

Flaccid paraplegia: Improvement of the muscle capillary supply after early-started daily functional electric stimulation (FES) in human permanent lower motoneuron denervation

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Abstract

Here we report histology and ultrastructure of capillaries in permanent lower motoneuron-denervated human skeletal muscles. Spinal motoneuron-denervated patients show muscle fiber atrophy and degeneration with fat substitution. Mean number of capillaries per fiber was reduced (2.0 ± 0.1 SE) in comparison to normal adult muscle (4.10 ± 0.2 SE). Numerous small vessels show endothelial changes and thickening and/or duplication of basal lamina. In the subjects, who underwent several years of daily FES training, the vascular network appears almost normal in number (mean number of capillaries per fiber: 3.4 and 3.6, respectively) and ultrastructural morphology. Meantime light and electron microscopy analyses show an evident recovery of myofiber size and structure with significant reduction of fatty infiltration. These preliminary observations strongly support FES as a strategy to recover mass and function of long term denervated muscle, in particular when the FES regime starts early after SCI.

Key Words: human muscle, permanent denervation of the lower extremity, FES, muscle recovery, muscle capillary.

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Force and endurance of leg muscle of spastic paraplegic patients (i.e., with lesion of the upper motoneuron) are suboptimal even after successful rehabilitation strategies such as body weight-supported treadmill training (BWSTT), electrically induced cycle training (EICT) and Functional Electrical Stimulation (FES).

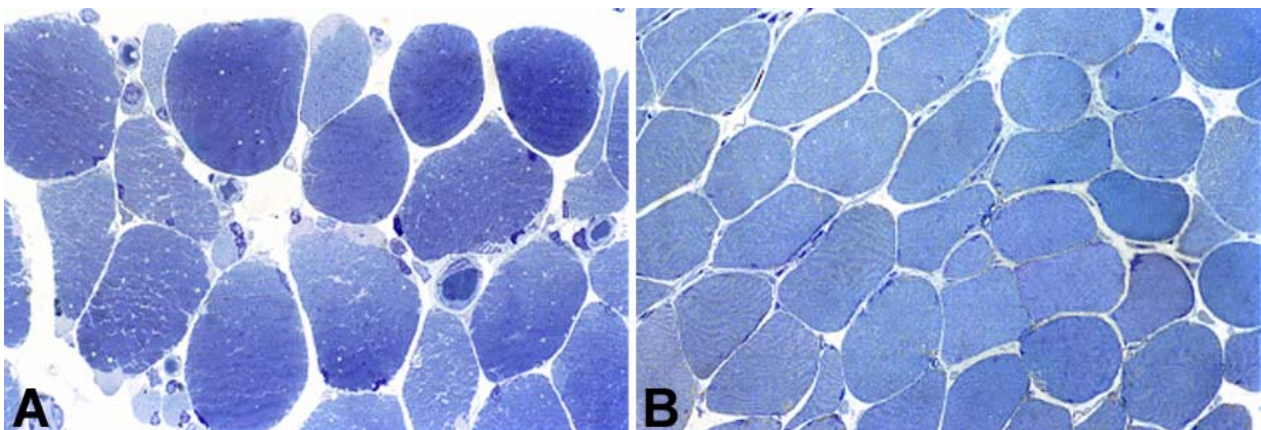


Figure 1. A, Myofiber degeneration and atrophy in a flaccid paraplegic 9 months after traumatic spinal cord lesion. B, Recovery of myofiber size and structure with almost normal vascular bed in flaccid paraplegia after 9 years of FES training. (Toluidine blue; original magn. 100X).

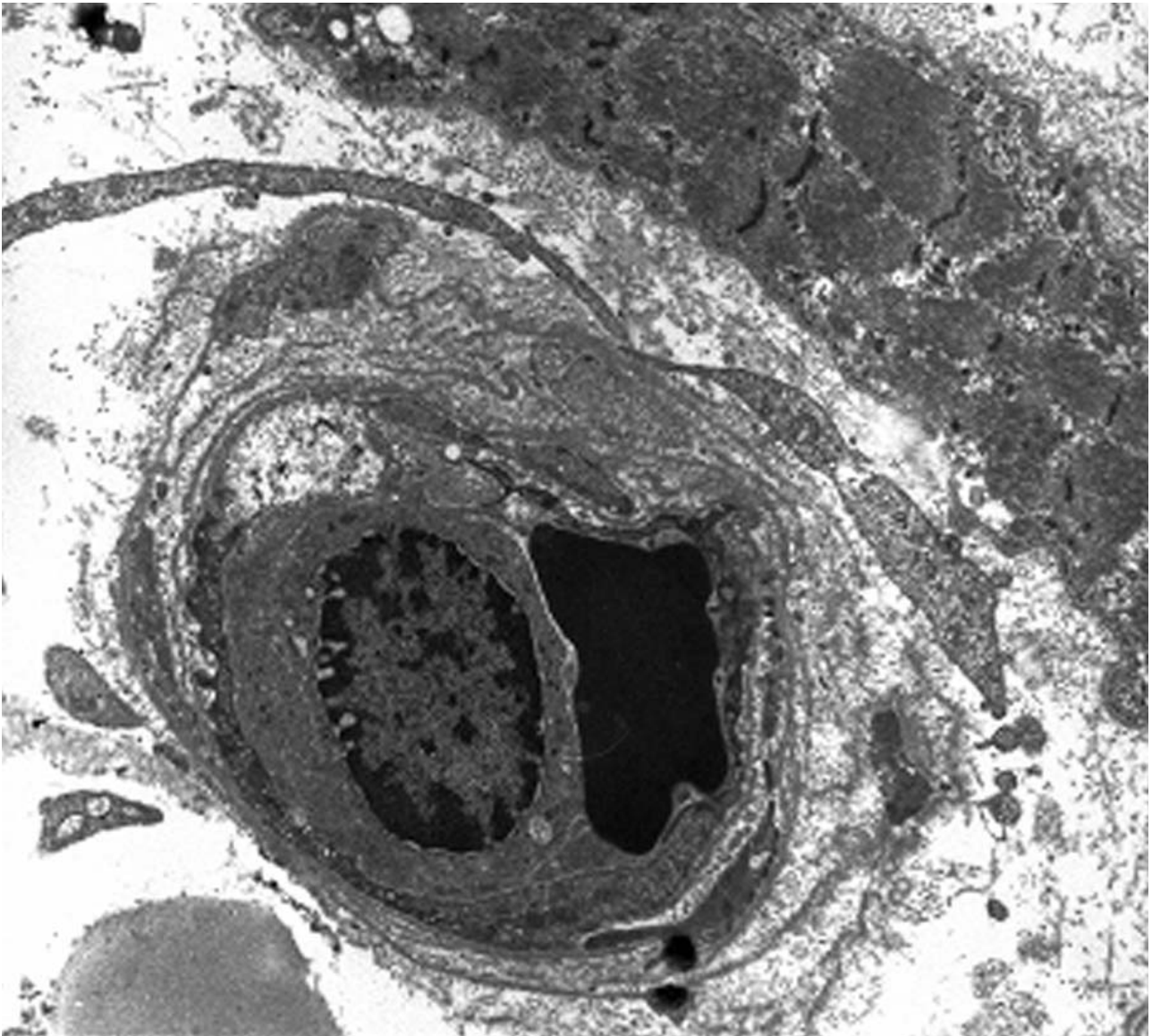


Figure 2. *Electron microscopy of flaccid patient with spinal lesion of 3 years. Thickening and reduplication of basal lamina of a intramuscular capillary. Original magnification 3000X.*

Even more difficult is to normalize muscle performance when the injury involves lower motoneurons (permanent flaccid paraplegia) since many months after spinal cord injury (SCI) muscle atrophy is complicated by fibrosis and fat substitution. We are testing the hypothesis that capillary network changes and /or muscle blood perfusion control may contribute to the unsatisfactory muscle performance. Here we report histological and ultrastructural analyses of capillary supply in permanent motoneuron-denervated human skeletal muscles. Capillary intramuscular network was studied in two groups of patients enrolled in the RISE Trial, without or after a new life-long FES training. Vastus lateralis biopsies from four patients with traumatic spinal cord and conus-cauda lesions of 9 months – 3 years (group 1) were compared to biopsies from two patients with similar lesions since 9.6 and 10.6 years, who underwent 7.7 and 9.3 years of FES training, respectively (group 2). Spinal motoneuron-denervated patients show muscle fiber atrophy and degeneration with fat substitution (figure 1). Mean number of capillaries per fiber was reduced (2.0 ± 0.1 SE) in comparison to normal adult muscle (4.10 ± 0.2 SE). Numerous small vessels show endothelial changes and thickening and/or duplication of basal lamina (figure 2). In the two subjects, who underwent several years of daily FES training, the vascular network appears almost normal in number (mean number of capillaries per fiber: 3.4 and 3.6, respectively) and ultrastructural morphology. Meantime light and electron microscopy analyses show an evident recovery of myofiber size and structure with significant reduction of fatty infiltration. We believe that these preliminary observations strongly support FES as a strategy to

recover mass and function of long term denervated muscle, in particular when the FES regime starts early after SCI.

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