THE DYNAMIC SENSITIVITY OF MUSCLE SPINDLES IN THE KITTEN

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This is a report on further studies of the dynamic responsiveness of kitten muscle spindles, previously found to be low. We show that the threshold to vibration is higher than in the adult and the responsive frequency range is smaller. The response to large stretches shows an apparent saturation, not seen in the adult, which may have its origin in the mechanical properties of the immature receptor.

We have been studying muscle receptors in kittens for several years, building on the pioneering observations of Skoglund (1960). We now know that muscle spindles in the new-born already have a functional fusimotor innervation and that within the first week of life fusimotor fibres can be identified as having either static or dynamic actions (Gregory and Proske, 1985, 1986). At birth many fusimotor axons are unmyelinated and the process of myelination takes several weeks to complete. There is a higher than normal incidence of skeleto-fusimotor or beta innervation suggesting that during development some motor terminals on intrafusal fibres will be eliminated, as is known to occur for extrafusal fibres (Bagust et al., 1972).

The topic we would like to discuss in more detail here is the dynamic sensitivity of spindles. In the adult spindle it is the primary ending, with its terminals on the equatorial regions of nuclear bag and nuclear chain fibres, which has a high dynamic sensitivity. Secondary endings, lying in a more polar location on nuclear chain fibres, are predominantly length detectors and are rather insensitive to dynamic stimuli. This difference between the two kinds of endings is recognisable right from birth, both in the conduction velocity of the afferent fibres and the pattern of responses during muscle stretch (Gregory and Proske, 1987). However, while the response of the secondary ending in the kitten typically looks just like a scaled down version of the adult response, that of the primary ending differs in the shape of its dynamic component. Here it should be mentioned that the overall rates of firing of all kitten muscle receptors are much lower than in the adult, presumably because of the immaturity of the innervating axons.
Fig. 1. Discharge (upper trace) of a soleus muscle spindle primary ending in a 1 day old kitten during a ramp-and-hold stretch (bottom trace) and muscle twitch elicited by stimulation of the muscle nerve at the end of the ramp. Tension shown in middle trace. Note that discharge is initiated by stretch and silenced during twitch.

During our study of receptors in the new-born we encountered a problem which Skoglund had already faced twenty-five years earlier. In very young animals, muscle spindles have no resting discharge. Furthermore, at muscle lengths up to the optimum for a whole muscle twitch the response to stretch consists of only a few impulses during the length change and there is no maintained response during the hold phase of stretch. A hold response appears only at longer lengths. As a result it is often quite difficult to determine what kind of receptor one is dealing with. However, once a maintained response is obtained it is possible to test whether or not the discharge can be unloaded by a muscle twitch and thereby distinguish spindles from tendon organs (Fig.1).

Skoglund solved the problem of receptor identification by giving the animal succinyl choline. At low concentrations this drug selectively induces a resting discharge in primary endings of muscle spindles. Once a receptor had acquired a resting discharge Skoglund was able to apply the twitch test successfully. It is now known that succinyl choline exerts its action by inducing a contracture in nuclear bag intrafusal fibres (Gladden, 1976). One important consequence of this is that spindles not only develop a resting discharge but they show a large increase in dynamic response during muscle stretch (Rack and Westbury, 1966). When we tried using succinyl choline we made the unexpected observation that in the new-born, primary endings did not show a significant increase in dynamic response (Gregory and Proske, 1987). Not until two or more weeks later did a clear-cut increase begin to emerge. Here then was an aspect of receptor responsiveness in the kitten which differed fundamentally from the adult and an understanding of which might provide new insight into the mechanism of generation of all dynamic responses. This conclusion forms the basis of the series of experiments presented here.

The experiments were carried out on kittens aged between 1 and 14 days (80-300 g wt) and one adult cat (2.8 kg wt). Anaesthesia was