Nerve Cut? No Problem

(Neuromodulation of lumbosacaral spinal networks after complete paraplegia)

Belkees Salem Alowami*, Iman Elfergani**

Faculty of Basic Medical Science

Libyan International Medical University

INTRODUCTION

Spinal cord injury (SCI) is damage to the spinal cord causing temporary or permanent changes in its function. Spinal sensorimotor networks disconnected from the brain due to SCI can be activated via epidural electrical stimulation (EES) to restore motor activity in humans with paralysis.[1] Previously, there was a case of sensorimotor paralysis of the lower extremities where EES restored the ability to stand and the ability to control step-like activity while side-lying or suspended vertically in a body-weight support system (BWS).[2] Training in the presence of EES and multimodal rehabilitation (MMR), was performed for 43 weeks and resulted in stepping on a treadmill, independent from trainer assistance or BWS. It also enabled independent stepping over ground while using a front-wheeled walker with trainer assistance at the hips to maintain balance. This study presents a revolutionary change and a sense of hope to paralysed patients.

CASE

A 26-year-old male with a traumatic fracture and dislocation of the eighth thoracic vertebra resulting in a SCI and loss of function below the sixth thoracic spinal segment three years before study enrollment. Following injury onset, he received emergency medical care, and his spine was surgically fused from the 5th to 11th thoracic vertebrae.

PROCEDURE

1. Neurophysiologic and Clinical evaluation of spinal cord injury.
2. Locomotor training.
3. EES system implantation and Refinement of electrical epidural stimulation settings to enable motor functions.
4. Multimodal rehabilitation and EES parameter adjustment.
5. Home-based EES exercise sessions.
6. Data recordings during MMR sessions.

RESULTS

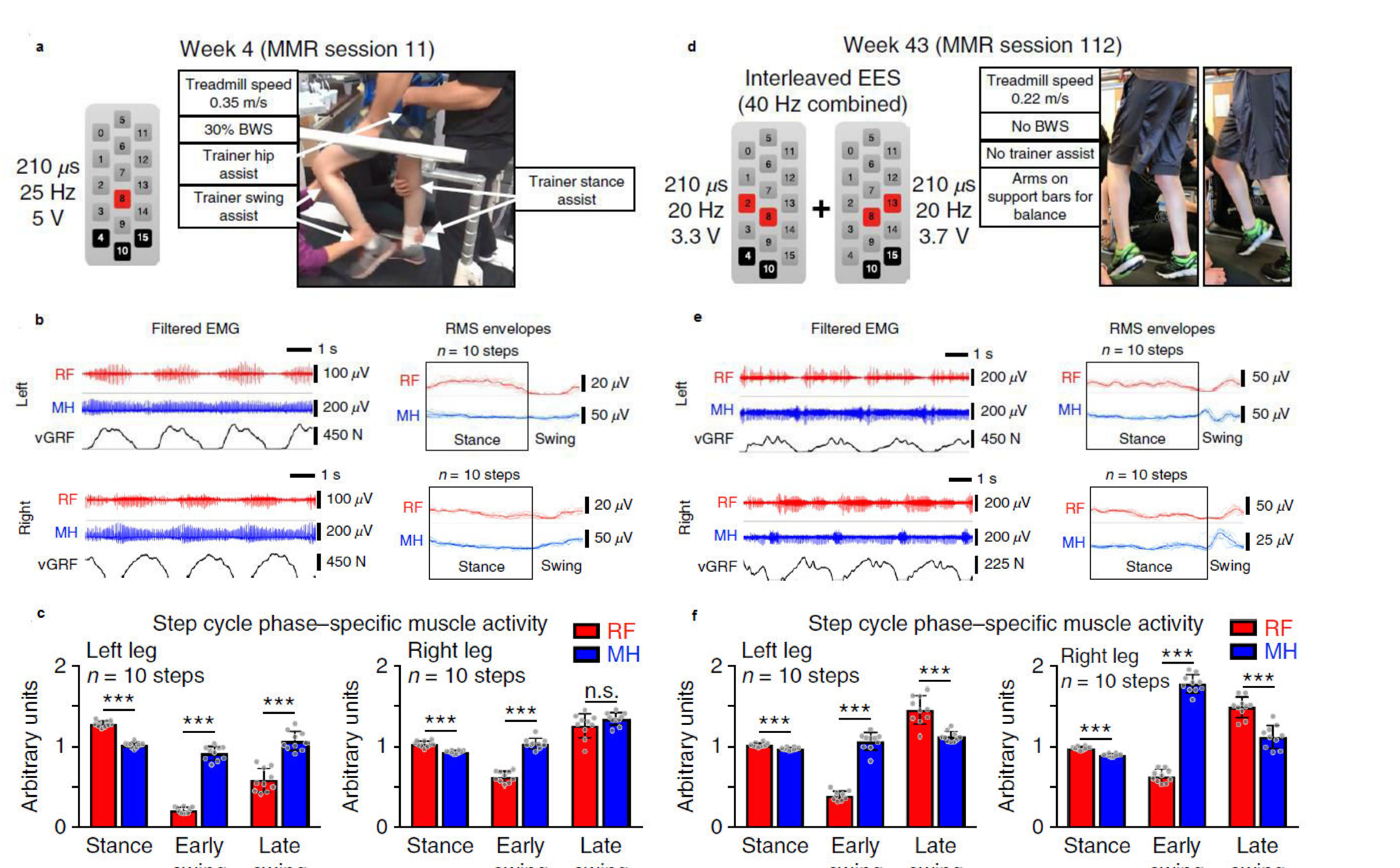

Fig. 1 | Progression of EES-enabled stepping performance on a treadmill. week 4 (a) and week 43 (d) depicting trainer assistance and BWS needed to achieve stepping. Filtered Electromyography (EMG) and averaged RMS from the RF and MH with the vertical ground reaction force recordings under each foot at week 4 (b) and week 43 (e). Differences in RF and MH activity during stance, early swing phase, and late swing phase are shown at week 4 (c) and week 43 (f).

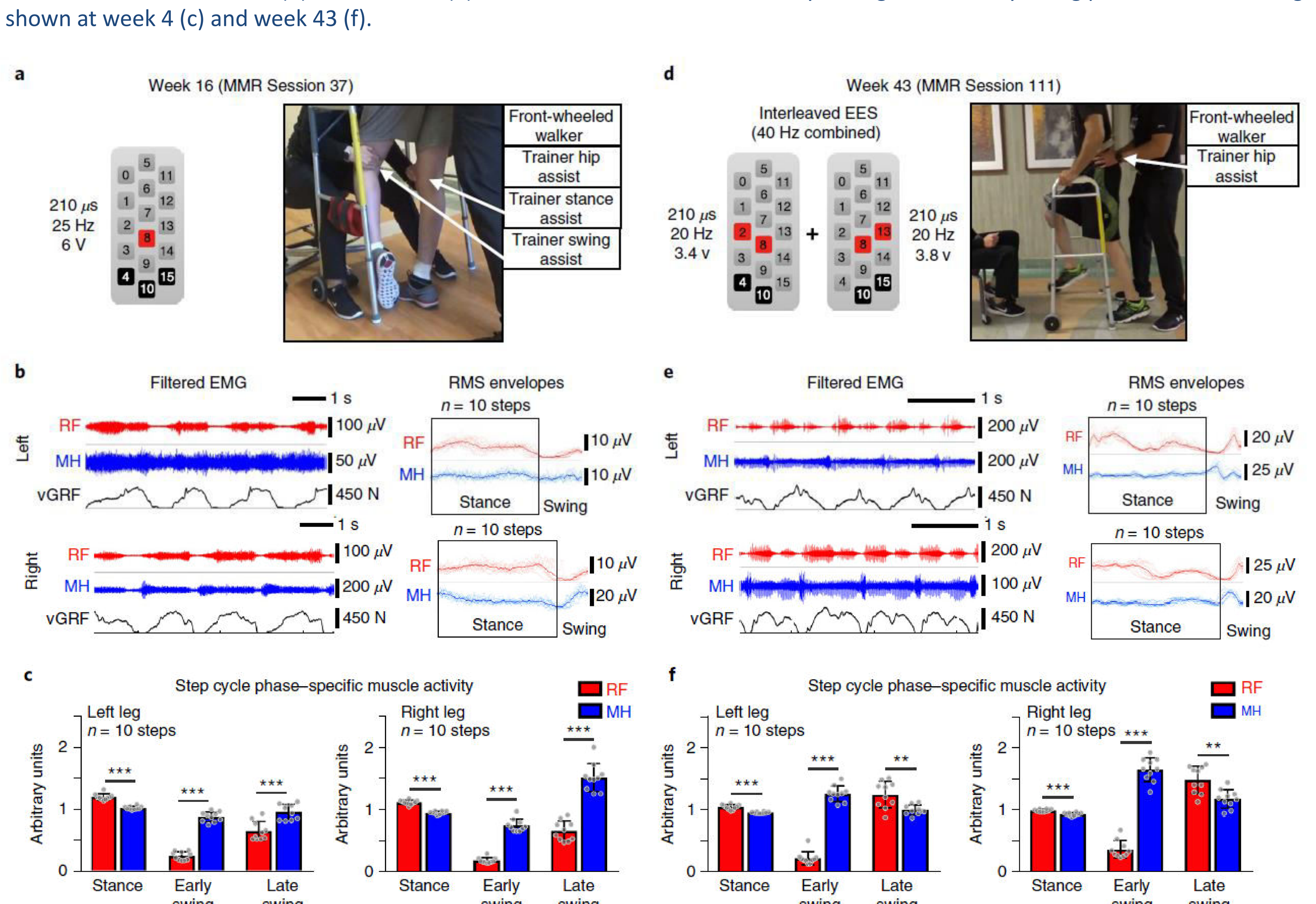

Fig. 2 | Progression of EES-enabled stepping performance over ground. EES settings and images from week 16 (a) and week 43 (d) showing trainer assistance needed to achieve stepping. Filtered EMG and averaged RMS from the RF and MH with vGRF recordings under each foot at week 16 (b) and week 43 (e). Differences in RF and MH activity during stance, early swing phase, and late swing phase are shown as means at week 16 (c) and week 43 (f).

DISCUSSION

During treadmill stepping at week 4 of MMR, single-program EES was applied allowing the patient to step on a treadmill moving at 0.35 m/s. This was done with 30% BWS and trainer assistance at the hip, knee, and ankle of each leg. Root mean square (RMS) of EMG recordings during 20 consecutive steps showed a lack of coordinated activity across muscles during the swing phase of the step cycle.

Table . 1 | Muscle activity throughout different phases measured at week 4 *Rectus Femoris (RF), Medial Gluteus (MG), Medial Hamstring (MH), and Tibialis Anterior (TA)

Stance Phase	RF + MG > MH + TA Followed by MH > RF = Cocontraction
Early swing phase	MH + TA > RF + MG
Late swing phase	MH + TA > RF + MG (MH = RF) + (TA > MG)

During step training over ground at week 16 of MMR, single program EES enabled stepping over ground with a front wheeled walker and trainer assistance to control the swing phase of one leg while bracing the contralateral limb to maintain stance, as well as to facilitate weight shifting and to maintain balance. RMS envelopes of EMG recordings from the RF and MH showed a lack of coordinated activity during the swing phase of the left leg, while the right leg muscles showed modest levels of coordination. EMG results were similar to week 4 of treadmill stepping.

From week 25 to 42 of MMR, interleaved EES programming and a front-wheeled walker were used for over-ground stepping activities. During this time, EES-enabled step speed improved from 0.05 m/s at week 25 to 0.20 m/s at week 42. The maximum number of steps taken during a single MMR session was 331, and the maximum distance traveled was 102 m. For both legs, total step cycle, stance, and swing phase durations all decreased from week 16 to week 43.

By week 43 of MMR, the use of two interleaved EES programs improved the patient's ability to control each leg in order to achieve independent stepping on the treadmill at a speed of 0.22 m/s without trainer assistance or BWS. Stepping over ground while using a front-wheeled walker and only intermittent trainer assistance was needed to facilitate weight shifting and to maintain balance.

Table . 2 | Muscle activity throughout different phases measured at week 43 *Rectus Femoris (RF), Medial Gluteus (MG), Medial Hamstring (MH), and Tibialis Anterior (TA)

Stance phase	Increase RF activity during stance with inhibition at early swing MH = tonic
Early swing phase	MH + TA > RF + MG
Late swing phase	RF > MH = Load acceptance

CONCLUSION

A paralysed patients' biggest hope is to regain motor activity. This test enabled stepping on a treadmill independent from trainer assistance or BWS, as well as independent stepping over ground while using a front-wheeled walker with trainer assistance at the hips to maintain balance. It has been demonstrated that human spinal networks can be transformed years after spinal cord injury to reach states which allow independent stepping and standing providing hope and a possible end to some patients.

REFERENCES

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* 3rd year Faculty of Basic Medical Science student at Libyan International Medical University

** Supervisor at Libyan International Medical University