Clinician's Commentary on Kawashima et al.¹

Well-executed case studies can offer invaluable insights into mechanisms underlying the effects of rehabilitation interventions. Functional electrical stimulation (FES) therapy is one intervention aimed at restoring function following a stroke. The work of Kawashima and colleagues provides clues that may help explain the functional benefits seen with FES therapy.¹ Their case study reports the effects of FES therapy in a person 2 years post stroke, when natural recovery is expected to have plateaued, whose enduring stroke-related impairments included impaired arm movement and function.¹ Although the client had voluntary muscle activity in the wrist flexors/extensors and biceps brachii, she showed very little voluntary activity in the rest of the shoulder and wrist muscles and none in the triceps brachii (TB) and first distal interosseous (FDI) muscles. The therapeutic intervention included a combination of intensive FES (incorporating voluntary movements assisted with FES) and manual assistance. The client was also asked to imagine the movement to be performed. A variety of different stimulation methods exist, including focal stimulation of muscles at the wrist joint only.² It is important to note that multiple muscles in the shoulder, elbow, and wrist (but no hand muscles) were stimulated in the study by Kawashima and colleagues.¹ The exercises performed were guided by the therapist to provide important sensory feedback related to naturally occurring movement. Thus, the elements of FES therapy used in this study were unique in the literature.^{2,3}

It is significant that while FES therapy resulted in functional improvements, specifically a significantly improved ability to draw a circle and improved joint range of motion, these changes were not robust enough to alter the motor impairment level as measured by the Motricity Index (MI) and the Chedoke-McMaster stages of motor recovery (CMSMR). Significant improvement on the Fugl-Meyer Assessment, a scale of motor impairment that has strong positive correlation with the MI,⁴ has been reported in response to a similar protocol of FES therapy.³ In that study, however, it was the acute stroke group that showed robust changes; the chronic stroke group did not show significant changes in function or motor impairment.³ Kawashima and colleagues used sensitive measures to assess the smallest of changes in function, as well as measures to assess the mechanisms of change.¹ Their case study of a person with chronic stroke (expected to be less amenable to therapy³) demonstrated improvements using sensitive measures such as the circle-drawing test and joint kinematics during movements; they also found that the size of the flexor carpi radialis H-reflex was almost halved and that this change was accompanied by improved ability to voluntarily contract and relax muscles. It is remarkable to see that their client was able to voluntarily activate previously paralyzed muscles (TB, FDI) after 12 weeks of training.

Although improvement in muscle strength in response to FES has previously been reported in people with acute stroke,² Kawashima and colleagues found no change in muscle strength, maximum M wave, or maximum voluntary contraction (MVC). This may be because they stimulated multiple muscles and the voluntary movement repetitions focused on movement quality rather than on strength. Muscle strength may also improve with higher FES intensity, or when FES is combined with resistance

training. Indeed, muscle weakness in people with stroke can be overcome with high-intensity resistance training exercises that have been shown to have no adverse effect on spasticity.⁵

The decrease in spinal excitability (H-reflex depression) that Kawashima and colleagues observed, combined with the absence of change in muscle strength or MVC post training, suggests improved cortical mechanisms of motor control. Another possibility is retraining of the spinal contributions to arm movements following stroke,⁶ especially since the FES therapy in this case study focused on accurate movement-related sensory feedback of a repetitive nature. A more obvious example of the spinal contributions to leg movements was reported in a case study of a child with spinal-cord injury who began taking independent steps after locomotor training on a treadmill with body-weight support and manual assistance, while at the same time the child's voluntary motor capacity remained very low and unchanged.⁷ Future studies will need to discriminate cortical- and spinal-level excitability changes using transcranial magnetic stimulation and H-reflexes.

Finally, there is a need for terminology that accurately describes the nature of therapy delivered. Key training variables of the type of FES used in the study by Kawashima and colleagues were stimulation of multiple muscles, movement repetition, manual assistance, voluntary effort, and motor imagery. The broad term "FES therapy," therefore, does not do justice to other important elements of the therapeutic intervention that may have contributed, to varying degrees, to the patient's functional improvement. Future studies should use more descriptive terminology that encompasses all elements of the training regimen.

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REFERENCES

1. Kawashima N, Popovic MR, Zivanovic V. Effect of intensive functional electrical stimulation therapy on upper limb motor recovery after stroke: case study of a patient with chronic stroke. *Physiother Can.* 2012;65(1):20–8. <http://dx.doi.org/10.3138/ptc.2011-36>
2. Rosewilliam S, Malhotra S, Roffe C, et al. Can surface neuromuscular electrical stimulation of the wrist and hand combined with routine therapy facilitate recovery of arm function in patients with stroke? *Arch Phys Med Rehabil.* 2012;93(10):1715–21.e1. <http://dx.doi.org/10.1016/j.apmr.2012.05.017>. Medline:22676906
3. Thrasher TA, Zivanovic V, McIlroy W, et al. Rehabilitation of reaching and grasping function in severe hemiplegic patients using functional electrical stimulation therapy. *Neurorehabil Neural Repair.* 2008;22(6):706–14. <http://dx.doi.org/10.1177/1545968308317436>. Medline:18971385
4. Platz T, Pinkowski C, van Wijck F, et al. Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer Test, Action Research Arm Test and Box and Block Test: a multicentre study. *Clin Rehabil.* 2005;19(4):404–11. <http://dx.doi.org/10.1191/0269215505cr8320a>. Medline:15929509

5. Patten C, Lexell J, Brown HE. Weakness and strength training in persons with poststroke hemiplegia: rationale, method, and efficacy. *J Rehabil Res Dev*. 2004;41(3A):293–312. <http://dx.doi.org/10.1682/JRRD.2004.03.0293>. Medline:15543447
6. Zehr EP, Loadman PM, Hundza SR. Neural control of rhythmic arm cycling after stroke. *J Neurophysiol*. 2012;108(3):891–905. <http://dx.doi.org/10.1152/jn.01152.2011>. Medline:22572949
7. Behrman AL, Nair PM, Bowden MG, et al. Locomotor training restores walking in a nonambulatory child with chronic, severe, incomplete cervical spinal cord injury. *Phys Ther*. 2008;88(5):580–90. <http://dx.doi.org/10.2522/ptj.20070315>. Medline:18326054

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