STUDIES ON THE MUSCLE SPINDLES IN ALBINO RAT IN POSTNATAL LIFE

THESIS

Submitted for Fulfilment of the
Master Degree of M. Sc. in
(ANATOMY)

By
ELSYED ALY MAHRAN
M. B., B. Ch.

Supervisors

Prof. Dr. FAXHRY AMIN ESKANDER
Prof. Dr. SAWSAN AHMED ABD-EL RAHMAN

Faculty of Medicine
Ain Shams University

1984

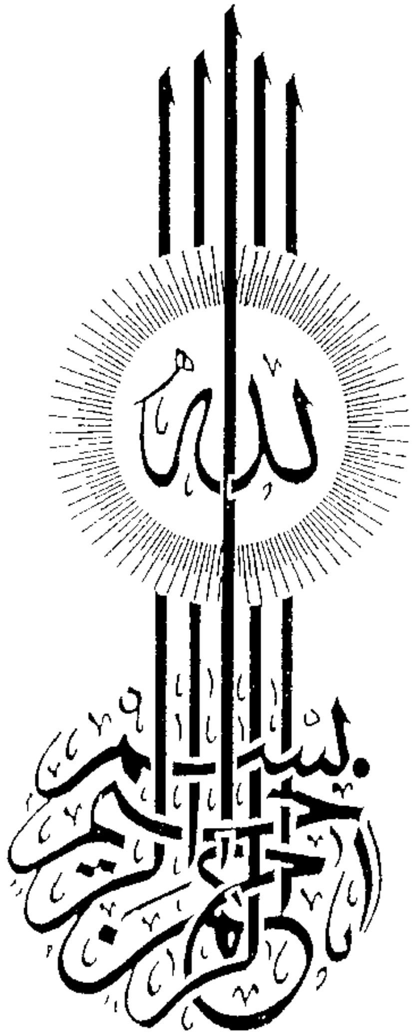
ACKNOWLEDGEMENTS

I would like to express my deepest thanks and gratitude to Prof. Dr. FAKHRY AMIN, Head of the Anatomy Department, Faculty of Medicine, Ain Shams University, for his supervision of this work, sincere help and encouragment.

My cordial thanks are due to Prof. Dr. SAWSAN AHMED ABD-EL RAHMAN, Professor of Anatomy Faculty of Medicine, Ain Shams University, and Head of the Anatomy Department El-Minia University, who suggested the topic of this research and assisted me throughout the work by her helpful discussion, criticism, and encouragment. To her I am specially endebted.

My deepest thanks and gratitude are due to Dr. KARIMAN MOHAMED ABD-EL FATAH EL-GOHARY, Lecturer of Anatomy, Ain-Shams University, for her sincere help and encouragment.

I am greatly endebted to all members of the Anatomy Deaprt-ment, Faculty of Medicine Ain Shams University for their kind cooperation and help throughout the whole work.


بسم الله الرحمن الرحيم

C O N T E N T S

***

INTRODUCTION AND AIM OF THE WORK

INTRODUCTION AND AIM OF WORK

The term muscle spindle (muskel spindeln) was first introduced by Kuhne (1863) to describe the structures made up of groups of relatively small (intrafusal) muscle fibres enclosed within a connective tissue capsule.

Cajal (1888) described two types of endings in the spindles of the frog; a polor one with morphological characteristics of the motor end-plates, and the other one in the equatorial region which was more complex. He assumed that these endings were respectively motor and sensory. These observations were confirmed by Onanoff (1980) in the dog, and Sherrington (1894) in the cat and monkey as a result of their degeneration experiments. The prenatal development of muscle spindles has been studied by some authors using the light microscope (Tello, 1907, 1922; Cuajunco, 1927; Zelena and Hnik,1960). Recently, the electron microscope was employed to investigate the same problem (Milburn, 1973; Barker and Milburn, 1972; Landon, 1972). Muscle spindles were also studied in new born rats by Zelena and Hnik (1960), and in adult rats by Milburn (1973) and Marchand and Eldred (1968). The spindles were also demonstrated in the muscles derived from the branchial arches as the facial muscles of the rabbit (Bawden and Mahran.1956) and dog and grivit (Abd-El Rahman, 1969). Lucas Keen (1961) found muscle spindles in the human laryngeal muscles, while Abo-El Enene (1967) detected them in the laryngeal muscles of cat and kitten. Classical spindles were also identified in the cricothyroid muscle of the dog (Ibrahim, Abd-El Rahman and Mahran, 1980). For the first time, muscle spindles were demonstrated in the striated muscles of the oesophagus in dogs (Asaad, Abd-El Rahman , Nawar and Mikhail, 1983).

AIM OF WORK:

Reviewing the available literature, it became evident that most of the studies were performed on the prenatal development of muscle spindles. However, the study of the postnatal development of muscle spindle received little attention. The aim of the present work was to investigate the postnatal development of muscle spindles of the calf muscles in albino rat from birth to adult hood. The postnatal changes in the intrafusal muscle fibres included, their number, size, diameter as well as the diameter of the spindle at the equatore and its nerve supply. The study of the enzymatic activities of the muscle spindles were planned to include the true-and pseudocholinesterase, succinic dehydrogenase and glycogen content of the intrafusal muscle fibres compared to that of the extrafusal.

REVIEW OF LITERATURE

THE DEVELOPMENT OF MUSCLE SPINDLE:

Tello (1907 and 1922) studied the development of muscle spindle in the chicken embryo and found that the nerve terminations upon the intrafusal muscle fibres were confined in two places; around the equator and at the poles. The nerve termination around the equator of the intrafusal muscle fibre was in continuity with a medullated nerve fibre; while the polar endings came from nerve fibres that became non-medullated near the intrafusal muscle fibre.

Cuajunco (1927) studied the development of the muscle spindles in the pig. He noticed that all the spindles were formed in embryos before 160 mm length. He suggested that, the increase in the number of the intrafusal muscle fibres was either due to the incorporation of near by extrafusal muscle fibres or due to the develoment of intracapsular myoblasts. He also found that the annulo-spiral and flower-spray types of sensory endings were more common, whereas the plate endings were rather rare.

Cuajunco (1940) studied the development of muscle spindles in the human foetuses (10-39 weeks). He noticed that, at 10 weeks, the nerve fibrils came in contact with the myoblasts with no evidence of union between them. At 11 weeks, the characteristic sensory terminations in the form of loose network with tiny enlargements around one or more myoblasts were formed. At 12 weeks, the myoblasts that formed the future intrafusal muscle fibres became differentiated by developing many nuclei in the equatorial region, while the polar region became more striated. At this period, the first layer of the capsule appeared, while the slit-like periaxial lymph space started to appear at 14 weeks. He also noticed that the muscle spindle had completely acquired its different components at 14 weeks. No increase in the number of muscle spindles occurred in human foetuses after 15 weeks of prenatal life. He suggested that the increase in the number of the intrafusal muscle fibres was either due to the longitudinal splitting of the existent muscle fibres or due to the incorporation of extrafusal muscle fibres.

Zelena (1957) studied the development of muscle spindles in the calf muscles of the rat and rabbit. He found that the first appearance of muscle spindles in the hind-limb muscles was 3 days before birth in the rat, and 7 days before birth in the rabbit. He demonstrated failure of development of the intrafusal muscle fibres and the connective tissue capsule i.e. no differentiation of muscle spindles occurred in denervated muscles after sectioning the sciatic nerve in the rat and rabbit foetuses by an intrauterine operation. He suggested that this failure of differentiation of muscle spindles might be due to loss of the influence of sensory nerve fibres which had only innervated the normal muscles at this time. He also found that the immature muscle spindles in tne denervated muscles of the newly born rats were rapidly disintegrated. The fusimotor innervation also developed late in rat embryos and it was not even completely developed at birth.

Zelena and Hnik (1960) studied the muscle spindles in the hind-limb of new-born rats by unilateral crushing of the sciatic nerve immediately after birth. Reinnervation was done after that in the extensor digitorum longus muscle. They noticed that inspite of the reinnervation of the muscle by sensory fibres, muscle spindles did not regenerate in muscles reinnervated at a later stage of development. Atypical muscle spindles were formed inspite of the regeneration of sensory fibres reaching the muscles.

Marchand and Elderd (1968) studied the post-natal development of muscle spindles in the hind-limb muscles of the rat by making serial sections stained by modified vanGieson. They found that, at time of birth, the muscle spindles contained only two intrafusal muscle fibres, one large with a greater number of nuclei in the equatorial region and one small. The number increased to four fibres at the 10th postnatal day by longitudinal splitting of the primary fibres to yield the secondary fibres. The splitting was seen to begin at one pole proceeding along the fibre to the other pole.
They also found that the large intrafusal muscle fibre underwent division at day 2-4 while the smaller one divided later from the 4th to the 6th postnatal day. They suggested that the two fibres present at birth represented the parent nuclear bag and nuclear chain fibres and that the nuclear complement for the intrafusal muscle fibres was determined prior to birth.

Liu and Maneely (1969) classified the development of the muscle spindles in the embryonic tail muscles of the lizard hemidactylus bouringi "gray" according to Dufoure and Huberts classification (1961). At stage 9 (the younger myofibril stage) there were thin muscle fibres about one-eighth the diameter of the surrounding myofibrils. These thin fibres having centrally placed nuclei and distinct striations were enclosed in delicate collagenous connective tissue sheath. The slender muscle fibres represented the intrafusal muscle fibres of the adult muscle spindle. At this stage, the early innervation was noticed at the proximal portion of the tail. The muscle segments became innervated by branches of inter segmental nerves which also reached the equatorial region of the primitive muscle spindles. At stage 10, lizard embryos, the thin intrafusal muscle fibres became spindle-shaped containing closely packed nuclei in their well marked equatorial region. The capsule surrounding the intrafusal fibres was thin and delicate but with defined dual nerve supply.

Liu and Maneely (1969) described the mature muscle spindles in the adult tail muscles of the lizard. They stated that: "The mature muscle had only one type of muscle spindles namely the long capsulated type in which the intrafusal muscle fibre was thin, unbranched and had a wide equatorial region. The nuclei were centrally placed in the whole length of the intrafusal muscle fibre except in the equatorial region where they were closely packed together. The nerves supplying these muscle spindles were thin or thick; the thin nerve was found to penetrate the capsule and wind spirally around the intrafusal muscle fibre close to the equator while the thick nerve was seen to become divided into two main branches near the capsule at the pole. Each branch gave rise to simple short secondary branches and ended in terminal branches that surrounded the intrafusal muscle fibres in a spiral form.

Barker and Milburn (1972) studied the development of muscle spindles in the hind-limb muscles of the rat using the electron microscope. They stated that "The earliest detectable spindles were seen in 19½ day foetus and consisted of a single nuclear bag fibre (fibre 1) having primary sensory terminals enclosed within the equatorial capsule. The polar regions of this (fibre 1) were myotubular and similar in size and structure to the near by extrafusal myotubes. Uninucleated myoblasts were found to lie in close proximity to fibre (1) throughout its length. At 20 days foetal stage, another nuclear bag fibre (fibre 2) developed which had fewer nuclei than that of fibre (1). The two fibres were found to lie together in close apposition. The deep surface of fibre (2) was found to extend into the sarcoplasm of fibre (1) in the form of pseudopodial inpushings, but never fused with it. The poles of both fibres remained myotubular. At 20½ days of foetal life, the myoblasts were seen lying between fibre (1) and fibre (2) along one side and some of them contained thin myofibrils. At birth (21 days), a third (fibre 3) developed and it was found lying in pseudopodial apposition with one or both of the preceding fibres. Fibre (3) was smaller in diameter than the other fibres and had a nuclear chain. The muscle spindles reached their full complement of intrafusal fibres at the 4th postnatal day when fibre (4) developed. Fibre (4) was the second chain fibre and was placed in pseudopodial apposition with one of the other fibres. At this stage the nuclei of fibre (1) became peripheral at the poles.

Landon (1972) studied the fine structure of the developing rat muscle spindles in the gastrocnemius muscle at the age from 18 days of gestation to 14 days after birth. He found that at the 18 th day of gestation several spindles were present in early stages of morphogenesis. The simple contact of a single myotube with the large unmyelinated intramuscular nerve terminals led to rapid encirclment of the myotube by the nerve terminals. This was followed by extension of the