

Muscle disuse enhances performance of rat medial gastrocnemius on a standard fatigue test in situ

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The effects of decreased neuromuscular usage on the fatigability of the affected muscles remains controversial. The model of disuse induced by blockage of motor nerve impulses by chronic nerve superfusion with the sodium channel blocker tetrodotoxin (TTX) provides an unequivocal means of addressing this issue, since it evokes complete motoneurone silence which is quickly reversed when TTX is removed. In the present study, we examined fatigue resistance of a rat ankle extensor subjected to 2 weeks of complete disuse, using an in situ fatigue regimen which is frequently used to distinguish motor unit types in cat and rat muscles. We have found that previously disused muscles are more fatigue resistant, and perform more contractile work, in spite of severe fiber atrophy and a decreased activity of the mitochondrial marker enzyme succinate dehydrogenase (SDH) in muscle fibers.

Female Sprague-Dawley rats (225 g) had one hindlimb paralyzed for 2 weeks by blocking sciatic nerve impulses chronically with TTX, using a surgically-implanted constant-delivery system described previously (St-Pierre et al.1988). After 14 days of paralysis, isometric in situ contractile properties of the left medial gastrocnemius in response to sciatic nerve stimulation were recorded from anesthetized animals. After recording twitch and tetanic (200 Hz) responses, fatigue resistance was monitored for 5 minutes, using the stimulation protocol described by Burke et al. (1973). Muscles were subsequently frozen at rest length in melting isopentane, sections were cut at -20°C , and treated for the quantitative measurement of SDH activity (Martin et al.1985).

As in previous experiments (St-Pierre et al.1988), the main effect of TTX-induced disuse included decreased maximum tetanic force (by 70%) which was attributable to fiber atrophy (65%). In addition, twitch/tetanic ratios were significantly elevated after disuse (from $.18 \pm .01$ to $.50 \pm .02$). In response to the Burke fatigue protocol (Fig. 1A), previously disused muscles began contractions at a higher percentage of maximum tetanic force (68%) than control muscles, and showed less potentiation of forces during the first 15 seconds. At all time intervals up to 5 minutes, disused muscles generated significantly ($p < .01$) higher relative forces than controls. Fatigue index (measured as the force drop relative to peak response) was significantly higher after 2 and 4 minutes for disused muscles, indicating increased fatigue resistance in spite of generating higher forces relative to maximum tetanic force, compared to controls (Fig. 1B). As a post hoc consideration, we added a control group in which fatigue resistance was measured in response to stimulation at a frequency which would result in initial high relative forces similar to those seen for the disused muscles (75 Hz, 100 ms, once per s). In the latter, fatigue resistance was similar to that seen in the control muscles subjected to the Burke procedure. In contrast to the greater performance of the disused muscles during the fatigue protocol, the activity of the mitochondrial enzyme SDH was significantly reduced (by 26%) in individual muscle fibers (Fig. 1C).

The results support previous demonstrations with the models of suspension hypokinesia (Fell et al.1985) and immobilization (Robinson et al.1991) that muscle disuse enhances fatigue resistance. The latter occurred in spite of reduced activity of a mitochondrial marker enzyme, thus substantiating the hypothesis (Hamm et al.1988) that fatigue resistance and muscle oxidative potential may be coincidentally related among the various motor unit types. The altered frequency-tension relationship and the lack of potentiation in disused muscles suggests that calcium mobilization mechanisms are involved. Lower mitochondrial content may reduce calcium uptake by these organelles during fatigue, maintaining calcium availability for continued uptake and release (Tate et al.1978). This model is currently being studied to determine the factors limiting contractile performance in this altered muscular state.

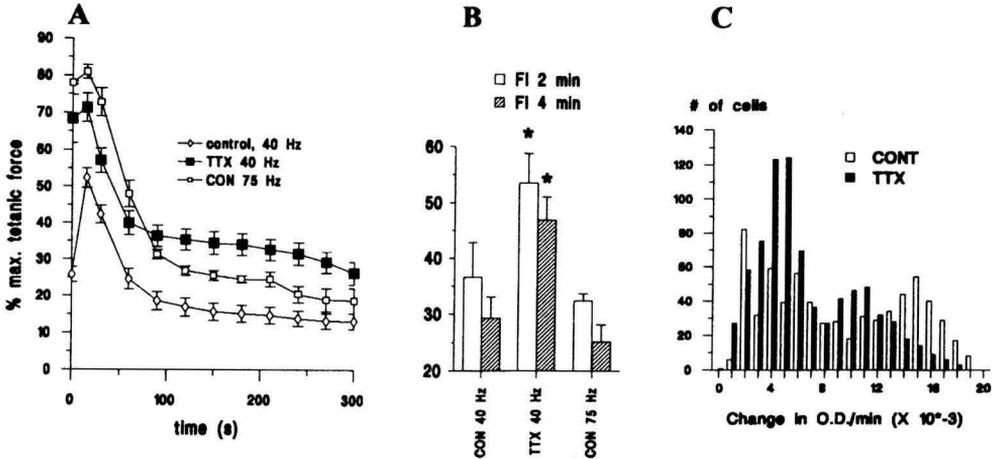


Figure 1.(A) Force decrements of the three groups during the fatigue protocol. (B) Fatigue index. (C) Histogram of fiber SDH activities for control and TTX muscles.

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