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Musculus Sartorius Metrology in the Fetal Period

Metrologia *musculus sartorius* w okresie płodowym

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Abstract

Objectives. The goal of the study was a musculus sartorius metrological analysis in the fetal period.
Material and Methods. The experiment material consisted of sartorius muscle specimens derived from 71 fetuses (25 females), aged 14–28 weeks of fetal life. The following methods were used: anatomical dissection, anthropological, computer and acquisition methods as well as statistical methods.
Results. The sartorius muscle's symmetry and sexual dimorphism as well as growth rate were analyzed. The examined material revealed statistically significant sexual dimorphism of thigh length and sartorius muscle length (bigger sizes were observed in female fetuses, respectively by 2.7 mm and 4.3 mm) although *v-tub* and *v-pl* lengths did not reveal significant difference.
Conclusions. Significant asymmetry in thigh length was detected (the left side longer than the right one by 1.1 mm on average). Thigh length and sartorius muscle length rate was stable and amounted to 0.8 mm/week and 1.2 mm/ /week respectively. However, age classes IV and VII were scarce **(Adv Clin Exp Med 2011, 20, 5, 567–574)**.

Key words: sartorius muscle, fetal period, anatomy, morphometry.

Streszczenie

Cel pracy. Analiza metrologii *musculus sartorius* w okresie płodowym.
Materiał i metody. Materiał badawczy stanowiły preparaty mięśnia krawieckiego 71 płodów (w tym 25 żeńskich), w wieku 14–28 tygodni. Zastosowano następujące metody: preparacyjną, antropologiczną, komputerową, akwizycyjną oraz metody statystyczne. Pomiary były wykonywane w programie komputerowym ImageJ.
Wyniki. Analizowano symetrię, dymorfizm płciowy oraz tempo wzrostu mięśnia krawieckiego. W badanym materiale zaobserwowano statystycznie istotny dymorfizm płciowy dla długości uda i długości mięśnia krawieckiego (dłuższe wymiary wystąpiły u płodów żeńskich, odpowiednio o 2,7 mm i 4,3 mm), mimo że nie było istotnej różnicy w długościach ciała *v-tub* i *v-pl*.
Wnioski. Stwierdzono istotną asymetrię długości uda (strona lewa dłuższa od prawej średnio o 1,1 mm). Tempo wzrostu długości uda i mięśnia krawieckiego było stałe i wynosiło odpowiednio 0,8 mm/tydz. i 1,2 mm/tydz. Należy jednak podkreślić, że klasy wiekowe IV i VII były nieliczne **(Adv Clin Exp Med 2011, 20, 5, 567–574)**.

Słowa kluczowe: *m. sartorius*, okres płodowy, anatomia, morfometria.

The sartorius muscle, also called the longest thigh muscle, belongs to the thigh muscle anterior group. The origin is situated on the anterosuperior iliac spine. In its course, the muscle wraps spirally around the thigh running towards the thigh median plane were its distal attachment along with semitendinosus and gracilis muscles' tendons form a "duckfoot shovel". It consists of two layers – a superficial one (formed of sartorius muscle tendon) and a deep one (formed from semitendinosus and gracilis muscles) [6]. The literature provides information about sartorius muscle segmentary vascularization into 5–11 vascular branches, however the number 6–8 is most commonly reported. Their two main branches (proximal and distal) were described. The proximal group penetrates 80% of the muscle whereas the distal one at 90%. Besides this, the muscle is characteristic for its rich and complicated anastomosis rete which enables muscle fragment collection. These qualities allow clinical application of the musculus sartorius in muscular lobe formation [11, 17, 18]. The vessels are accom-

panied by nerves forming neurovascular bundles. The muscle innervation comes from the femoral nerve [16].

The goal of the study was the evaluation of topography, metrology, growth rate and morphological variants of the sartorial muscle with special consideration to muscle symmetry in the two limbs as well as of sexual dimorphism.

Material and Methods

The following methods were incorporated into the study: anatomical dissection, anthropological and computer methods with digital image acquisition [7, 8]. The measurements were made with the ImageJ computer program [5] as well as with statistical methods (STATISTICA program).

Symmetry, sexual dimorphism and sartorial muscle growth rate were analyzed. The muscle width was taken in 3 sites as well as its length and femoral length (Fig. 1).

The material consisted of sartorial muscle specimens from 71 fetuses (25 females) aged 14–28 weeks ($\overline{x}$ = 21.2; *SD* = 2.1) of *v-tub* length from 78 to 207 mm ($\overline{x}$ = 162; *SD* = 21). Table 1 presents the fetuses' basic somatic feature statistics.

The male and female fetus groups were homogeneous with respect to age and body mass and sizes which were checked with a Student's *t*-test at the level of $p < 0.05$. Basic statistics for sartorial muscle and thigh sizes were evaluated in different sex groups and these features' mean values were compared in male and female fetuses (F vs. M) applying the Student's *t*-test for related variables. Earlier, a Shapiro-Wilk's test was used to verify the measurable features' empiric distribution normality. The distribution of all parameters were close to normal ($P > 0.05$). Regression and correlation analysis was used to assess the size growth rate. Linear regression function parameters were estimated and significance tests were done for correlation coefficients as well as for regression straight line directional coefficients. The correlation diagrams present the dispersion of the results. They also include mathematical models of their increase in fetal age function (in weeks).

Results

The analyzed structures' results were statistically analyzed. Mean value and standard deviation ($\overline{x} \pm SD$), median value (*Me*) as well as extreme values (min ÷ max) were calculated for each parameter (separately and then collectively for males and females). Table 2 presents the calculations and test results.

Female fetus right thigh length was longer than male fetus length on average by 2.8 mm (Fig. 2) and this difference was statistically significant ($P < 0.05$). Also, left thigh length was greater in females (by 2.7 mm) but the difference was not statistically significant ($p > 0.05$). After female and male fetus result integration, a "no asymmetry" hypothesis was verified with a Student's *t*-test for paired samples (Fig. 3). Left limb thigh length was greater than those of the right limb on average by 1.1 mm and the difference was statistically significant ($P < 0.05$).

Also, female fetus left limb sartorial muscle length was significantly longer (by 4.3 mm) (Fig. 4). The difference in sartorial muscle right limb length in males and females (2.8 mm) as well as in left and

Table 1. Descriptive statistics (x ± SD) of examined somatic features

Tabela 1. Statystyki opisowe cech somatycznych badanych płodów

	Female fetuses (Płody żeńskie) n = 25	Male fetuses (Płody męskie) n = 46	Comparison result (Wynik porównania) F vs. M
Age – week of fetal life (Wiek – tydzień życia płodowego)	21.1 ± 1.7	21.3 ± 2.3	P = 0.789
Crown-rump length *v-tub* – mm (Długość ciemieniowo-siedzeniowa – mm)	163.1 ± 17.2	162.0 ± 23.6	P = 0.835
Total length *v-pl* – mm (Długość całkowita – mm)	235.0 ± 30.9	231.0 ± 36.4	P = 0.648
Body mass *m* – g (Masa ciała – g)	301 ± 103	280 ± 101	P = 0.401

n – number; $\overline{x}$ – mean value; *SD* – standard deviation; *P* – Student's *t*-test significance.

n – liczba obserwacji; $\overline{x}$ – wartość średnia; *SD* – odchylenie standardowe; *P* – obliczeniowy poziom istotności testu *t*-Studenta.

Table 2. Basic statistics (mean value ± standard deviation; median; min–max) of thigh and sartorial muscle of female (F) and male (M) fetuses on the right (R) and left (L) side

Tabela 2. Podstawowe statystyki (średnia ± odchylenie standardowe; mediana; min.–maks.) wymiarów uda i mięśnia krawieckiego płodów żeńskich (F) i męskich (M) po stronie prawej (R) i lewej (L)

Size (Wymiar) mm	Gender (Płeć)		Total (Razem) (F + M) (N = 71)	Comparison result (Wynik porównania)	
	female (F) (N = 25)	male (M) (N = 46)		F vs. M*	L vs. R**
l_F^L: $\bar{x}$ ± SD Me min–max	46.5 ± 6.5 48.0 31.5–54.6	43.7 ± 6.4 42.7 31.2–59.2	44.7 ± 6.5 44.0 31.2–59.2	P = 0.091	P = 0.035
l_F^R: $\bar{x}$ ± SD Me min–max	45.4 ± 5.3 45.3 35.1–56.9	42.6 ± 5.3 42.8 31.0–58.2	43.6 ± 5.4 43.6 31.0–58.2	P = 0.039	
l_{MS}^L: $\bar{x}$ ± SD Me min–max	46.1 ± 7.2 47.0 30.4–56.7	41.8 ± 7.5 41.3 24.5–60.9	43.3 ± 7.6 42.3 24.5–60.9	P = 0.023	P = 0.112
l_{MS}^R: $\bar{x}$ ± SD Me min–max	44.0 ± 5.1 43.7 33.7–54.7	41.3 ± 6.6 41.2 26.9–54.7	42.3 ± 6.2 42.2 26.9–54.7	P = 0.072	
b_{MS1}^L: $\bar{x}$ ± SD Me min–max	3.3 ± 1.2 3.3 1.3–7.4	3.4 ± 1.1 3.2 1.7–6.2	3.4 ± 1.1 3.3 1.3–7.4	P = 0.850	P = 0.778
b_{MS1}^R: $\bar{x}$ ± SD Me min–max	3.3 ± 0.9 3.1 1.5–5.2	3.4 ± 0.9 3.2 1.4–5.5	3.3 ± 0.9 3.2 1.4–5.5	P = 0.744	
b_{MS2}^L: $\bar{x}$ ± SD Me min–max	4.0 ± 0.9 3.9 2.6–5.7	3.7 ± 1.0 3.6 1.9–7.0	3.8 ± 1.0 3.8 1.9–7.0	P = 0.205	P = 0.761
b_{MS2}^R: $\bar{x}$ ± SD Me min–max	3.8 ± 0.9 3.7 2.4–6.0	3.7 ± 0.8 3.7 2.1–6.0	3.8 ± 0.9 3.7 2.1–6.0	P = 0.726	
b_{MS3}^L: $\bar{x}$ ± SD Me min–max	2.8 ± 1.0 2.8 1.2–6.0	2.4 ± 0.6 2.3 0.7–3.6	2.5 ± 0.8 2.4 0.7–6.0	P = 0.024	P = 0.799
b_{MS3}^R: $\bar{x}$ ± SD Me min–max	2.7 ± 0.7 2.6 1.8–4.6	2.5 ± 0.8 2.3 0.9–4.7	2.6 ± 0.8 2.5 0.9–4.7	P = 0.299	

* Student's *t*-test (independent samples t-test); ** Student's *t*-test (paired samples t-test).
l_F^L – left thigh length; l_F^R – right thigh length; l_{MS}^L – left muscle length; l_{MS}^R – right muscle length; b_{MS1}^L – left muscle width at level 1; b_{MS1}^R- right muscle width at level 1; b_{MS2}^L – left muscle width at level 2; b_{MS2}^R – right muscle width at level 2, szerokość mięśnia prawego na poziomie 2; b_{MS3}^L – left muscle width at level 3; b_{MS3}^R – right muscle width at level 3.

l_F^L – długość uda po stronie lewej; l_F^R – długość uda po stronie prawej; l_{MS}^L – długość mięśnia po stronie lewej; l_{MS}^R – długość mięśnia po stronie prawej; b_{MS1}^L – szerokość mięśnia lewego na poziomie 1; b_{MS1}^R – szerokość mięśnia prawego na poziomie 1; b_{MS2}^L – szerokość mięśnia lewego na poziomie 2; b_{MS2}^R – szerokość mięśnia prawego na poziomie 2; b_{MS3}^L – szerokość mięśnia lewego na poziomie 3; b_{MS3}^R – szerokość mięśnia prawego na poziomie 3.

right limb in all fetuses (1.1 mm) were statistically non significant ($P > 0.05$). Sartorial muscle width measured at level III in females was bigger on average by 0.5 mm and the difference is statistically significant ($P < 0.05$) (Fig. 5).

Other analyzed sizes differed significantly ($p > 0.05$) neither between left and right sides nor between males and females (Tab. 2).

In order to analyze thigh and sartorial muscle size growth rate, the male and female results as

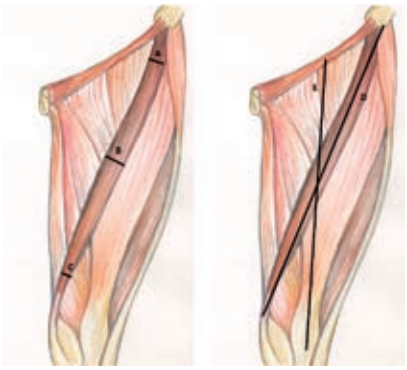

Fig. 1. Sartorial muscle. Defined sizes: A – width at primary attachment, B – width in the central part, C – width at the final attachment, D – muscle length, E – thigh length

Ryc. 1. Mięsień krawiecki, oznaczenia: A – szerokość w części początkowej b_{MS1}, B – szerokość w części środkowej b_{MS2}, C – szerokość w części końcowej b_{MS3}, D – długość mięśnia l_{MS}, E – długość uda l_F

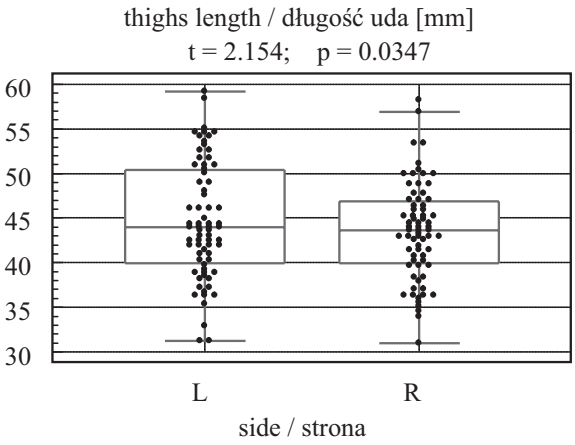

Fig. 3. Left and right thigh length collective comparison in male and female fetuses and Student's *t*-test result for paired samples

Ryc. 3. Porównanie długości uda lewego i prawego płodów żeńskich oraz wynik testu *t*-Studenta dla zmiennych powiązanych

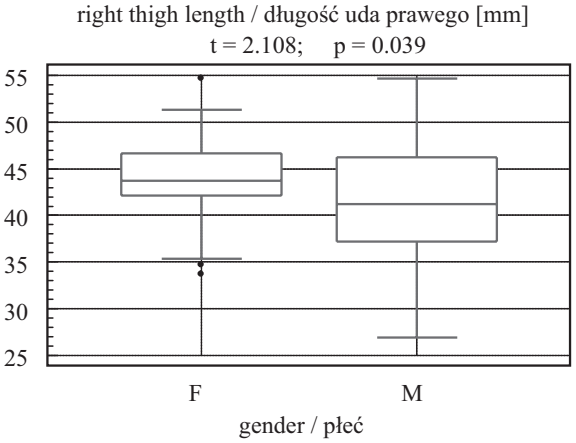

Fig. 2. Right thigh length comparison in male and female fetuses, Student's *t*-test results for independent samples

Ryc. 2. Porównanie długości uda prawego płodów żeńskich i męskich oraz wynik testu *t*-Studenta dla zmiennych niepowiązanych

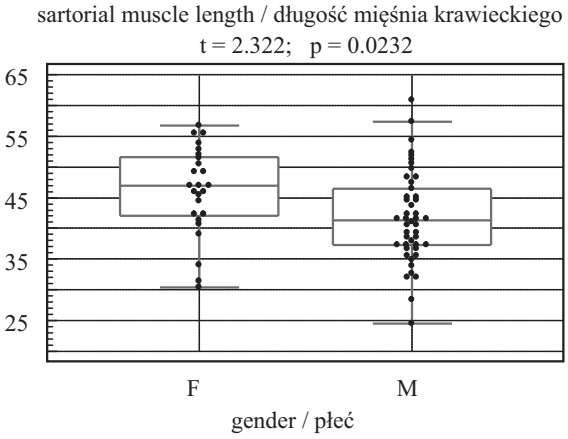

Fig. 4. Sartorial muscle length (mm) comparison in female fetuses left limb and Student's *t*-test result for independent samples

Ryc. 4. Porównanie długości (mm) mięśnia krawieckiego lewego płodów żeńskich i męskich oraz wynik testu *t*-Studenta dla zmiennych powiązanych

well as left and right side results were collected. Table 3 presents the size variation analysis by age group (monthly). Correlation diagrams (Fig. 6) present these sizes' linear regression analysis with respect to age, shown in weeks. Thigh and sartorial muscle growth is characteristic for their linear character. These lengths' weekly increases amount to 0.8 and 1.2 mm. In turn, in the examined material, the muscle widths taken at levels I and III can be regarded as stable (1.8 and 3.3 mm). The muscle width at level 3 increases linearly 0.08 mm/week.

Discussion

The application of a method of preparation along with image acquisition and analysis with the use of computer programs enables the evaluation of anatomical structure geometry while avoiding autopsical material damage. The available literature discussing sartorial muscles is not very detailed. It considers the musculus sartorius muscle's significance in adult life, especially in reference to its clinical use in plastic and reconstructive surgery.

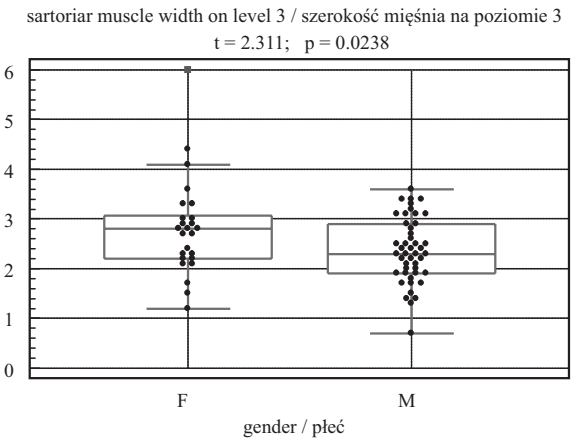

Fig. 5. Sartorial muscle width comparison measured at level 3 in male and female fetuses, Student's *t*-test result for independent samples

Ryc. 5. Porównanie szerokości [mm] mięśnia krawieckiego na poziomie 3. płodów żeńskich i męskich oraz wynik testu *t*-Studenta dla zmiennych niepowiązanych

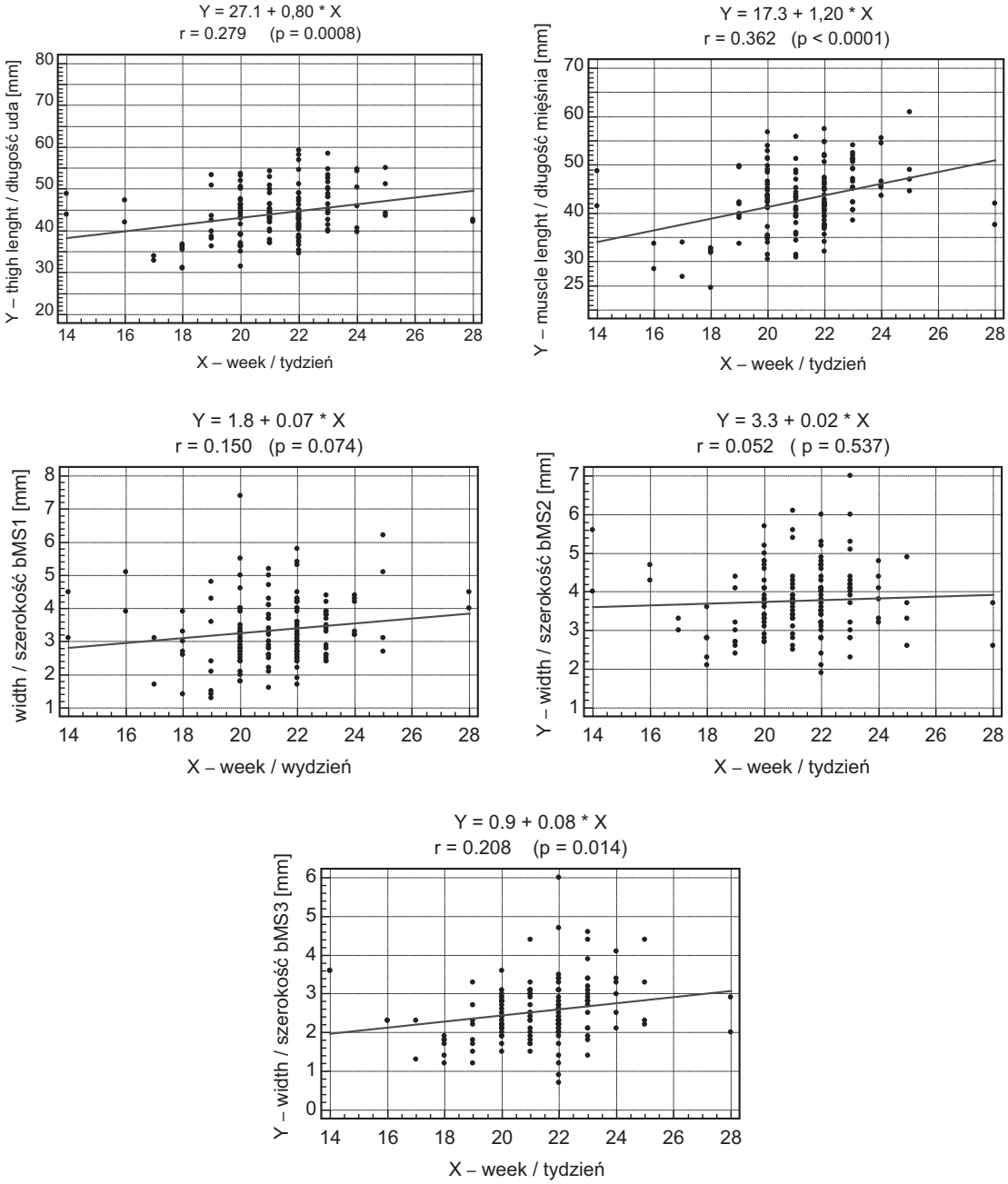

Fig. 6. Correlation diagrams and regression models of dependence between thigh length as well as sartorial muscle length and width and fetus age

Ryc. 6. Diagramy korelacyjne i modele regresyjne długości i szerokości mięśnia krawieckiego w zależności od wieku płodu

Table 3. Thigh and sartorial average muscle sizes in age groups, variation analysis result

Tabela 3. Średnie wartości wymiarów uda i mięśnia krawieckiego w grupach wiekowych i wynik analizy wariancji

Sizes (Wymiary) mm	Month of fetal life (Miesiąc życia płodowego)				ANOVA
	IV	V	VI	VII	
Thigh length (Długość uda) l_F	45.5 ± 3.1	41.7 ± 6.5	45.1 ± 5.6	46.5 ± 5.4	P = 0.012
Sartorial muscle length (Długość mięśnia) l_{MS}	38.1 ± 8.9	40.7 ± 7.8	43.8 ± 6.0	46.8 ± 8.0	P = 0.021
Muscle width (Szerokość mięśnia) b_{MS1}	4.1 ± 0.9	3.1 ± 1.2	3.4 ± 0.9	4.3 ± 1.3	P = 0.016
Muscle width (Szerokość mięśnia) b_{MSI2}	4.6 ± 0.7	3.6 ± 0.8	3.9 ± 0.9	3.5 ± 0.9	P = 0.048
Muscle width (Szerokość mięśnia) b_{MS3}	2.9 ± 0.8	2.2 ± 0.6	2.7 ± 0.8	2.8 ± 0.8	P = 0.015

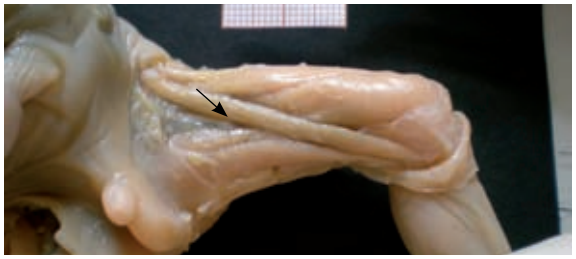

Fig. 7. Sartorial muscle (classical type)

Ryc. 7. Mięsień krawiecki (typ klasyczny)

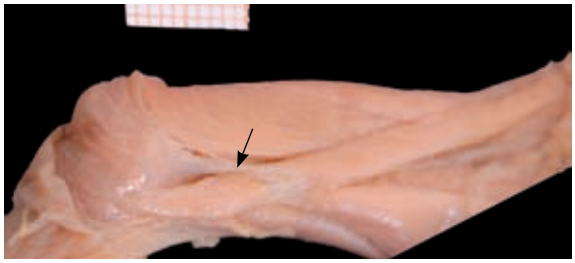

Fig. 8. Sartorial muscle with extra tendon present

Ryc. 8. Mięsień krawiecki z dodatkowym ścięgnem

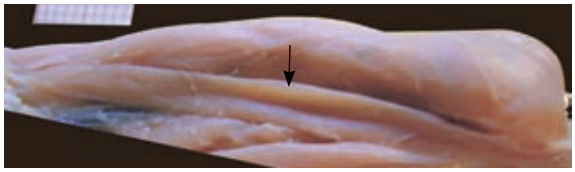

Fig. 9. Initial process of muscle bifurcation manifested by antrum presence

Ryc. 9. Początkowy proces bifurkacji mięśnia wyrażony obecnością wgłębienia

Two types of morphological varieties were observed: rectangular (classical type) (Fig. 7) and cone-shaped. Also, some anomalies were recognized sporadically and they included: the presence of an extra tendon (Fig. 8), the start of muscle duplication in the form of a hollow (Fig. 9), partial duplication of the muscle distal fragment (Fig. 10) and 'discontinuous' muscle (Fig. 11). In sites of the first anomaly observation, the muscle belly was normally formed and the extra tendon branched in the inferior area at the muscle's 1/3 length. In turn, partial bifurcation had started in the muscle's median part and gave the beginning of two muscle bellies of the same size. That is why musculus sartorius had two distal attachments: the posteriomedial was an element of the "duckfoot shovel" whereas the anteriolateral part was parallel to the former one and adhered laterally. Duplication is described in the literature. M. G. El-Badawi [2] as well as M. Melling, K. Zweymueller [10] described the same type of bifurcation. In both cases, the described muscle lateral part was relatively smaller in comparison to the median one the course of which was typical for a sartorial muscle as it ended in the pes anserinus. In M.G. El-Badawi's observations, the lateral belly's attachment was situated in the femoral bone median condyle upper part, whereas in Melling's and Zweymueller's studies, it attached to the median meniscus. Available reports also discuss cases of sartorial muscle proximal ending bifurcation (Bhatnagar and Narayan 3 anomalies of this type [2]) or this muscle's absolute absence (Williams and Warwick [2]). Initial muscle bifurcation in the form of a hollow (little pan) along the muscle's long axis was another anomaly. In turn, discontinuous muscle consisted of three muscular parts and two connecting tendinous parts.

The literature provides numerous descriptions of musculus sartorius' clinical use. Due to its rich vascularization and segmental structure, the muscle can be used in flap formation, widely applied in both reconstructive and plastic surgery in the groin, genual, cluneal and abdominal areas. Musculus sartorius flaps are used not only in vascular transplants covering the groin area and limiting infection danger or anastomosis breakdown, but

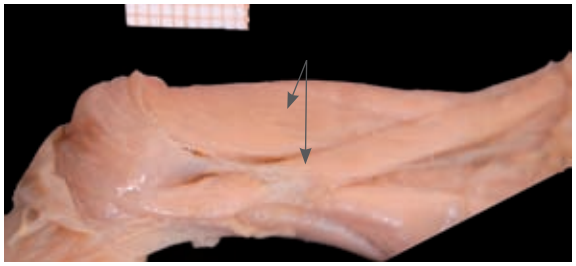

Fig. 10. Muscle fragment partial duplication

Ryc. 10. Częściowa duplikacja dystalnego fragmentu mięśnia

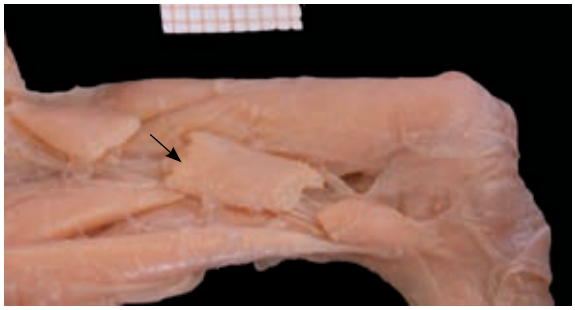

Fig. 11. Discontinuous muscle

Ryc. 11. Mięsień „przerywany"

also in the treatment of already infected grafts. After lymphadenectomy procedures, necrotic areas are filled with the flaps in order to cover the vessels and protect the healing process [9, 12–14]. In the genual area, the flaps are used in soft tissue reconstruction and knee rigidity treatment [1, 4]. Musculus sartorius flaps are also used in extensive reparative surgical procedures. In the case of the abdominal wall, such a defect may include the wall total thickness [15]. In the cluneal area, the flaps are used when musculus tensor fasciae latae flaps prove to be insufficient [3].

The authors concluded that statistically significant sexual dimorphism of thigh length and sartorial muscle length were observed (sizes longer by 2.7 mm and 4.3 mm respectively were found in female fetuses although no statistically significant difference was found in body lengths v-tub and v-pl). Thigh length significant asymmetry was detected (left side longer than the right by 1.1 mm on average). Thigh length and sartorial muscle length growth rates were stable and amounted to 0.8 mm/ /week and 1.2 mm/week respectively. However, IV and VII age groups were scarce.

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