AN ANATOMICAL STUDY OF ADAPTIVE PROCESSES

IN MUSCLE

A thesis presented in partial fulfilment
of the requirements for the Degree of
Doctor of Philosophy at Massey University.

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This work is dedicated to Dr W J Pryor, Assistant Director, Department of Primary Industry, Australia and former Dean of the Faculty of Veterinary Science, Massey University, who first cleared a way for me in the direction of my aspirations.

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The mechanisms involved in the adaptability of muscle to functional changes have been tested using sheep as the experimental animal.

(1) A quantitative study of the antenatal and postnatal development of skeletal muscle was undertaken using the semitendinosus muscle of eighteen fetuses from 60 days gestation to birth and of fifteen sheep from birth to adulthood. The muscle was also used as an experimental model to test antenatal anticipation of postnatal muscle functions. The alkali-stabile myosin ATPase technique was used to identify and quantify the histochemical ATPase low (AL) and ATPase high (AH) fibres and to follow both fibre and fascicular growth within the muscle. Histochemical changes occurring within the developing fibres were also recognized.

Presumptive AL fibres had centrally occupying nuclei up to 80 days. A smaller secondary fibre population formed the presumptive AH fibres during this period of development. From eighty days of gestation onwards, two distinct fibre types could be observed histochemically in the muscle. The AL fibre stained pale while the AH fibre stained dark.

Areas of variable fibre type population density were distinct within the muscle in all stages studied from 80

days of gestation. The highest population density of ATPase low fibres was observed in the craniomedial aspect of the muscle (AL dense area). The lowest AL fibre population density was seen in the caudolateral aspect of the muscle (the AL sparse area). The AL fibre percentage within the AL dense area of the muscle increased from about 10% to about 30% from 80 days of gestation to adulthood whereas in the AL sparse area the AL fibre type population density remained at about 4% throughout this period.

Simultaneous electromyographic studies using the semitendinosus muscle of three adult sheep suggested that the AL dense area is preferentially used for posture and during quiet co-ordinated activity, while the AL sparse area is recruited only intermittently when the hip and stifle joints are less co-ordinated in movement. By using angiographic studies on the muscle, many large and closely spaced blood vessels were seen to run in the AL dense area. Thus, a metabolic and nutritional prerequisite for the mechanically disadvantageous disposition of the AL fibres in the deep part of a muscle with a heterogeneous fibre type distribution has been suggested.

A postural and propulsive involvement of the muscle and an increase in percentage of AL fibres along with increasing body weight suggests a functional adaptatory change. The part of this change occurring antenatally is expected to be the result of genetic anticipation.

A marked reduction in perimysial connective tissue occurred antenatally but no significant changes occurred postnatally. The change involving endomysial connective tissue, on the

other hand, was less marked throughout the development. Also, the number of fibres per fascicle was constant both antenatally and postnatally. The perimysial enclosed fascicles increased in number antenatally but remained constant postnatally. This suggests a role for the connective tissue framework of a muscle in constraining the growth in number of fascicles and fibres.

(2) The function of one hind limb of the sheep was modified to study the growth changes in the musculoskeletal system. Seven lambs treated with one hind limb bound to the body with the hip fully flexed and the stifle and hock fully extended were reared from the day after birth to about three months of age, together with two untreated controls. A carcass dissection study was made of the treated and control lambs. Changes which occurred in the semitendinosus muscle were studied using histochemistry and electron microscopy.

All the supporting limbs of the treated lambs showed growth related changes induced by the treatment, suggesting a diagonal support of body weight. The semitendinosus muscle of the bound limb was heavier than that of the controls and that of the supporting limb, while the quadriceps muscle was heavier on the supporting side and lighter on the bound side. These results from the semitendinosus and quadriceps muscles support the view that stretch is an important requirement of muscle hypertrophy. The semitendinosus muscle, stretched over two joints, hypertrophies to a greater extent than a muscle like the semimembranosus, stretched over one joint. The size increase of other muscles such as the extensors of the stifle joint of the supporting hind limb may also have been due to stretch. A trend was observed for the femur

and tibia to be more mineralised and thicker, but shorter, on the supporting than on the bound side of the body.

The histochemical study of the semitendinosus muscle indicated that both AL and AH fibres are induced to grow by the stretch stimulus. An increase in the AL fibre type population as a percentage of the regional fibre population in the deep part of the semitendinosus muscle suggests that chronic abnormal usage of a muscle can produce an adaptive response. Thus, this exaggerates a similar effect observable during normal growth of an animal because of its increase in body weight. During the growth of a muscle under immobilized but stretched conditions, the shape, the amount of connective tissue and the size of fascicle and fibre components appear to maintain isometric proportions.

Electron microscopically, no abnormalities in the arrangement of the subcellular components and in the proportions of myofibrillar, sarcoplasmic and mitochondrial elements within the fibres of the hypertrophied semitendinosus muscle were revealed.

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