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Growth Dynamics of the Triceps Brachii Muscle in the Human Fetus

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article; **G** – other

Abstract

Background. The triceps brachii muscle, the strongest extensor of the elbow joint, is characterized by the three heads: long, lateral and medial.

Objectives. In the present study we aimed to examine the linear parameters (length, width) of the fetal triceps brachii muscle and to provide their growth dynamics.

Material and Methods. Using anatomical dissection, digital image analysis (Multiscan v.14.02), and statistics (Student's *t*-test, regression analysis) we measured in mm the length and width of the triceps brachii in 30 fetuses of both sexes (12♂,18♀) aged 12–29 weeks.

Results. Neither sex nor laterality differences were found. All the parameters studied increased proportionately with age. The linear functions were computed as follows: y = 6.797 + 2.079 x Age (r = 0.886) for length of the long head's belly, y = – 0.041 + 0.215 × Age (r = 0.786) for width of the long head's belly, y = 1.889 + 0.174 × Age (r = 0.796) for length of the long head's proximal tendon, y = 0.158 + 0.052 × Age (r = 0.864) for width of the long head's proximal tendon, y = 5.270 + 1.809 × Age (r = 0.855) for length of the lateral head's belly, y = 0.348 + 0.284 × × Age (r = 0.829) for width of the lateral head's belly, y = 0.942 + 1.837 × Age (r = 0.839) for length of the medial head's belly, y = 0.314 + 0.234 × Age (r = 0.852) for width of the medial head's belly, y = – 3.191 + 0.984 × Age (r = 0.929) for lenght of the common tendon, and y = – 0.478 + 0.133 × Age (r = 0.933) for width of the common tendon.

Conclusions. Neither male-female nor right-left differences are observed in morphometric parameters of the triceps brachii muscle. The long head's belly is the thinnest, while the lateral head's belly is the widest one. The long head is the longest and the medial head is the shortest one. The developmental dynamics of the triceps brachii muscle follow proportionately (**Adv Clin Exp Med 2014, 23, 2, 177–184**).

Key words: triceps brachii muscle, attachments, length, width, regression analysis.

The triceps brachii muscle, the primary extensor of the elbow and shoulder joints and a helping adductor at the shoulder joint (long head), is relevant for the normal functioning of the upper limb. As a natural antagonist to the biceps brachii, it solely occupies the posterior compartment of the arm [1]. The long head normally springs from the infraglenoid tubercle. The lateral head originates from the lateral intermuscular septum and from the humerus, superior to the radial groove, while the medial head arises from the medial intermuscular septum and from the humerus, inferior to the radial groove [2, 3]. The whole muscle extends distally to be inserted via a common tendon onto the olecranon. According to Keener et al. [4], in 14 specimens aged 71 years, the mean tendon width at its insertion was found to be approximately 78% of the maximum width of the olecranon.

The triceps brachii may get accessory muscle slips arising from the humerus, shoulder capsule, coracoid process, and even from some muscles, such as the subscapularis, latissimus dorsi, anconeus, and extensor carpi ulnaris [2–9]. The aforementioned anatomical variations of the triceps brachii are known to potentially cause compression of the radial and ulnar nerves [2, 8, 9]. Because of its overload, the triceps brachii insertion may result in triceps tendinitis, being manifested by chronic posterior elbow pain with active extension, mostly in energetic men, e.g. throwing athletes at the age of 30–40 years [10]. Triceps brachii tendon ruptures have been described as the least common (2%) of all tendon injuries [11–13], as a result of a fall onto an outstretched hand or a direct blow to the triceps tendon. Injury to the triceps brachii occurs at the distal tendon-olecranon, myotendinous or intramuscular junctions, and proximally at the origin of the lateral head [14, 15]. These conditions spontaneously tend to accompany systemic diseases (rheumatoid arthritis, systemic lupus erythematosus, hyperparathyroidism, chronic renal failure and hemodialysis, Marfan syndrome) and chronic steroid use [16, 17] that alter the structural integrity of the tendon.

To date, little attention has been given to the quantitative anatomy of the growing triceps brachii in the fetus. Therefore, in the present study the following three objectives were set in order to examine the following:

1) normal values for the three heads (in terms of their length and width) and two tendons, one proximal and one distal (in terms of their length and width) at varying gestational ages,

2) the growth curves for normal development of the features studied, and

3) the impact of sex and size on the values of the parameters examined.

Material and Methods

This study was performed in accordance with the approval of our University Research Ethics Committee (KB 72/2012). The examination was carried out on 30 human fetuses of both sexes (12 males, 18 females) from spontaneous abortions and stillbirths. The whole fetal material included specimens at the age of 12–29 weeks. All fetuses were preserved in 10% neutral formalin solution for 24–36 months. Every triceps brachii muscle was dissected to visualize its attachments, then recordered with a millimeter scale (Figs. 1 and 2) using a SONY camera α 330 and analyzed by digital image analysis system (Multiscan v. 14.02). For each muscle the following 10 parameters were computed:

1) length of the long head's belly, measured from its origin to its termination,

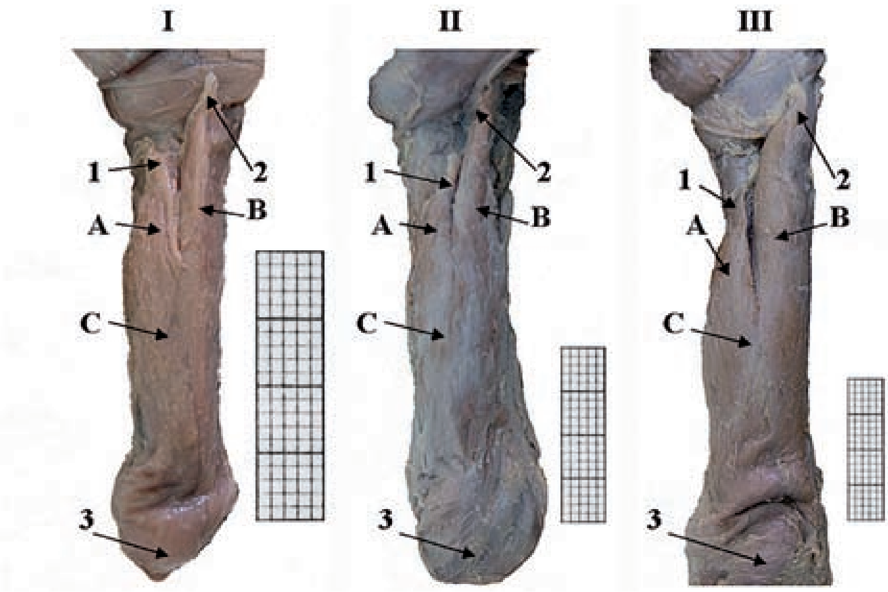

Fig. 1. The triceps brachii muscle in fetuses aged 14 (I), 19 (II), and 29 weeks (III) 1 – lateral head's proximal tendon, 2 – long head's proximal tendon, 3 – common tendon, A – lateral head's belly, B – long head's belly, C – common belly

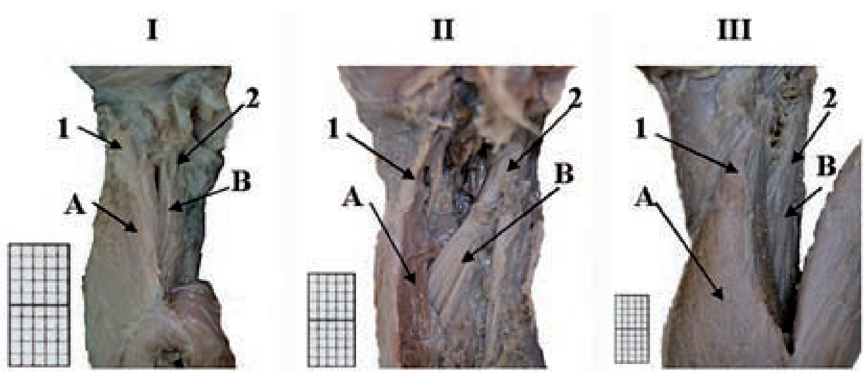

Fig. 2. The triceps brachii muscle in fetuses aged 14 (I), 19 (II), and 29 (III) 1 – lateral head's proximal tendon, 2 – medial head's proximal tendon, A – lateral head's belly, B – medial head's belly

2) length of the lateral head's belly, measured from its origin to its termination,

3) length of the medial head's belly, measured from its origin to its termination,

4) length of the proximal tendon of the long head, measured from the infraglenoid tubercle to its end,

5) length of the common tendon, measured from the end of the common belly to the olecranon,

6–8) three widths, one for every head, measured at their widest levels,

9) width of the proximal tendon of the long head, measured at its widest level,

10) width of the common tendon, measured at its widest level.

The statistical analysis was started by assessing the probability of appearance of statistically significant differences in values with relation to sex (Student's *t*-test for unpaired variables) and laterality (Student's *t*-test for paired variables) using Statistica 9.0. The particular parameters were correlated to fetal age. Regression analysis was used to derive the curve of best fit for the plot for each morphometric parameter vs. gestational age. Differences were considered significant at $p < 0.05$.

Results

The three heads of the triceps brachii muscle always extended typically. All individual numerical data obtained for the triceps brachii muscle have been presented in Table 1. Neither laterality nor sex differences ($p > 0.05$) between the parameters studied were found. As a result, we did not attempt to separate further the numerical data into sex and the side. As presented in Table 2, the statistically significant correlation between each parameter studied and fetal age was found, being expressed by p value and correlation coefficient (r). The statistically significant correlation ($p < 0.01$) between every parameter studied and fetal age was observed. The examined features revealed a proportionate increase in values when related to advancing fetal age. This was presented using regression analysis, including regression formulae of best fit, statistics values (F), and coefficients of determination (R^2) – (Table 2).

When compared to its lateral (37.06 mm) and medial (33.24 mm) heads, the mean length (43.36 mm) of the long head was statistically greater ($p = 0.0002$; $p = 0.0003$). When compared to its both medial (4.42 mm) and long (3.74 mm) head's bellies, the mean width of the lateral head's belly measured at its widest level (5.34 mm) was found to be statistically greater ($p = 0.001$; $p = 0.008$).

Long Head of Triceps Brachii

In the examined age-group the values for length of the long head ranged from 27.43 to 63.15 mm respectively, and averaged 43.36 mm. The values for width of the long head varied from 2.05 to 5.76 mm respectively, with the mean of 3.74 mm. The values for length of the long head's tendon ranged from 3.26 to 6.11 mm respectively, and averaged 4.95 mm. The values for width of the long head's proximal tendon fluctuated from 0.79 to 1.45 mm respectively, to average 1.07 mm. All the aforementioned parameters revealed a proportionate increase when plotted against gestational age (Table 2).

Lateral Head of Triceps Brachii

During the analyzed period the values for length of the lateral head varied from 23.63 to 55.64 mm, respectively, and averaged 37.06 mm. The values of width of the lateral head ranged from 3.21 to 8.14 mm respectively, to average the value of 5.34 mm. The lateral head increased linearly in both length and width (Table 2).

Medial Head of Triceps Brachii

Between 12 and 29 weeks, the values for length of the medial head ranged from 19.74 to 51.45 mm respectively, with the mean of 33.24 mm. The values for width of the medial head varied from 2.67 to 6.44 mm respectively, and averaged 4.42 mm. As indicated in Table 2, the growth of the medial head followed proportionately.

Common Tendon of Triceps Brachii

In the study period, the values for length of the common tendon ranged from 10.21 to 28.30 mm respectively, and averaged 14.11 mm. The width of the common tendon varied from 1.01 to 3.02 mm, respectively, with the mean of 1.86 mm. Both parameters were found to rise in accordance with linear functions (Table 2).

Discussion

The present study describes a cross-sectional interpretation of 10 quantitative parameters of the triceps brachii muscle, based on the evidence from 30 fetuses at ages of 12–29 weeks. Thus, it is rather a populational perspective than a true representation of longitudinal muscle growth in itself. The main limitation of this study is the number of fetuses. Were we able to collect more fetuses,

Table 1. Individual numerical data of the fetal triceps brachii muscle

Fetal number	Age (weeks)	Sex F – Female M – Male	Side R – right L – left	Long head (mm)				Lateral head (mm)		Medial head (mm)		Common tendon (mm)	
				belly length	belly width	proximal tendon length	proximal tendon width	belly length	belly width	belly length	belly width	common tendon length	common tendon width
1	12	F	R	34.41	2.22	3.99	0.79	26.70	4.27	22.91	3.10	10.21	1.01
			L	35.32	2.51	4.10	0.83	28.27	4.36	23.52	3.21	10.53	1.05
2		M	R	28.41	2.11	3.26	0.82	24.34	3.77	19.97	2.92	10.41	1.05
			L	27.43	2.05	3.35	0.85	23.63	3.60	19.74	2.71	11.41	1.08
3	13	F	R	30.63	2.42	3.78	0.80	25.94	3.43	21.90	2.86	10.81	1.15
			L	29.82	2.43	3.80	0.83	26.22	3.21	21.72	2.67	11.20	1.14
4	15	F	R	31.80	2.61	3.93	0.83	26.30	3.34	22.19	3.00	11.71	1.54
			L	32.00	2.71	4.01	0.83	26.61	3.48	22.44	2.88	11.92	1.58
5		M	R	35.61	3.00	4.01	0.84	29.87	4.83	23.38	3.73	11.72	1.17
			L	36.52	3.21	4.03	0.88	31.26	5.11	23.53	4.14	12.72	1.16
6		M	R	35.73	3.12	4.10	0.91	29.00	3.95	24.32	3.86	11.65	1.75
			L	34.81	2.89	4.12	0.93	29.20	4.13	25.09	3.61	11.35	1.79
7	16	F	R	37.00	3.59	4.27	0.91	34.02	4.77	31.52	3.92	11.98	1.34
			L	38.25	3.70	4.23	0.89	34.52	4.64	31.81	3.72	12.08	1.32
8		F	R	39.39	2.91	4.32	0.85	33.87	5.62	30.20	3.60	13.12	1.37
			L	40.66	3.21	4.36	0.82	35.91	5.10	29.73	4.06	12.82	1.34
9		F	R	41.44	3.20	5.02	0.98	34.73	5.03	30.96	4.13	12.78	1.62
			L	39.73	2.93	5.14	0.95	33.87	4.83	30.55	4.23	13.21	1.66
10		M	R	41.94	4.01	4.89	1.04	35.56	4.64	31.51	4.41	12.40	1.80
			L	41.42	3.71	4.76	1.07	35.92	4.53	31.82	4.58	12.80	1.83
11		M	R	42.41	3.32	5.21	0.87	34.85	5.14	31.53	4.19	12.45	1.83
			L	40.70	3.41	5.17	0.89	33.92	4.99	31.39	3.93	13.05	1.88
12		F	R	47.76	3.94	5.32	1.03	42.90	4.87	39.75	4.51	13.59	1.76
			L	48.06	3.74	5.42	1.10	42.50	5.10	39.93	4.61	12.21	1.78

Fetal number	Age (weeks)	Sex F – Female M – Male	Side R – right L – left	Long head (mm)				Lateral head (mm)		Medial head (mm)		Common tendon (mm)	
				belly length	belly width	proximal tendon length	proximal tendon width	belly length	belly width	belly length	belly width	common tendon length	common tendon width
13	17	F	R	41.84	3.40	5.09	0.94	36.32	5.26	34.32	4.20	13.48	1.92
			L	42.13	3.60	5.04	0.99	36.81	5.40	34.27	4.67	13.48	1.98
14		M	R	44.50	3.79	4.92	1.05	37.25	4.80	33.45	4.26	12.60	1.92
			L	45.62	4.11	5.00	1.09	38.38	4.92	33.96	4.18	12.50	1.90
15		M	R	44.91	4.10	5.13	1.03	38.70	4.84	34.30	4.13	13.17	1.81
			L	45.45	3.81	5.18	1.02	40.61	4.91	35.72	4.32	14.07	1.83
16		F	R	46.43	3.69	5.34	1.07	39.92	5.58	34.91	4.56	13.48	1.86
			L	44.22	3.54	5.31	1.10	37.73	5.36	35.11	4.78	13.48	1.68
17		M	R	46.61	3.33	5.20	1.21	40.37	5.39	37.30	4.70	13.82	1.86
			L	45.83	3.26	5.21	1.24	40.05	5.19	37.54	4.53	12.42	1.89
18	18	F	R	38.11	3.91	4.41	1.06	33.65	6.22	29.93	4.54	13.49	2.03
			L	36.72	3.50	4.52	1.05	34.82	5.91	30.52	4.60	13.21	2.05
19		F	R	49.35	4.20	5.29	1.12	45.89	6.62	40.87	4.86	13.42	1.89
			L	47.86	4.82	5.23	1.21	45.32	6.30	41.60	4.91	13.32	1.84
20		M	R	46.82	4.27	5.31	1.12	40.30	5.22	37.42	4.85	14.12	1.95
			L	46.81	4.32	5.28	1.11	40.25	5.39	37.62	4.88	14.52	1.96
21	19	F	R	47.40	4.05	5.84	1.20	41.68	6.61	37.96	4.94	13.86	2.12
			L	47.21	3.75	5.92	1.22	41.12	6.10	38.23	4.83	14.21	2.11
22		F	R	46.63	5.13	5.33	1.20	37.64	6.62	34.11	5.92	14.01	2.16
			L	45.45	5.76	5.50	1.23	36.90	6.45	34.53	5.53	13.71	2.12
23		F	R	49.57	4.13	5.43	1.17	43.79	7.18	40.65	4.68	15.23	2.10
			L	48.93	5.22	5.49	1.13	44.07	6.92	40.76	4.71	15.63	2.12
24		F	R	44.62	4.10	5.26	1.16	37.34	5.78	32.72	5.23	17.04	2.13
			L	44.21	3.92	5.19	1.19	37.44	6.15	34.30	5.42	17.81	2.12
25		M	R	47.12	3.44	5.09	1.32	34.72	4.80	31.10	3.99	14.88	2.17
			L	45.92	3.28	5.00	1.28	35.09	4.88	31.36	3.87	14.88	2.19
26	20	F	R	45.44	4.16	5.29	1.30	40.70	5.53	36.25	4.95	18.51	2.24
			L	45.52	4.36	5.32	1.33	39.82	5.55	35.94	4.55	18.24	2.27
27		F	R	51.11	4.32	5.57	1.39	42.30	6.27	39.53	5.37	15.34	2.48
			L	51.53	4.81	5.60	1.35	41.47	7.14	39.22	5.93	15.04	2.49
28		M	R	53.32	5.31	5.93	1.24	41.56	5.92	38.58	5.58	19.28	2.23
			L	52.81	5.37	5.87	1.25	41.20	6.21	39.50	5.27	17.04	2.22
29	21	F	R	52.31	4.15	5.56	1.41	44.71	6.10	38.93	5.10	16.34	2.49
			L	52.68	4.33	5.69	1.45	46.08	6.20	39.12	5.51	16.36	2.51
30	29	M	R	61.96	5.24	6.11	1.45	54.39	7.93	49.98	6.12	28.19	3.02
			L	63.15	5.25	6.03	1.44	55.64	8.14	51.45	6.44	28.30	3.01

Table 2. Statistics of the triceps brachii muscle

Triceps brachii muscle						
Part	**Parameter**	**Regression equation**	**R**	**R^2**	**F**	**p**
Long head	belly length	y = 6.797 + 2.079 × Age	0.886	0.785	212.1	< 0.01
	belly width	y = – 0.041 + 0.215 × Age	0.786	0.618	94.1	< 0.01
	proximal tendon length	y = 1.889 + 0.174 × Age	0.796	0.634	100.8	< 0.01
	proximal tendon width	y = 0.158 + 0.052 × Age	0.864	0.747	171.2	< 0.01
Lateral head	belly length	y = 5.270 + 1.809 × Age	0.855	0.731	158.1	< 0.01
	belly width	y = 0.348 + 0.284 × Age	0.829	0.688	128.1	< 0.01
Medial head	belly length	y = 0.942 + 1.837 × Age	0.839	0.705	138.3	< 0.01
	belly width	y = 0.314 + 0.234 × Age	0.852	0.726	154.2	< 0.01
Common tendon	length	y = – 3.191 + 0.984 × Age	0.929	0.864	367.1	< 0.01
	width	y = – 0.478 + 0.133 × Age	0.933	0.872	394.0	< 0.01

the growth dynamics obtained would be more detailed. Fortunately, the adequate digital program of Multiscan v. 14.02 appears to compensate for that disadvantage by means of objective, precise, and repeatable semi-automatic evaluation of the muscle parameters studied in digital pictures.

During the 5th week of embryogenesis, the triceps brachii musculature develops from the dorsal muscle mass of the upper limb bud [2]. Seldom do we find variations of the triceps brachii muscle in the medical literature. As it turned out, the fourth head of the triceps brachii may have developed from various points of the shoulder joint capsule, the scapula, the humerus, and the coracoid process [2, 18]. Autopsy studies by Eiserloh et al. [3] and Handling et al. [5] confirmed a constant capsular contribution to every orgin of the long head of the triceps brachii. This partly remains contradictory to Huber and Putz [19], who noticed the long tendon of triceps brachii pass to the glenoid labrum in 38% of individuals. Soubhagya et al. [18] described the fourth head of the triceps brachii, being attached to the medial aspect of humerus, just below the insertion of the latissimus dorsi and teres major tendons. Macalister [20] found the fourth head of the triceps, as a split of the long head, with a long, slender tendon attached to the shoulder capsule. Furthermore, Tubbs et al. [2] reported an accessory head, being derived from the medial head with its anomalous tendinous attachment into the posterior aspect of the surgical neck of humerus.

As far as entrapment syndromes are concerned, the radial nerve was reported to be compressed by both the lateral [21, 22] and medial [2, 23] heads of the triceps brachii, with a potential radial nerve palsy. Spinner et al. [24] described the so-called "snapping elbow syndrome" as a consequence of ulnar nerve entrapment from the hypertrophied medial head of the triceps, when flexing the elbow joint. Furthermore, in 17% of individuals the medial head of the triceps may bridge over the ulnar groove of humerus to form the anconeus epitrochlearis, which compresses the ulnar nerve [23]. On the contrary, according to Tubbs et al. [25], deep fibers of the medial head are responsible for the formation of the anconeus muscle, which tends to tether the medial component of the triceps brachii, thus decreasing the likelihood that it would compress the ulnar nerve.

After reviewing the professional literature, we failed to find reference data, Kędzia et al. [26] aside, concerning triceps brachii dimensions. No significant sex and laterality differences between all the triceps brachii parameters were found. Neither sex nor laterality differences remain in agreement with our previous findings concerning the fetal semimembranosus [27] and semitendinosus [28] muscles. Interestingly enough, according to Kędzia et al. [29], the sartorial muscle length was found to be significantly larger both in female fetuses and on the left side. In the material under examination, the growth dynamics of all muscle features studied followed proportionately, thereby being expressed by linear regressions. The strongest correlations referred to the following: the lengths of the common tendon, long, lateral, and medial heads, and long head's proximal tendon, the widths of the common tendon, medial and lateral heads, and long head's proximal tendon, and the weakest to the width of the long head. Our findings confirmed a balanced growth of the triceps brachii, being precisely expressed by straight lines.

Of note, Kędzia et al. [26] in 70 fetuses aged 15–28 weeks measured the widths of the three heads of triceps brachii muscle. The mean values for widths of the long, medial and lateral heads ranged 6.0 mm, 4.6 mm, and 6.1 mm, respectively. In the material under examination, the lateral head's belly was also the widest, but the long head's belly was the thinnest.

In the present study, the balanced, proportionate growth of the triceps brachii muscle resembles that of different skeletal muscles, reported in the literature [27, 28, 30–32]. This may be exemplified by the morphometric analysis of the semimembranosus [27] and semitendinosus [28], the biceps femoris [30], deltoid [31], and biceps brachii [32] in the human fetus. The lack of information in the medical literature concerning the parameters studied obviously limits discussion on this subject. We believe that the normative data of the triceps brachii muscle in the fetus obtained in this study will provide the background for future autopsy studies.

The authors concluded that neither sex differences nor laterality differences are observed in morphometric parameters of the fetal triceps brachii muscle. The lateral head's belly is the widest, while the long head's belly is the thinnest. The long head is the longest, while the medial head is the shortest. The growth dynamics of the triceps brachii muscle follow proportionately.

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