ACRM AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2024;105: 191−5

INFORMATION/EDUCATION PAGE

Neuromuscular Electrical Stimulation for Children With Stroke

Research into neuromuscular electrical stimulation (NMES) for children with cerebral palsy and children post-stroke is limited. However, a recent review suggests that evidence for NMES is sufficient for improvement of gait and muscle strength as well as hand function and walking speed when combined with botulinum toxin and task-specific training.[1] NMES is also referred to as electrical stimulation (eStim), functional electrical stimulation (FES), or muscle stimulation.

What is it?

NMES uses an electrical current to trigger a contraction in a weak or partially paralyzed muscle.

NMES has been shown to:

- Improve motor function.[2-4]
- Increase muscle strength and range of motion.[5-7]
- Reduce muscle spasticity.[4,8,9]
- Replace muscle function (ie, orthotic use).

NMES can be done while the child is at rest or while they are using that muscle to perform an activity. NMES is well-tolerated by children of all ages, including infants. Some NMES units have a trigger mechanism, which allows muscle stimulation to be timed with task performance. Research suggests that using NMES while trying to activate a muscle is the most effective.[10] If used in this way, NMES can assist a child to do tasks that would otherwise be too difficult. Thus, along with increasing task execution an advantage of NMES may be to enhance motivation and engagement.

Most portable home-based NMES units offer 2 channels which allow up to 2 muscle groups to be stimulated simultaneously or in a reciprocal manner. Such units usually deliver asymmetrical biphasic electrical stimulation, although some units may be programmable for symmetrical stimulation. There are also larger, more complex NMES systems that can stimulate up to twelve muscle groups at a time while a child participates in a functional activity. See figure 1 for 2 examples of how NMES is used.

How does it work?

NMES bypasses the brain and spinal cord to trigger a response at the motor unit junction (most common) or depolarizes a nerve before it reaches the muscle. NMES at the neuromuscular junction releases a chemical signal which leads to a muscle contraction allowing for stimulation of specific muscles (figure 2). Yet adjacent muscles may be stimulated simultaneously with use of larger electrodes. Depolarization of a nerve before it reaches a muscle stimulates all muscles supplied by the nerve distal to the point of stimulation. This may be desirable to target several muscles at once (eg, wrist, finger, and thumb extensors). Setup can be adjusted to recruit different types of muscle fibers or to reach deeper fibers within a muscle. Increasing the amplitude or pulse width results in recruitment of smaller diameter fibers and recruits deeper muscle fibers. Increasing the distance between electrodes recruits deeper muscle structures.

Research shows how the brain may change with NMES: (1) motor-evoked potentials increase (an

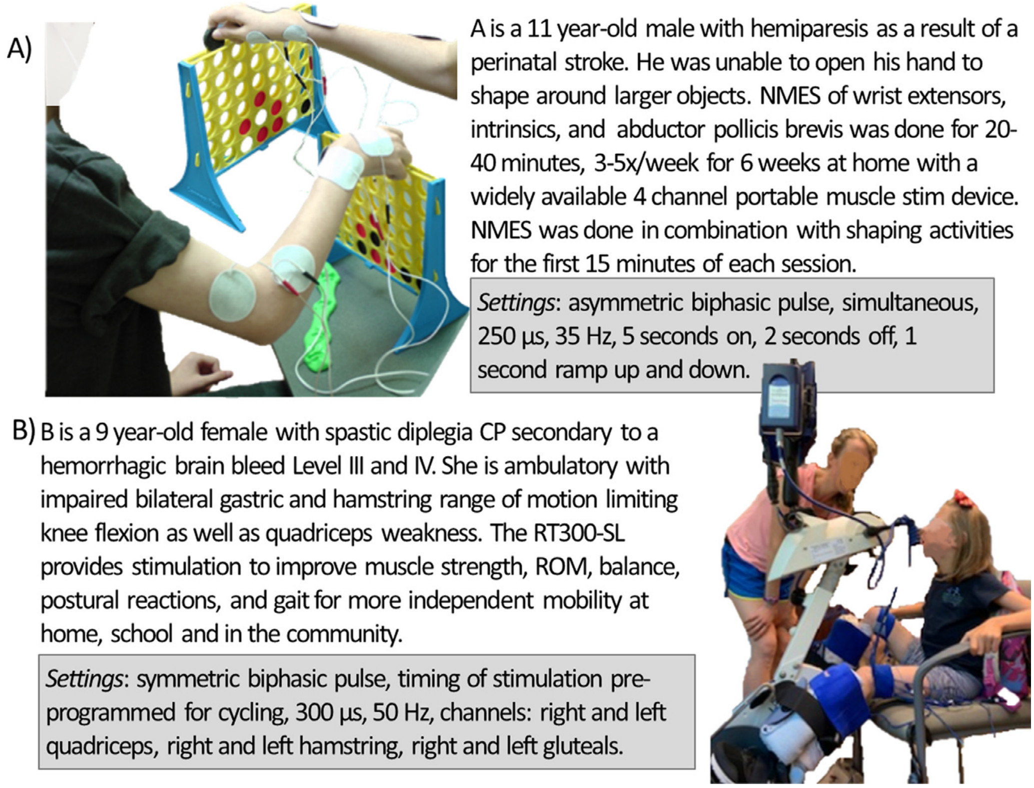

Fig 1 Examples of NMES use: **(A)** task-based NMES for shaping around objects. **(B)** functional electrical stimulation bike.

indicator of how easily the brain produces movement); (2) blood flow to brain regions associated with movement increases; (3) genes that code factors important to brain plasticity are more active; and (4) new neurons form around the lesion.[10,11] It is recommended that in children with select neurologic conditions, treatment should be provided at a minimum dose of

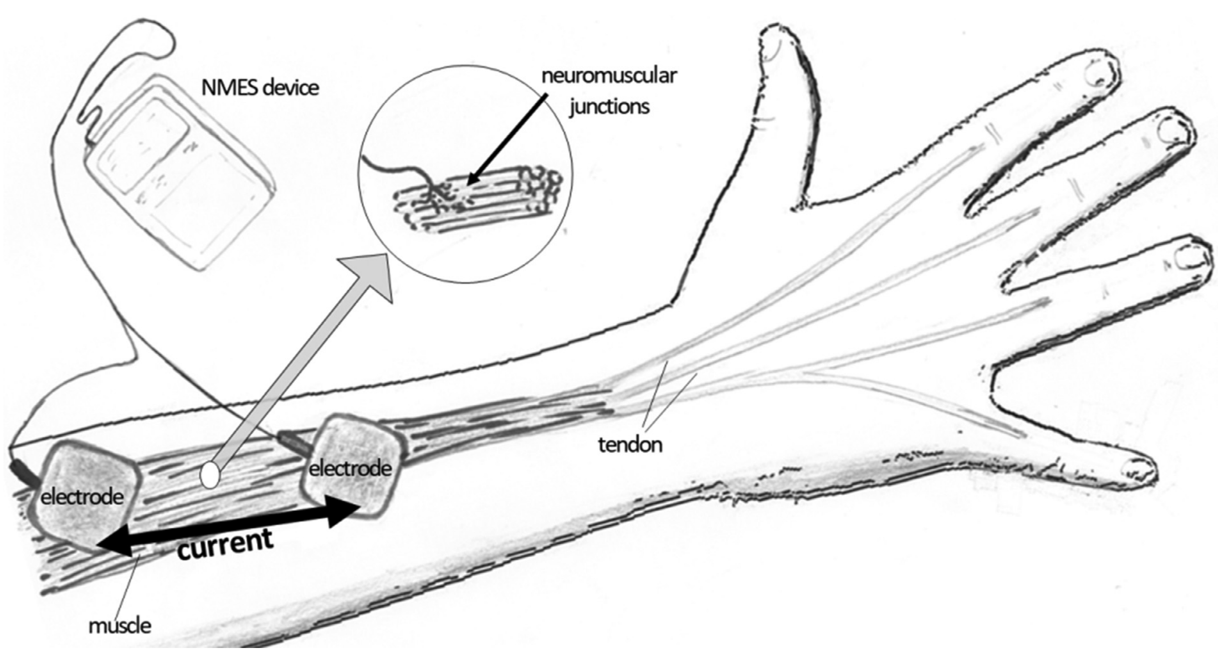

Fig 2 Physiology and typical clinical setup of neuromuscular electrical stimulation for extensor digitorum communis.

20 minutes/day, 5 days/week for 2 to 6 weeks to improve arm function.[12]

When is NMES a potential option?

Indications

- Improve ability of a specific muscle or muscle group to activate during task performance.
- Activate muscle(s) opposing those muscles with spasticity that are limiting function.
- Increase body awareness or proprioception to influence function.
- Replace an orthotic (eg, activate dorsiflexors during gait).
- Stabilize joints (eg, minimize shoulder subluxation).

Considerations

- Studies support the benefit of combining NMES with task-based training or providing passive NMES plus traditional therapy.
- Select the muscle(s) to target based on clinical assessment and therapy goals.
- Requires an effective dose as with any therapy.
- Setup time (varies).
- Must educate child and family about the purpose, sensation, and dosage.
- Consider strategies to increase child engagement: the parent or clinician may receive NMES at the same time on their limb, allow the child to adjust the amplitude, or use the trigger.
- Use strategies to increase comfort as needed (eg, adjust parameters, use larger electrodes, ensure the electrode is not dry, try reusable rubber electrodes with gel).
- Distraction may be helpful initially until the child becomes accustomed to the sensation.
- Use child-friendly language such as "tickle stickers."
- Parameter settings (table 1).

Limitations

- Child anxiety with novel treatment and unfamiliar sensations.
- Access to equipment.
- Clinician expertise.
- Muscles fatigue more quickly with NMES than with voluntary activation.
- Target muscle must be accessible (eg, difficult to target shoulder external rotators).

Contraindications

- Uncontrolled seizures (no known evidence of harm, but not usually done).
- High risk of bleeding (NMES increases blood flow).
- Pacemaker, deep brain or vagal nerve stimulator (some types are fine).

Risks & precautions

- Risks include skin irritation or burn and autonomic dysreflexia.
- Be cautious if sensation is impaired; check skin integrity before and after NMES.
- Power down before moving or removing electrodes.
- Ensure electrodes do not touch each other.
- Amplitude may vary depending on muscle fatigue and skin moisture; begin at 0 each session and increase slowly.
- No water/wet surfaces/wet hands during NMES.

Final thoughts

NMES is a promising and potentially powerful adjunct to improve motor control, reduce spasticity, and, most importantly, improve function and participation for children. It is important to combine the information provided with clinical reasoning considering each child and family's circumstances when deciding to use NMES. In addition, clinicians should be aware that stimulation settings and electrode pad placement can vary between NMES devices and individuals. Personal response to the stimulation is the most important indicator and guide for treatment.

Authorship

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Table 1 NMES parameter settings

	Settings Reported in Cited Trials[2,6,8,9]	Considerations
Pulse type	Biphasic symmetrical; biphasic asymmetrical	A symmetrical pulse is often required to create a substantial contraction in a larger muscle (trunk or lower extremity). An asymmetrical pulse is more comfortable for smaller muscles. Not all units allow selection of pulse type. For a small child, biphasic asymmetrical may be sufficient regardless of the muscle target and preferable for comfort.
Frequency	25-60 Hz	Higher values result in a stronger contraction but will more quickly induce fatigue.
Pulse duration	200-300 μs	Higher values recruit larger and deeper motor units.
On time/cycle	*trigger; 10-12 s	Use of a trigger overrides cycle settings. A trigger allows timing stimulation when a muscle is naturally recruited during a task rather than trying to pace the task to match when stimulation is on. Must consider how long a muscle typically contracts during a select component of a task.
Off time/cycle	*trigger; 7-12 s	As above. Consider that longer “off” times allow for more recovery but reduce the amount of stimulation across a session.
Ramp up/down	0.5-2 s	Longer ramp time is more comfortable but will decrease the amount of stimulation at full intensity. A longer ramp time may be helpful if spasticity is a concern.
Amplitude	Sufficient for contraction but tolerable; some studies included a max of 25 or 45 mA	Higher values create a stronger contraction but will also induce fatigue more quickly and result in overflow of stimulation to surrounding muscles.

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References

1. Novak I, Morgan C, Fahey M, et al. State of the evidence traffic lights 2019: systematic review of interventions for preventing and treating children with cerebral palsy. Curr Neurol Neurosci Rep 2020;20:3.
2. Xu K, Wang L, Mai J, He L. Efficacy of constraint-induced movement therapy and

electrical stimulation on hand function of children with hemiplegic cerebral palsy: a controlled clinical trial. Disabil Rehabil 2012;34:337–46.
3. Elbasan B, Akaya KU, Akyuz M, Oskay D. Effects of neuromuscular electrical stimulation and Kinesio Taping applications in children with cerebral palsy on postural control and sitting balance. J Back Musculoskelet Rehabil 2018;31:49–55.
4. Pool D, Valentine J, Bear N, Donnelly CJ, Elliott C, Stannage K. The orthotic and therapeutic effects following daily community applied functional electrical stimulation in children with unilateral spastic cerebral palsy: a randomised controlled trial. BMC Pediatr 2015;15:154.
5. Pool D, Elliott C, Bear N, et al. Neuromuscular electrical stimulation-assisted gait increases muscle strength and volume in children with unilateral spastic cerebral palsy. Dev Med Child Neurol 2016;58:492–501.
6. Karabay İ, Öztürk GT, Malas FÜ, et al. Short-term effects of neuromuscular electrical stimulation on muscle architecture of the tibialis anterior and gastrocnemius in children with cerebral palsy: preliminary results of a prospective controlled study. Am J Phys Med Rehabil 2015;94:728–33.
7. Stackhouse SK, Binder-Macleod SA, Stackhouse CA, McCarthy JJ, Prosser LA, Lee SCK. Neuromuscular electrical stimulation versus volitional isometric strength training in children with spastic diplegic cerebral palsy: a preliminary study. Neurorehabil Neural Repair 2007;21:475–85.
8. Scheker LR, Chesher SP, Ramirez S. Neuromuscular electrical stimulation and dynamic bracing as a treatment for upper-extremity spasticity in children with cerebral palsy. J Hand Surg Edinb Scotl 1999;24:226–32.
9. Yıldızgören MT, Nakipoğlu Yüzer GF, Ekiz T, Özgirgin N. Effects of neuromuscular electrical stimulation on the wrist and finger flexor spasticity and hand functions in cerebral palsy. Pediatr Neurol 2014;51:360–4.
10. Barsi GI, Popovic DB, Tarkka IM, Sinkjaer T, Grey MJ. Cortical excitability changes following grasping exercise augmented with electrical stimulation. Exp Brain Res 2008;191:57–66.
11. Everaert DG, Thompson AK, Chong SL, Stein RB. Does functional electrical stimulation for foot drop strengthen corticospinal connections? Neurorehabil Neural Repair 2010;24:168–77.
12. Bosques G, Martin R, McGee L, Sadowsky C. Does therapeutic electrical stimulation improve function in children with disabilities? A comprehensive literature review. J Pediatr Rehabil Med 2016;9:83–99.