

Muscle Spindle and Comparison of Fish Muscle Spindle with Other Vertebrates

Review / Derleme

Received / Geliş Tarihi
27.09.2017

Accepted / Kabul Tarih
11.12.2017

DOI
10.28955/alinterizbd.340209

ISSN 2564-7814
e-ISSN 2587-2249

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Abstract: The aim of this study is to bring together the literature knowledge on muscle spindels that has been made up to until now and compare fish muscle spindels with other vertebrates. Muscle spindles are stretch receptor of skeletal muscles which detect the rate and degree of muscle length. According to the available literature, this review is considered as a one in making a comparison of fish muscle spindle and other vertebrates. Fish muscle spindle possesses single intrafusal muscle fiber similar to snake and lizard muscle spindle and have a double capsule similar in all vertebrates have studied. No significant differences in the length and diameter of intrafusal muscle fibers by comparison of muscle size. In fish and other vertebrates muscle spindles are supplied with one sensory ending (exception in mammalian may, in addition, be supplied with one or more secondary sensory endings) and receive its motor innervation from branches of axons that also innervate extrafusal muscle fibers. No investigation has been done about motor innervation of fish muscle spindle.

Keywords: Muscle spindels, fish anatomy, fish muscle

Kas İğleri ve Balık Kas İğlerinin Diğer Omurgalılar İle Karşılaştırması

Öz: Bu çalışmanın amacı bugüne kadar kas iğleri üzerine yapılan çalışmalarını bir araya getirmek ve balıklar ile diğer omurgalıların kas iğlerini karşılaştırmaktır. Kas iğleri kas uzunluğunun oran ve yoğunluğunu belirleyen iskelet kaslarının germe reseptörleridir. Bu çalışma mevcut literatürlere göre diğer omurgalılar ile balık kas iğlerinin bir karşılaştırması olarak düşünülmüştür. Balık kas iğ yapısı tek intrafuzal kas lifi yılan ve kertenkelelere benzer ve bugüne kadar çalışılmış diğer omurgalılarda olduğu gibi çift kapsüllüdür. Kas büyüklüğü karşılaştırıldığında intrafuzal kas fibrillerinin uzunluk ve çapında önemli farklılıklar yoktur. Balık ve diğer omurgalılarda kas iğleri bir algılayıcı ile sonlanır (memeliler hariç, bir veya birkaç algılayıcı ile de sonlanabilir) ve ektrafuzal kas liflerini sinir sistemine de bağlayan aksonların kollarından motor sinir bağlantısını sağlar. Balık kas iğlerinin motor sinir bağlantıları hakkında herhangi bir çalışma bulunmamaktadır.

Anahtar Kelimeler: Kas iği, balık anatomisi, balık kası

1. INTRODUCTION

Muscle spindles are complex neuromuscular end- organ in skeletal muscles of vertebrates sensitive to muscle length and changes in muscle length. They were first noticed and described in frog muscle by Weisman (1861). The essential feature of the muscle spindle its containment of nerve and muscle components. They are composed of small (intrafusal) muscle fibers that lie as bundles in parallel with ordinary (extrafusal) muscle fibers and receive both a sensory and a motor innervation. The middle region of spindle is called equatorial region and regions on both sides of the equatorial region is called polar regions (Sherrington, 1894). Although most of the previous studies indicate that the fish lacks the muscle spindle (Fesard and Sand, 1937; William et al., 1979), Maeda et al. (1983) have proposed appearance in the jaw closing muscle of fish, and has found monofibril spindles in this muscle in salmon. In fish the first observation was made by Maeda et al. (1983) where they observed it among the superficial extrafusal fibers of jaw- closing muscle, adductor mandibular in *Oncorhynchus masou* (Brevoort, 1856). The receptor has not been confirmed; meanwhile Saed (1990) has made a comprehensive research for the receptor in the jaw-closing muscle of trout. There are no extensive

studies on fish muscle spindle and little attention has been paid for it. The aim of the present study was to give a background on muscle spindle and compare fish muscle spindles with other vertebrates.

Intrafusal Muscle Fibers

Based on the study which carried out by Maeda et al. (1983) fish muscle spindle has single intrafusal muscle fiber and this homologous of snake (Palot and Ridge, 1972) and lizard (Proske, 1969) muscle spindle which possessed single intrafusal muscle fiber and this incompatible with Amphibian and Mammals muscle spindle which possessed more than one intrafusal muscle fiber inside their capsules named as bag₁, bag₂ and chain fibers in Mammals (Banks et al., 1974) and as large and small intrafusal muscle fibers in Amphibians and bird spindles contained two or three types of intrafusal fiber but not categorized to nuclear bag and nuclear chain fibers and separable into types based on differences in myosin heavy chain composition and motor innervation (Mair, 1992).

Length and Diameter

The histological study performed by Maeda et al. (1983) on salmon muscle spindle revealed that the long of the intrafusal muscle fiber was 1.800 μm and the diameter 2.8 μm at polar region.

In frog large intrafusal fibers have mean diameters ranging between 9-37 μm depending on the muscle of origin, while small fibers have mean diameters 9-48 μm (Yoshimura et al., 1990).

In the avian muscle spindle the diameter of intrafusal muscle fiber in two synergistic skeletal muscles, the anterior (ALD) and posterior (PLD) latissimus dorsi varied from 5.0 to 16.0 μm and 4.5 to 18.5 μm , respectively (William K, 1999).

In mammals spindles, the bag fibers are the longest, the bag₂ generally being longer than the bag₁. Kucera (1982) reported that mean polar lengths of 29.47 μm for bag₂ fibers, 27.60 μm for bag₁, and 12.31 μm for typical chains (tenuissim of cat, frozen sections).

Capsule

Almost all vertebrates, including fish have the same capsule structure (Ovalle, 1976). Muscle spindle has an outer and an inner capsule. The capsule is lamellate structure that encloses the sensory innervation, its width range between 100 to 150 μm at equator and the length usually between 2 to 4 mm and varies according to the number of sensory endings present. The capsule lamellae are consists of several concentric and tangent cell layers alternating with layers filled with collagenous fibrils. The outermost capsule layer is composed of thick collagenous fibrils and scattered fibrocytes. The innermost layer is composed of a lining of fibrocytes (Ovall and Dow, 1988)

Number and Distribution

Different muscles possess characteristic number of spindles, although there is considerable individual variability, at least in an outbred population (Chin et al., 1962). Quantitative comparisons have normally been made using spindle density, which is simply the number of capsules per gram of the adult muscle. On this basis it is often stated that spindles are relatively common in small muscles involved in fine control, such as the intrinsic muscles of the hand (Cooper, 1960). Several detailed maps are available showing the distribution of spindles and other encapsulated receptors in a variety of muscles. Some of the best, together with additional references, are given by Van der Wal (1988).

Two important features of the distribution of spindles emerge from the maps, as originally described by Gregor (1904) and Yellin (1969):

- i) Spindles are concentrated in the region of nerve entry and around the subdivisions of the intramuscular nerves.
- ii) They occur preferentially among extrafusal fibers with a high proportion of oxidative.

Innervations

The muscle spindle has both sensory and motor components.

Sensory innervation

According to the study conducted by Maeda and his colleagues on the salmon, there is primary nerve ending in which makes a large spiral course around the intrafusal fibre.

In mammals Primary and secondary sensory nerve fibers spiral around and terminate on the central portions of the intrafusal muscle fibers (equatorial regions) in innulospiral form, providing the sensory component of the structure via stretch-sensitive ion-channels of the axons and Spirals are common and more extensive around chain fibers than bag fibers (Hulliger, 1984)

Secondary endings terminate on one or both sides of the primary, and most secondaries terminate next to the primary (Van der Wal, 1988).

Motor innervation

The study has conducted on the salmon muscle spindel hasn't refer to the motor innervation and at the same time there have been many studies on innervation of extrafusal fibers (Johnston and Moon, 1981) and also physiological studies about fish proprioception (Williams and Hale, 2015; Rivera et al., 2014) where they have mentioned that the sense of position and movement of the paired and/or unpaired fins is critical for executing rapid motor behavior in fishes. However, the location of the proprioceptive receptors involved in proprioception of fin movement is unknown.

In Mammals including humans, the motor component is provided by up to a dozen gamma motoneurons and to a lesser extent by one or two beta motoneurons (Vallbo and Falahe, 1990). Gamma and beta motoneurons are called fusimotor neurons, because they activate the intrafusal muscle fibers. Gamma motoneurons innervate only intrafusal muscle fibers, whereas beta motoneurons innervate both extrafusal and intrafusal muscle fibers and so are referred to as skeletofusimotor neurons (Taylor, 2005).

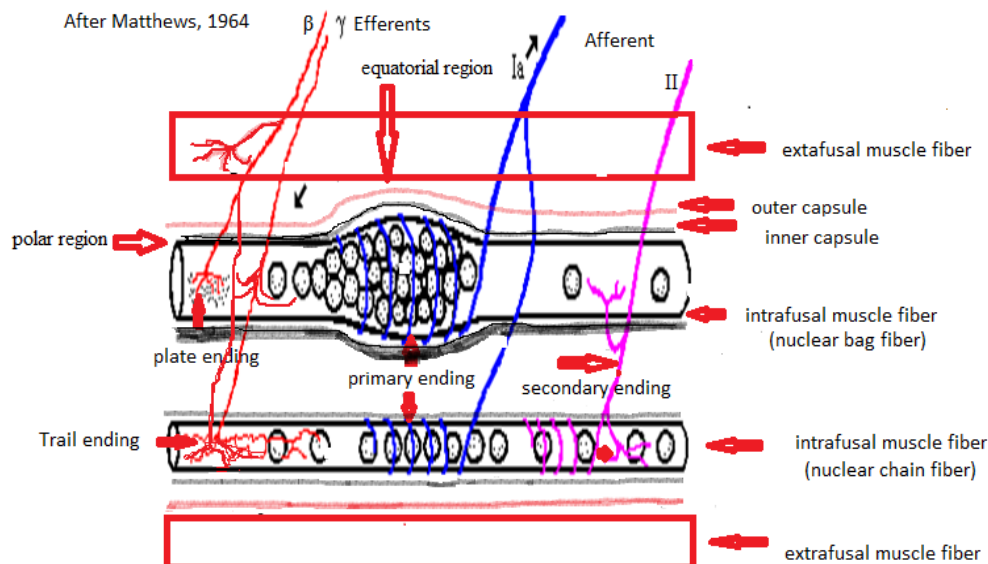


Figure 1. Diagram showing the principle components of typical muscle spindle, (modified from Matthews, 1964)

2. CONCLUSION

The majority of studies on muscle spindle morphology, distribution and function have been conducted on mammalian skeletal muscles (Matthews, 1962; Barker, 1974; Boyd and Smith, 1984). Comparatively little information exists on fish muscle spindles and the degree to which they resemble or differ from those of other vertebrates therefore these comparisons were made. So the aim of this review article was to summarize and compare recent and previous findings on fish muscle spindle and other vertebrates.

Maeda et al., (1983) showed that the muscle spindle has a single intrafusal muscle fiber and this is similar to snake and lizard muscle spindle (Proske, 1996) and compatible with capsule structure of most vertebrate by its content on inner and outer capsule (Ovalle, 1976). There are measurement differences in length and diameter of intrafusal muscle fiber and capsule among muscle spindles of vertebrates and those refer to the differences in size and location of the muscles (Barker, 1974). The number and distribution of muscle spindle varies through species and this finding agrees with the earlier reports by Zelena (1994) that each muscle contains a characteristic number of spindle which also species – specific and is apparently genetically encoded.

The sensory innervation in salmon similar to most vertebrate classes in having one primary ending exception in some Mammals contain primary and secondary sensory end (Adal, 1984).

No investigation has been made on motor innervation in fishes. Therefore, comprehensive research should be carried out for muscle spindle in fish muscles in different species.

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