obturator nerve [28].

There is a segmental arterial supply to the muscle by the external branches of femoral artery and branches of the deep artery of the thigh — mainly from the medial circumflex femoral artery. Vessels supplying this muscle make it a well pedunculated muscle flap [11, 19, 20, 21, 28, 33].

Due to its characteristic placement, the muscle acts across two joints. In the hip joint it acts mainly as an adductor. Depending on the position of the hip joint it can extend or flex it, rotate it externally or internally. Together with other adductors it prevents excessive abduction. Acting on the knee joint, it flexes it and while in the flexed position, it rotates the tibia internally. Through its action on the knee joint it maintains body balance when placed on a broad, unstable object in between the lower limbs, for example during horse riding [3, 16, 22, 31].

Topography of the gracilis creates great possibilities for reconstructive and plastic surgery. Aside from being nourished on many levels, the gracilis flap is additionally characterised by extensive rotational range of the dissected fragment, enabling coverage of defects located within the perineum, sciatic as well as inguinal areas. Therefore, such flap can be applied in the reconstruction of the penis (also in the transsexuals), labia, or parts of the vagina as well as anal sphincters. It is possible to join an extensive island flap to the muscle flap. As the flap possesses a single vascular pedicle, it can be transferred to distant parts of the body as a free flap [2, 4, 10, 12, 14, 23, 25, 32, 40].

Morphology of the distal tendon makes it a frequent choice as a graft in reconstruction of the anterior cruciate ligament and other knee joint ligaments, e.g. posterior cruciate ligament, collateral ligament, patellofemoral ligament [5, 29, 34, 35, 38]. The tendon of this muscle may also be used in more distant parts of the body, e.g. for reconstruction of the coracoclavicular ligament in dysfunction of the acromioclavicular joint [37].

A phenomenon was recently discovered relating to the fact that the distal tendon of the gracilis muscle rebuilds after harvesting [8]. The tendon grows back in most patients within the first year after tendotomy [6]. It grows in distal direction, reaching its attachment in the fascial and tendinous structures of the knee joint [1, 17].

The aim of the work was to evaluate the proportion of components of the gracilis muscle: the belly and the distal tendon, in adult as well as foetal specimen.

MATERIALS AND METHODS

Ten human gracilis muscles obtained from adults and ten gracilis muscles collected from human foetuses between 15 and 21 weeks of gestational age

were examined. Examined muscles came from lower limb preparations and foetal preparations preserved in 10% formaldehyde solution that had been in possession of the local Department of Descriptive and Clinical Anatomy at the Medical University of Warsaw. Studies were carried out with classical methods of dissection. The foetal material required application of an surgical magnifying glass NY Dornwell 3.0X, Stereo microscope — Nikon SM 1500, and microsurgical tools. Morphometry of selected parts of muscles was examined and the photographic documentation was taken. Morphology and morphometry of the material from adults and foetuses were compared (Fig. 1).

During the study the following measurements were carried out in adult and foetal specimen labelled as follows:

- LLL — length of the lower limb measured from the anterior superior iliac spine to the medial malleolus;
- TL — length of the thigh measured from the anterior superior iliac spine to the medial aspect of knee joint gap;
- A — total length of the muscle, measured from origin to distal insertion;
- B — total length of the distal tendon;
- C — external part of the distal tendon — length of the part of the distal tendon outside the muscle belly; the section not covered by muscle fibres;
- D — internal part of the distal tendon — length of the tendon section partially and completely covered with muscle fibres;
- E — width of the muscle belly measured in the mid-part of muscle belly.

Additionally, the following measurements were obtained in adult specimen:

- F — length of the distal tendon section partially covered by the muscle belly;
- G — length of the distal tendon section completely hidden inside the muscle belly;
- H — length of the muscle belly.

Morphometric data results were subjected to basic statistical analysis, including calculation of the arithmetic means (avg.), standard deviations (SD) and ratios of B/A, C/A, C/B, E/H as well as correlations between selected parameters.

RESULTS

Results of morphometric examinations of the gracilis muscle that were carried out on adult and on foetal specimen are presented in the Table 1.

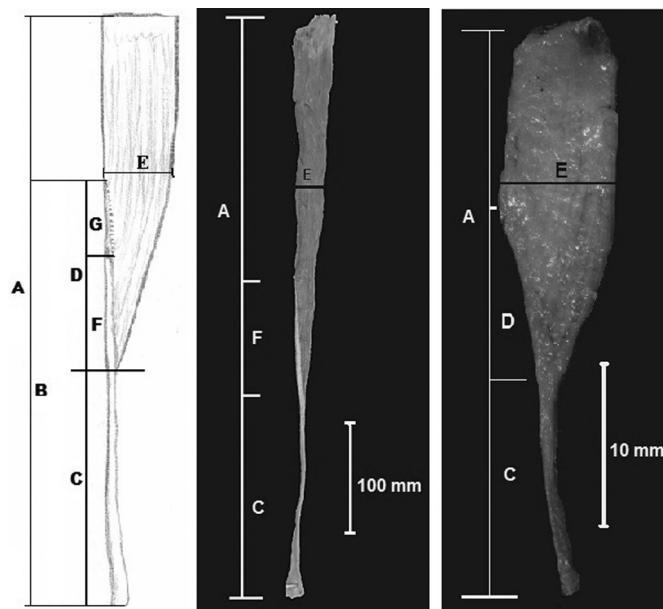


Figure 1. A scheme of gracilis muscle structure (left) in an adult (middle) and a foetus at 15 weeks of gestation (right). Selected morphological data were marked in the figures; A, B, C, D, E, F, G — abbreviations see 'Materials and methods'.

Table 1. Morphological characteristics of the gracilis muscle in adults [mm]

No.	LLL	TL	Side	A	B	C	D	E	F	G	H	E/H	B/A	C/A	C/B
1	750	440	R	420	230	100	130	35	65	65	320	0.11	0.55	0.24	0.43
2	790	460	L	470	250	120	130	25	75	55	350	0.07	0.53	0.26	0.48
3	840	500	L	490	310	140	170	34	40	130	350	0.097	0.63	0.29	0.45
4	890	520	L	500	330	160	170	38	90	80	340	0.11	0.66	0.32	0.48
5	850	500	L	530	290	150	140	36	50	90	380	0.09	0.55	0.28	0.52
6	920	540	L	500	340	140	200	40	105	95	360	0.11	0.68	0.28	0.41
7	910	520	L	530	320	160	160	28	100	60	370	0.08	0.60	0.3	0.5
8	770	450	L	430	260	130	130	28	110	20	300	0.09	0.60	0.3	0.5
9	930	540	L	490	330	140	190	30	90	100	350	0.09	0.67	0.29	0.42
10	780	430	L	460	280	150	130	25	65	65	310	0.08	0.61	0.33	0.54
Avg.	843	490		482	294	139	155	31.9	79	76	343	0.09	0.61	0.29	0.47
SD	67.5	41.6		37.4	38.1	18.5	26.8	5.4	23.8	30.1	25.8	0.01	0.05	0.03	0.04

Abbreviations — see text

Gracilis muscle runs between the inferior pubic ramus, the ramus of the ischium and the proximal end of tibia. In adults, the muscle belly is narrow (31.9 ± 5.4) and long (343 ± 5.1). The distal tendon of the muscle is extremely long: 294 ± 38.1 mm. Its total length is measured from the origin of fibres hidden inside the muscle belly to the distal insertion of the tendon. The distal tendon contains an external part, visible on the outside, completely free from muscle fibres; its length being 294 ± 38.1 mm on average.

Moreover, there is also an internal part of the distal tendon, either partially covered by muscle fibres or completely hidden inside the muscle belly. Length of the section partially covered by muscle fibres was 79 ± 23.8 mm while the average length of the part contained in the muscle belly was 76 ± 30.1 mm (Table 1).

In foetuses, the belly is wider than in adults. The ratio of width to length of the belly in foetuses is 0.19. It is two times greater than that found in adults (0.09).

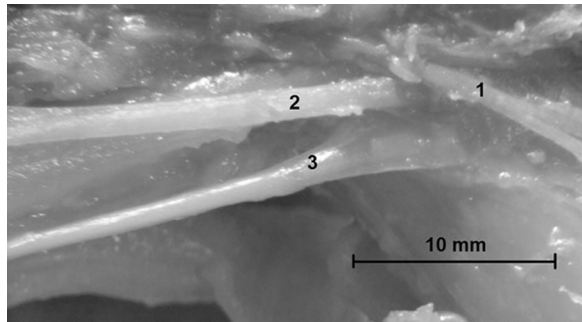


Figure 2. Pes anserinus in a foetus at 17 weeks of gestation. Distal tendons of the muscles: 1 — sartorius; 2 — gracilis; 3 — semitendinosus.

Examinations carried out on the foetal material confirmed the presence of both the internal and the external parts of the distal tendon.

Both in the adults as well as foetuses the distal tendon reaches its insertion medially to the tibial tuberosity, arranging itself between the distal tendons of sartorius and semitendinosus muscles, forming pes anserinus (Fig. 2).

In foetuses the distal tendon is relatively longer compared to adults (B/A). In foetuses, it constitutes (on average) 0.77 of the whole muscle length, while in adults the ratio is 0.61. The differences in ratios of the length of external part of the tendon to the whole muscle (C/A) were smaller; in foetuses average ratio was 0.34, while in the adults it amounted to 0.29.

The ratios of the length of the external part of the tendon to the total length of the tendon (C/B) were similar in both groups: averaging 0.47 in adults and 0.44 in foetuses (Tables 1, 2).

In the adults the length of the muscle is highly correlated with the length of the lower limb (A-LLL), between the length of the muscle and the length of the thigh (A-TL), while the length of the whole tendon correlates with the length of the whole muscle (B-A) and the length of the external part of the tendon correlates with the length of the muscle (C-A).

Almost complete correlation is present between the length of the external part of the distal tendon and the length of the lower limb (B-LLL) as well as the length of the thigh.

In foetuses all of the above-mentioned correlations are almost complete (classification of correlations according to J. Guilford) (Table 3).

DISCUSSION

Gracilis is a long and narrow muscle ending with a cylindrical tendon. The length of the whole muscle determined in our material, 480 mm on average, did not differ significantly from morphometric data in the literature [28, 33]. Larger discrepancies could be found in relation to the distal tendon. Available literature reports a broad range of dimensions, between 80 mm and 230 mm [30, 33, 36]. This is due to the fact that only the visible part of the tendon

Table 2. Morphological characteristics of the gracilis muscle in the foetal material [mm]

No.	HBD	LLL	TL	Side	A	B	C	D	E	H	E/H	B/A	C/A	C/B
P1	17	87	52	L	43	33	13	20	5.0	30	0.17	0.77	0.30	0.39
P2	21	124	72	L	59	48	21	27	11	38	0.29	0.81	0.36	0.44
P3	21	126	73	R	60	50	22	28	10	38	0.26	0.83	0.37	0.44
P4	17	93	53	R	48	36	15	21	5.5	33	0.17	0.75	0.31	0.42
P5	17	92	53	L	47	37	16	21	6.0	31	0.19	0.79	0.34	0.43
P6	17	88	49	L	44	35	14	21	5.5	30	0.18	0.80	0.32	0.4
P7	15	82	50	R	41	32	15	17	4.0	26	0.15	0.78	0.37	0.47
P8	15	83	51	L	41	31	14	17	4.0	27	0.15	0.76	0.34	0.45
P9	15	72	42	L	37	26	13	13	5.0	24	0.17	0.70	0.35	0.5
P10	15	74	43	R	36	24	12	12	4.5	24	0.19	0.67	0.33	0.5
Avg.	17	92.1	53.8		45.6	35.2	15.5	19.7	6.05	30.1	0.19	0.77	0.34	0.44
SD	2.31	18.64	10.57		8.25	8.36	3.37	5.23	2.44	5.11	0.05	0.05	0.02	0.04

Abbreviations — see text

Table 3. Correlation coefficients for selected morphometric data

Correlation — morphometric symbol	Adult	Foetal
A-LLL	0.795	0.992
A-TL	0.764	0.975
B-LLL	0.936	0.988
B-TL	0.900	0.938
B-A	0.740	0.993
C-A	0.774	0.958
D-A	0.522	0.968
C-B	0.762	0.959
D-B	0.894	0.979

Abbreviations — see text

or its fragment that had been successfully harvested without dividing into external and internal parts was measured. The total length of the tendon in our adult material ranged from 230 mm to 340 mm. Length of the external part of the tendon outside muscle belly not covered by muscle fibres was significantly lesser, ranging 100–160 mm.

The remaining fragment (the intramuscular part) is either partially or completely covered by muscle fibres. The length of the part totally contained inside muscle belly was 100–130 mm. Obviously, these dimensions were significantly smaller in fetuses although the proportions were similar. However, higher proportion of the total length of the tendon to the total length of the muscle is a reflection of smaller muscle mass in fetuses compared to adults.

We noted that both the external as well as internal parts of the distal tendon were present in the examined fetuses. Moreover, correlations between the lengths of the distal tendon and of the lower limb, thigh and the whole muscle were almost complete. Similarly, in the foetal material almost complete correlations were demonstrated between individual parts of the tendon and the total length of the distal tendon and muscle. In adults correlations between individual lengths were not as strong.

Long intramuscular course of the tendon enables attachment of a significantly greater number of muscle fibres in the distal area of the tendon. Intramuscular course of tendons is an insufficiently investigated and rarely described anatomical phenomenon [9] with potentially significant biomechanical and clinical implications.

CONCLUSIONS

These studies illustrate the complex anatomy of the gracilis muscle and the differences resulting from ontogenetic development. The main limitation of our work is a small number of specimens. A larger sample would be more representative and would allow for a more detailed statistical analysis. We plan to study other muscles, include a greater number of specimens, and perform imaging studies of the muscle-tendon unit in living individuals.

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