# Neuromuscular Electrical Stimulation for Motor Restoration in Hemiplegia

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**KEYWORDS**

• Stroke rehabilitation • Upper limb hemiplegia • Neuroplasticity • Medical device • Electrical stimulation therapy

**KEY POINTS**

- Hemiparesis following stroke is associated with significant upper and lower limb impairment, activity limitation, and reduced quality of life.
- Neuromuscular electrical stimulation as a motor relearning tool reduces upper and lower limb motor impairment following stroke.
- Neuromuscular electrical stimulation as a neuroprosthesis improves ambulation function of stroke survivors but not more than the standard of care ankle-foot orthoses.
- Research is needed to more firmly establish the effects of electrical stimulation on upper limb activity limitations and quality of life.
- The benefit of upper limb neuromuscular electrical stimulation modalities relative to alternative therapies or standard of care remains to be fully elucidated.

## INTRODUCTION

Motor impairment is common after stroke and directly impacts the stroke survivor's function and quality of life. Neuromuscular electrical stimulation (NMES) may reduce disability by improving recovery of volitional movement (therapeutic effect) or by

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assisting and replacing lost volitional movement (neuroprosthetic effect). This article describes NMES treatment modalities for upper and lower limb stroke rehabilitation and summarizes the research literature regarding the therapeutic and neuroprosthetic efficacy of those modalities. The scope of this article is limited to NMES interventions that produce limb movement by direct stimulation of the peripheral nerves or motor points of target muscles for the purpose of restoring motor function and, therefore, does not cover somatosensory electrical stimulation,[1] electrical stimulation for post-stroke shoulder pain,[2] or brain stimulation modalities.[3]

## NEUROMUSCULAR ELECTRICAL STIMULATION FUNDAMENTALS

NMES is the use of electrical current to produce contractions of paralyzed or paretic muscles. Lower motor neurons to target muscles must be intact for NMES to effectively produce muscle contractions; therefore, NMES is usually only applicable to patients whose paralysis or paresis is caused by upper motor neuron injury (eg, stroke, spinal cord injury, and so forth). NMES can be applied to paretic muscles with surface electrodes positioned on the skin over the motor points of target muscles or with electrodes that are implanted near or on the muscle motor points or nerves that innervate target muscles. The electrical current generated by most NMES devices can be characterized as a waveform of pulses having a particular pulse frequency, width, and amplitude. Adjusting the pulse parameters can modulate the strength of evoked muscle contraction. Typically, the stimulation frequency is set between 12 and 50 Hz; the strength of the muscle contraction is modulated by changing either the pulse amplitude (typically 0–100 mA) or pulse width (typically 0–300 μs).

An NMES device fundamentally consists of electrodes that are connected to a stimulator and a controller (**Fig. 1**). A pair of electrodes constitutes a stimulus channel. Surface (ie, transcutaneous) electrodes, percutaneous intramuscular wire electrodes, and implanted epimysial, intramuscular or nerve cuff electrodes may be used. The stimulator (ie, pulse generator) may have a controller built into it or have a separate controller attached or wirelessly linked to it. The controller regulates the timing and intensity of stimulation delivered through one or multiple stimulus channels. Input to the stimulator's controller may be via buttons, switches, and/or various types of external or implanted sensors or recording (eg, electromyographic) electrodes.

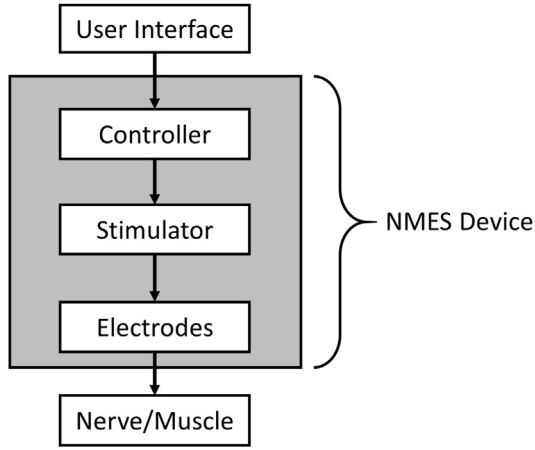


**Fig. 1.** Diagram of a basic NMES device.