over-the-muscle electrical stimulation activates faster-contracting motor units and that submotor NMES provides cutaneous feedback that alters the population of motor units activated during an H-reflex. By these means, it appears possible to preferentially activate faster-contracting motor units, perhaps those that are normally only active at high exercise intensities under voluntary conditions. This selectivity can be a useful adjunct to various rehabilitation interventions. One example would include situations in which strong muscle contractions would be detrimental to an injured extremity.

Neuromuscular electrical stimulation, either in conjunction with or in alternation with voluntary exercise, may provide a more effective means of training high threshold motor units.

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References


Commentary

Objective assessment of the effects of neuromuscular electrical stimulation (NMES) is greatly dependent on the ability to predict what underlying structures are excited by the stimulus. In animal studies, invasive techniques allow direct access to peripheral nerves and nerve roots, which greatly facilitates the control of both stimulation and recording protocols. In the clinic, the ease of application of percutaneous stimulation replaces invasive procedures and, in so doing, introduces additional complicating factors to the controlled delivery of stimuli (eg, variable thickness of subcutaneous tissues, nonuniform distribution of the electrical field associated with the stimulus). A direct consequence of these complications is a loss of predictability of resultant neuron activity generated by the stimulus, further detracting from a quantitative assessment of NMES effects. Through a unique application of time-honored electrophysiological measurement techniques and basic neuromuscular principles, Trimble and Enoka have provided important basic information concerning the probable recruitment order of motor neurons during NMES. Such information is critical to our understanding of the neuronal activation schemes associated with NMES and should assist us in appreciating what happens, from a neurophysiological perspective, when an electrical stimulus is applied to a patient.
As stated by the authors, the order of motor unit activation is determined not only by axon diameter but also by the additional complicating factor of the distance between stimulating electrode and underlying axons. It is therefore encouraging that, despite these complications, a remarkable similarity is found between the findings of Trimble and Enoka and results from more easily controlled, yet analogous, animal experiments. Results from decerebrate cat experiments, in which stimulating electrodes were placed directly onto nerves and nerve rootlets, were qualitatively identical (see Fig. 8 in the article by Clamann et al.) to those of Figure 1 in Trimble and Enoka's article. These results, from both human and animal experiments, support the conclusion that direct submaximal activation of motor neurons activates a faster-contracting population of motor units than voluntary (or reflex-generated) submaximal contractions.

The 11% average decrease in contraction times recorded during NMES, in conjunction with a 2% variability in pre- and post-NMES contraction time measurements, is convincing indirect evidence for activation of faster-contracting motor units during NMES. Demonstration of concomitant increases in peak twitch forces would have considerably strengthened this conclusion, yet twitch forces remained unchanged (Tabs. 1, 2). Resolution of this dissociation of results may reside in a more quantitative assessment of H-reflexes and M-responses relative to maximum M-response effects. A fundamental question concerns what particular fraction of the motor neuron pool was evaluated in the control and experimental conditions. Maximum H-reflexes, relative to maximum M-responses, vary widely among individuals, and interpretation of motor neuron excitability changes has been shown to be strongly influenced by the fraction of the pool that is analyzed. Resultant mechanical effects, as measured in this study, may equally be influenced by the size of reflex studied. Tables 1 and 2 reveal wide ranges of peak twitch forces, but no information relative to maximum peak twitch forces is given. If control conditions were restricted to the use of small H-reflexes, a greater proportion of higher-threshold motor neurons would be available for recruitment. Twitch force enhancement, which may be masked when larger control H-reflexes are used, such as may have occurred in this study, might therefore more readily be revealed with smaller control H-reflexes.

The results of Trimble and Enoka's study nonetheless represent an important step in our understanding of the mechanisms underlying NMES. The lack of a concomitant increase in twitch force with decreases in contraction time warrants caution in a definitive acceptance of their conclusion and points to a need for further experimentation in this important area of clinical research.

Finally, the authors focus on the role of cutaneous afferent feedback as the principal means of altering recruitment order in these experiments. The nonselective stimulation used in NMES would be expected to activate the entire spectrum of neuron sizes, including muscle as well as cutaneous afferent fibers. Although cutaneous inputs have been shown to alter recruitment order, other factors, including muscle afferent modulated presynaptic mechanisms, may be of equal importance. The sorting out of cutaneous and muscle afferent effects is a formidable, yet necessary, task for a more complete understanding and appreciation of the underlying mechanisms associated with NMES.

References


Author Response

Despite substantial paradigmatic differences between reduced-animal experiments and studies on conscious humans, our observations on human subjects were consistent with the animal-derived hypothesis that submaximal electrical stimulation of nerve results in the activation of a faster-contracting population of motor units than that associated with submaximal voluntary activation. This conclusion, which has profound clinical implications, was based on differences in the time course of the twitch elicited by the H-reflex and the M-response and on the effect of submotor neuromuscular electrical stimulation (NMES) on the contraction.
Commentary
Carl G Kukulka

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