

Are there any differences of the size of muscle spindles in the EDL muscle of a mouse and has same distribution of muscle spindles been shown in every EDL muscle?

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Summary

The muscle spindle is one of the famous mechanoreceptors in the muscle ruled by central nervous system via sensory nervous system and motor nervous system.

It is usually thought to be related with the stretch reflex to protect muscle injury by strongly stretched. The shape of the muscle spindles is believed one typical one in the meaning of textbook of physiology. This paper is described the review of the muscle spindle at first. At the second different size were found and the distribution of the muscle spindles of 20 extensor digitorum longus (EDL) of 10 mice were studied. At the third a few type of connection of the muscle spindles were shown.

(Review of the muscle spindle)

The muscle spindle is one of famous and important mechanoreceptors for animals that

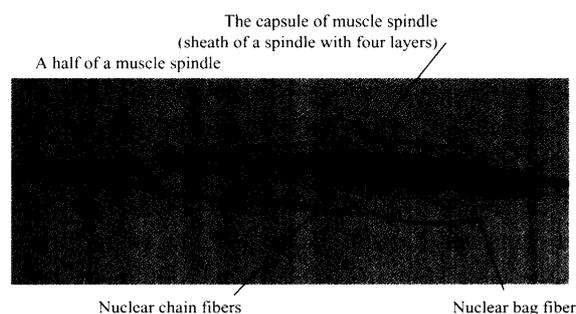


Fig. 1-a

have them. In the text book of physiology and anatomy the muscle spindle of a rodent is illustrated or figured like 1-a (real, longitudinal), Fig 1-b ((real, longitudinal), and Figure 1-c (real, horizontal).

A half of a muscle spindle
The Group Ia sensory nerve coiled on the nuclear bag fiber
Nuclear chain fiber

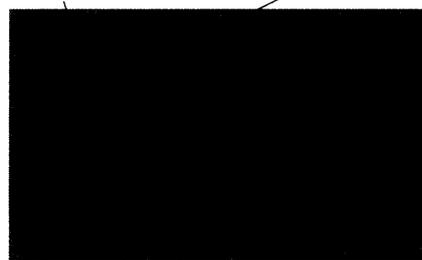


Nuclear bag fiber
Sensory and motor neuron go through nuclear bag fiber
Two thick intrafusal fibers are called the nuclear Sheath of the spindle bag fiber. They have many layered nuclear chain fiber at the region.

Fig. 1-b (real, horizontal)

(A muscle spindle of horizontal) (Fig. 1-c)

Horizontal photographed of a muscle spindle
group Ia sensory neuron Nuclear bag fibers



Nuclear chain fibers extrafusal fibers
Sheath (the capsule of a muscle spindle with four layers)

Fig. 1-c

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Two thin intrafusal fibers are called the nuclear region. Four intrafusal fibers are chain fibers. Their nuclear are in line found in rodent skeletal muscle.

A muscle spindle has four-layered capsule around spindle and has the spindle shape at region (This capsule is believed originated from the body membrane.¹⁾ In a capsule, there are two types of intrafusal muscle fibers. One type is called a dynamic nuclear bag fiber and a static nuclear bag fiber. Another is called dynamic nuclear chain fiber and a static nuclear fiber.¹⁾²⁾³⁾⁴⁾

The part of the central part of the capsule is called the part. Usually muscle spindle is longitudinally showed Figure 1-a and Figure 1-b (real longitudinal). In the horizontal view is Figure 1-c.

Muscle spindle has the central part that is called a part and two thinner ending parts. This is the reason why it is named spindle.

In the part each intrafusal muscle fiber has nuclear and enrolled afferent sensory nerve as group Ia

At the region, Ia afferent sensory nerve coils one or two intrafusal fibers. (Fig 1-a, Fig 1-b, and Fig 1-c). Motor nerve rules intrafusal fibers to contract via γ motor neuron a part from region (Fig 1-a and Fig 1-b)

Usually muscle spindles are located in parallel with extrafusal fibers. If extrafusal fibers are strongly stretched, Ia sensory nerve is extended and feels the extension. Ia afferent sensory neuron sends this stimulation to spinal cord, then central nervous system controls γ motor neuron and contracts intrafusal muscle. Extrafusal muscle fibers are contracted to protect muscle injury by strong stretching.¹⁾²⁾³⁾⁴⁾

However, Bridgeman indicated another role of muscle spindles. He suggested muscle spindles have a role as a receptor of pressure.⁵⁾⁶⁾

A real muscle spindle was shown along and in extrafusal muscle. It is stained PGP 9.5.(Fig 2) Usually length of a muscle spindle is believed

Nerve fibers



Group Ia sensory neuron coils around intrafusal fibers

Fig. 2 A muscle spindle in a EDL muscle stained PGP 9.5

from about 80 to 100 μ m. Diameter is also done from about 20 to 50 μ m.

Our questions are two in this study. One question is if all muscle spindles have the same shape and lengths in each EDL muscle or not. Second one is if the muscle spindles are distributed same in every EDL muscles which control four fingers of lower extremities with four tendon or not.

Materials and Methods

Ten normal ICR mice were used. Each mouse was anesthetized by Nembtal (0.5ml/10g). Weight of mice was from 29g to 32g. They were from 8 weeks to ten weeks birth.

After anesthetization, bilateral lower extremities were desected instantly and fixed by 4% formalin. After fixation each EDL muscle under tibialis anterior was removed and put on the plastic laboratory silicone coating dish with five pins after distal tendon was torn as distal tendon was able to divided four tendons which were related each foot fingers from II to V.

After these preparations, 20 EDL muscles of 10 mice on the dish with pinned on five tendons were longitudinally torn every few extrafusal muscle fibers under a stereoscopy using X32 magnification with two tweezers. When each muscle spindle were found and picked up, a

picked up muscle spindle was arranged side by side in parallel with other spindles as well as possible. Each arranged muscle spindle was measured its length and diameter at the region. Distribution of muscle spindles in 20 EDL muscles from 10 mice were studied.

Results

1 Differentiation of size of the muscle spindle of 20 EDL muscles in 10 mice.

198 muscle spindles were dissected from 20 EDL from 10 mice. We classified three types in the shape and length of 198 muscle spindles in EDL of 10 mice. (Table -1) One type is named the thinner and longer type. Numbers of them were dissected 72 in 198 spindles. The average length of type one was $2739.3 \pm 730.6 \mu\text{m}$. The average maximum diameter at the part was $40.3 \pm 7.1 \mu\text{m}$.

The second type was named standard type that was dissected 115 per 198 muscle spindles. The average length was $2244.5 \pm 686.1 \mu\text{m}$. The average maximum diameter at the part was $52.0 \pm 7.5 \mu\text{m}$.

The smallest type was found 11 in 198 spindles. The average length of them was 1447.6

$\pm 371.3 \mu\text{m}$. The average diameter was 35.6 ± 5.0 .

As we classified the longitudinal length and diameter of the part, we did not calculate significant difference in this study. However, in our next study of pig EDL we found significant difference in this concept.

A is type one: the thinner and Longer type.
B is type two: standard type.
C is type three: smallest type



Fig 3 Three types of muscle spindles

2 How were muscle spindles located in 20 EDL muscles in 10 mice?

There were 20 EDL muscles from 10 mice. Dispersion from seven to fourteen muscle

	Rate of appearance	Longitudinal length ()	Diameter()
The longer type	72/198 (36%)	2739.3 ± 730.6	40.3 ± 7.1
Standard Type	115/198 (58%)	2244.5 ± 686.1	52.0 ± 7.5
The smaller Type	11/198 (6%)	1447.6 ± 371.3	35.6 ± 5.0

Table 1 Comparison of three types of muscle spindles

	Numbers of EDL	Dispersed pattern	III pattern	III IV pattern	V pattern
Numbers of muscle spindles	20	7	6	4	3
Rate (%)	100	35.0	30.0	20.0	15.0

Table 2 Four types of dispersion of muscle spindles in 20 EDL muscles Numbers of EDL

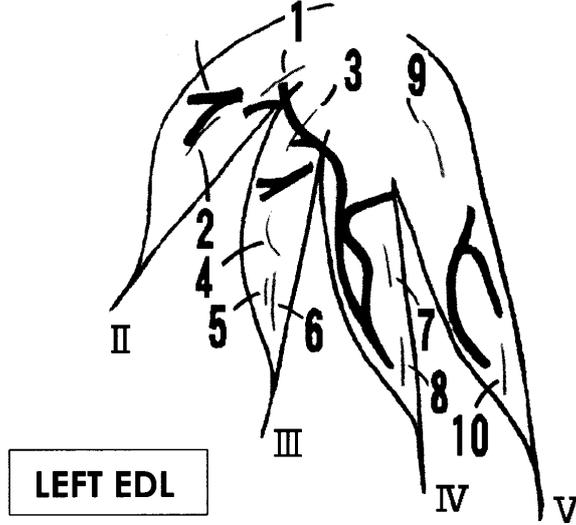
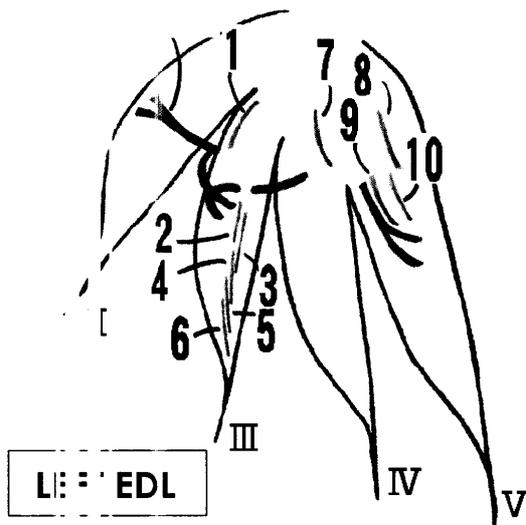
spindles was found in each EDL muscle.

Three types of dispersion of muscle spindles in EDL muscle were classified. One is evenly dispersed in every tendon from II to V tendon. This was named standard dispersed type and

seven of them were found among 20 EDL muscles. Second one was found six muscle spindles at III tendon. This was named III concentrated type and six of them were found among 20 EDL muscles. The third type was III and IV concentrated. (Fig. 2 and Table 3)

II Type

Standard Dispersed Type



III and IV Type

V Type

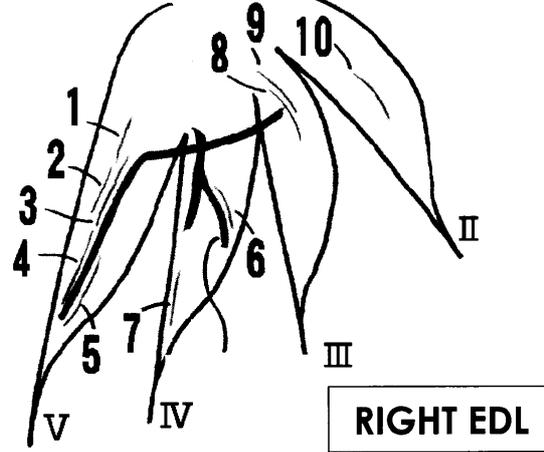
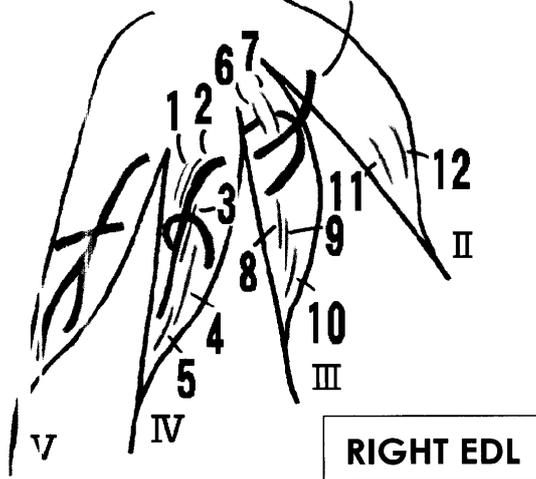


Fig. Distribution of Muscle spindles in 20 EDL muscles in 10 mice Blue lines are indicated the nerve. Muscle spindles are illustrated in red.

How many muscle spindles were distributed in each muscle of the EDL?

Table 3 shows the number of the muscle spindles picked up from each muscle of the EDL. Muscle III of the EDL contained the most spindles. Seventy-eight out of 204 spindles that

corresponded to 38.2% of the total spindles were located in muscle III. In some cases, two muscle spindles appeared to be connected at their terminal (Fig. 5) . Forty-eight out of 204 muscle spindles belonged to this type.

Number of muscle spindles	Total	II	III	IV	V	Two muscle spindles combined
Numbers of muscle spindle	204	22	78	63	35	48
Percentage (%)	100	10.8	38.2	30.9	17.2	23.5

Table 3 Distribution of muscle spindles of 20 EDL muscle in 10 mice

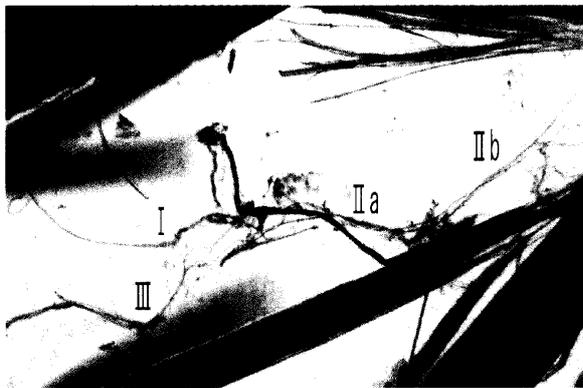


Fig. 5 Two muscle spindles were connected at their terminal that had shown layer. Two types of connection of muscle spindles I, IIa, IIb, and III were muscle spindles. IIa and IIb are combined at their terminal layer.

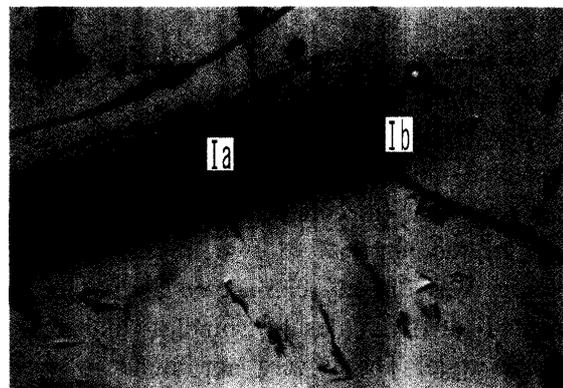


Fig. 6 This was shown as one spindle with two regions.

Discussion

1 Three types of the muscle spindle in 20 EDL muscles from 10 mice

In previous study there were few researches and text books in anatomical and physiological fields indicated that there were a few types of the muscle spindle in the same muscle in this case EDL muscle in the view point of shape of muscle spindle.

This study showed three types form the viewpoint of shape and length and diameter at

the area in 20 EDL muscles of 10 mice. As this was only studied at stereo microscopy level, it was not able to show clearly structural difference in these three types of muscle spindles. Further study is needed to make these three types of differences from the viewpoint of anatomical structure and physiological function.

2 Dispersion of muscle spindles in 4 separated tendonated EDL muscle

In this point, there were also few studies. Most

important results were that every tendoned EDL muscles did not have same numbers and dispersion muscles spindles, so classification was one of thinking. Although distribution of muscle spindles were not equal in every EDL muscles, each mouse in 10 mouse did not show different function in their bilateral lower extremities, in other words, these mice were not able to find any different movement in the means of physiology, kinesiology, and kinematic function or motor control.

This dispersion of muscle spindles remind us they had normal function and moved normally, but they must have had individualities in their motor function.

3 Longitudinal or tandem connection of two muscle spindles

In a few EDL muscle, two muscle spindles were connected tandem were found. There were at least two different connections. One was found layer of the terminal of two muscle spindles. Another was directly connected at the end of terminal of two muscle spindles like really tandem style. These were not found in every EDL muscle.⁷⁸⁾

Therefore these were also indicated individuality of motor function in a mouse.

Conclusion

1 Three different length and diameter of muscle spindles were classified in 20 EDL muscles of 10 mice.

2 Four types of different distribution of muscle spindles were studied in 20 EDL of 10 mice.

3 Two different longitudinal connection of muscle spindle were shown.

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