Biocybernetics and Biomedical Engineering
2012, Volume 32, Number 4, pp. 33–45

Variability and Plasticity of Motor Unit Properties in Mammalian Skeletal Muscle

JAN CELICHOWSKI*, PIOTR KRUTKI

Department of Neurobiology, University School of Physical Education, Poznań, Poland

In the majority of mammalian skeletal muscles, contractile properties of motor units are variable and three main types of these units can be distinguished. The present review summarizes: results of studies of motor unit properties in the medial gastrocnemius muscle and their variability in two species, cats and rats, and studies on differences of motor unit properties in two genders. Moreover, plasticity of motor unit properties in rat medial gastrocnemius evoked by two kinds of spinal cord injury, total transection and hemisection, is reviewed, and effects of two types of training, treadmill locomotor and whole-body vibration training, are summarized. Finally, changes in the motor unit properties during the aging process are presented.

K e y w o r d s: motor unit, plasticity, contractile properties, motor unit action potentials

1. Introduction

Motor units, each composed of one motoneuron and a group of muscle fibers innervated exclusively by this neuron, are the smallest functional structures of mammalian skeletal muscles. As revealed with a glycogen depletion technique, all muscle fibers within one motor unit are of the same physiological and histochemical type [1–3] and therefore three basic types of muscle fibers: SO, FOG and FG [4] correspond to three basic types of the motor units: S (slow), FR (fast resistant to fatigue) and FF (fast fatigable), respectively [1]. The classification of motor units into three above-mentioned types, first proposed for cat medial gastrocnemius muscle, was confirmed for several other hind limb muscles, first in cats [1, 5, 6] and later in rats [7–9]. Additionally, data for two basic experimental species turned our attention toward interspecies differences in the motor unit contractile properties and the expected

* Correspondence to: Jan Celichowski, Department of Neurobiology, University School of Physical Education, 55 Grunwaldzka St., 60-352 Poznań, Poland, e-mail: celichowski@awf.poznan.pl
Received 04 April 2012; accepted 24 April 2012

differences in relation to the human motor units. The results of these studies will be reviewed in this paper. Due to obvious methodological difficulties, the motor units in human muscles are poorly understood and the contractile properties of only a few muscles have been described in detail [10, 11].

It is evident that in nearly all species of mammals sexual dimorphism concerns body size and muscle mass. However, till now only a limited number of studies stressed the differences of muscle fiber and motor unit properties in two genders. English et al. [12, 13] found a higher proportion and greater sizes of fast muscle fibers in the masseter of male rabbits. Moreover, these authors revealed some differences in the contractile properties between the male and female masseter motor units: in males the motor units' contraction time was shorter but the twitch forces were higher than in females. In this muscle Eason et al. [14] described a higher proportion of IIb muscle fibers and a lower one of IIa fibers in male mice compared with female mice. These observations concerning masticatory muscles drew our attention to possible differences between the motor unit properties in the locomotor muscles. The observed differences between the motor unit properties in two genders will be summarized. The results may at least partly explain different sport achievements of men and women.

The motor unit contractile properties are plastic and their changes are a form of adaptation to changes in time and intensity of muscle activity. Spinal cord injury dramatically reduces muscle activity, mainly abolishing anti-gravity and locomotor activity. Several studies had described a response of the motor units in cat muscles to the spinal cord transection [15–17], but such changes in rat muscle were unknown. The problem was especially interesting in light of considerable differences between the cat and rat motor unit properties [18]. Moreover, all previously published reports concerning the motor unit plasticity following spinal cord injury described the effects of total spinal cord transection, whereas the effects of a partial lesion of the spinal cord had not been studied.

Although numerous aspects of muscle plasticity and changes of their neuronal control evoked by increased activity were of interest to many authors [19–21], the changes of the motor unit contractile properties in such circumstances had not been investigated. Results concerning this aspect of the motor unit plasticity are presented here. In this study training effects of increased voluntary activity were investigated. In our laboratory model of increased activity, treadmill locomotor training was applied first and the properties of motor units of a trained group of animals were compared to those of untrained animals. The second series of the experimental studies concerned the effects of increased muscle activity by whole-body vibration, which evokes muscle activation mainly by the Ia afferent loop [22, 23].

Another series of experiments concerned the motor unit plasticity during the aging process; the motor unit contractile properties as well as the properties related to force regulation were analyzed for the control group of young adult rats and three groups of old rats (20–21, 24–25 and 28–30 months old).