

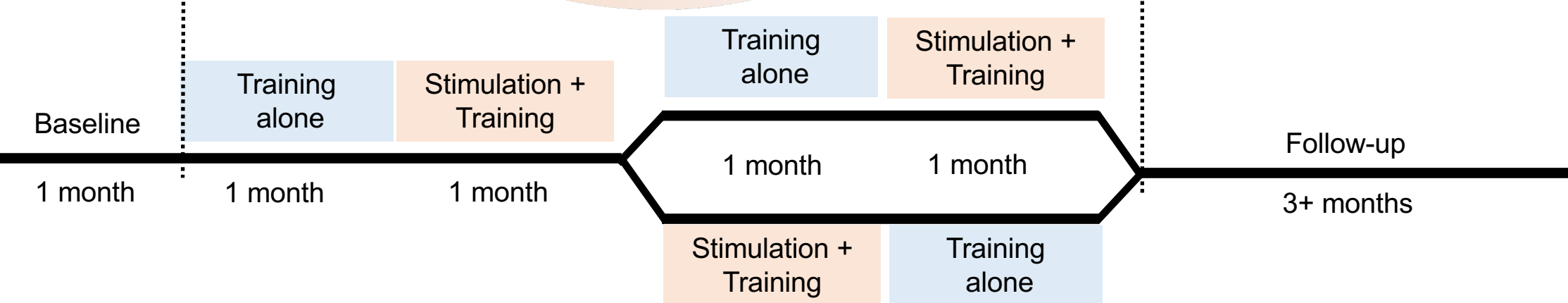
Introduction

- Restoring hand and arm movements is the highest treatment priority for people with paralysis.¹
- Spinal cord stimulation is an emerging neuromodulation strategy to restore motor function.²⁻⁵
- Here we show that non-invasive, transcutaneous spinal stimulation leads to rapid and sustained recovery of hand function, even after complete paralysis.



Methods

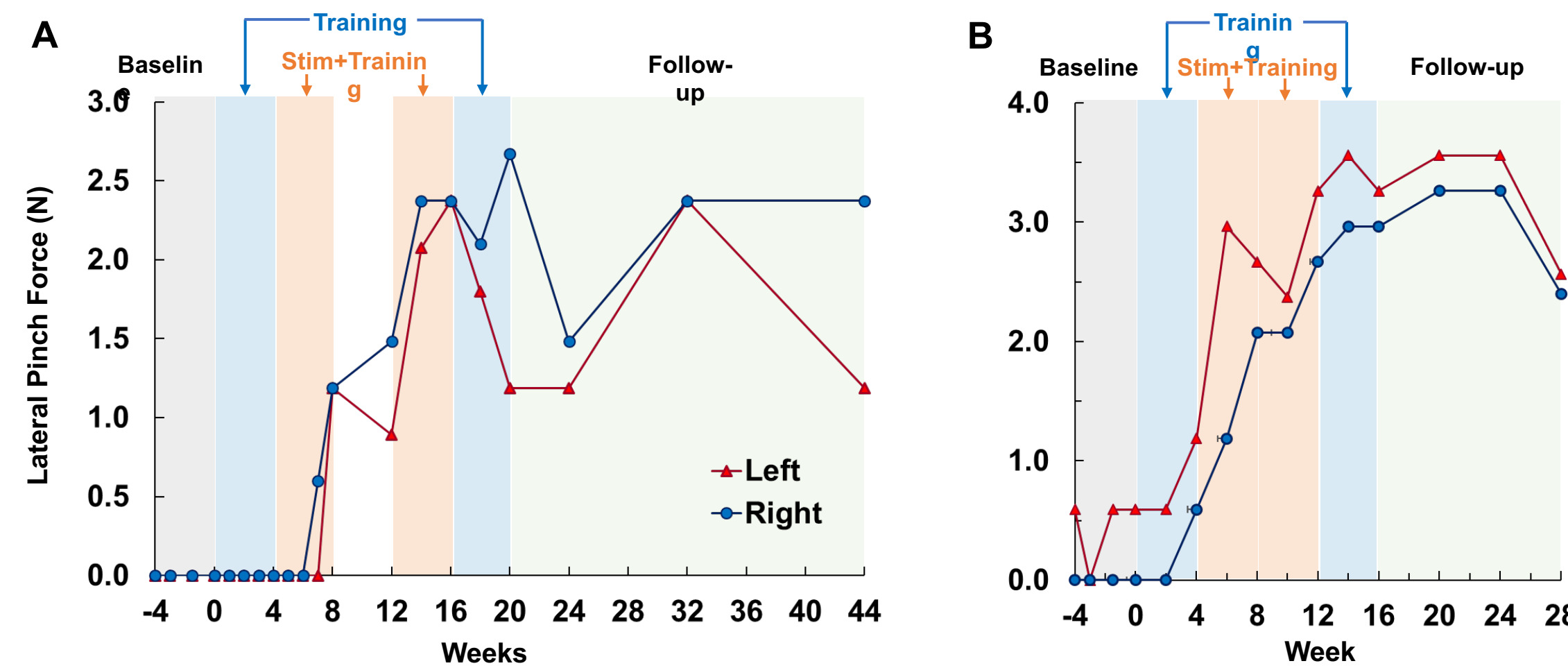
Transcutaneous spinal stimulation combined with hand & arm training



A prospective, open-label, cross-over study with 6 participants. 1 month of baseline measurements was followed by functional task practice 'training' alone for the first month of treatment. Then stimulation paired with the same training was provided during the second month for all participants. For the last two months of treatment, the order was determined by each participant's injury severity. We continued delivering stimulation to participants with motor complete injuries (AIS B), and interleaved a second month of training alone for those with incomplete injuries (AIS C-D). Inset: stimulation using 1 ms bursts of 10 k Hz transcutaneous cervical spinal cord stimulation delivered at 30 Hz.

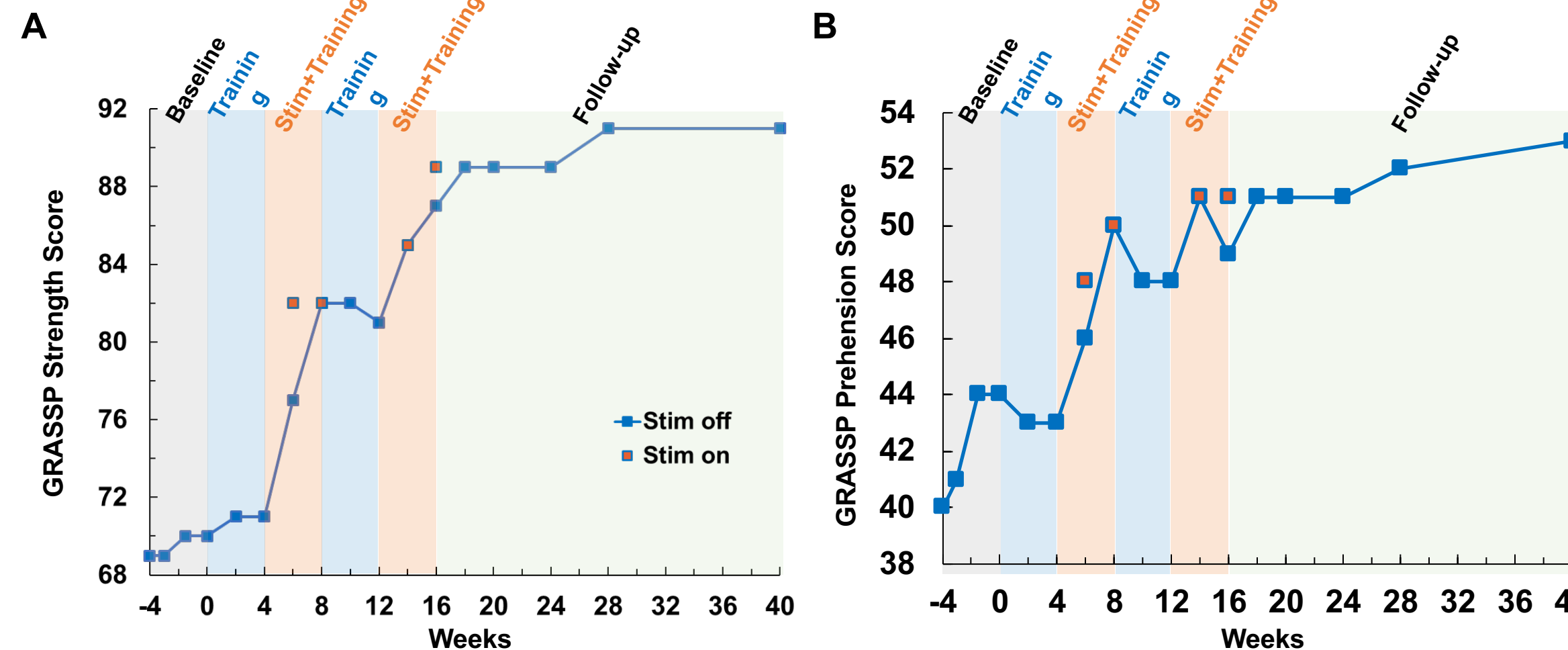
Results

Stimulation restores finger & thumb movement after complete paralysis



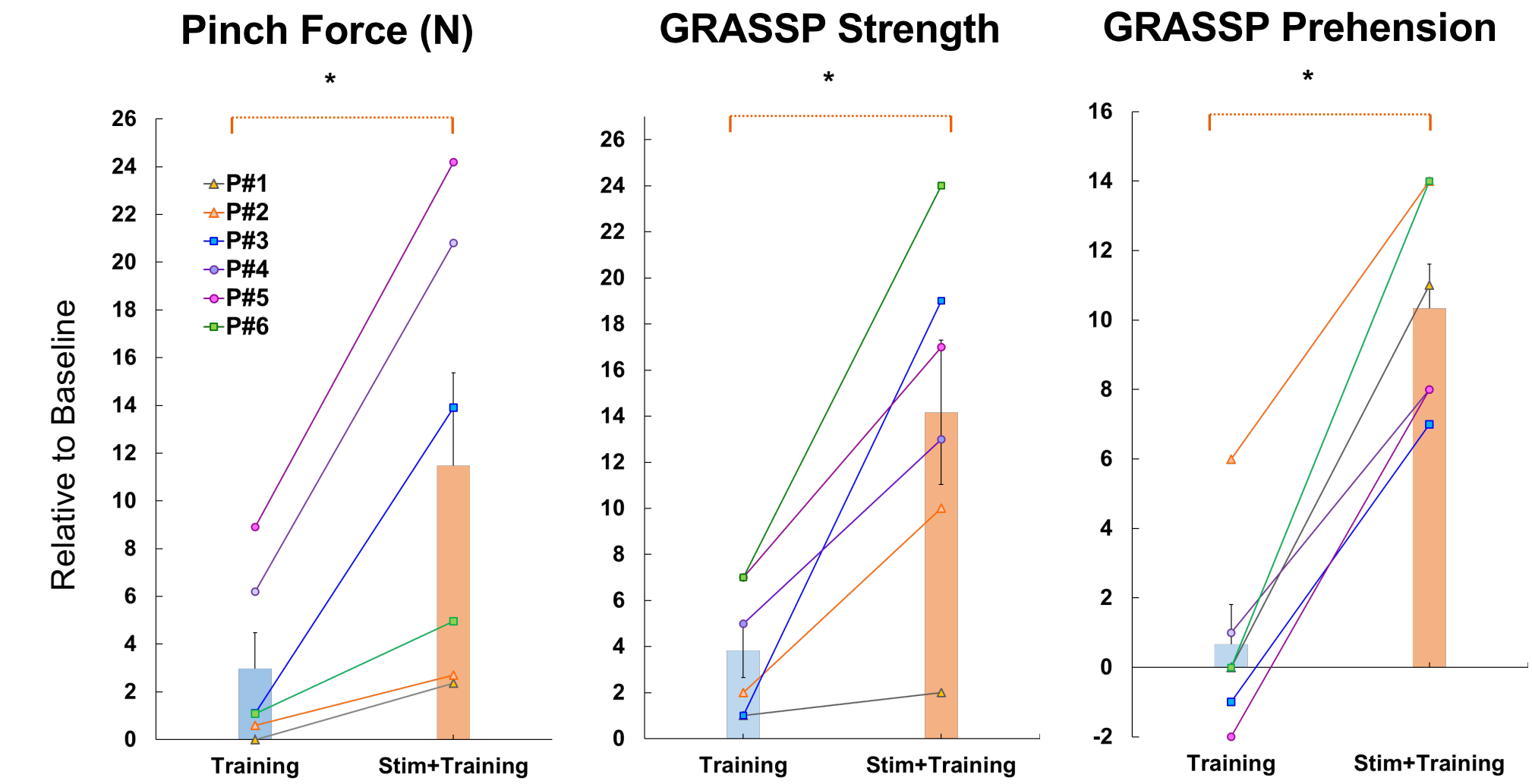
A: Participant 1 (C5 AIS B) had no movement distal to both wrists. Only with stimulation (stim) paired with training did this participant regain volitional movement of his fingers and thumbs that enabled him to produce measurable pinch force. Gains were maintained for six months of follow-up without further treatment.
B: Participant 2 (C5 AIS B) began the study with no function in either hand (left). Pinch force in both hands improved during stimulation and was largely sustained for three months of follow-up without further treatment.

Hand function improved with stimulation up to 12 years after spinal cord injury



Strength and quantitative prehension measured by the Graded Redefined Assessment of Strength Sensation and Prehension (GRASSP). Participant 3 (C5 AIS C) began the study 12 years after injury. **A:** Strength in both hands and arms improved during periods of stimulation paired with training. **B:** GRASSP prehension score also improved during periods of stimulation and training. All improvements were sustained throughout 6-months of follow-up.

Stimulation improved hand function in all six participants



Stimulation combined with training led to greater improvements than training alone in bilateral pinch force ($p = 0.024$), GRASSP strength ($p = 0.010$), and prehension ($p < 0.001$).

Conclusions

- Transcutaneous spinal stimulation combined with training leads to rapid and sustained recovery of hand function.
- All six participants maintained their gains for three to six months beyond stimulation, indicating functional recovery mediated by long-term neuroplasticity.
- Several participants resumed their hobbies, such as oil painting and playing the guitar, during and after the study.



References & Acknowledgments

- Anderson, K. D. *J Neurotrauma* 21, 1371-1383, 2004
- Lu *et al. Neurorehabil Neural Repair* 30, 951-962, 2016
- Gad *et al. J Neurotrauma* 35, 2145-2158, 2018
- Inanici *et al. IEEE TNSRE* 26, 1272-1278, 2018
- Freyvert *et al. Scientific reports* 8, 15546, 2018