Types Of Muscle Fibres And Fibre Size Distribution Of Nerve To The Triceps Surae Muscle

Dr. Thin Thin Aung

Medical Lecturer, Department of Anatomy, Faculty of Medicine and Sciences, Universiti Sultan Zainal Abidin, (UniSZA), Kampus Kota, Jalan Sultan Mahmud, 20400, Kuala Terengganu, Terengganu, Malaysia, Email: thinpotatoe@gmail.com

Abstract
The purpose of this study was to observe the types of muscle fibres and fibre size distribution of nerve to the triceps surae muscle. Ten adult human donated embalmed cadavers (five males and five females) in the Department of Anatomy, Medical University (1), Yangon, Myanmar and five human foetuses, three male foetuses and two female foetuses (crown rump lengths ranging from 18 cm to 28 cm) from North Okkala General Hospital, Yangon, Myanmar, making a total of thirty lower limbs on both sides were dissected. The back of thigh, back of knee region and back of leg of both sides of the lower limbs were dissected.

Nerves to triceps surae of one adult specimen were post-fixed and stained neurohistologically with osmic acid to study the fibre size distribution of nerve and histochemically to demonstrate the types of muscle fibres. Altogether thirty adult human cadavers were used in this study.

Histochemically, triceps surae muscle was found to be composed of white, intermediate and red type fibres with red fibres predominating. Morphometrically, nerve to medial gastrocnemius muscle in adult human cadaver contained (1605) myelinated fibres on the right side and (1860) myelinated fibres on the left side. Nerve to lateral gastrocnemius contained (1191) on right side and (1075) on left side. Nerve to soleus muscle contained (628) on right side and (574) on left side. Fibre sizes of these nerves ranged from less than 2.5 µ to 17.5 µ. Histogram of each nerve showed unimodal distribution with a peak between (7.5 µ) to (10 µ).

Keywords: Histogram, myelinated nerve fibres, red muscle fibres, Triceps surae muscle

I. INTRODUCTION
TRICEPS surae is a tripartite muscle (from Latin, surae, calf) “three – headed calf” muscle which is an important postural and locomotor muscle. It is formed by the medial and lateral heads of gastrocnemius and soleus which are prominent superficial calf muscles of the posterior group and chief plantar flexors of the foot. Gastrocnemius and soleus fuse to form a common tendon called tendo Achilles which derives its name from a hero of Greek mythology. These two leg muscles are red fibre type and low threshold slow twitch fibres. They are small in diameter and rich in higher contents of myoglobin which can provide a steady supply of oxygen. So their speed of contraction is slow and they contract less forcefully, but do not get fatigued easily. The two muscles are supplied by the tibial nerve or internal popliteal part of the sciatic nerve.
which is formed by the five anterior rami of sacral plexus (L₄, 5 and S₁, 2, 3).

A. Type of Muscle Fibre Of Triceps Surae

The muscle fibres are divided into two types, red and white. Striated muscle fibres are classified as red, white and intermediate depending upon their diameters and their myoglobin contents.

Ham & Cormack [16] described that contraction time was generally two to three times longer in red than white muscle. The relatively slow 'tonic' twitch or 'S' type lasting about 75 msec and fast 'phasic' or 'F' type with a duration of 25 msec.

Reis & Wooten [23] stated that the twitch contraction took longer duration and they were more easily tetanized. Therefore red fibres, being capable of sustained activity for longer period than white fibres, were well adapted, to supply their energy requirement. White fibres were able to undergo faster contraction and were more suitable for short burst of activity. He also stated that blood flow was three times greater in the red muscle than in the white muscle in the limbs. Alkaline phosphatase activity was also significantly greater in red than in white ones.

Dubowitz & Pearse [11] mentioned that there were two types of skeletal muscle, Type I, slow twitch fibres and type II, fast twitch fibres. Type I fibres containing many mitochondria, stained strongly with succinate dehydrogenase activity and myoglobin although they did not stain with phosphorylase. Type II fibres were longer and containing few mitochondria and thus stained less strongly with succinate dehydrogenase activity. However, these fibres stained intensely, black with phosphorylase activity and show no reaction for myoglobin. Intermediate fibres stained brown for phosphorylase activity although they showed only moderate staining for both myoglobin and succinate dehydrogenase activity.

B. Fibre size distribution of nerve to striated muscle in general with special reference to the nerve supplying the triceps surae.

The peripheral nerve had been generally divided into myelinated and unmyelinated fibres by the presence or absence of myelin sheaths enveloping the axons.

Truex and Carpenter [24] stated that the slender axons were enveloped by thin Schwann cells sheath, its basement membrane and fine strands of collagen fibres in the peripheral nervous system.

Ham and Cormack [16] observed that the numerous unmyelinated fibres were also found in gray and white matter of the spinal cord and brain in the central nervous system.

Elliott [12] mentioned that the motor fibres comprised the large myelinated efferents of ventral gray column motor neurones (alpha efferents) which supplied extrafusal muscle fibres, the smaller myelinated gamma efferents which ran to muscle spindles and the fine non-myelinated autonomic efferents which supplied vascular smooth muscle. The sensory fibres comprised a range of myelinated fibres distributed to the muscle spindles, neurotendinous sensory endings, terminals in the fascia and non-myelinated pain afferents of uncertain origin. The essential elements of the peripheral nerves were the afferent sensory fibres and the efferent motor fibres. Major difference between these fibres (except their terminals) was in their diameters.

The myelinated peripheral nerve fibres in which axon or axis cylinder was composed of delicate neurofibrils embedded in a semifluid neoplasm. It was surrounded by a relatively thick myelin sheath and outside this a nucleated membranous neurilemma sheath. The myelin sheath consisted of a fatty substance, myelin, supported by a reticulum.

Fulton [14] classified them, based on relative conduction velocities, functional nature of fibres, total fibres diameter. The fibres were divided into three major categories, A, B and C corresponding to three peaks in distribution of velocities. The group A fibres further divided into three sub groups termed alpha, beta, and gamma efferents and C fibres were non-myelinated. The group A alpha fibres were both the widest and the
most rapidly conducting, and the C fibres, the narrowest and slowest conducting. In mammals a subclass of
non-autonomic fibres similar in conduction speed to B fibres existed, these were termed Aδ fibres.

The afferent (sensory) fibres were divided into the Aα, Aδ and C groups. The largest of these (Aα fibres)
included the axons of the encapsulated cutaneous, joint and muscle receptor and some large alimentary or
related interoceptors. The Aδ fibres belonged to various nociceptors and the C fibres had thermoceptive,
nociceptive and interoceptive functions.

The somatic efferent fibres included Aα, Aβ and Aγ fibres. The Aγ fibres innervated extrafusal muscle only
being up to 22µ in diameter and conducting at a maximum of 120 m/sec. The Aβ fibres were restricted to
collaterals of Aα fibres, forming plate endings on intrafusal muscle fibres and the Aγ fibres were exclusively
fusimotor nerves to plate and trail endings on intrafusal muscle fibres. Autonomic efferent comprised the
preganglionic B fibres and post ganglionic sympathetic and parasympathetic axons of the C (non-
myelinated) group.

Elliott [12] described the histograms of myelinated nerve fibre size of muscle nerves, cutaneous nerves,
dorsal roots and vertral roots. Histogram of muscular nerves showed two peaks with a plateau between them.
One peak occurred around 14-15 µ in diameter were sensory and those of smaller diameters were motor to
main (extrafusal) muscle fibres. The second peak occurred around 4-5 µ in diameter and also contained both
afferent and efferent fibres, the gamma efferents consisting large part of this group. The cutaneous nerves
also showed two peaks. One peak was around 9-10 µ in diameter and the second peak was around 4-5 µ in
diameter.

Bowden & Mahran [4] discussed that unimodal fibre size distribution in the muscle innervated by several
nerves did not necessarily mean that spindles were absent and bimodal ones did not imply that it was the
only nerve supplying the spindles.

II. Objectives

A. The purpose of this study was
1. To study the types of muscle fibres of triceps surae muscle
2. To study the fibre size distribution of nerve to the triceps surae muscle.
B. Null-hypothesis
1. There will be no difference between the types of muscle fibres in triceps surae muscle
2. There will be difference between the fibre size distributions of nerve to the triceps surae muscle.

III. Results

A. Type of Muscle Fibre of Triceps Surae

1) Materials and Methods

The medial & lateral gastrocnemius and the soleus muscle of ten human cadavers and five fetuses were
fixed in 10% formalin, embedded in 20% gelatin and cut transversely at 40µ. Then the sections were stained
with Sudan Black B stain to differentiate the types of muscle fibres.

2) Results

The medial & lateral gastrocnemius muscle and the soleus muscle of human cadavers were found to be
composed of red, white and intermediate fibres with red fibres predominating. The photograph of the cross
section of the gastrocnemius muscle of human cadaver showing muscle types was taken.
3) Discussion

Le Gros Clark [20] described that there were two main types of striated muscle fibres, red and white. More slowly contracting fibres predominated in the deeper components of fasciculi and they also tend to be reddish in colour. He also stated the presence of transitional form between the two main types.

Boyd [5] mentioned that the muscle fibres could be differentiated into three types, red, white and intermediate. The present findings of red, white and intermediate fibres in triceps surae muscle supported his statement.

Ranvier [22] found that red fibres predominated than white fibres and intermediate fibres. The red fibres had a slower, more prolonged contraction which generated the sustained tonic forces characteristic of postural muscle. Slow twitch muscles were red because contained large amount of protein myoglobin while fast twitch muscles were paler in colour.

Chusid [6] stated that the white fibres are wider and have lesser amount of myoglobin and cytochrome in a few mammals, such as the rabbit and guinea pig. However in most of the muscles there are mixtures of red and white fibres. The redness of fibres depends upon its content of muscle haemoglobin. The white muscle fibres have large number of sarcostyle (myofibrils) and a minimum of sarcoplasm.

Bloom and Fawcett [3] discussed that the red muscle fibres have the reverse with fewer sarcostyles, and increased amount of sarcoplasm. They are characterized by their small diameter, more sarcoplasm, poor cross striations and better longitudinal striations. Red fibres have many lipid droplets and nuclei occupied more central position and are rarely found at the periphery.

Cooper [9] classified that there were two types of skeletal muscle, fast twitch and slow twitch fibres. Predominance of type II fibres (fast twitch fibres) were observed in the periphery of fasciculi and fewer type I fibres (slow twitch fibres) were found in periphery rather than in central region.

James [19] mentioned that Type I, slow twitch fibres were small and contained many mitochondria and lipid. Type II, fast twitch fibres were often large and contained few mitochondria and much glycogen.

Fulton [14] observed that most muscles showed a mixture of fibres which were known as type I (slow) and type II (fast) fibres.

Thus, the triceps surae muscle seemed to be slow twitch fibre. Triceps surae is composed of white, intermediate and red type with predominance of red type fibres. Therefore, finding of predominance of red type fibres in the triceps surae suggest that the muscle is a slow twitch type of muscle with abundant stretch receptors.
Fig. 1 represents the cross section of the gastrocnemius muscle of human cadaver showing red muscle fibre (r), intermediate muscle fibre (i), white muscle fibre (w), sudan black stain x 40

B. Fibre Size Distribution Of Nerve To Striated Muscle In General With Special References To The Nerve Supplying The Triceps Surae

1) Materials and Methods

The nerves supplying the respective heads of the triceps surae muscles of human adult cadavers and foetuses were taken at almost the same distance from their parent nerve trunks, from both left and right sides. They were fixed in 10% formalin and then post fixed and stained with 2% osmic acid for seven days. The tissues were then embedded in 20% gelatin and cut by frozen sections. Transverse sections of 10 μ thicknesses were prepared for light microscopy using routine histological procedure. The nerve was cut just below the point of origin from main nerve. The myelinated fibres was counted and measured in group of 2.5 intervals by using an eye piece micrometer under the light microscope. Histograms were drawn for each nerve.

2) Results

In the present work, the nerve to triceps surae muscle of right and left lower limbs showed the followings.

(1) In case of right side, total numbers of myelinated nerve fibres counted were (1605) for medial gastrocnemius, (1191) for lateral gastrocnemius and (628) for soleus. In case of left side, total numbers of myelinated nerve fibres counted were (1860) for medial gastrocnemius, (1075) for lateral gastrocnemius and (574) for soleus.

(2) Size of nerve fibres ranged from less than 2.5 μ to 17.5 μ on both sides of these muscles.

(3) The histogram showed unimodal distribution with a peak between (7.5μ) to (10μ). This observation was not mentioned in available literature. Thus our finding coincides with the literature.
TABLE I
THE DISTRIBUTION OF MYELINATED NERVE FIBRE OF NERVE (N) TO MEDIAL GASTROCNEMIUS (MG), LATERAL GASTROCNEMIUS AND SOLEUS (S) MUSCLE IN ADULT HUMAN RIGHT(RT) SIDE AND LEFT (LT) SIDE

<table>
<thead>
<tr>
<th>Names of the n</th>
<th>Diameter of the nerve fibres on µ</th>
<th>Total number of myelinated fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-2.5</td>
<td>2.6-5</td>
</tr>
<tr>
<td>N to MG (RT)</td>
<td>150</td>
<td>335</td>
</tr>
<tr>
<td></td>
<td>9.3%</td>
<td>20.9%</td>
</tr>
<tr>
<td>N to LG (RT)</td>
<td>115</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>9.7%</td>
<td>18.5%</td>
</tr>
<tr>
<td>N to S (RT)</td>
<td>11</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>1.8%</td>
<td>8.6%</td>
</tr>
<tr>
<td>N to MG (LT)</td>
<td>180</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>9.7%</td>
<td>19.9%</td>
</tr>
<tr>
<td>N to LG (LT)</td>
<td>130</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>12.1%</td>
<td>17.2%</td>
</tr>
<tr>
<td>N to S (LT)</td>
<td>17</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>3.0%</td>
<td>23.7%</td>
</tr>
</tbody>
</table>

Fig. 2 Histogram of the fibre size distribution of nerve to medial gastrocnemius muscle of adult human right side
Fig. 3 Histogram of the fibre size distribution of nerve to medical gastrocnemius muscle of adult human left side

Fig. 4 Histogram of the fibre size distribution of nerve to soleus muscle of adult human right side

Fig. 5 Histogram of the fibre size distribution of nerve to soleus muscle of adult human left side
3) Discussion
Lloyd [21] classified the myelinated fibres into group I, II, III and non-myelinated fibres forming group IV fibres. Group I fibres were large in diameter (12 – 22 µ) and included the primary sensory fibres of the muscle spindles (Group Ia) and the slightly smaller fibres of the Golgi tendon organs (Ib). Group II comprised the fibres of the secondary terminals of muscle spindles with diameter of about 6 to 12 µ. Group III fibres, 1 – 6 µ in diameter, had free nerve endings in the connective tissue sheaths surrounding and within muscle and appeared to be nociceptive related to the experience of "pressure pain". The paciniform endings of muscle sheaths might also contribute fibres to this class. Group IV included non-myelinated fibres below 1.5 µ again with free nerve endings in muscle sheath and interior chiefly with nociceptive function.

In present work, the associated nerve fibres were noted as myelinated fibres and their populations and diameter were measured.
Size of nerve fibres for right and left nerve to triceps surae muscle were found to be ranging from \((2.5\,\mu\text{m})\) to \((17.5\,\mu\text{m})\) and these data revealed that the nerve supplying the triceps surae muscle contained all three groups of fibres namely group I, II and III according to the classification of the myelinated fibres by Loyd [21].

Elliott [12] classified myelinated fibres into three anatomical groups, A, B and C depending on decreasing order of diameter as well as decreasing order degree of myelination. Group A fibres had heavy myelination with a diameter of \(11 – 20\,\mu\text{m}\); Group B fibres had moderate myelination with a diameter of \(5 – 11\,\mu\text{m}\) and Group C fibres were unmyelinated and had diameter of \(0.5 – 4\,\mu\text{m}\).

Hunt [18] stated that myelinated fibres varied greatly in size. The fine fibres had diameter from \(1 - 4\,\mu\text{m}\), those of medium size \(5 – 10\,\mu\text{m}\) and the largest from \(11-20\,\mu\text{m}\). The myelinated fibres conducted more rapidly than unmyelinated ones. The speed was proportional to the diameters of fibres and more especially to the thickness of the myelin sheath.

Hunt [18] described that the relationship between nerve fibre size and type of receptors. Afferent nerves having spindles and tendon organs had a bimodal fibre size distribution with peak between \(4-8\,\mu\text{m}\) and \(14-20\,\mu\text{m}\), whereas those having only tendon organs had a unimodal distribution with most fibres above \(12\,\mu\text{m}\). The muscle spindles were supplied by fibres of Group I (12-20\,\mu) and Group II (4-12\,\mu). Tendon organs were supplied by Group I (12-20\,\mu) fibres only. In a mixed nerve to a muscle, Group II fibres overlapped nerve fibres supplying other sensory organs such as pacinian corpuscle and extrafusal motor endings.

There were numerous muscle spindles observed in the triceps surae muscle in the present finding. Group I fibres contributed to primary sensory endings of muscle spindles and group II and group III fibres contributed to secondary sensory ending of muscle spindles. This finding was in accordance with his statement.

Gray [15] stated that the presence of large fibres greater than \(14\,\mu\text{m}\) could be taken as presumptive evidence for the presence of stretch receptors and a bimodal distribution of nerve fibre size would be strongly suggestive of the presence of muscle spindles.

However, in the present finding, histogram of the sizes of nerve fibres supplying the triceps surae muscle revealed unimodal distribution in spite of the presence of muscle spindles and tendon organs. This may be due to a variety of conditions that altered the diameters of the nerve fibres.

Cooper [9] mentioned that there were many pitfalls in making nerve fibre counts, for example, the extent of shrinkage of nerve fibre during preparation caused difficulties in assessing the diameter of nerve fibres in the nerves of very young and very old individuals.

Elliott [12] described that histogram of muscular nerves showed two peaks. The peak which occurred around \(4-5\,\mu\text{m}\) in diameter contained both afferent and efferent fibres, the gamma efferents consisting large part of this group.

The fibres ranging from \((2.6\,\mu\text{m})\) to \((5\,\mu\text{m})\), observed in the present work suggests that it also carried gamma efferent fibres to the intrafusal muscle fibres.

**IV. CONCLUSION**

The triceps surae is a tripartite muscle formed by the medial and lateral heads of gastrocnemius and soleus. Triceps surae is composed of white, intermediate and red type with predominance of red type fibres. Therefore, finding of predominance of red type fibres in the triceps surae suggest that the muscle is a slow twitch type of muscle with abundant stretch receptors.

Total numbers of right and left myelinated nerve fibres counted were (1605 & 1860) for medial gastrocnemius, (1191 & 1075) for lateral gastrocnemius and (628 & 574) for soleus, respectively.

The size of fibres ranged from less than \((2.5\,\mu\text{m})\) to \((17.5\,\mu\text{m})\). The histograms for individual nerve show unimodal distribution with a peak between \((7.5\,\mu\text{m})\) to \((10\,\mu\text{m})\) diameters. The data from present work reveals
that the nerves supplying the triceps surae muscle contain all three groups of fibres namely, group I, II and III.

It is generally accepted that the tendon organ is supplied by group I fibre and the muscle spindle is supplied by group I and group II fibres, and myelinated fusimotor fibres filled into group III. Therefore, the present finding shows that the nerves supplying the triceps surae muscle carried group I (12 µ - 20 µ) and group II (6 µ - 12 µ) sensory fibres, which contribute to the primary and secondary endings respectively of muscle spindle. The fibres ranging from (2.6 µ) to (5 µ), observed in the present work suggests that it also carried gamma efferent fibres to the intrafusal muscle fibres. Therefore, the nerve supplying the triceps surae contains afferent fibres to sensory organs in addition to its motor fibres to the extrafusal and intrafusal fibres.

REFERENCES


