VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 65, No. 4, pp. 329–336

ISSN 0015–5659
www.fm.viamedica.pl

A contribution to the discussion concerning the variability of the third peroneal muscle: an anatomical analysis on the basis of foetal material

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[Received 1 December 2005; Revised 6 September 2006; Accepted 8 September 2006]

The aim of the work was to make a systemic study of the variability of the human musculus peroneus tertius *during the foetal period. Examination was made of 193 foetuses of ages ranging from 84 to 256 days after conception. The results obtained indicated that the* musculus peroneus tertius *was present in 83.16% of the human foetuses studied and that its intrauterine development was progressive and almost proportional. Previous studies have not revealed dimorphic or bilateral differences with respect to any of the features examined. On the basis of the examinations and bibliographical data a uniform typology of the* musculus peroneus tertius *variants was created and three final types were distinguished: the pithecogenic (44% cases), eugenic (34% cases) and progenic (22% cases).*

Key words: fibular muscles, foetal development, preparatory examinations

INTRODUCTION

The *musculus peroneus tertius* is an extremely interesting subject of research for anatomists and clinicians because of its enormous variability and its significant influence on the shape and biomechanics of the foot. This has been demonstrated in works which describe the preparatory examinations carried out on adults and foetuses and the observations made of living individuals [3, 4, 7, 8, 15–20]. It was decided to analyse this muscle as the available literature dealing with assessment of *musculus peroneus tertius* variability is incomplete. In our view this is because it contains neither detailed analysis of the development of this muscle during the foetal period nor evaluation of its metric parameters and descriptive traits. As a result the Department of Normal Anatomy in Wroclaw has drawn special attention to this anatomical feature during studies made on the variability of the leg muscles. The aims of this paper are therefore to evaluate the variability of the *musculus peroneus tertius*, to identify the basic metric parameters according to foetal age and to assess the incidence of the individual forms.

MATERIAL AND METHODS

The observations were carried out on 193 foetuses aged from 84 to 252 days after conception. The foetuses were from our own collection drawn from Wroclaw gynaecological clinics during the years 1970–1995. The ages of the foetuses were estimated on the basis of data stating the date of the last menstruation and verified by our own method of foetal age estimation [5]. The dissected foetuses were classified according to age into six 28-day groups.

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Table 1. Numerical strength of the analysed foetal material according to age group

Age class	Age	Extremities numerical force	Male foetuses	Female foetuses	MPIII frequency
4	To 112	40	20	20	32
5	113–140	80	38	42	66
6	141–168	82	42	40	68
7	169–196	84	44	40	71
8	197–224	80	38	42	68
9	225–252	20	10	10	16

MPIII frequency — number of the extremities with the presence of the *musculus peroneus tertius*

A breakdown by age of the material examined is presented in Table 1. Before the preparation an autopsy was performed on each foetus to detect and exclude from the study individuals with visible malformations. Measurements were made with the digital slide calliper Mitutoyo No. 573-125-10 and the observations were recorded by means of diagrams and photographs taken with a Practica photographic kit consisting of a camera with a Carl-Zeiss and Tamron lens, a set of photographic rings and a table equipped with a tripod to ensure a constant positioning of the camera in relation to the object.

The statistical analysis was made by means of the Statistica PL package. The arithmetic means obtained were interpolated at the centre of the age group on the basis of the Lagrange method in order to achieve the equal distances between the individual age groups necessary for the precise evaluation of foetal development and of sexual differences. The selection of statistical tests was based on the available literature [14].

RESULTS

The *musculus peroneus tertius* was present in 83.16% of the examined foetal material taken as a whole. However, this value does not hold for all the age groups as the study carried out clearly demonstrated the presence of slight deviations in the incidence of this muscle in the individual age groups. The differences seen are simply the result of variability within the population of foetuses.

It was demonstrated that the belly of the *musculus peroneus tertius* occurs, in agreement with the observations of Przystasz [16], in three forms:

— I — the completely formed belly, clearly distinct from the *musculus extensor digitorum longus* (Fig. 1);

— II — the belly, partially fused with the *extensor digitorum longus* muscle and with the independent tendon;

— III — no belly; with the presence only of the independent tendon which leaves the belly of the *musculus extensor digitorum longus* (Fig. 2).

It was found that the frequency of incompletely developed forms of the *musculus peroneus tertius,* especially the form which occurs as an independent tendon split from the *musculus extensor digitorum longus*, increases with age. The completely developed belly of the *musculus peroneus tertius*, therefore, can be found only in about 50% of the material

Figure 1. *Musculus peroneus tertius* — the completely formed belly (arrow).

Figure 2. *Musculus peroneus tertius* — a single independent tendon that leaves the belly of the *musculus extensor digitorum longus* (arrow).

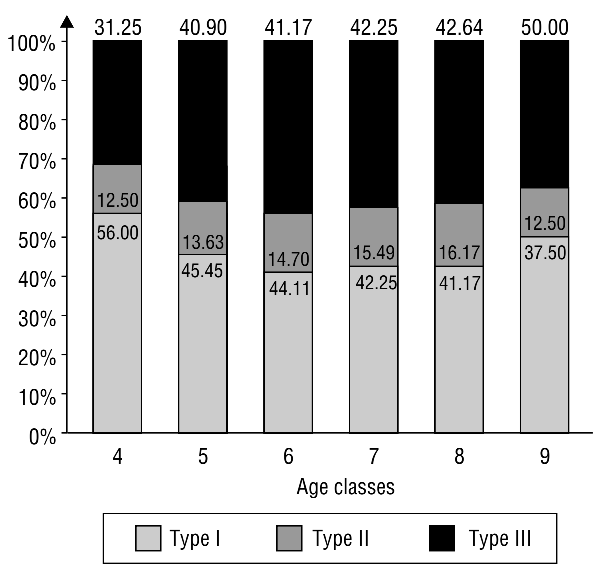

Figure 3. The incidence of individual types of the *musculus peroneus tertius* belly in human foetuses in separate age groups; type I — completely formed belly; type II — partial fusion of belly; type III — no belly.

as a whole (Fig. 3). This finding is of especial importance in analysis of the metric traits of the muscle because only 50% of the material obtained can be analysed.

The data presented in Table 2 demonstrate the dynamics of the development of the elementary metric dimensions of the muscle. The increase in all the traits analysed follows a regular course. The length of the proximal attachment grows by about 200% during the period of foetal ontogenesis analysed, which is slightly little slower than the development of the complete length of the belly, which increases by about 260% over the whole observation period.

When the observable differences in the dynamics of increase were taken into consideration, the ratio of the length of the proximal attachment to the complete length of the belly was calculated and defined as index I (attachment-length; Fig. 4).

Analysis of the index value variability showed that during the foetal period a statistically significant delay occurs in the increase of the initial attachment length in relation to the belly length. We may thus speak of the "stepping in" of the initial attachment of the muscle referred to during the development of the foetus.

The increase in maximum muscle width is proportional to its length and amounts to about 270%. This width-length of the belly as calculated was defined as index II. Its value fluctuates slightly from 0.10 to 0.12.

The traits described above refer only to the muscles with the completely developed belly. All foetuses in which the presence of *musculus peroneus tertius* was demonstrated were included in the evaluation of the maximum length of the tendon. The tendon length increases by about 280% during the foetal period under examination. The calculated ratio

Table 2. Basic statistics of the *musculus peroneus tertius* in the period of foetal ontogenesis analysed

Age class	$\bar{x}_p$ [mm]	s_p	$\bar{x}_l$ [mm]	s_l	$\bar{x}_w$ [mm]	s_w	$\bar{x}_t$ [mm]	s_t
4	7.97	1.10	10.76	1.23	1.23	0.31	3.64	0.69
5	9.84	1.39	15.10	2.17	1.65	0.63	6.25	1.27
6	11.43	2.04	18.61	2.03	2.00	0.82	10.12	2.36
7	13.30	2.09	22.66	1.76	2.55	0.70	12.09	2.37
8	15.29	1.52	25.78	1.58	3.09	0.89	14.77	2.24
9	16.94	1.73	28.44	2.18	3.39	0.73	16.99	2.36

$\bar{X}$ — mean value interpolated into mean age group; s — standard deviation; p — proximal attachment length; l — belly length; w — belly width; t — tendon length

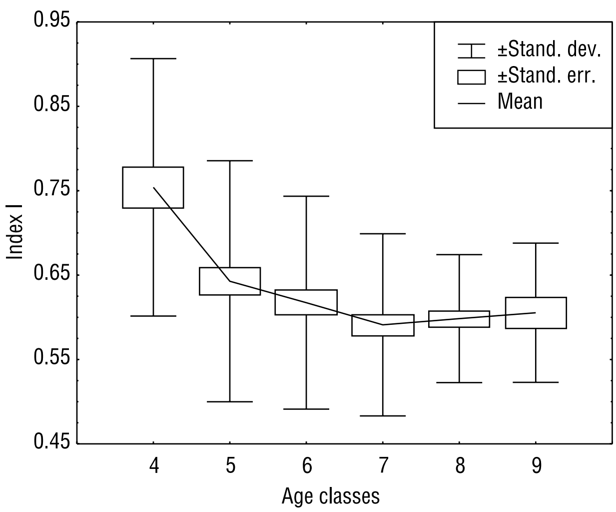

Figure 4. Index I (proximal attachment length *vs.* belly length) variability in human foetuses.

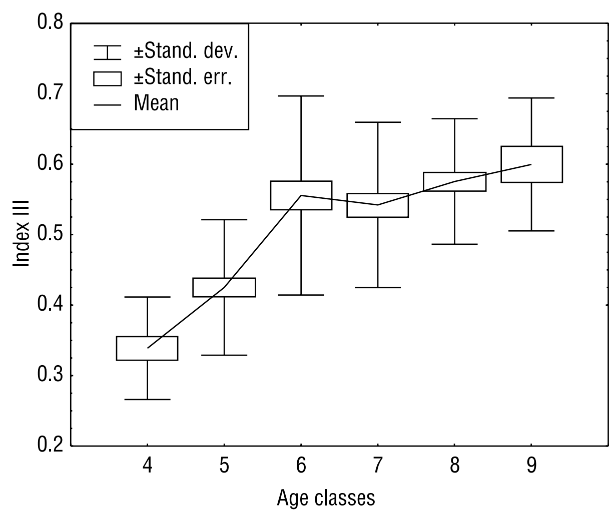

Figure 5. Index III (tendon length *vs.* belly length) variability in human foetuses.

of the tendon length to the belly length of the *musculus peroneus tertius*, index III, showed a decrease in the relative length of the belly in relation to tendon length (Fig. 5).

The final attachment of the muscle examined contains the fourth and the fifth metatarsal bones. It has been demonstrated on the basis of the variable location of the distal attachment that the muscle in question occurs in several forms. The typology is based mainly on the observation of adults by Sokołowska-Pituchowa et al. [18, 19] and was used to analyse the variability of location of the final attachment. The results obtained were classified into four types:

— type I — containing the basic attachment located asymmetrically on the fading each other surfaces of the fourth and fifth metatarsal bones; found in 57.63% of all cases (Fig. 6);

— type II — containing the basic attachment located symmetrically on the fading each other surfaces of the fourth and fifth metatarsal bones

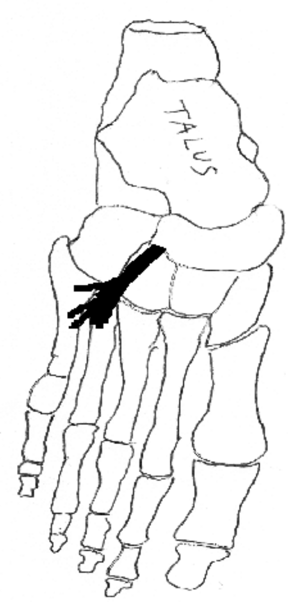

Figure 6. *Musculus peroneus tertius* — asymmetric distal attachment localised at the fourth and fifth metatarsal bones (own drawing modified in ACDSee and CorelDraw).

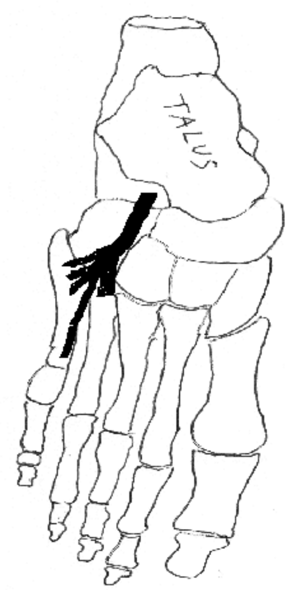

Figure 7. *Musculus peroneus tertius* — symmetric distal attachment with the accessory attachment to the distal part of the fifth metatarsal bone (own drawing modified in ACDSee and CorelDraw).

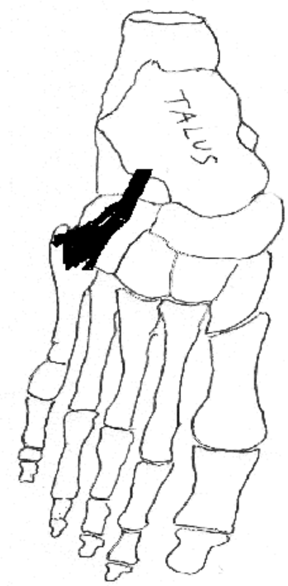

Figure 8. *Musculus peroneus tertius* — distal attachment localised on the proximal part of the fifth metatarsal bone (own drawing modified in ACDSee and CorelDraw).

and marked by the presence of additional attachments (the dorsal aponeurosis of the fifth phalanx and the base of the fifth metatarsal bone); found in 19.93% of cases (Fig. 7);

— type III — with the basic attachment occurring on the upper and external surfaces of the base of the fifth metatarsal bone with additional attachments (the dorsal aponeurosis of the fifth phalanx; the base of the fourth metatarsal bone); found in 12.46% of cases;

— type IV —with the basic attachment only, which is located in the range of the upper and external surfaces of the fifth metatarsal bone, often in the form of a fan; found in 9.96% of cases (Fig. 8).

The incidence of the individual types of *musculus peroneus tertius* distal attachment in relation to foetal age is presented in Figure 9.

On the basis of the studies of Loth [11, 12], Kaneff [8, 9] and Sokołowska-Pituchowa et al. [18, 19] it was decided to create a uniform typology of the *musculus peroneus tertius* in order to standardise and simplify the classification of its varieties. Loth [11, 12], describing in his papers the most common variants if the soft tissue structures in humans, also specifies, by means of comparative anatomy, the first appearance of this feature in animals. On this basis he creates his own typology of the human varieties by using evolution chronology. Among numerous types the following are distinguished:

— the pithecogenetic, which contains those human traits that were manifest for the first time among Primates, such as superciliary arches and specific ear shape;

— the anthropogenetic, which includes the varieties manifest for the first time in the highest Primates.

These types indicate the presence of traits which have come from human ancestors and are still manifest in variability analysis of the structure of the soft tissues of the body in contemporary humans. Loth [11, 12] also probes ahead, demonstrating the presence of structural variants of the soft tissues indicative of future developmental tendencies. The following forms are also distinguished:

— the eugenic (i.e. present only in humans, the change in shape of the pectoral muscles or the triceps muscle of the calf for instance);

— the progenic (i.e. typical for the human of the future, such as the development of the risorius muscle or the atrophy of the tendinous intersections of the *rectus abdominis* muscle).

To sum up, the final typology was based on the assumptions of Loth [11, 12] with regard to the evolutionary origin of the particular varieties of the *musculus peroneus tertius* found. The following three final varieties of the muscle under examination were therefore distinguished.

In type I (the pithecogenetic) the muscle was seen to be only a split-off from the fifth tendon of the *musculus extensor digitorum longus*. Its final attachment

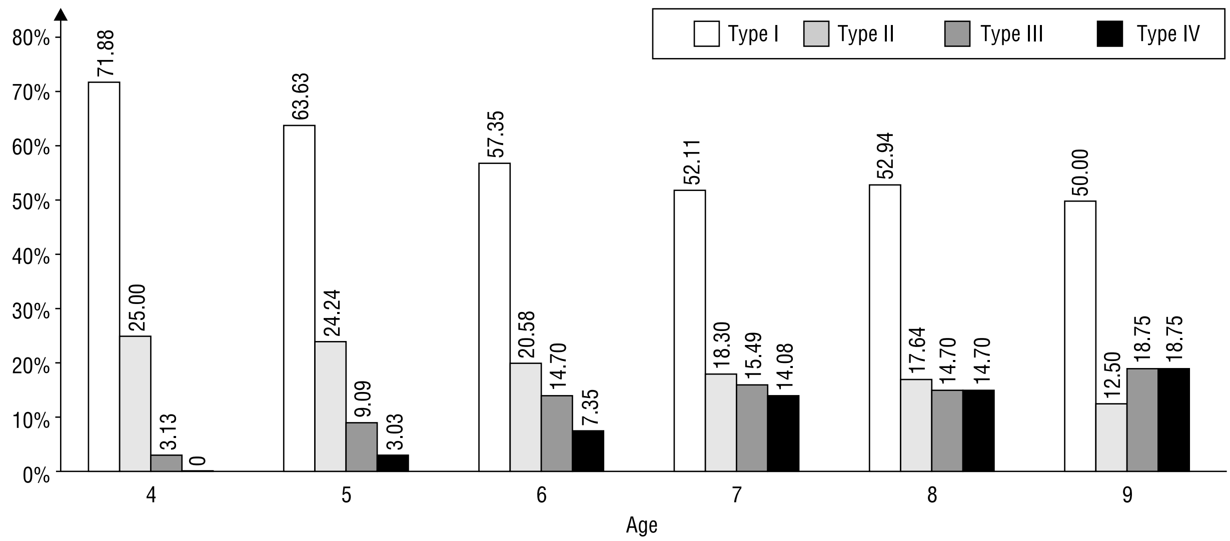

Figure 9. Incidence of individual types of the *musculus peroneus tertius* distal attachment at the stages of human foetal ontogenesis studied; I, II, III, IV — types of distal attachment of the muscle.

usually contained the fourth and fifth metatarsal bones. It was, at the same time, the most frequently encountered form and so may be defined as the basic form and typical for the foetal period.

In type II (the eugenic) the belly of the muscle was found to be only partially split from the *musculus extensor digitorum longus* with the final attachment containing the fourth and fifth metatarsal bones or being located in the range of the fourth and the fifth metatarsal bones with the presence of additional attachments.

In type III (the progenic) the muscle was typified by a completely independent belly and the attachment located most frequently in the range of the fifth metatarsal bone (Fig. 10).

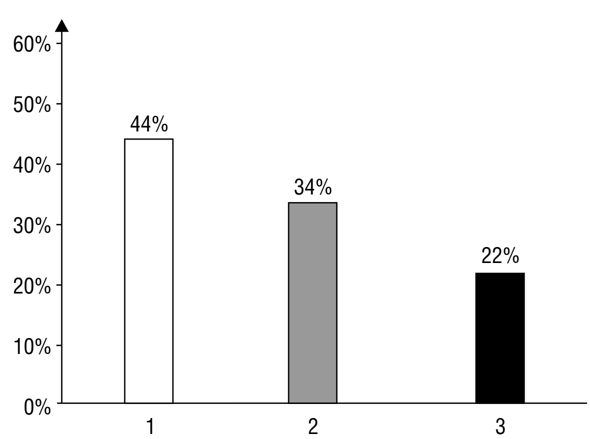

Figure 10. Final typology of the *musculus peroneus tertius* — incidence of the individual types; 1— pithecogenic; 2 — eugenic; 3 — progenic.

The analysis with respect to dimorphic differences and bilateral basic parameters of the *musculus peroneus tertius* demonstrated no statistically significant essential differences.

DISCUSSION

There is a rich anatomical literature regarding the variability of the *musculus peroneus tertius*, which contains studies carried out on adult individuals as well observations of human foetuses and Primates. The incidence of the muscle described varies among the authors referred to (Table 3). Current studies and the observations of Sokolowska-Pituchowa et al. [18, 19] and Kaneff [8, 9] demonstrate a lower incidence of the *musculus peroneus tertius* in human foetuses than at adults. Furthermore, data from the worldwide literature demonstrate the very late evolutional origin of this muscle, which was visible for the first time in anthropoids only and which became completely developed only in homo sapiens [1, 2, 7, 10, 13].

On the basis of the numerous scientific papers describing the muscle, especially those of Austrian researchers [10], it must be recognised that the reason for the presence of the *musculus peroneus tertius* in humans and in some monkeys is the change of lifestyle of these species. Krammer et al. [10] points to the example of gorillas, which move on the ground and lean on only two extremities. The bipedal gait results in the necessity of changing the position of the feet to stabilise the body and maintain balance [6, 7, 10]. Monkeys living in trees move on the ground with the external surface of the foot

Table 3. Incidence of the *musculus peroneus tertius* in humans and Primates (data obtained from own studies and the available literature)

Loth [1931] Pan troglodytes	Morton gorilla [1924]	Kaneff [1980]	Sokołowska--Pituchowa [1979]	Current work [2005]	Posmykiewicz [1934]	Joshi [2005]	Krammer [1979]	Sokołowska--Pituchowa [1974]
Primates		Human foetuses			Human adults			
5%	18%	89.7%	78.6%	83.16%	91.7%	92.6%	92.9%	92.1%

and this, as in orang-utans, makes it practically impossible to straighten it. A similar foot structure, not adapted to gait, can be seen in analysis of the structure of the human foetus. Many transformations are necessary before a bipedal stance can be taken, the most crucial being the shift of the point of maximal foot workload towards the medial border of the foot. This change in position is caused not only by the transformation of the osteoarticular system but also by the new human muscle, the *musculus peroneus tertius*, whose function consists in the return and abduction of the foot.

In the literature the *musculus peroneus tertius* is classified according two criteria [3, 7, 13–17]. The one assesses the proximal part of the muscle, while the other is based on evaluation of the final attachment and the course taken by its tendon.

The results obtained for the proximal part of the muscle were compared to the data taken from the adults, as there were no available studies of the foetal stage. The set of data obtained clearly shows that during the foetal period there is a greater incidence of independent muscle belly (18.2% in adults as against about 45% in foetuses). Only Joshi et al. [7] describe the presence of a completely formed *musculus peroneus tertius* in almost 90% at adults. Other researchers present different data.

The second classification of the *musculus peroneus tertius* is based on evaluation of its final attachment location and variability. A comparison of its location in the foetal period to that in adults shows significant differences. The results of authors for the foetal period also differ. This may be caused by the fact that the foetal material of Sokolowska-Pituchowa et al. [19] was limited to foetuses between 14 and 24 weeks of age, foetuses therefore which fall into the younger age groups, whereas our studies also take into consideration older foetal material. A comparison of the findings in foetuses in the younger age groups only to the results of Sokolowska-Pituchowa et al. [19] shows that the differences are not significant and may be the effect of inter-population differentiation. It was decided to take into account both the criteria referred to in making our own proposal for a typology of the muscle in question at the foetal stage. The typology is based on the thesis that emerged from the studies of Loth [11, 12], in which particular stress is laid on the evolutionary aspect of the development of the human soft parts.

We recognised type I as the pithecogenetic form, type II as the eugenic form and type III as the progenic form of the muscle. It should be noted that the high incidence of the *musculus peroneus tertius* in the examined foetal material as a whole should also be recognised as arising from the progenic form. The embryonic development of the *musculus peroneus tertius* is based on the progressive separation of this muscle from the extensor group as well as the removal of its final attachment toward the lateral border of the foot [1, 8, 10]. The presence of a relatively high proportion of more primitive forms of the *musculus peroneus tertius* and a lower incidence of the described muscle in foetuses than in adults may suggest that during the postnatal period this muscle is still developing as a result of the continuous increase, together with age, of physical activity. The relatively high degree of morphological and topographical variability in its individual development is the result of the substantial changes in the biomechanics of the shank and foot associated with the progressive adoption of the upright position by the small child as well as the extremely changeable physical forces acting on the lower leg during the process of education in walking. These factors, factors with a generally recognised background, have a decisive impact on the final shape of this muscle in human ontogenesis.

CONCLUSIONS

1. The *musculus peroneus tertius* is characterised by a proportional and almost linear development during human foetal ontogenesis.

2. Our present study does not reveal the presence of statistically significant bilateral and dimorphic

differences in analysis of the foetal development of the *musculus peroneus tertius*.

3. Three final varieties of the muscle under examination were distinguished: the pithecogenic (incidence 44%), the eugenic (34%) and the progenic (22%).

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