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The Normal Growth of the Biceps Brachii Muscle in Human Fetuses

Normatywny wzrost mięśnia dwugłowego ramienia u płodów człowieka

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Abstract

Background. The biceps brachii muscle, the strongest flexor and supinator at the elbow joint, and an accessory flexor of the glenohumeral joint is characterized by the two heads, long and short.

Objectives. The purpose of this study was to examine the linear parameters (length and width) of the biceps brachii in human fetuses and to provide their mathematical growth models.

Material and Methods. Using methods of anatomical dissection, digital analysis (Multiscan v.14.02), and statistics (Student's t-test and regression analysis) the authors bilaterally measured the length (mm) and width (mm) of the biceps brachii muscle in 30 fetuses of both sexes (14♂, 16♀), aged 17–30 weeks.

Results. Neither sex nor laterality differences were found. All the parameters studied increased proportionally with age. Both the mean length (5.68 mm) and widths, measured at its mid-length (0.60 mm) and at the widest level (0.65 mm) of the long head's belly, were found to be statistically shorter (5.93 mm, 0.65 mm and 0.72 mm, respectively) when compared to its short head's belly. For these parameters, the following linear models were generated in relation to the long head's belly: $y = -0.801 + 0.276 \times \text{Age}$ ($R^2 = 0.591$), $y = -0.254 + 0.036 \times \text{Age}$ ($R^2 = 0.201$) and $y = -0.238 + 0.038 \times \text{Age}$ ($R^2 = 0.226$), and in relation to the short head's belly: $y = -0.134 + 0.258 \times \text{Age}$ ($R^2 = 0.551$), $y = -0.227 + 0.038 \times \text{Age}$ ($R^2 = 0.241$) and $y = -0.316 + 0.044 \times \text{Age}$ ($R^2 = 0.333$). The tendon length turned out to be the only significantly greater value for the long head (1.89 mm vs. 1.09 mm). The following linear models $y = 1.024 + 0.037 \times \text{Age}$ ($R^2 = 0.084$) for the long and $y = 0.177 + 0.039 \times \text{Age}$ ($R^2 = 0.157$) for the short heads were computed.

Conclusions. Neither sex differences nor laterality differences are observed in morphometric parameters of the biceps brachii muscle. The long head's belly is shorter and thinner than that of the short head's belly. The long head's tendon is longer than that of the short head. The developmental dynamics of the biceps brachii muscle follow proportionately (*Adv Clin Exp Med* 2013, 22, 1, 17–26).

Key words: human fetuses, biceps brachii muscle, attachments, length, width, regression analysis.

Streszczenie

Wprowadzenie. Mięsień dwugłowy ramienia, najsilniejszy zginacz i supinator stawu łokciowego oraz pomocniczy zginacz stawu ramiennego ma dwie głowy – długą i krótką.

Cel pracy. Zbadanie parametrów liniowych (długość, szerokość) mięśnia dwugłowego ramienia u płodów człowieka i opracowanie matematycznych modeli jego wzrostu.

Materiał i metody. Za pomocą dysekcji anatomicznej, cyfrowej analizy obrazu (Multiscan v. 14.02) i analizy statystycznej (test t-Studenta, analiza regresji) zmierzono obustronnie długość (mm) i szerokość (mm) mięśnia dwugłowego ramienia u 30 płodów człowieka obu płci (14♂, 16♀) w wieku 17–30 tygodni.

Wyniki. Nie wykazano różnic płciowych i bilateralnych. Wartości badanych parametrów wzrastały proporcjonalnie względem wieku. Zarówno średnia długość (5,68 mm), jak i szerokość mierzona w połowie (0,60 mm) oraz w najszerszym miejscu brzuszka głowy długiej (0,65 mm) były istotnie ($p < 0,05$) mniejsze (odpowiednio: 5,93 mm; 0,65 mm; 0,72 mm) w porównaniu z jego głową krótką. Dla tychże parametrów opracowano następujące liniowe modele wzrostu: $y = -0,801 + 0,276 \times \text{wiek}$ ($R^2 = 0,591$), $y = -0,254 + 0,036 \times \text{wiek}$ ($R^2 = 0,201$), $y = -0,238 + 0,038 \times \text{wiek}$ ($R^2 = 0,226$) dla głowy długiej oraz $y = -0,134 + 0,258 \times \text{wiek}$ ($R^2 = 0,551$), $y = -0,227 + 0,038 \times \text{wiek}$ ($R^2 = 0,241$), $y = -0,316 + 0,044 \times \text{wiek}$ ($R^2 = 0,333$) dla głowy krótkiej. Jedyną istotnie większą wartością dla głowy długiej ($p < 0,05$) była długość ścięgna (1,89 mm vs. 1,09 mm). Jego wzrost przebiegał liniowo: $y = 1,024 + 0,037 \times \text{wiek}$ ($R^2 = 0,084$) dla głowy długiej i $y = 0,177 + 0,039 \times \text{wiek}$ ($R^2 = 0,157$) dla głowy krótkiej.

Wnioski. Mięsień dwugłowy ramienia nie wykazuje różnic płciowych i bilateralnych. Brzusiec głowy długiej jest krótszy i węższy niż brzusiec głowy krótkiej. Ścięgno głowy długiej jest dłuższe niż głowy krótkiej. Mięsień dwugłowy ramienia wzrasta proporcjonalnie na długość i szerokość (*Adv Clin Exp Med* 2013, 22, 1, 17–26).

Słowa kluczowe: płody człowieka, mięsień dwugłowy ramienia, przyczepy, szerokość, długość, analiza regresji.

The biceps brachii, a thick fusiform muscle in the anterior compartment of the arm, crosses in front of both shoulder and elbow joints, acting as a moderate flexor at the former and the strongest flexor and supinator at the latter [1]. The dynamic action of the long head produces anterior shoulder stability, especially in the late cocking phase of the throwing motion, when the shoulder is abducted and externally rotated [2–5]. The biceps brachii has also been found to diminish the stress placed on the inferior glenohumeral ligament [6].

The biceps brachii muscle proximally starts with the two separately attached heads, long and short ones, originating as proximal tendons from the supraglenoid tubercle and glenoid labrum (long head), and the coracoid apex (short head). The tendon of the long head runs through the top of the glenohumeral joint [7, 8] and turns into the intertubercular sulcus, being covered with a capsular reflection, the tendon sheath [9, 10].

Both bicipital proximal tendons end in elongated bellies, which join each other to form one belly, the common tendon of which inserts onto the radial tuberosity [11]. A third head, which is present in 3–22.9% of cases, may spring from the superomedial part of the brachialis muscle, or beneath the distal extremity of the coracobrachialis, or from the intertubercular sulcus of the humerus, being usually crossed in front by the brachial vessels [1, 12–15]. Like the tendons of the rotator cuff, the long head's tendon can also be affected at its origin [8, 16–18] and its termination [16, 18, 19] by calcific tendinitis (hydroxyapatite deposition disease) in both young and middle-aged patients with shoulder pain. The shoulder pain of biceps tendinosis occurs in the intertubercular sulcus and radiates down into the biceps brachii, being considerably exacerbated by overhead activities [19].

To date, little is known about the detailed morphometric parameters of the biceps brachii muscle. Thus, in the present study the following three objectives were set to examine: 1) the normal values for the two heads (in terms of length and width) and three tendons (in terms of length):

two proximal and one distal at varying gestational ages, 2) the growth curves of best fit for normal development of the features studied, and 3) the influence of sex and laterality on the values of the parameters examined.

Material and Methods

The examinations were carried out on 30 spontaneously aborted human fetuses of both sexes (14 males, 16 females) aged 17–30 weeks [20], as a result of placental insufficiency in the years 1989–1999. The present study was approved by the University Research Ethics Committee (KB 72/2012). For fixation, the specimens were preserved in 10% neutral formalin solution for 24–36 months. For every fetus, the examined material consisted of the right and left biceps brachii. Each biceps brachii was grossly dissected to visualize it from its attachments to its insertion, and recorded with a millimeter scale, using a camera (Canon EOS550D). The digital pictures of the biceps brachii were quantitatively evaluated with the use of digital image analysis (MultiScan v. 14.02), which semi-automatically estimated all the features studied. For every specimen, the following 10 measurements (in mm) on either side were done:

- 1) the length of the long head's belly, measured from its origin to its termination,
- 2) the length of the short head's belly, measured from its origin to its termination,
- 3), 4) the lengths of the two proximal tendons, measured from the coracoid apex and supraglenoid tubercle respectively, to their bellies,
- 5) the length of the distal tendon, measured from the end of the common belly to the radial tuberosity,
- 6)–9) two widths for each head, measured at their mid-length and widest levels,
- 10) the width of the biceps brachii belly, measured at its widest level.

The digital method made it possible to precisely estimate all measurements with an accuracy

of 0.1 mm. All data obtained was subjected to statistical analysis using Statistica v. 9.0 (StatSoft Inc., USA). The data obtained was checked for normality of distribution using the Shapiro-Wilk test. As the first step in the statistical analysis, the probability of appearance of statistically significant differences in values between the two sexes, and between the parameters of the right and left biceps brachii was assessed using a Student's t-test for unpaired variables (sex) and paired variables (laterality). The correlations between different variables with relation to sex and laterality were examined with the use of an automatically proposed test included in Statistica. The parameters obtained were correlated to fetal age in order to present their growth dynamics. Regression analysis was used to derive the line of best fit for the plot for each morphometric parameter vs. gestational age. Differences were considered significant at $p < 0.05$.

Results

The two heads of the biceps brachii muscles extended typically (Fig. 1), without any variability. The individual values for the parameters studied with regard to sex and side have been displayed in Table 1. No statistically significant differences ($p > 0.05$) were found in the values of the examined variables with relation to sex and laterality. As a result, the authors did not attempt to separate further the numerical data into sex and side. As presented in Table 2, a statistically significant correlation ($p < 0.05$) between each parameter studied and fetal age was found. The mean length (5.68 mm) and width measured at its mid-length (0.60 mm) and at the widest level (0.65 mm) of the long head's belly were found to be statistically shorter (5.93 mm, 0.65 mm and 0.72 mm, respectively) when compared to its short head's belly. All the examined features indicated a proportionate increase in values when related to advanced fetal age. This was presented using regression analysis, including regression formulae of best fit, statistics values (F), and coefficients of determination (R^2) – (Table 3).

Long Head

The length of the long head's belly revealed an increase in values from 3.26 to 8.84 mm, respectively, which followed linearly: $y = -0.801 + 0.276 \times \text{Age}$ ($R^2 = 0.591$). The width at the mid-length of the long head ranged from 0.17 to 1.62 mm, following the linear model: $y = -0.254 + 0.036 \times \text{Age}$ ($R^2 = 0.201$). The width at the widest level of the long head increased from 0.24 to 1.67 mm respectively, according to the linear fashion: $y = -0.238 +$

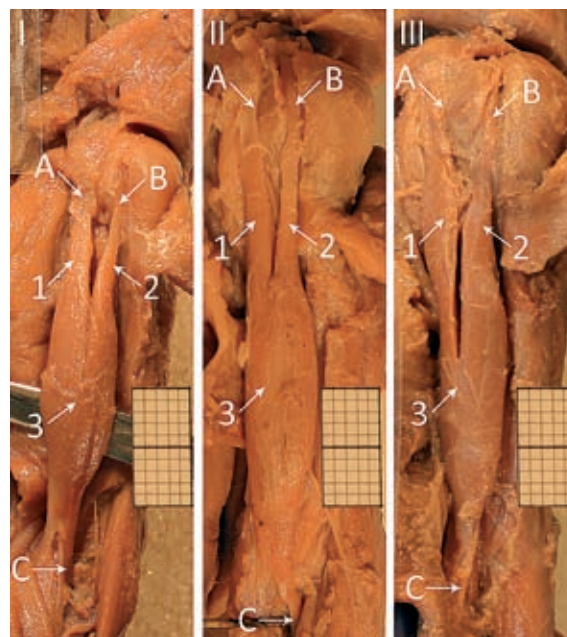


Fig. 1. The biceps brachii muscle in fetuses aged 17 weeks (I), 24 weeks (II) and 27 weeks (III): 1 – short head's belly, 2 – long head's belly, 3 – common belly, A – short head's tendon, B – long head's tendon, C – distal tendon

Ryc. 1. Mięsień dwugłowy ramienia u płodów w wieku 17 tygodni (I), 24 tygodni (II) i 27 tygodni (III): 1 – brzusiec głowy krótkiej, 2 – brzusiec głowy długiej, 3 – brzusiec wspólny, A – ścięgno głowy krótkiej, B – ścięgno głowy długiej, C – ścięgno końcowe

$0.038 \times \text{Age}$ ($R^2 = 0.226$). The length of the proximal tendon of the long head increased from 1.02 to 2.89 mm to generate the linear model: $y = 1.024 + 0.037 \times \text{Age}$ ($R^2 = 0.084$).

Short Head

The values for length of the short head's belly ranged from 3.49 to 8.93 mm to create the linear model: $y = -0.134 + 0.258 \times \text{Age}$ ($R^2 = 0.551$). The width values at the mid-length of the short head increased from 0.19 to 1.21 mm respectively, in accordance with the linear fashion: $y = -0.227 + 0.038 \times \text{Age}$ ($R^2 = 0.241$). The width at the widest level of the short head grew from 0.22 to 1.32 mm respectively, according to the formula: $y = -0.316 + 0.044 \times \text{Age}$ ($R^2 = 0.333$). The length of the proximal tendon of the short head increased from 0.54 to 2.10 mm respectively, following the linear regression: $y = 0.177 + 0.039 \times \text{Age}$ ($R^2 = 0.157$).

The Biceps Brachii Belly and Distal Tendon

The width of the biceps brachii belly ranged from 0.69 to 2.21 mm respectively, in accordance

Table 1. Individual morphometric results of the biceps brachii
Tabela 1. Wyniki indywidualne parametrów m. dwugłowego ramienia

Fetal number (Numer płodu)	Age – weeks (Wiek – tygodnie)	Sex F – female M – Male (Płeć F – żeńska M – męska)	Side R – right L – left (Strona R – prawa L – lewa)	Long head (Głowa długa) [mm]				Short head (Głowa krótka) [mm]				Common belly and distal tendon (Brzusiec wspólny i ścięgno końcowe) [mm]	
				attachment length (długość przyczepu początkowego)	belly length (długość brzucha)	belly width at its mid-length (szerokość brzucha w połowie długości)	the widest belly width (szerokość brzucha w najszerszym miejscu)	attachment length (długość przyczepu początkowego)	belly length (długość brzucha)	belly width at its mid-length (szerokość brzucha w 1/2 długości)	the widest belly width (szerokość brzucha w najszerszym miejscu)	common belly width (szerokość brzucha wspólnego)	distal tendon length (długość przyczepu końcowego)
1	17	F	R	1.57	4.28	0.42	0.42	0.55	4.55	0.24	0.35	0.73	0.73
			L	1.46	4.49	0.41	0.44	1.02	4.80	0.50	0.53	1.07	1.26
2	18	M	R	1.83	3.82	0.30	0.35	0.56	4.42	0.47	0.52	1.04	0.61
			L	2.12	4.13	0.49	0.59	0.89	5.03	0.65	0.70	1.19	0.92
3	19	M	R	1.05	4.01	0.30	0.45	0.72	4.14	0.60	0.69	1.18	1.03
			L	1.46	3.95	0.62	0.66	0.88	3.93	0.57	0.58	1.11	0.91
4		F	R	1.38	5.03	0.43	0.44	0.66	5.94	0.53	0.60	0.75	0.85
			L	1.31	5.24	0.33	0.39	0.84	5.31	0.49	0.49	0.71	1.06
5	20	M	R	1.03	3.27	0.27	0.32	0.65	3.50	0.54	0.43	0.98	0.75
			L	1.47	4.45	0.60	0.60	1.08	4.13	0.22	0.22	0.70	1.07
6	21	M	R	1.94	4.49	0.65	0.66	1.41	5.15	0.34	0.36	0.95	1.10
			L	1.47	4.30	0.75	0.78	0.89	4.09	0.66	0.70	1.30	1.20

7	22	M	R	2.73	5.59	0.41	0.44	1.41	6.04	0.88	0.92	1.11	1.34
8		M	L	2.16	6.42	0.68	0.71	1.27	6.63	0.61	0.61	1.14	1.27
9		F	R	1.54	5.18	0.43	0.45	0.74	5.81	0.67	0.78	0.88	1.29
			L	1.75	5.21	0.42	0.42	0.76	5.74	0.43	0.43	0.91	0.82
			R	1.86	4.96	0.38	0.44	1.35	6.25	0.74	0.76	1.23	1.14
			L	2.13	5.58	0.66	0.66	1.05	5.71	0.68	0.71	1.35	1.29
10		F	R	1.60	4.99	0.34	0.39	0.75	5.31	0.62	0.69	1.26	0.97
			L	2.12	4.82	0.53	0.60	0.93	5.08	0.43	0.52	0.82	1.12
11		F	R	2.23	4.51	0.32	0.64	1.42	5.13	0.46	0.45	1.09	0.96
			L	1.18	4.65	0.58	0.59	0.64	4.74	0.83	0.87	1.30	1.08
12	23	F	R	1.98	6.23	0.82	0.84	0.78	6.52	0.20	0.24	0.84	1.90
			L	2.06	5.73	0.36	0.39	0.97	6.65	0.71	0.76	0.93	1.43
13		F	R	1.79	5.70	0.19	0.27	1.04	5.95	0.82	0.85	1.14	1.56
			L	1.87	5.57	0.67	0.83	0.90	4.87	0.66	0.69	1.32	1.94
14		F	R	2.14	6.59	0.67	0.72	1.61	6.24	0.36	0.37	0.95	1.52
			L	2.25	6.26	0.52	0.64	1.50	6.12	0.58	0.61	1.02	0.83
15	24	M	R	2.13	5.21	0.45	0.45	0.89	6.09	0.69	0.74	1.50	1.71
			L	1.71	6.59	0.39	0.46	1.26	6.84	0.65	0.79	1.49	1.62
16		M	R	1.77	5.70	0.62	0.77	1.35	6.11	0.57	0.63	1.47	1.32
			L	1.43	5.81	0.47	0.58	1.14	5.64	0.85	0.73	1.71	2.00

Table 1. Individual morphometric results of the biceps brachii – continued
Tabela 1. Wyniki indywidualne parametrów m. dwugłowego ramienia (cd.)

Fetal number (Numer płodu)	Age – weeks (Wiek – tygodnie)	Sex F – female M – Male (Płeć F – żeńska M – męska)	Side R – right L – left (Strona R – prawa L – lewa)	Long head (Głowa długa) [mm]				Short head (Głowa krótka) [mm]				Common belly and distal tendon (Brzusiec wspólny i ścięgno końcowe) [mm]	
				attachment length (długość przyczepu początkowego)	belly length (długość brzucha)	belly width at its mid-length (szerokość brzucha w połowie długości)	the widest belly width (szerokość brzucha w najszerszym miejscu)	attachment length (długość przyczepu początkowego)	belly length (długość brzucha)	belly width at its mid-length (szerokość brzucha w 1/2 długości)	the widest belly width (szerokość brzucha w najszerszym miejscu)	common belly width (szerokość brzucha wspólnego)	distal tendon length (długość przyczepu końcowego)
17	24	M	R	2.87	5.46	0.89	0.91	1.27	5.40	0.56	0.63	1.43	1.35
			L	1.99	6.09	1.02	1.05	1.17	5.95	0.53	0.55	1.57	1.30
18		M	R	2.03	7.16	0.65	0.79	1.17	7.20	0.84	0.84	1.03	0.98
			L	1.84	6.67	0.85	0.88	1.06	6.92	0.65	0.72	1.56	1.30
19		M	R	2.17	5.90	0.90	0.97	1.36	5.54	0.56	0.65	1.26	1.45
			L	2.46	5.12	0.85	0.86	1.09	5.83	0.94	1.00	1.71	1.45
20		F	R	2.28	5.57	0.62	0.54	1.33	5.94	0.83	0.99	2.00	1.27
			L	2.25	5.97	0.17	0.24	1.65	5.75	0.44	0.96	1.58	1.15
21		F	R	1.50	7.92	0.54	0.56	0.74	8.39	0.42	0.51	1.32	1.14
			L	2.11	4.97	0.81	0.87	1.01	5.05	0.88	0.96	1.65	1.67
22		F	R	2.49	4.87	0.65	0.72	0.90	5.26	0.87	0.94	1.59	1.66
			L	2.16	6.22	1.03	1.04	1.25	6.22	0.54	0.61	1.40	1.40
23		F	R	2.59	5.42	0.26	0.35	2.10	5.75	0.19	0.40	0.76	0.71
			L	1.36	6.63	0.87	0.93	1.36	6.66	0.73	0.74	1.68	1.94
24		F	R	1.42	5.06	0.89	0.91	0.98	5.32	1.14	1.17	1.93	0.97
			L	2.50	5.11	0.71	0.73	0.77	5.80	1.21	1.32	1.86	1.42

25	27	M	R	2.03	6.09	0.68	0.75	1.26	6.21	0.65	0.68	1.30	1.36
			L	2.17	6.98	0.78	0.79	1.33	7.42	0.35	0.65	1.09	0.82
26	28	M	R	2.65	6.70	0.98	1.05	1.99	6.89	1.05	1.07	1.76	1.40
			L	2.89	5.43	0.60	0.71	1.65	5.88	1.04	1.07	1.59	0.95
27	29	F	R	2.31	6.62	1.05	1.08	1.18	6.61	1.10	1.17	2.13	1.91
			L	1.36	6.66	0.50	0.58	1.36	6.99	1.15	1.16	1.45	1.32
28		F	R	1.81	7.64	0.58	0.81	0.57	7.63	1.01	1.07	1.72	1.10
			L	1.05	6.93	0.34	0.40	1.02	6.69	0.63	0.67	1.18	1.21
29		F	R	2.10	8.84	0.92	1.00	1.03	8.93	0.97	0.99	1.79	0.90
			L	2.22	7.76	0.70	0.85	0.88	8.37	1.01	1.04	1.49	1.42
30	30	M	R	1.34	8.63	1.62	1.68	1.41	7.92	0.84	1.01	2.21	1.26
			L	1.78	6.15	0.45	0.36	1.11	7.24	0.45	0.76	1.22	1.26

with the formula: $y = -0.304 + 0.068 \times \text{Age}$ ($R^2 = 0.368$). The values for distal tendon length revealed an increase in values from 0.60 to 2.00 mm, respectively. Plotted against the fetal age, these values generated the linear model: $y = -0.504 + 0.031 \times \text{Age}$ ($R^2 = 0.112$).

Discussion

The biceps brachii muscle is characterized by the relatively greatest variability in comparison to other muscles in the arm. The long head's tendon of the biceps brachii is attached in a dual manner to the supraglenoid tubercle and the superior glenoid labrum [21–25]. Vangness et al. [4] reported the variability of both the glenoid and labral attachments of the biceps brachii, with a strong posterior orientation. The orientation of the glenoid attachment was mainly posterior (51%), neutral (44%) or anterior (5%), corresponding to the left glenoid with 1 o'clock, 12 o'clock and 11 o'clock positions, respectively. Similarly, the labral attachment was related only to the posterior labrum (22%), mostly to the posterior labrum with a small contribution to the anterior labrum (33%), with equal contributions to both the anterior and posterior labra (37%), and mostly to the anterior labrum with a small contribution to the posterior labrum (8%).

The short head of the biceps brachii originates from the coracoid process, as a member of the coracoid bunch, together with the pectoralis minor and coracobrachialis muscles. Doyle and Botte [26] suggest that the attachment sites on the coracoid process were interspersed, thereby muscle bundles started on it may even have been intermingled. Another variety accounts for the third head of the biceps brachii, being present in 3–22.9% of the population [12–15]. Pacholczak et al [13] described a three-headed biceps brachii, the third head of which is an infero-medial humeral one, originating beneath the distal extremity of the anterior surface of the humerus. Apart from this, because of the absence of the musculocutaneous nerve, the whole anterior compartment of the arm was unusually innervated by the median nerve. Kervancioglu and Orhan [15] reported 2 cases of the three-headed biceps brachii, which were selected out of 24 examined upper limbs. The first case was characterized by the third head starting from the antero-medial surface of the humerus, distal to the coracobrachialis insertion and medial to the brachialis. In the second case, an accessory head arose from the lateral side of the coracobrachialis insertion.

The biceps musculotendinous unit, consisting of the long and short heads, is thought to coalesce into a single belly and a single distal tendon. How-

Table 2. Correlation analysis of examined parameters of the biceps brachii**Tabela 2.** Analiza korelacji badanych wskaźników mięśnia dwugłowego ramienia

Part of the biceps brachii (Część mięśnia dwugłowego ramienia)	Parameter vs. age (Wskaźnik vs. wiek)	r	p
long head	belly length	0.773	0.000
	width at the mid-length of belly	0.453	0.003
	width at the widest level	0.479	0.000
	length of the proximal tendon	0.266	0.024
short head	belly length	0.748	0.000
	width at the mid-length of belly	0.495	0.000
	width at the widest level	0.584	0.000
	length of the proximal tendon	0.380	0.001
biceps brachii belly	width	0.604	0.000
distal tendon	length	0.308	0.008

Table 3. Regression analysis of examined parameters of the biceps brachii**Tabela 3.** Analiza regresji badanych wskaźników mięśnia dwugłowego ramienia

Part of the biceps brachii (Część mięśnia dwugłowego ramienia)	Parameter of biceps brachii vs. age (Wskaźnik mięśnia dwugłowego ramienia vs. wiek)	Regression equation (Równanie regresji)	F	R ²
long head	belly length	$y = -0.801 + 0.276 \times \text{Age}$	83.908	0.591
	width at the mid-length of belly	$y = -0.254 + 0.036 \times \text{Age}$	14.622	0.201
	width at the widest level	$y = -0.238 + 0.038 \times \text{Age}$	17.012	0.226
	length of the proximal tendon	$y = 1.024 + 0.037 \times \text{Age}$	5.3326	0.084
short head	belly length	$y = -0.134 + 0.258 \times \text{Age}$	71.385	0.551
	width at the mid-length of belly	$y = -0.227 + 0.038 \times \text{Age}$	18.444	0.241
	width at the widest level	$y = -0.316 + 0.044 \times \text{Age}$	29.000	0.333
	length of the proximal tendon	$y = 0.177 + 0.039 \times \text{Age}$	10.840	0.157
biceps brachii belly	width	$y = -0.304 + 0.068 \times \text{Age}$	33.808	0.368
distal tendon	length	$y = -504 + 0.031 \times \text{Age}$	7.3776	0.112

ever, in the material of Athwal et al. [27], consisting of 15 adult upper extremities, in 2 specimens the two heads, including both bellies and distal tendons, were completely independent of each other. Furthermore, in 8 specimens, the two heads (bellies and tendons) could be easily separated, whereas in the 5 remaining specimens, the short and long heads of muscle bellies coalesced distally and their corresponding distal tendons were interconnected. These authors challenged the concept that the distal biceps tendon is a simple cylindrical tendon. The distal tendon of the short head was inserted at the distal ulnar aspect on the radial tu-

berosity, while the distal tendon of the long head was inserted at its proximal ulnar aspect.

Having reviewed the medical literature on the biceps brachii, the authors failed to find reference data for its dimensions. Therefore, in this study the digital-image analysis system was used to gather detailed normative data on the developing biceps brachii muscle at varying gestational ages from 17 to 30 weeks. In this study, it was found that during the analyzed period both the lengths of the two heads, the common tendon length and the common belly width increased 2-fold approximately, whereas the widths of both heads at their widest points, as many

as 3-fold. In this respect, the present results are in close accordance with the statement of Szpinda et al. [28], concerning morphometric data of the biceps femoris. Therefore, the width at mid-length of the short head was found to increase more (a 4-fold increase) than that of the long head (a 3-fold increase). Furthermore, the long head's belly was found to be significantly shorter than that of the short head's belly. Similarly, the belly width was observed to be greater in relation to the short head.

As presented in Table 2, the strongest correlations between each parameter were related to the length of the long ($r = 0.773$) and short ($r = 0.748$) heads, the intermediate to the widths at the mid-length and at the widest level for the long ($r = 0.453$, $r = 0.479$) and short ($r = 0.495$, $r = 0.584$) heads, and to the width of the biceps brachii belly ($r = 0.604$), and the weakest to the tendons of the long ($r = 0.266$) and short ($r = 0.380$) heads, and to the distal tendon ($r = 0.308$).

In the material under examination, the growth of all the muscle features studied followed proportionately, being expressed by linear regression models (Table 3). Authors' observations compared to the other authors [29, 30] confirm the linear growth of

different skeletal muscles in human fetuses. Badura et al. [29, 30] proved that the semitendinosus and semimembranosus muscles grew proportionately during gestation. The authors also failed to find any sex or laterality influence on the values of the parameters studied, as Szpinda et al. [28] did so in relation to the biceps femoris muscle. On the contrary, Kędzia et al. [31] found that the length of the sartorius was statistically ($P < 0.05$) greater on the left. They also showed that the sartorial length was significantly larger in female fetuses.

The lack of information concerning the parameters studied limits discussion on this subject. The authors believe that the normative data of the biceps brachii muscle obtained in this study provides the background for future autopsy studies.

The authors concluded that neither sex differences nor laterality differences are observed in morphometric parameters of the biceps brachii muscle. The long head's belly is shorter and thinner than that of the short head's belly. The long head's tendon is longer than that of the short head. The developmental dynamics of the biceps brachii muscle follow linearly.

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