

Advances in Motor Learning and Rehabilitation after Brain Injury.

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Disclosure

Candy Tefertiller is a paid educational consultant for Onward Medical.

Learning Objectives

After participating in this session, attendees will be able to:

- **Identify** current advances in motor rehabilitation for acquired brain injury and explain how these developments inform evidence-based clinical practice.
- **Evaluate** key components of contemporary clinical practice guidelines and their implications for optimizing patient outcomes and functional recovery.
- **Apply** innovative, guideline-informed strategies to enhance patient engagement, treatment effectiveness, and integration of new research into everyday rehabilitation practice.

CLINICAL PRACTICE GUIDELINES

Clinical Practice Guideline to Improve Locomotor Function Following Chronic Stroke, Incomplete Spinal Cord Injury, and Brain Injury

Hornby, T. George PT, PhD; Reisman, Darcy S. PT, PhD; Ward, Irene G. PT, DPT, NCS; Scheets, Patricia L. PT, DPT, NCS; Miller, Allison PT, DPT, NCS; Haddad, David PT, DPT; Fox, Emily J. PT, PhD, NCS; Collaborators; Fritz, Nora E. PT, PhD, NCS; Collaborators; Hawkins, Kelly PT, PhD, NCS; Collaborators; Henderson, Christopher E. PT, PhD, NCS; Collaborators; Hendron, Kathryn L. PT, PhD, NCS; Collaborators; Holleran, Carey L. PT, DHS, NCS; Collaborators; Lynskey, James E. PT, PhD; Collaborators; Walter, Amber PT, DPT, NCS; Collaborators

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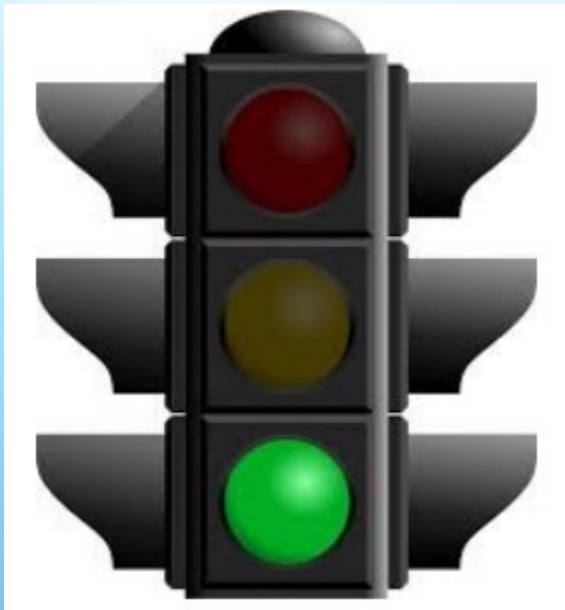
All studies reviewed to support this recommendation included individuals who were already independent walkers and were greater than 6 months post-injury

Action Statement 1: MODERATE- TO HIGH INTENSITY WALKING TRAINING FOLLOWING ACUTE-ONSET CENTRAL NERVOUS SYSTEM (CNS) INJURY. Based on the preponderance of evidence for individuals poststroke, limited evidence in individuals with iSCI, and no evidence for individuals with TBI, clinicians should use moderate- to high-intensity walking training interventions to improve walking speed and distance in individuals greater than 6 months following acute-onset CNS injury as compared with alternative interventions (evidence quality: I-II; recommendation strength: strong for individuals with stroke)

Action Statement 2: VIRTUAL REALITY WALKING TRAINING FOLLOWING ACUTE-ONSET CENTRAL NERVOUS SYSTEM (CNS) INJURY. Based on the preponderance of evidence for individuals poststroke and no evidence for individuals with iSCI or TBI, clinicians should use virtual reality training interventions coupled with walking practice for improving walking speed and distance in individuals greater than 6 months following acute-onset CNS injury as compared with alternative interventions (evidence quality: I-II; recommendation strength: strong for individuals with stroke).

Clinical Practice Guideline to Improve Locomotor Function Following Chronic Stroke, Incomplete Spinal Cord Injury, and Brain Injury

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Moderate to High Intensity

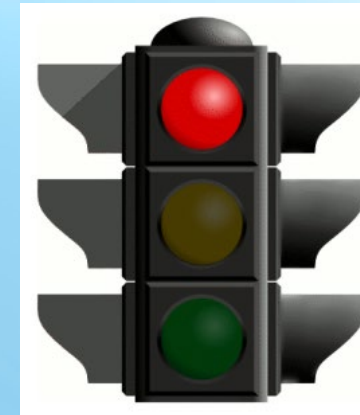


- 60-80% HRR or 70-85% HRmax
- $\geq 15/20$ on Borg Scale of Rate of Perceived Exertion

- Primary predictors of improved walking capacity during inpatient rehabilitation for stroke were steps/day, baseline impairments, and age (Moore et al 2020)
- 70-80% max HR improves walking > 30-40% HR (Holleran et al 2015)
- 85% max HR improves walking even after plateau (Moore et al 2010)



- Strength training at $\geq 70\%$ of 1 rep max
- Circuit training, cycling, or recumbent stepping at 75-85% of HRmax
- Balance training with virtual reality



- Static or dynamic standing balance activities including pre-gait training
- BWSTT with emphasis on kinematics
- Robot-assisted gait training

TBI Literature

ORIGINAL ARTICLE

CLINICAL STUDIES

Comparative Efficacy of High-Intensity Training Versus Conventional Training in Individuals With Chronic Traumatic Brain Injury: A Pilot Randomized Controlled Study

Abbey Plawcki¹, Christopher E. Henderson^{1,2}, Jennifer K. Lotter¹, Lindsay H. Shoger¹, Erin Inks^{1,2}, Molly Scofield¹, Christina J. Voigtmann¹, Sheryl Katta-Charles^{1,2} and T. George Hornby^{1,2*}

Abstract

Numerous studies have evaluated the efficacy of interventions to improve locomotion after acute-onset brain injury, although most focus on patients with stroke, with less attention toward traumatic brain injury (TBI). For example, a number of studies in patients post-stroke have evaluated the effects of high-intensity training (HIT) attempting to maximize stepping practice, while no studies have attempted this intervention in patients with TBI. The purpose of this blinded-assessor randomized trial was to evaluate the effects of HIT focused on stepping practice versus conventional training on walking and secondary outcomes in individuals with TBI. Using a crossover design, ambulatory participants with TBI >6-months duration performed HIT focused on stepping in variable contexts (overground, treadmill, stairs) or conventional training for up to 15 sessions over five weeks, with interventions alternated >4 weeks later. HIT focused on maximizing stepping practice while trying to achieve higher cardiovascular intensities (>70% heart rate reserve), while conventional training focused on impairment-based and functional exercises with no restrictions on intensities achieved. Greater increases in 6-min walk test and peak treadmill speed during graded exercise testing were observed after HIT versus conventional training, with moderate associations between differences in stepping practice and outcomes. Greater gains were also observed in estimates of aerobic capacity and efficiency after HIT, with additional improvements in selected cognitive assessments. The pres-

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Keyw

RCT: N=17

- No significant differences in walking speed between groups
- Significant differences in walking endurance
- Mixed results regarding cognitive changes.



- ↓ ankle torque in TBI → ↓ Gait Speed (Williams et al 2010)
- Ankle torque in TBI → Most significant mobility predictor (Williams 2013)
- Self selected walking speed >1.0m/s predicts running (Williams et al 2010)

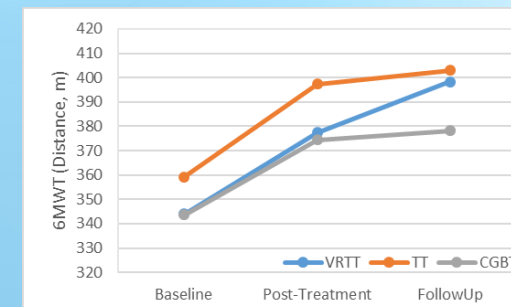
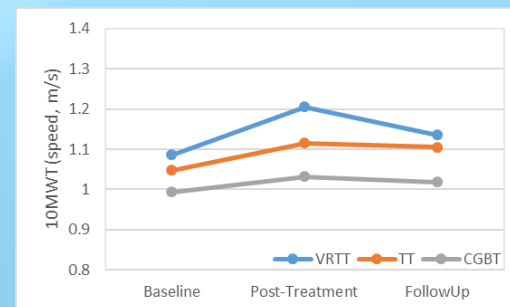
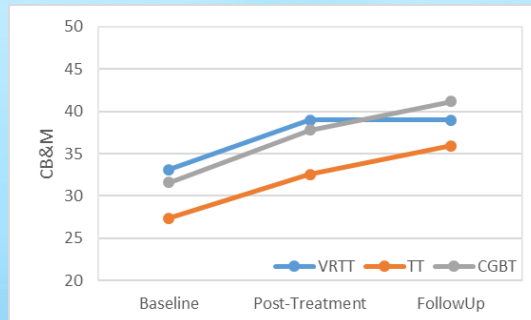
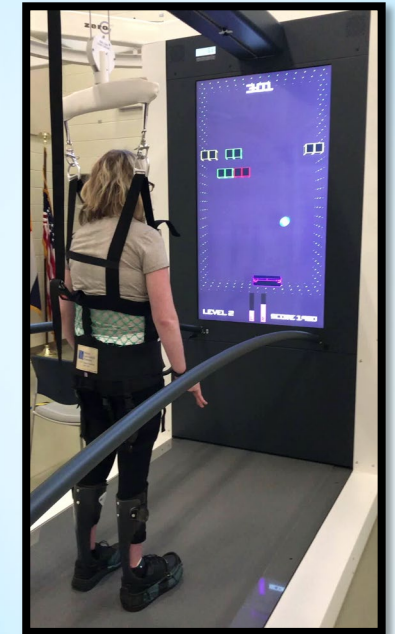
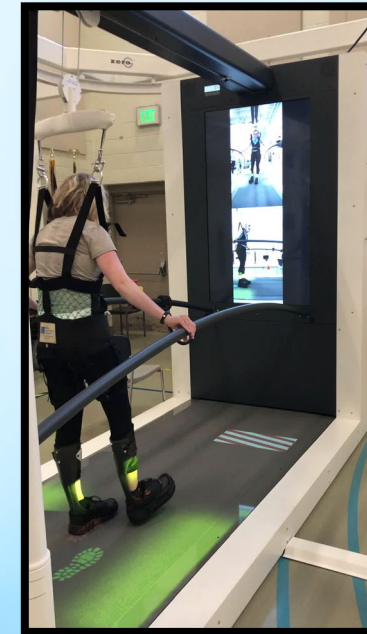
Pilot Study: Virtual Reality and High Intensity

Randomized Controlled Trial > Brain Inj. 2022 Jun 7;36(7):898-908.
doi: 10.1080/02699052.2022.2096258. Epub 2022 Jul 14.

Feasibility of virtual reality and treadmill training in traumatic brain injury: a randomized controlled pilot trial

Candace Tefertiller ¹, Jessica M Ketchum ¹, Patricia Bartelt ¹, Mackenzie Peckham ¹, Kaitlin Hays ¹

Affiliations + expand
PMID: 35834738 DOI: 10.1080/02699052.2022.2096258



Tefertiller C, Ketchum JM, Bartelt P, Peckham M, Hays K. Feasibility of virtual reality and treadmill training in traumatic brain injury: a randomized controlled pilot trial. Brain Inj. 2022 Jun 7;36(7):898-908. .

RCT In Progress: High Intensity Step Training (VR)



TBIMS

Traumatic Brain Injury
Model System

Since 1987

The **primary objective** of this study is to evaluate High Intensity Step Training (HIST) with and without Virtual Reality (VR) in Individuals with **Subacute TBI (< 6 months)**

3-Arm Randomized-Controlled Trial

1. Conventional Gait and Balance Training (CGBT)
2. HIST
3. HISTVR

Intervention

- 5x/week
- 30 sessions
- 4-week follow-up

Outcomes

1. Mobility
2. Balance
3. Cognition

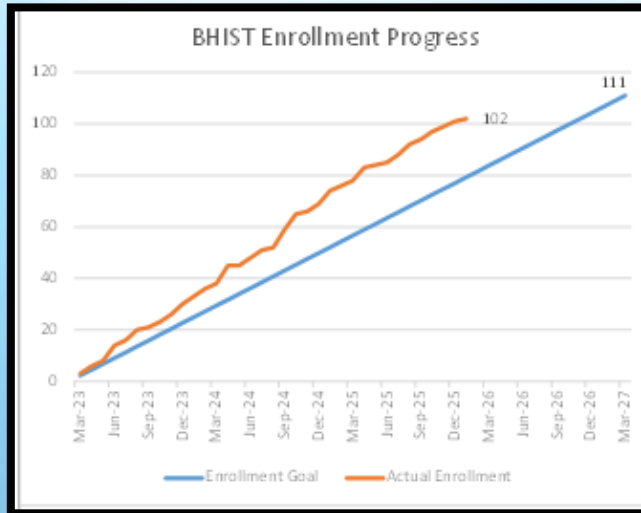
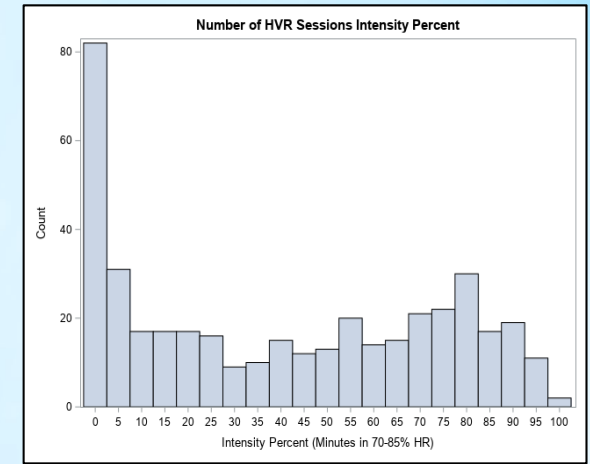
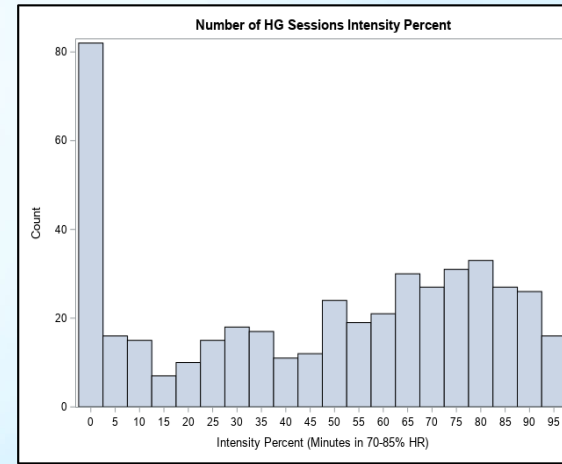
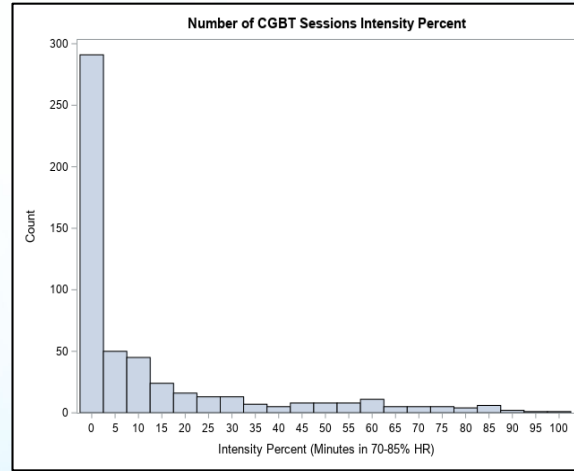
| | N | Total N = 85 | |
|----------------------|----|-----------------|------|
| | | Mean | SD |
| Age | 84 | 31.0 | 12.5 |
| GCS | 69 | 6.7 | 3.7 |
| TFC Days | 58 | 13.8 | 19.0 |
| PTA Days | 61 | 49.6 | 32.3 |
| CARE Total | | | |
| Baseline | 84 | 68.1 | 25.4 |
| Discharge | 84 | 111.2 | 20.7 |
| CARE Mobility | | | |
| Baseline | 84 | 43.9 | 17.4 |
| Discharge | 84 | 73.4 | 15.2 |

| | N | Total N = 85 | |
|-----------------------------------|----|-----------------|-------|
| | | Mean | SD |
| 10-Meter Walk Test | | | |
| Comfort 1 | 84 | 18.1 | 28.8 |
| Comfort 2 | 84 | 14.7 | 20.0 |
| Comfort Average | 84 | 16.4 | 23.5 |
| Fast 1 | 83 | 11.2 | 16.5 |
| Fast 2 | 83 | 10.7 | 16.6 |
| Fast Average | 83 | 11.0 | 16.3 |
| Average | 83 | 13.2 | 19.1 |
| 6-Minute Walk Test | 83 | 279.9 | 139.6 |
| Berg Balance Scale | 85 | 36.7 | 18.3 |
| Functional Gait Assessment | 85 | 12.8 | 9.6 |
| HiMAT | 66 | 11.7 | 11.9 |
| BTACT | | | |
| Composite Score | 72 | -1.13 | 1.09 |
| Episodic Memory | 72 | -1.21 | 0.93 |
| Executive Functioning | 72 | -1.09 | 1.30 |





Intensity



Sessions: $N = 1406$ (79 Subjects)

| | <i>N</i> | Mean | SD | Minimum | P25 | Median | P75 | Maximum | Missing |
|--|----------|-------|-------|---------|-----|--------|-----|---------|---------|
| All Groups | | | | | | | | | |
| Intensity Time (Minutes in 70-85% HR) | 1395 | 12.50 | 13.26 | 0 | 0 | 7 | 24 | 94 | 11 |
| Intensity Percent (% of time in 70-85% HR) | 1395 | 32.10 | 32.74 | 0 | 0 | 20 | 63 | 99 | 11 |
| CGBT Group | | | | | | | | | |
| Intensity Time (Minutes in 70-85% HR) | 528 | 5.46 | 10.07 | 0 | 0 | 1 | 6 | 89 | 5 |
| Intensity Percent (% of time in 70-85% HR) | 528 | 12.67 | 21.72 | 0 | 0 | 1 | 15 | 99 | 5 |
| HG Group | | | | | | | | | |
| Intensity Time (Minutes in 70-85% HR) | 457 | 17.78 | 12.69 | 0 | 5 | 20 | 29 | 40 | 5 |
| Intensity Percent (% of time in 70-85% HR) | 457 | 47.07 | 32.15 | 0 | 13 | 53 | 76 | 96 | 5 |
| HVR Group | | | | | | | | | |
| Intensity Time (Minutes in 70-85% HR) | 410 | 15.68 | 13.55 | 0 | 2 | 14.5 | 27 | 94 | 1 |
| Intensity Percent (% of time in 70-85% HR) | 410 | 40.45 | 32.94 | 0 | 5 | 40 | 72 | 99 | 1 |

Virtual Reality

Virtual reality training enhances gait poststroke: a systematic review and meta-analysis

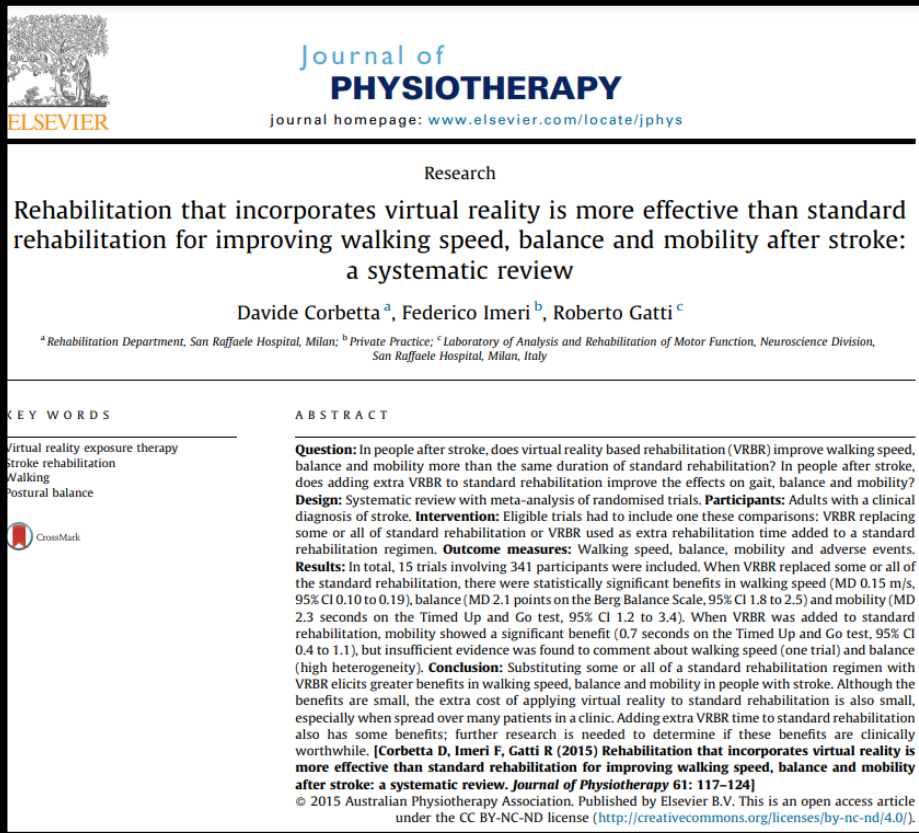
Shashank Ghai,^{1,2} Ishan Ghai,³ and Anouk Lamontagne^{1,2}

¹School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada. ²Feil & Oberfeld Research Centre of the Jewish Rehabilitation Hospital, Centre for Interdisciplinary Research of Greater Montreal (CRIR), Laval, Quebec, Canada. ³Rsgbiogen, New Delhi, India

Address for correspondence: Shashank Ghai, Feil & Oberfeld Research Centre of the Jewish Rehabilitation Hospital, Centre for Interdisciplinary Research of Greater Montreal (CRIR), CISSS-Laval Research Site, 3205 Place Alton-Goldbloom, Laval, QC H7V 1R2, Canada. shashank.ghai@mail.mcgill.ca

Virtual reality (VR)-based interventions are gaining widespread attention for managing neurological disorders such as stroke. A metastatistical consensus regarding the intervention is strongly warranted. In this study, we attempt to address this gap in the literature and provide the current state of evidence for the effects of VR on gait performance. We conducted both between- and within-group meta-analyses to provide a state of evidence for VR. Moreover, we conducted a search adhering to PRISMA guidelines on nine databases. Out of 1866 records, 32 studies involving a total of 809 individuals were included in this review. Considering all included studies, significant enhancements in gait parameters were observed with VR-based interventions compared with conventional therapy. A between-group meta-analysis reported beneficial significant *medium* effects of VR training on cadence (Hedge's $g = 0.55$), stride length (STrL; Hedge's $g = 0.46$), and gait speed (Hedge's $g = 0.30$). Similarly, a within-group meta-analysis further revealed positive *medium* effects of VR on cadence (Hedge's $g = 0.76$), STrL (Hedge's $g = 0.61$), and gait speed (Hedge's $g = 0.69$). Additional subgroup analyses revealed beneficial effects of joint application of VR and robot-assisted gait training on gait speed (Hedge's $g = 0.50$). Collectively, findings from this review provide evidence for the effectiveness of VR-based gait training for stroke survivors.

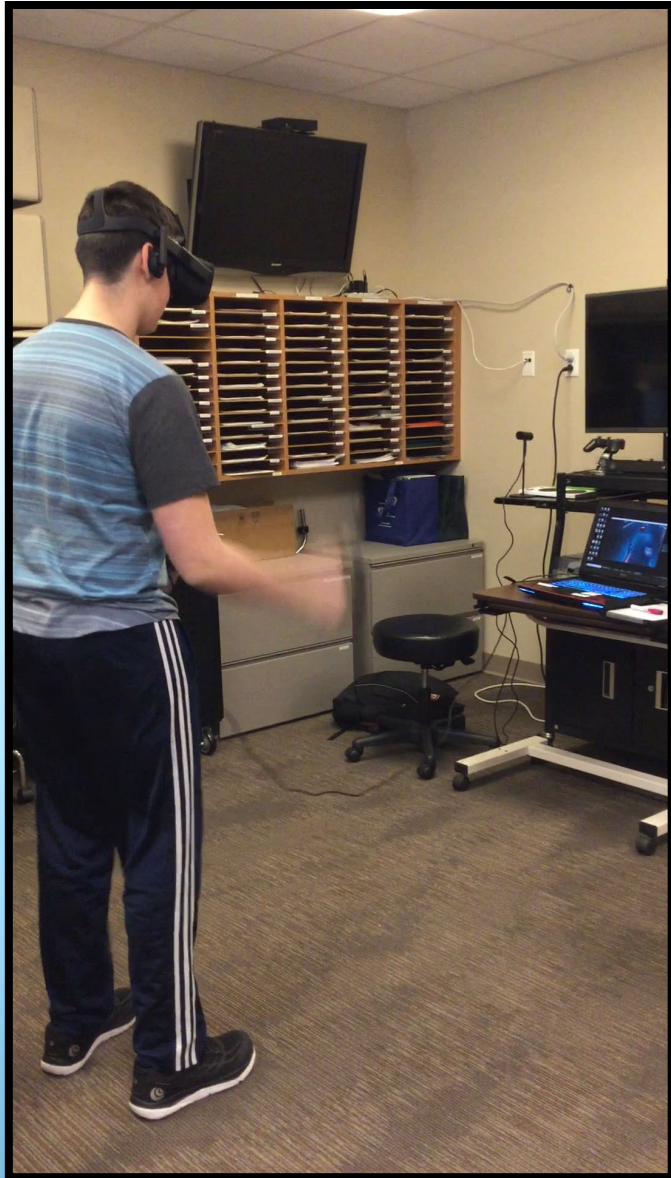
- 32 Trials: VR compared to standard rehabilitation
- Medium effects cadence, gait speed, and stride length



The image shows the cover page of the Journal of Physiotherapy. At the top left is the Elsevier logo. The journal title 'Journal of PHYSIOTHERAPY' is centered at the top, with the homepage URL 'www.elsevier.com/locate/jphys' below it. The article title 'Rehabilitation that incorporates virtual reality is more effective than standard rehabilitation for improving walking speed, balance and mobility after stroke: a systematic review' is prominently displayed. Below the title are the authors: Davide Corbetta, Federico Imeri, and Roberto Gatti. The article is categorized as 'Research'. There are sections for 'KEY WORDS' (Virtual reality exposure therapy, Stroke rehabilitation, Walking, Postural balance) and 'ABSTRACT'. The abstract text describes the study's purpose, methods, results, and conclusions. At the bottom, there is a copyright notice for 2015 Australian Physiotherapy Association, published by Elsevier B.V., under a CC BY-NC-ND license.

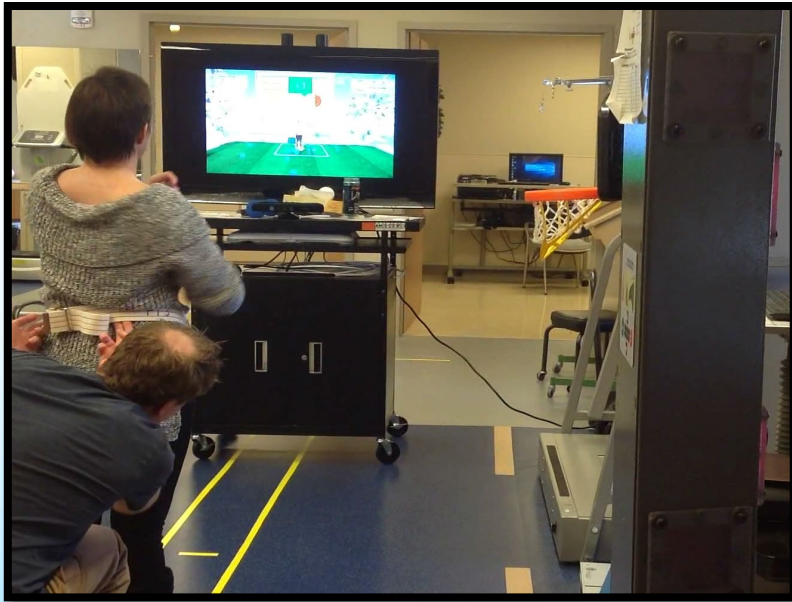
- 15 Trials: VR replaced some or all standard rehabilitation
- Statistically significant improvements in walking speed, balance, and mobility in comparison to conventional therapy

Virtual Reality



Action Statement 6: BALANCE TRAINING FOLLOWING ACUTE-ONSET CENTRAL NERVOUS SYSTEM (CNS) INJURY. Based on a preponderance of evidence in individuals poststroke, limited evidence in TBI, and no evidence in iSCI, clinicians may consider use of static and dynamic (nonwalking) balance strategies when coupled with virtual reality or augmented visual feedback to improve walking speed and distance in individuals greater than 6 months following acute-onset CNS injury (evidence quality: I-II; recommendation strength: strong for individuals with stroke).

Augmented Reality



ACRM
AMERICAN CONGRESS OF
REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2019;100:1409-16

ORIGINAL RESEARCH

Results From a Randomized Controlled Trial to Address Balance Deficits After Traumatic Brain Injury

Candace Tefertiller, PT, PhD
Audrey Natale, PT, DPT
Mitch Sevigny, MS, C. C.

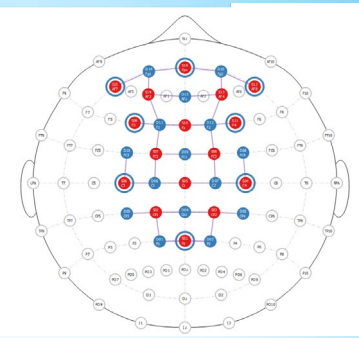
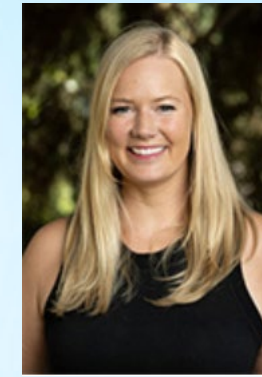
From the *Department of Physical Therapy, University of Colorado; and †Department of Research, University of Colorado

Abstract
Objective: To evaluate the efficacy of a home-based exercise program to improve balance in individuals with chronic TBI.
Setting: Home-based exercise program.
Participants: Individuals (N=63) who were currently receiving PT services.
Main Outcome Measures: Primary: Activities-Specific Balance Confidence (ABC). Secondary: Timed Up and Go (TUG) test.
Results: No significant between-group differences were found for ABC (P=.8822); TUG (P=.4343) and from baseline to 6, 12, and at 12 weeks. A detectable change of 8 points on the ABC was not achieved.
Conclusion: This study did not find significant differences between groups in both treatment groups in the home environment.
Archives of Physical Medicine and Rehabilitation 2019;100:1409-16
© 2019 by the American Congress of Rehabilitation Medicine

RCT N= 63
Results: No significant differences between VR and traditional HEP groups;

- Both groups (chronic) demonstrated statistically significant improvements from baseline balance scores;
- 52% of all met or exceeded clinically meaningful differences (CB&M, BESTest).

Cortical Excitability: Functional Near-Infrared Spectroscopy (fNIRS)



FOCUS ON CLINICAL RESEARCH AND PRACTICE

Assessing Task-Dependent Neurophysiology During Virtual Reality Treadmill Training in Adults With Traumatic Brain Injury: A Functional Near-Infrared Spectroscopy Feasibility Study

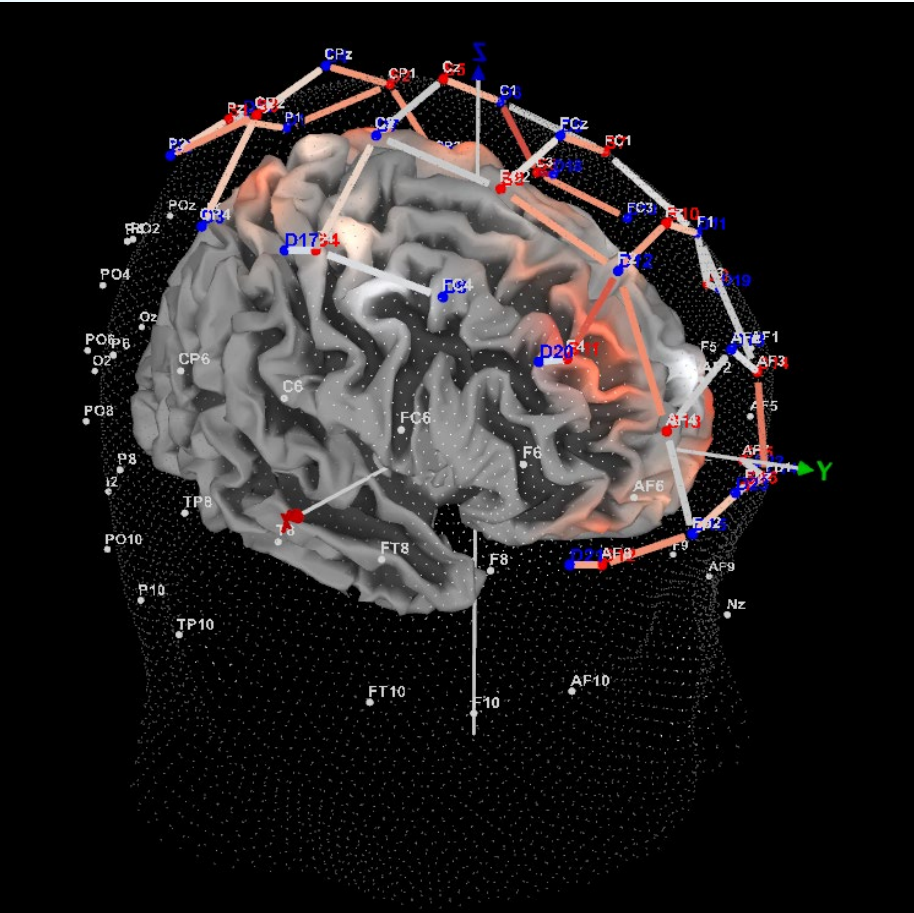
Stephens, Jaclyn PhD, OTR/L; Hays, Kaitlin PT, DPT, NCS; Winden, Haylee PT, DPT, NCS; Busch, Brandon BS; Tefertiller, Candace PT, DPT, PhD

[Author Information](#)

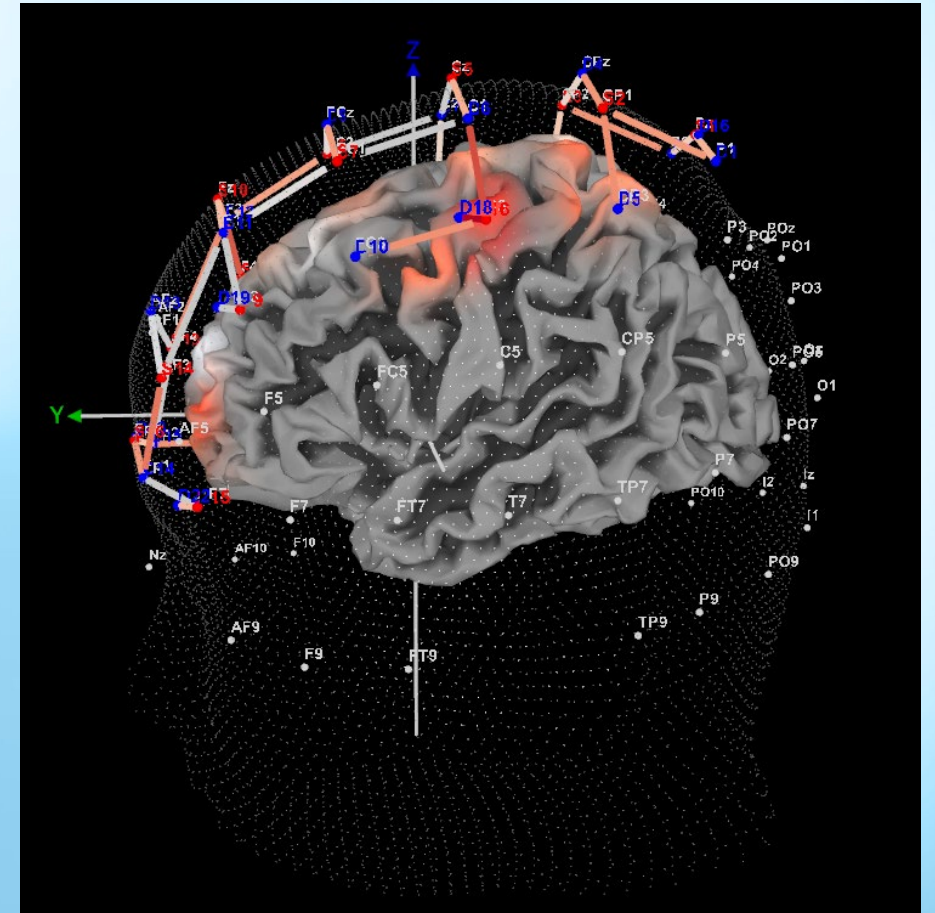
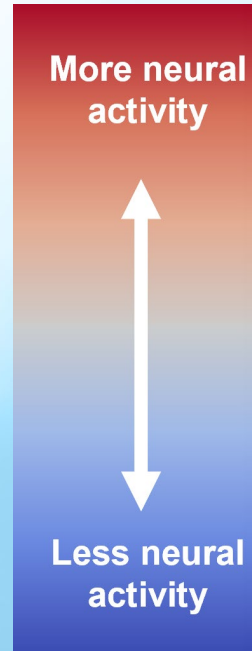
Journal of Head Trauma Rehabilitation 41(1):p E59-E67, January/February 2026. | DOI: 10.1097/HTR.0000000000001057

Treadmill Task with VR vs. Treadmill Task Alone

*Late Epochs Only (N=7)



Right Hemisphere



Left Hemisphere

Disorders of Consciousness (DoC)

Feasibility of overground exoskeleton gait training during inpatient rehabilitation after severe acquired brain injury

Jaime Gillespie^a, Molly Trammell^a, Christa Ochoa^b, Simon Driver^b, Librada Callender^b, Rosemary Dubiel^a, and Chad Swank^{a,b}

^aPhysical Medicine and Rehabilitation, Baylor Scott and White Institute for Rehabilitation, Dallas, Texas, USA; ^bPhysical Medicine and Rehabilitation, Baylor Scott and White Research Institute, Dallas, Texas, USA

ABSTRACT

Objective: To describe the safety, feasibility, and tolerability of overground exoskeleton gait training (OEGT) integrated into clinical practice for patients after severe acquired brain injury (ABI).

Setting: Inpatient rehabilitation hospital.

Participants: Eligible patients with severe ABI met the following criteria: age > 18, medically stable, met exoskeleton frame limitations, and a score of ≤ 3 on the motor function portion of the Coma Recovery Scale – Revised (CRS-R). Presence of consciousness disorder was not exclusionary.

Design: Prospective observational study.

Main Measures: Outcomes examined safety (adverse events), feasibility (session count and barriers to session completion), and tolerability of OEGT (session metrics and heart rate).

Results: Ten patients with ABI completed 10.4 ± 4.8 OEGT sessions with no adverse events. Barriers to session completion included clinical focus on prioritized interventions. Sessions [median up time = 17 minutes, (IQR: 7); walk time = 13 minutes, (IQR: 9); step count = 243, (IQR: 161); device assist = 74, (IQR: 28.0)] were primarily spent in Very Light to Light heart rate intensities [89%, (IQR: 42%) and 9%, (IQR: 33%), respectively].

Conclusion: OEGT incorporated into the rehabilitation plan of care during inpatient rehabilitation after severe ABI was observed to be safe, feasible, and tolerable. However, intentional steps must be taken to facilitate patient safety.

ARTICLE HISTORY

Received 18 January 2023

Revised 7 February 2024

Accepted 7 February 2024

KEYWORDS

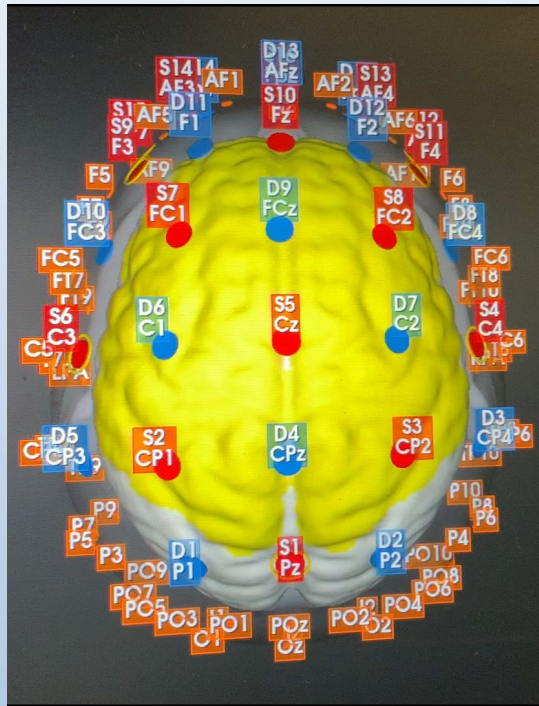
Robotic exoskeleton;
neurological rehabilitation;
brain injuries; rehabilitation
hospital; physical therapists;
consciousness disorders

- No adverse events in case series of 10 individuals with severe ABI
- Rare AEs: Skin abrasions and hypotension during inpatient exoskeleton training

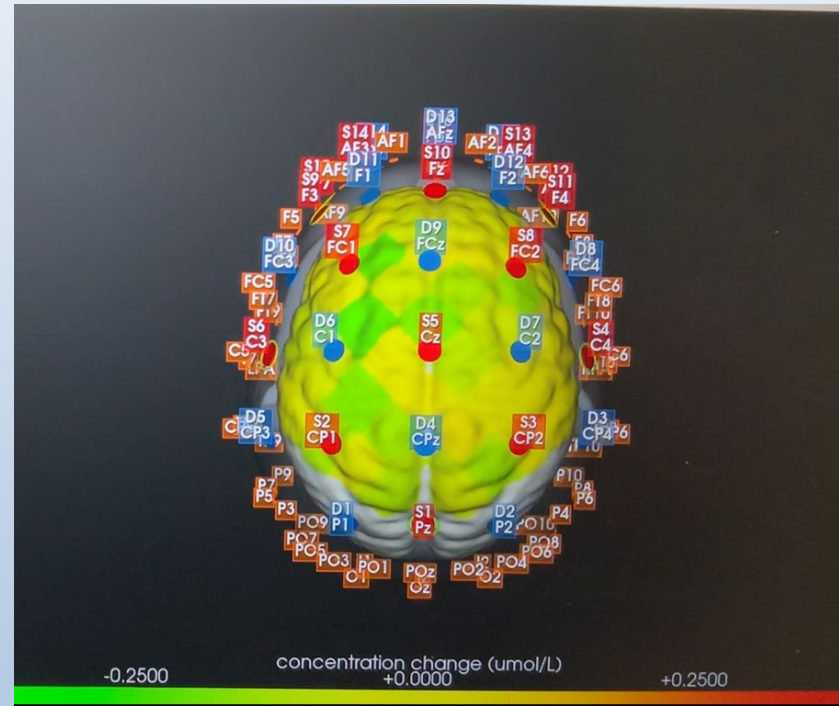
“Future trials should measure arousal and consider further associating this with neurophysiological measures”

DOC: fNIRS





Quiet Rest



Mental Imagery



Exoskeleton-Assisted Walking

TBI: Chronic Disease Model

Review > Lancet Neurol. 2023 Jun;22(6):517-528. doi: 10.1016/S1474-4422(23)00065-0.

Epub 2023 Apr 20.

Traumatic brain injury as a chronic disease: insights from the United States Traumatic Brain Injury Model Systems Research Program

Kristen Dams-O'Connor¹, Shannon B Juengst², Jennifer Bogner³, Nancy D Chiaravalloti⁴, John D Corrigan³, Joseph T Giacino⁵, Cynthia L Harrison-Felix⁶, Jeanne M Hoffman⁷, Jessica M Ketchum⁶, Anthony H Lequerica⁸, Jennifer H Marwitz⁹, A Cate Miller¹⁰, Risa Nakase-Richardson¹¹, Amanda R Rabinowitz¹², Angelle M Sander¹³, Ross Zafonte¹⁴, Flora M Hammond¹⁵

Affiliations + expand

PMID: 37086742 DOI: 10.1016/S1474-4422(23)00065-0

Functional Independence

Cardiovascular Health/Mortality

Frailty

Mobility Disability

Cognitive Decline

Falls

Hospitalization

All Cause Mortality

WHITE PAPER: "WALKING SPEED: THE SIXTH VITAL SIGN"

White Paper: "Walking Speed: the Sixth Vital Sign"

Fritz, Stacy PT, PhD¹; Lusardi, Michelle PT, PhD²

Author Information

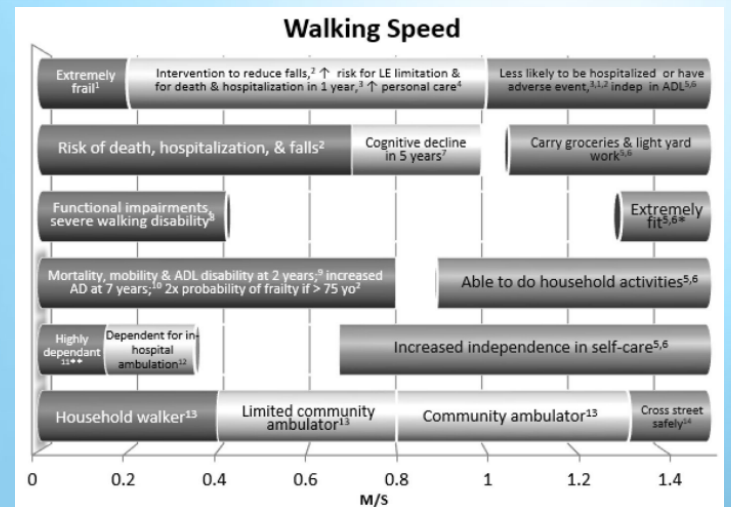
Journal of Geriatric Physical Therapy 32(2):p 2-5,

Walking Speed: The Functional Vital Sign

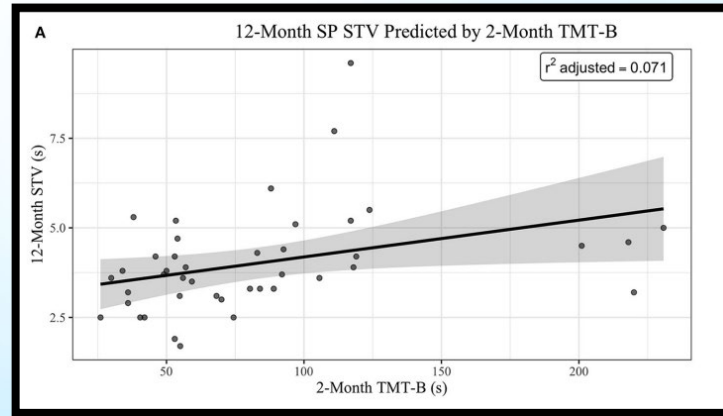
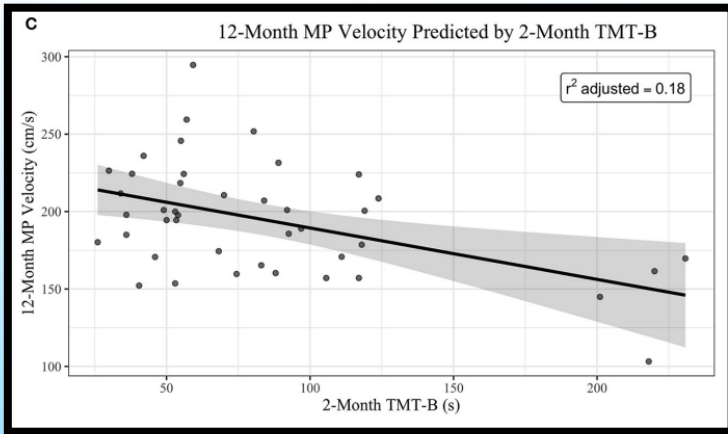
Addie Middleton, PT, DPT, Stacy L. Fritz, PT, PhD, and Michelle Lusardi, PT, PhD
University of South Carolina, Department of Exercise Science, Physical Therapy Program, Columbia, South Carolina (Middleton, Fritz); Sacred Heart University, Department of Physical Therapy & Human Movement Science, College of Health Professions, Fairfield, Connecticut (Lusardi)

Abstract

Walking speed (WS) is a valid, reliable, sensitive measure appropriate for assessing and monitoring functional status and overall health in a wide range of populations. These capabilities have led to its designation as the "6th vital sign". By synthesizing the available evidence on WS, this scholarly review article provides clinicians with a reference tool regarding this robust measure. Recommendations on testing procedures for assessing WS, including optimal distance, inclusion of acceleration/deceleration phases, instructions, and instrumentation are given. After assessing an individual's WS, clinicians need to know what this value represents. Therefore, WS cut-off values and the corresponding predicted outcomes, as well as minimal detectable change values for specific populations and settings are provided.



Gait and Cognition: Neural Internetwork Model



Relationship Between Cognition and Gait at 2- and 12-Months Post-Traumatic Brain Injury

Veronica Vuong^{1,2,3*}, Kara K. Patterson^{4,5,6}, Lauren Patricia Cole¹, Tara Lynn Henechowicz¹, Conor Sheridan^{4,6}, Robin E. A. Green^{4,6} and Michael H. Thaut^{1,2,6}

¹ Music and Health Science Research Collaboratory, Faculty of Music, University of Toronto, Toronto, ON, Canada, ² Institute of Medical Science, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada, ³ Rotman Research Institute, Baycrest Health Sciences, Toronto, ON, Canada, ⁴ Knowledge, Innovation, Talent, Everywhere (KITE) Research Institute, University Health Network, Toronto, ON, Canada, ⁵ Department of Physical Therapy, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada, ⁶ Rehabilitation Sciences Institute, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada

TABLE 3 | Correlations between cognition and gait 2-months post-admittance to the traumatic brain injury (TBI) recovery program.

| Condition | Gait variable | Cognitive variable | Correlation coefficient | P-value |
|-----------|---------------|--------------------|-------------------------|----------------|
| MP | Velocity | TMT-B | -0.28 | 0.0096* |
| SP | Velocity | TMT-B | -0.33 | 0.0028* |
| MP | Velocity | DS-F | 0.26 | 0.0199* |
| SP | Velocity | DS-F | 0.16 | 0.1393 |
| MP | SLV | TMT-B | 0.1 | 0.5225 |
| SP | SLV | TMT-B | 0.17 | 0.2531 |
| MP | STV | TMT-B | 0.32 | 0.0326* |
| SP | STV | TMT-B | 0.39 | 0.0073* |
| MP | SLV | DS-F | -0.02 | 0.9185 |
| SP | SLV | DS-F | -0.13 | 0.4113 |
| MP | STV | DS-F | -0.14 | 0.363 |
| SP | STV | DS-F | -0.06 | 0.6864 |

MP, max-paced; SP, self-paced; SLV, step length variation; STV, step time variation; TMT-B, Trail Making Test-B; DS-F, Digit Span-Forward.
* means Significant p-value = 0.05.

TABLE 4 | Correlations between cognition and gait 12-months post-admittance to the traumatic brain injury (TBI) recovery program.

| Condition | Gait variable | Cognitive variable | Correlation coefficient | P-value |
|-----------|---------------|--------------------|-------------------------|----------------|
| MP | Velocity | TMT-B | -0.2 | 0.1499 |
| SP | Velocity | TMT-B | -0.37 | 0.007* |
| MP | Velocity | DS-F | 0.22 | 0.1029 |
| SP | Velocity | DS-F | 0.34 | 0.0115* |
| MP | SLV | TMT-B | 0.19 | 0.2848 |
| SP | SLV | TMT-B | 0.33 | 0.0572 |
| MP | STV | TMT-B | 0.23 | 0.1839 |
| SP | STV | TMT-B | 0.32 | 0.0649 |
| MP | SLV | DS-F | -0.09 | 0.5989 |
| SP | SLV | DS-F | -0.1 | 0.57 |
| MP | STV | DS-F | -0.15 | 0.4039 |
| SP | STV | DS-F | -0.12 | 0.5028 |

MP, max-paced; SP, self-paced; SLV, step length variation; STV, step time variation; TMT-B, Trail Making Test-B; DS-F, Digit Span-Forward.
* means Significant p-value = 0.05

Conclusions (n=93): Significant associations and predictions between physical and cognitive recovery post-TBI were observed in this study. **Future directions may consider a “neural internetwork” model as a salient rehabilitation approach in TBI that integrates physical and cognitive functions.**

Aerobic Exercise and TBI

Review Articles

Effectiveness of aerobic exercise on cognition in individuals with traumatic brain injury: A systematic review

Anas R. Alashram 


Pages 266-274 | Published online: 12 Mar 2024

 Cite this article  <https://doi.org/10.1080/23279095.2024.2327829>



Research Article

Effectiveness of exercise in improving quality of life in patients with traumatic brain injury: A systematic review and meta-analysis

Chia-Wen Chang, Hsin-Ya Tzeng, Ching-Yuan Ma, Shih-Ting Li, Kuan-Jung Chen & Hui-Hsun Chiang 

Pages 140-146 | Received 25 Aug 2021, Accepted 02 Jan 2023, Published online: 09 Jan 2023

Reviews

Cognitive and neural effects of exercise following traumatic brain injury: A systematic review of randomized and controlled clinical trials

Bhanu Sharma, David Allison, Patricia Tucker, Donald Mabbott & Brian W. Timmons 

Pages 149-159 | Received 09 Nov 2018, Accepted 18 Oct 2019, Published online: 18 Nov 2019


Report

The preliminary effects of moderate aerobic training on cognitive function in people with TBI and significant memory impairment: a proof-of-concept randomized controlled trial

Carly L. A. Wender , Brian M. Sandroff, Denise Krch , Glenn Wylie, Christopher M. Cirnigliaro, Jill Wecht, ...show all

Pages 430-435 | Received 01 Jun 2021, Accepted 04 Oct 2021, Published online: 27 Oct 2021





 American Physical Therapy Association

CLINICAL PRACTICE GUIDELINES

A Clinical Practice Guideline for the Use of Ankle-Foot Orthoses and Functional Electrical Stimulation Post-Stroke

*Therese E. Johnston, PT, MSPT, PhD, MBA,**
Sarah Keller, PT, DPT, NCS,
Caitlin Denzer-Weiler, PT, DPT, NCS,
*and Lisa Brown, PT, DPT, NCS**

Department of Physical Therapy, Jefferson College of Rehabilitation Sciences, Thomas Jefferson University, Philadelphia, Pennsylvania and Ossur, Foothill Ranch, California (T.E.J.); Department of Physical Therapy, College of Health Sciences, Midwestern University, Downers Grove, Illinois (S.K.); Kessler Institute for Rehabilitation, Chester, New Jersey (C.D.-W); and Boston University College of Health and Rehabilitation Sciences: Sargent, Boston, Massachusetts (L.B.).

ABSTRACT

Background: Level of ambulation following stroke is a long-term predictor of participation and disability. Decreased lower extremity motor control can impact ambulation and overall mobility. The purpose of this clinical practice guideline (CPG) is to provide evidence to guide clinical decision-making for the use of either ankle-foot orthosis (AFO) or functional electrical stimulation (FES) as an intervention to improve body function and structure, activity, and participation as defined by the International Classification of Functioning, Disability and Health (ICF) for individuals with poststroke hemiplegia with decreased lower extremity motor control.

Methods: A review of literature published through November 2019 was performed across 7 databases for all studies involving stroke and AFO or FES. Data extracted included time post-stroke, participant characteristics, device types, outcomes assessed, and intervention parameters. Outcomes were examined upon initial application and after training. Recommendations were determined on the basis of the strength of the evidence and the potential benefits, harm, risks, or costs of providing AFO or FES.

Results/Discussion: One-hundred twenty-two meta-analyses, systematic reviews, randomized controlled trials, and cohort studies were included. Strong evidence exists that AFO and FES can each increase gait speed, mobility, and dynamic balance. Moderate evidence exists that AFO and FES increase quality of life, walking endurance, and muscle activation, and weak evidence exists for improving gait kinematics. AFO or FES should not be used to decrease plantarflexor spasticity. Studies that directly compare AFO and FES do not indicate overall superiority of one over the other. But evidence suggests that AFO may lead to more compensatory effects while FES may lead to more therapeutic effects. Due to the potential for gains at any phase post-stroke, the most appropriate device for an individual may change, and reassessments should be completed to ensure the device is meeting the individual's needs.

JNPT • Volume 45, April 2021

- Strong evidence exists that AFO and FES can each increase gait speed, mobility, and dynamic balance.
- Moderate evidence exists that AFO and FES increase quality of life, walking endurance, and muscle activation, and weak evidence exists for improving gait kinematics.
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CPG FOR THE USE OF AFOS AND FES POST STROKE

CLINICAL PRACTICE GUIDELINES

A Clinical Practice Guideline for the Use of Ankle-Foot Orthoses and Functional Electrical Stimulation Post-Stroke

Therese E. Johnston, PT, MSPT, PhD, MBA,*
Sarah Keller, PT, DPT, NCS,
Caitlin Denzer-Weiler, PT, DPT, NCS,
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Midwestern University, Downers
Grove, Illinois (S.K.); Kessler
Institute for Rehabilitation, Chester,
New Jersey (C.D.-W); and Boston
University College of Health and
Rehabilitation Sciences: Sargent,
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- Strong evidence exists that AFO and FES can each increase gait speed, mobility, and dynamic balance.
- Moderate evidence exists that AFO and FES increase quality of life, walking endurance, and muscle activation, and weak evidence exists for improving gait kinematics.
- AFO or FES should not be used to decrease plantar flexor spasticity.
- Studies that directly compare AFO and FES do not indicate overall superiority of one over the other. But evidence suggests that AFO may lead to more compensatory effects while FES may lead to more therapeutic effects.

JNPT • Volume 45, April 2021

CPG FOR THE USE OF AFOS AND FES POST STROKE

Action Statement 2: ANKLE-FOOT ORTHOSIS (AFO) OR FUNCTIONAL ELECTRICAL STIMULATION (FES) TO IMPROVE GAIT SPEED. Clinicians should provide an AFO or FES for individuals with decreased lower extremity motor control due to acute or chronic poststroke hemiplegia who have goals to improve gait speed (evidence quality: I; recommendation strength: strong).

Action Statement 3: ANKLE-FOOT ORTHOSIS (AFO) OR FUNCTIONAL ELECTRICAL STIMULATION (FES) TO IMPROVE OTHER MOBILITY. Clinicians should provide an AFO or FES for individuals with decreased lower extremity motor control due to acute or chronic poststroke hemiplegia who have goals to improve other mobility evidence quality: I; recommendation strength: strong).

Action Statement 4: ANKLE-FOOT ORTHOSIS (AFO) OR FUNCTIONAL ELECTRICAL STIMULATION (FES) TO IMPROVE DYNAMIC BALANCE. Clinicians should provide an AFO or FES for individuals with decreased lower extremity motor control due to acute or chronic poststroke hemiplegia who have goals to improve dynamic balance (evidence quality: I; recommendation strength: strong).

Practical Application: FES and AFOs



Patient Satisfaction (Kluding, 2013)

- Greater satisfaction and adherence with neuroprosthesis compared to standard AFO
- No significant differences in functional outcome measures between AFO and FES



Practical Application: Multi-Channel FES



**Action Statement 6: ANKLE-FOOT ORTHOSIS (AFO)
OR FUNCTIONAL ELECTRICAL STIMULATION
(FES) TO IMPROVE PLANTARFLEXOR SPASTICITY.**

Clinicians should not provide an AFO or FES for individuals with decreased lower extremity motor control due to acute or chronic poststroke hemiplegia who have primary goals to improve plantarflexor spasticity (evidence quality: II; recommendation strength: moderate).

- Muscle stretch causes 1a afferents to increase their firing rate
- Agonist and synergists contract in response
- Collateral interneurons activate 1a inhibitory neuron
- Results in relaxation of the antagonist
- Pathway activated during voluntary and electrically stimulated contractions



CPG: Upper Extremity Rehabilitation

Occupational Therapy Practice Guidelines for Adults With Stroke

Mary W. Hildebrand, Daniel Geller, Rachel Proffitt

Importance: Stroke is a leading cause of disability. Occupational therapy practitioners ensure maximum participation and performance in valued occupations for stroke survivors and their caregivers.

Objective: These Practice Guidelines are meant to support occupational therapy practitioners' clinical decision making when working with people after stroke and their caregivers.

Method: Clinical recommendations were reviewed from three systematic review questions on interventions to improve performance and participation in daily activities and occupations and from one question on maintaining the caregiving role for caregivers of people after stroke.

Results: The systematic reviews included 168 studies, 24 Level 1a, 90 Level 1b, and 54 Level 2b. These studies were used as the basis for the clinical recommendations in these Practice Guidelines and have strong or moderate supporting evidence.

Conclusions and Recommendations: Interventions with strong strength of evidence for improving performance in activities of daily living and functional mobility include mirror therapy, task-oriented training, mental imagery, balance training, self-management strategies, and a multidisciplinary three-stages-of-care rehabilitation program. Constraint-induced therapy has strong strength of evidence for improving performance of instrumental activities of daily living. Moderate strength of evidence supported cognitive-behavioral therapy (CBT) to address balance self-efficacy, long-term group intervention to improve mobility in the community, and a wearable upper extremity sensory device paired with training games in inpatient rehabilitation to improve social participation. Practitioners should incorporate problem-solving therapy in combination with CBT or with education and a family support organizer program.

What This Article Adds: These Practice Guidelines provide a summary of strong and moderate evidence for effective interventions for people with stroke and for their caregivers.

Hildebrand, M. W., Geller, D., & Proffitt, R. (2023). Practice Guidelines—Occupational therapy practice guidelines for adults with stroke. *American Journal of Occupational Therapy*, 77, 7705397010. <https://doi.org/10.5014/ajot.2023.077501>

Task-Oriented Training

Constrain Induced
Movement Therapy

Mental Imagery

Mirror Therapy

UE Gaming

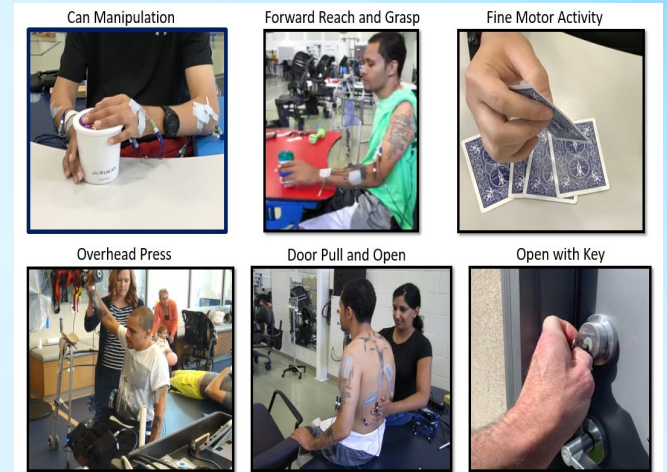
Long Term Group
Intervention

Cognitive Behavioral
Therapy

Task-Oriented Training

TOT that uses meaningful real-life activities such as functional tasks; specifically activity-based TOT is defined as client-centered, ABT focused on practice that is goal-directed and contextually specific to a patient's goals.

“This review shows the value of upper extremity task-oriented training as an effective intervention in stroke rehabilitation.”



Effectiveness of Activity-Based Task-Oriented Training on Upper Extremity Recovery for Adults With Stroke: A Systematic Review

N=16

Cheng-Yu Lee, Tsu-Hsin Howe

Importance: Interventions for improving upper extremity (UE) recovery have become a priority in stroke rehabilitation because UE disability can undermine a person's capacity to perform daily activities after stroke. A better understanding of the use of activity-based task-oriented training (TOT) will inform the development of more effective UE interventions in stroke rehabilitation.

Objective: To examine the effectiveness of activity-based TOT in improving the UE recovery of adults with stroke.

Data Sources: CINAHL Plus, MEDLINE, and PubMed.

Study Selection and Data Collection: Inclusion criteria included quantitative studies published between June 2012 and December 2022 that reported UE recovery as an outcome, including measurements of motor function, motor performance, and performance of activities of daily living (ADLs); a sample age ≥ 18 yr, with stroke in all phases; and interventions that incorporated real-world daily activities. We assessed articles for inclusion, quality, and risk of bias following Cochrane methodology and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Findings: Sixteen studies (692 participants, Level 1–4 evidence) were included. Strong to moderate evidence supported the effectiveness of activity-based TOT in UE motor function, motor performance, and ADL performance for adults with stroke. Strong evidence supported the effectiveness of hospital-based TOT, and moderate evidence supported the effectiveness of home-based TOT.

Conclusions and Relevance: The results not only showed the value of activity-based TOT as an effective UE intervention in stroke rehabilitation but also supported the occupational therapy philosophy of using functional and meaningful activities in practice. Further research on home-based TOT is needed.

Plain-Language Summary: This systematic review shows the effectiveness and value of using real-life activities in task-oriented training approaches for adult survivors of stroke. The authors found strong evidence for hospital-based task-oriented training interventions and moderate evidence for home-based interventions for improving upper extremity recovery. This review shows the value of upper extremity task-oriented training as an effective intervention in stroke rehabilitation. The review also supports the occupational therapy philosophy of using functional and meaningful activities in practice as well as the profession's use of evidence-based practice in stroke rehabilitation.

Lee, C.-Y., & Howe, T.-H. (2024). Effectiveness of activity-based task-oriented training on upper extremity recovery for adults with stroke: A systematic review. *American Journal of Occupational Therapy*, 78, 7802180070. <https://doi.org/10.5014/ajot.2024.050391>

Effects of task oriented rehabilitation of upper extremity after stroke: A systematic review

Maira Hussain¹, Arooj Fatima², Ashfaq Ahmad³, Syed Amir Gilani⁴ N=28

Abstract

Objective: To explore the current scientific evidence on the effects of task-oriented rehabilitation programme of upper extremity post-stroke.

Method: The systematic review comprised studies from 2012 to August 2020 which were both Hand-searched and explored on Cochrane, PubMed, PEDro and MEDLINE databases with authentic search techniques using population-intervention-control-outcomes format and Boolean operator. Randomised controlled trials on the use of task-oriented training for the improvement of upper extremity functional outcomes in subjects with stroke were shortlisted and reviewed. The risk bias tool was used to evaluate the biasness in the studies and the PEDro scale was used to evaluate the methodological quality of the studies.

Results: Of the 28 articles assessed, 16(%) were included for detailed review. All studies varied significantly with PEDro scores between 6 and 10. There were 12(75%) high-quality studies and 4(25%) fell in fair category. All the studies showed significant results in the improvement of upper extremity after stroke through task-oriented training rehabilitation ($p < 0.05$).

Conclusion: Evidence supports the beneficial effects of task-oriented rehabilitation for the improvement of upper extremity functions post-stroke.

Keywords: Conventional therapy, Stroke, Stroke rehabilitation, Task-oriented rehabilitation, Upper extremity paresis.

(JPMA 72: 1406; 2022) DOI: <https://doi.org/10.47391/JPMA.3864>

“All studies showed significant results in the improvement of the upper extremity after stroke through task-oriented training rehabilitation ($p < 0.05$).”

Constraint-Induced Movement Therapy

Open access

Original research

BMJ Open Interventional effects of modified constraint-induced movement therapy on upper limb function in patients who had a stroke: systematic review and meta-analysis

Jian Liu,¹ Zizhuo Wang,² Cheng Wang,³ Yunong Zhang⁴

To cite: Liu J, Wang Z, Wang C, et al. Interventional effects of modified constraint-induced movement therapy on upper limb function in patients who had a stroke: systematic review and meta-analysis. *BMJ Open* 2025;15:e094309. doi:10.1136/bmjopen-2024-094309

► Publication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<https://doi.org/10.1136/bmjopen-2024-094309>).

Received 29 September 2024
Accepted 09 May 2025

ABSTRACT

Objectives To systematically evaluate the intervention effect of modified constraint-induced movement therapy (m-CIMT) on upper limb function in patients who had a stroke.

Design Systematic review and meta-analysis.
Data sources A computer-based search was conducted in PubMed, Cochrane Library, Embase, Web of Science and China National Knowledge Infrastructure for randomised controlled trials (RCTs) on the intervention effect of m-CIMT on upper limb function in patients who had a stroke, with the search conducted up until 23 May 2024.

Eligibility criteria We included only RCTs in which patients who had a stroke performed m-CIMT or m-CIMT in addition to the control group, and the outcome was upper limb function.

Data extraction and synthesis Data extraction and synthesis used the reporting checklist for systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The risk of bias and methodological quality of included studies were evaluated by two independent investigators

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This systematic review, conducted in accordance with the PROSPERO 2020 guidelines, included relevant randomised controlled trials and systematically evaluated the effects of modified constraint-induced movement therapy on upper limb function in patients who had a stroke, yielding more reliable and robust results.

⇒ Additionally, the review explored the moderating effects of stroke type, disease duration, intervention period and intervention time, providing evidence-based recommendations for the development of future intervention protocols.

⇒ Although the review examined the moderating effects of individual factors and the 'dose-response' relationship, the combined effects of multiple factors were not addressed.

⇒ Due to the presence of publication bias and heterogeneity, the overall level of evidence in this systematic review is classified as low; thus, caution should be exercised when interpreting these findings.

Effects of constraint-induced movement therapy on activity and participation after a stroke: Systematic review and meta-analysis

Joyce Araújo de Azevedo¹, Felipe Douglas Silva Barbosa², Valquiria Martins Seixas¹, Kelly Regina Dias da Silva Scipioni³, Priscila Yukari Sewo Sampaio⁴, Daniel Marinho Cezar da Cruz^{5*}, Daniele Piscitelli^{6,7,8}, Kevin K. Chui⁹ and Aristela de Freitas Zanona¹

¹Department of Occupational Therapy, Federal University of Sergipe, São Cristóvão, Sergipe, Brazil, ²Department of Occupational Therapy, Federal University of Bahia, Salvador, Bahia, Brazil, ³Department of Occupational Therapy, Federal University of Paraná, Curitiba, Paraná, Brazil, ⁴Departamento de Medicina, Universidade Federal de Sergipe, São Cristóvão, Sergipe, Brazil, ⁵School of Health, Leeds Beckett University, Leeds, United Kingdom, ⁶School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada, ⁷School of Medicine and Surgery, University of Milano-Bicocca, Milan, Italy, ⁸Department of Kinesiology, University of Connecticut, Storrs, CT, United States, ⁹Department of Physical Therapy, Waldron College of Health and Human Services, Radford University, Roanoke, VA, United States

Conclusion: Our results show that CIMT results in more significant gains in the functional use of the upper limb in ADL and functional independence, demonstrating superior activity and participation results in stroke survivors when compared to conventional therapies.

DISABILITY AND REHABILITATION
2025, VOL. 47, NO. 4, 949-957
<https://doi.org/10.1080/09638288.2024.2361808>



RESEARCH ARTICLE

OPEN ACCESS

Investigating the acceptability of modified constraint-induced movement therapy among stroke survivors and carers: a qualitative study

Ashan Weerakkody^{a,b}, Erin Godecke^{b,c} and Barby Singer^b

^aDepartment of Health, Rehabilitation in the Home, South Metropolitan Health Service, Perth, Western Australia, Australia; ^bSchool of Medical and Health Sciences, Edith Cowan University, Perth, Western Australia, Australia; ^cDepartment of Health, Sir Charles Gairdner Hospital, North Metropolitan Health Service, Nedlands, Western Australia, Australia

ABSTRACT

Purpose: To investigate the acceptability of modified constraint-induced movement therapy (mCIMT) among stroke survivors and carers within an early-supported discharge (ESD) service, and to inform further adaptations of the program to enhance acceptability.

Methods: Qualitative study within a mixed methods process evaluation of mCIMT implementation. Semi-structured interviews were analysed using reflexive thematic analysis and mapped to the Capability, Opportunity, Motivation-Behaviour (COM-B) model.

Results: Fifteen stroke survivors and ten carers participated. Five themes were generated and mapped to the COM-B. Participants attributed functional improvements to the program whilst also encountering several challenges with returning home after stroke (Capability- physical); the importance of education (Capability- psychological); the benefits afforded by the structured nature of the program (Opportunity- physical); the challenges for carers to support mCIMT programs whilst navigating new relationship roles (Opportunity- social); the desire to improve (Motivation- automatic); and the influence each of the mCIMT program's components had in facilitating long term upper limb use (Motivation- reflective).

Conclusion: mCIMT was an acceptable intervention for stroke survivors and carers within the ESD service, offering considerable benefits compared to other therapies. The findings suggest that multifaceted education strategies could increase stroke survivor preparedness. Extending the mCIMT program duration may maximise functional improvements.

IMPLICATIONS FOR REHABILITATION

- Modified constraint-induced movement therapy (mCIMT) is an effective intervention to improve upper limb function after stroke.
- Tailored education strategies could enhance stroke survivors' preparedness for mCIMT, improving engagement and satisfaction.
- Structured rehabilitation programs like mCIMT can support the transition home for stroke survivors, providing guidance and hope without adding to carer burden.

Introduction

Up on pa me ha su me UL su a s int the res of

Despite this, the regular provision of these modified programs also remains limited [7]. The Australian Stroke Foundation Living

Conclusion: mCIMT was an acceptable intervention for stroke survivors and carers within the ESD service, offering considerable benefits compared to other therapies.

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Task Specificity

- RCT subacute CVA (Sham vs. Mirror in addition to conventional)
- N=40 (within 12 months post CVA)
- > ↑ Mirror vs. Conventional group FIM self care score/Brunnstrom
- No difference in spasticity (MAS)

Mirror Symmetric Bimanual Movement Priming Can Increase Corticomotor Excitability and Enhance Motor Learning

Winston D. Byblow^{1,4*}, Cathy M. Stinear^{3,4}, Marie-Claire Smith^{1,3}, Lotte Bjerre², Brian K. Florker², Alana B. McCambridge¹

- Healthy adults
- Mirror vs. flexion/extension without mirror
- ↑ cortical excitability and MEPs in mirror group (30 mins after)
- ↑ timed manual dexterity motor learning task mirror group
- **Maybe priming for UE task specific rehabilitation/recovery

Arch Phys Med Rehabil. 2008 Mar;89(3):393-8. doi: 10.1016/j.apmr.2007.08.162.

Mirror therapy improves hand function in subacute stroke: a randomized control

Yavuzer G¹, Selles R, Sezer N, Sütbeyaz S, Bussmann JB, Köseoğlu F, Atay MB, Stam HJ.



Video Augmented Mirror Therapy

Journal of Neurology (2023) 270:831–842
<https://doi.org/10.1007/s00415-022-11410-6>

ORIGINAL COMMUNICATION



Video augmented mirror therapy for upper extremity rehabilitation after stroke: a randomized controlled trial

Hyunjin Kim¹ · Junghyun Kim² · Sungbae Jo¹ · Kyeongjin Lee³ · Junesun Kim^{4,5,6} · Changho Song⁷

Received: 17 May 2022 / Revised: 27 September 2022 / Accepted: 28 September 2022 / Published online: 10 October 2022
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Abstract

Purpose To investigate the effects of mirror therapy using a newly developed video augmented wearable reflection device on reach-to-grasp motor control and upper extremity motor function.

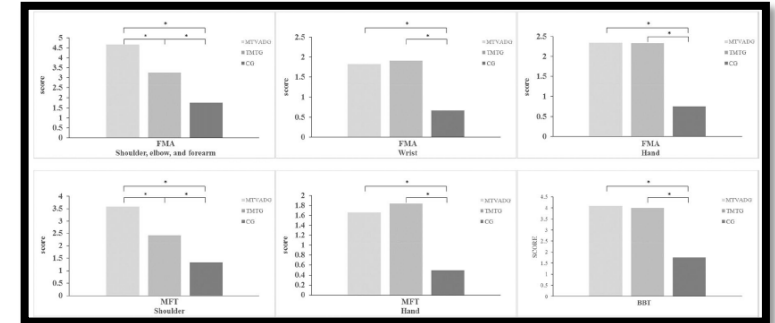
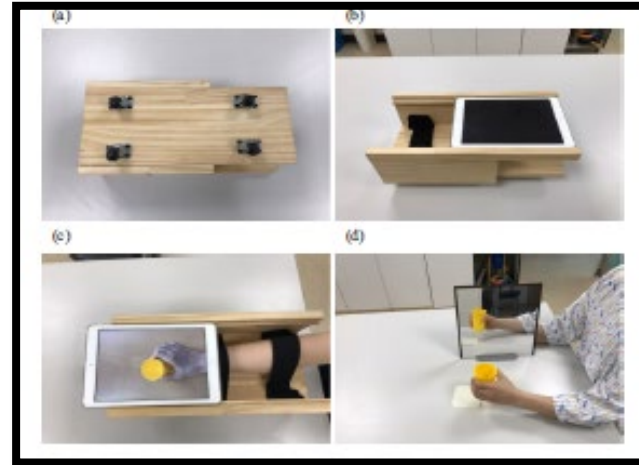
Methods Participants were randomly allocated to one of three groups: mirror therapy using a video augmented wearable reflection device group (MTVADG), $n = 12$; traditional mirror therapy group (TMTG), $n = 12$; and control group (CG), $n = 12$. Participants in the MTVADG and TMTG received conventional rehabilitation in addition to mirror therapy. Motor control during the reach-to-grasp movement was assessed using kinematic analysis. Each participant's upper extremity motor function was assessed using the Fugl-Meyer Assessment, Manual Function Test, and Box and Block Test.

Results While both the MTVADG and TMTG showed significantly improved reach-to-grasp movement. The MTVADG showed greater efficiency in kinematic performance than the TMTG. Moreover, while both the MTVADG and TMTG showed improved upper extremity motor function, the MTVADG showed significantly greater improvement in proximal upper limb function compared to the TMTG.

Conclusion Our results suggested that mirror therapy using a video augmented wearable reflection device is more efficient compared to traditional mirror therapy for patients with stroke.

Clinical trial registration unique identifier KCT0003047.

Keywords Stroke · Rehabilitation · Mirror therapy · Upper extremity · Kinematics



Our results suggested that mirror therapy using a video augmented wearable reflection device is more efficient compared to traditional mirror therapy for patients with stroke.

The effect of mirror therapy can be improved by simultaneous robotic assistance

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Abstract

Background: Standard mirror therapy (MT) is a well-established therapy regime for severe arm paresis after acquired brain injury. Bilateral robot-assisted mirror therapy (RMT) could be a solution to provide visual and somatosensory feedback simultaneously.

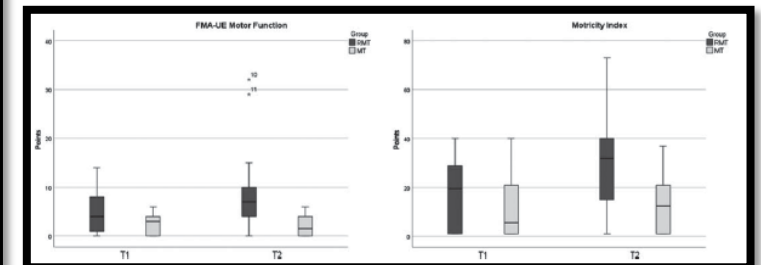
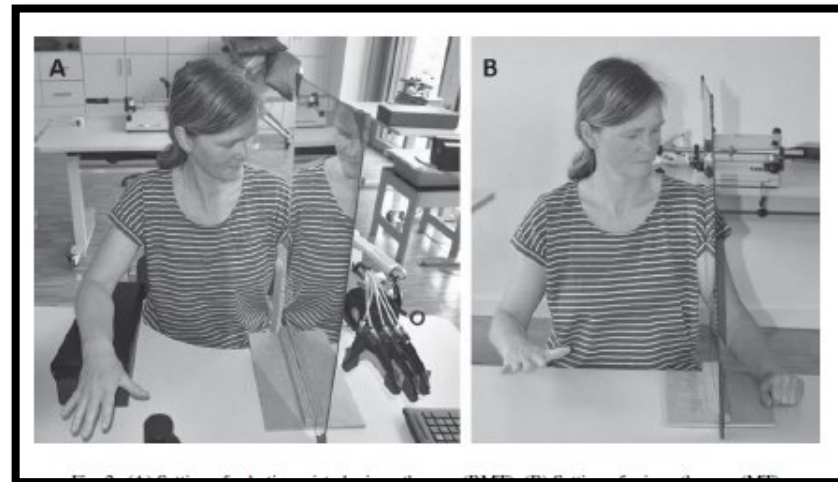
Objective: The study compares the treatment effects of MT with a version of robot-assisted MT where the affected arm movement was delivered through a robotic glove (RMT).

Methods: This is a parallel, randomized trial, including patients with severe arm paresis after stroke or traumatic brain injury with a Fugl-Meyer subscore hand/finger < 4. Participants received either RMT or MT in individual 30 minute sessions (15 sessions within 5 weeks). Main outcome parameter was the improvement in the Fugl-Meyer Assessment upper extremity (FMA-UE) motor score. Additionally, the Motricity Index (MI) and the FMA-UE sensation test as well as a pain scale were recorded. Furthermore, patients' and therapists' experiences with RMT were captured through qualitative tools.

Results: 24 patients completed the study. Comparison of the FMA-UE motor score difference values between the two groups revealed a significantly greater therapy effect in the RMT group than the MT group ($p = 0.006$). There were no significant differences for the MI ($p = 0.108$), the FMA-UE surface sensibility subscore ($p = 0.403$) as well as the FMA-UE position sense subscore ($p = 0.192$). In both groups the levels of pain remained stable throughout the intervention. No other adverse effects were observed. The RMT training was well accepted by patients and therapists.

Conclusions: The study provides evidence that bilateral RMT achieves greater treatment benefit on motor function than conventional MT. The use of robotics seems to be a good method to implement passive co-movement in clinical practice. Our study further demonstrates that this form of training can feasibly and effectively be delivered in an inpatient setting.

Keywords: Mirror therapy, robotics, somatosensory feedback, acquired brain injury, stroke, arm paresis, neurorehabilitation



Multimodal Mental Practice vs. Repetitive Task Practice

Research Article

Multimodal Mental Practice Versus Repetitive Task Practice Only to Treat Chronic Stroke: A Randomized Controlled Pilot Study

Stephen J. Page, Peter Levine

Importance: Occupational therapists are the primary clinicians tasked with management of the more affected upper extremity (UE) after stroke. However, there is a paucity of efficacious, easy-to-use, inexpensive interventions to increase poststroke UE function.

Objective: To compare the effect of a multimodal mental practice (MMMP) regimen with a repetitive task practice (RTP)-only regimen on paretic UE functional limitation.

Design: Secondary analysis of randomized controlled pilot study data.

Setting: Outpatient clinical rehabilitation laboratory.

Participants: Eighteen chronic stroke survivors exhibiting moderate, stable UE impairment.

Intervention: Participants administered RTP only participated in 45-min, one-on-one occupational therapy sessions 3 times per week for 10 wk; participants administered MMMP completed time-matched UE training sessions consisting of action observation, RTP, and mental practice, delivered in 15-min increments.

Outcomes and Measures: The Action Research Arm Test, the UE section of the Fugl-Meyer Scale, and the Hand subscale of the Stroke Impact Scale (Version 3.0) were administered 1 wk before and 1 wk after intervention.

Results: The MMMP group exhibited significantly larger ($p < .01$) increases on all three outcome measures compared with the RTP group and surpassed minimal clinically important difference standards for all three UE outcome measures.

Conclusions and Relevance: Because of the time-matched duration of MMMP and RTP, findings suggest that MMMP may be just as feasible as RTP to implement in clinical settings. Efforts to replicate results of this study in a large-scale trial are warranted.

What This Article Adds: This study shows the efficacy of an easy-to-use protocol that significantly increased affected arm function even years after stroke.

Most stroke survivors exhibit residual motor impairments (Cioncoloni et al., 2013; Lai et al., 2002; Mayo et al., 2002), and stroke survivor prevalence is increasing (Carandang et al., 2006; Virani et al., 2020), yielding a burgeoning number of survivors exhibiting motor impairments. Several interventions target upper extremity (UE) hemiparesis (e.g., Laver et al., 2015; Volpe et al., 2008; Wolf et al., 2006). However, many require extensive contact time (e.g., Wolf et al., 2006) and specialized equipment (Laver et al., 2015; Volpe et al., 2008), undermining their widespread adoption.

Both mental practice (MP) and action observation (AO) incorporate repeated cognitive rehearsal of paretic UE movements in the absence of physical movement attempts. Additionally, both techniques elicit brain activity comparable to the actual performance of the targeted task (Decety, 1996; Sale & Franceschini, 2012) and have shown promise in increasing paretic UE use and function (Franceschini et al., 2012; Page et al., 2007). Both MP and AO are portable and inexpensive; moreover, they require minimal training, equipment, and supervision. Thus, they constitute a practical

Results: The MMMP group exhibited significantly larger ($p < .01$) increases on all three outcome measures compared with the RTP group and surpassed minimal clinically important difference standards for all three UE outcome measures.

Virtual Reality and Gaming

Virtual Reality Training for Upper Extremity in Subacute Stroke (VIRTUES)
A multicenter RCT

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ABSTRACT

Objective: To compare the effectiveness of upper extremity virtual reality rehabilitation training (VR) to time-matched conventional training (CT) in the subacute phase after stroke.

Methods: In this randomized, controlled, single-blind phase III multicenter trial, 120 participants with upper extremity motor impairment within 12 weeks after stroke were consecutively included at 5 rehabilitation institutions. Participants were randomized to either VR or CT as an adjunct to standard rehabilitation and stratified according to mild to moderate or severe hand paresis, defined as ≥ 20 degrees wrist and 10 degrees finger extension or less, respectively. The training comprised a minimum of sixteen 60-minute sessions over 4 weeks. The primary outcome measure was the Action Research Arm Test (ARAT); secondary outcome measures were the Box and Blocks Test and Functional Independence Measure. Patients were assessed at baseline, after intervention, and at the 3-month follow-up.

Results: Mean time from stroke onset for the VR group was 35 (SD 21) days and for the CT group was 34 (SD 19) days. There were no between-group differences for any of the outcome measures. Improvement of upper extremity motor function assessed with ARAT was similar at the postintervention ($p = 0.714$) and follow-up ($p = 0.777$) assessments. Patients in VR improved 12 (SD 11) points from baseline to the postintervention assessment and 17 (SD 13) points from baseline to follow-up, while patients in CT improved 13 (SD 10) and 17 (SD 13) points, respectively. Improvement was also similar for our subgroup analysis with mild to moderate and severe upper extremity paresis.

Conclusions: Additional upper extremity VR training was not superior but equally as effective as additional CT in the subacute phase after stroke. VR may constitute a motivating training alternative as a supplement to standard rehabilitation.



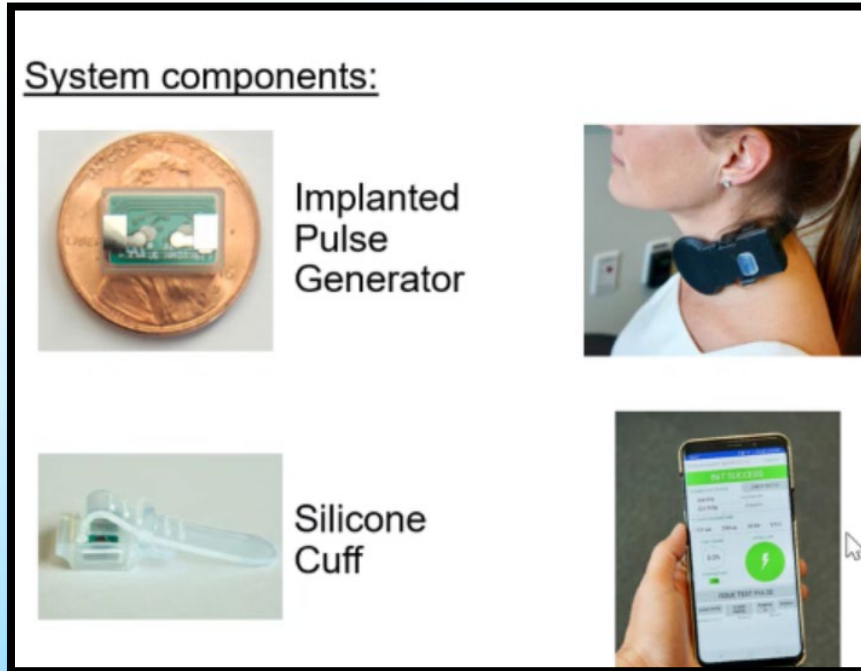
“Additional upper extremity VR training was not superior but equally as effective as additional CT in the subacute phase after stroke. VR may constitute a motivating training alternative as a supplement to standard rehabilitation.”

A photograph of two men sitting in wheelchairs outdoors, engaged in conversation. The man on the left is wearing a blue t-shirt, a white baseball cap, and a white face mask. The man on the right is wearing a green t-shirt and a black face mask. The background shows a building and some trees. The entire image has a blue overlay.

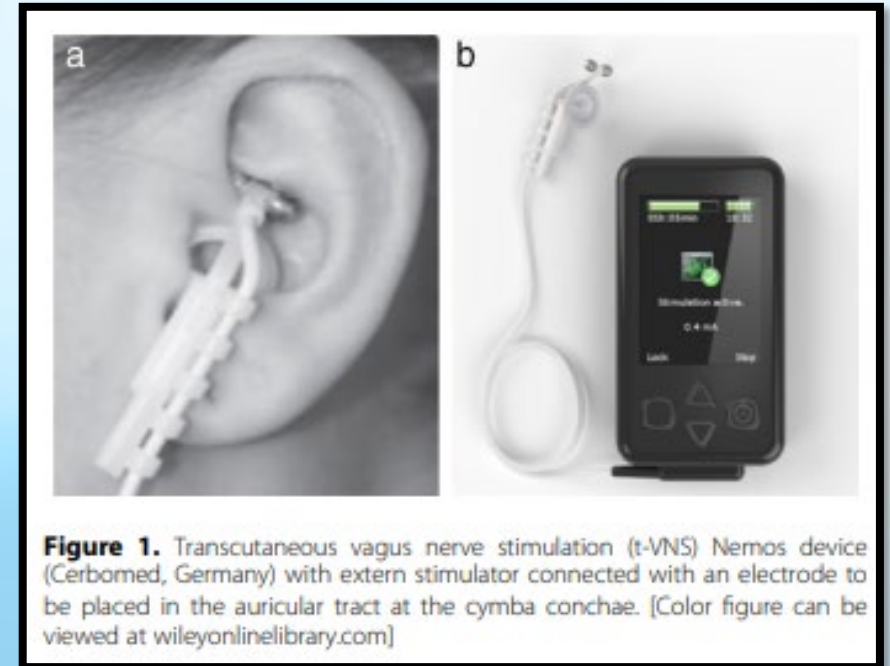
ADVANCES IN MOTOR REHABILITATION

Vagus Nerve Stimulation (VNS)

Implanted



Transcutaneous (ta)



“The U.S. Food and Drug Administration (FDA) on Aug. 27 approved the MicroTransponder Vivistim Paired VNS System (Vivistim System), a drug-free rehabilitation system that uses vagus nerve stimulation to treat moderate-to-severe upper extremity “

Implanted VNS: Stroke

“Augments task specific neuroplasticity by providing rapid cholinergic, noradrenergic, and serotonergic modulation.”

Vagus nerve stimulation paired with rehabilitation for upper limb motor function after ischaemic stroke (VNS-REHAB): a randomised, blinded, pivotal, device trial

Jesse Dawson, Charles Y Liu, Gerard E Francisco, Steven C Cramer, Steven L Wolf, Anand Dixit, Jen Alexander, Rushna Ali, Benjamin L Brown, Wuwei Feng, Louis DeMark, Leigh R Hochberg, Steven A Kautz, Arshad Majid, Michael W O'Dell, David Pierce, Cecilia N Prudente, Jessica Redgrave, Duncan L Turner, Navzer D Engineer, Teresa J Kimberley

Summary

Background Long-term loss of arm function after ischaemic stroke is common and might be improved by vagus nerve stimulation paired with rehabilitation. We aimed to determine whether this strategy is a safe and effective treatment for improving arm function after stroke.

Methods In this pivotal, randomised, triple-blind, sham-controlled trial, done in 19 stroke rehabilitation services in the UK and the USA, participants with moderate-to-severe arm weakness, at least 9 months after ischaemic stroke, were randomly assigned (1:1) to either rehabilitation paired with active vagus nerve stimulation (VNS group) or rehabilitation paired with sham stimulation (control group). Randomisation was done by ResearchPoint Global (Austin, TX, USA) using SAS PROC PLAN (SAS Institute Software, Cary, NC, USA), with stratification by region (USA vs UK), age (≤ 30 years vs > 30 years), and baseline Fugl-Meyer Assessment-Upper Extremity (FMA-UE) score (20–35 vs 36–50). Participants, outcomes assessors, and treating therapists were masked to group assignment. All participants were implanted with a vagus nerve stimulation device. The VNS group received 0.8 mA, 100 μ s, 30 Hz stimulation pulses, lasting 0.5 s. The control group received 0 mA pulses. Participants received 6 weeks of in-clinic therapy (three times per week; total of 18 sessions) followed by a home exercise programme. The primary outcome was the change in impairment measured by the FMA-UE score on the first day after completion of in-clinic therapy. FMA-UE response rates were also assessed at 90 days after in-clinic therapy (secondary endpoint). All analyses were by intention to treat. This trial is registered at ClinicalTrials.gov, NCT03131960.

Findings Between Oct 2, 2017, and Sept 12, 2019, 108 participants were randomly assigned to treatment (53 to the VNS group and 55 to the control group). 106 completed the study (one patient for each group did not complete the study). On the first day after completion of in-clinic therapy, the mean FMA-UE score increased by 5.0 points (SD 4.4) in the VNS group and by 2.4 points (3.8) in the control group (between-group difference 2.6, 95% CI 1.0–4.2, $p=0.0014$). 90 days after in-clinic therapy, a clinically meaningful response on the FMA-UE score was achieved in 23 (47%) of 53 patients in the VNS group versus 13 (24%) of 55 patients in the control group (between-group difference 24%, 6–41; $p=0.0098$). There was one serious adverse event related to surgery (vocal cord paresis) in the control group.

Mean FMA-UE score increased by 5.0 points (SD 4.4) in the VNS group and by 2.4 points (3.8) in the control group (between-group difference 2.6, 95% CI 1.0–4.2, $p=0.0014$). 90 days after in-clinic therapy, a clinically meaningful response on the FMA-UE score was achieved in 23 (47%) of 53 patients in the VNS group versus 13 (24%) of 55 patients in the control group (between-group difference 24%, 6–41; $p=0.0098$).

Vagus Nerve Stimulation Paired With Rehabilitation for Upper Limb Motor Impairment and Function After Chronic Ischemic Stroke: Subgroup Analysis of the Randomized, Blinded, Pivotal, VNS-REHAB Device Trial

Jesse Dawson, MD¹, Navzer D. Engineer, PhD², Steven C. Cramer, MD³, Steven L. Wolf, PhD⁴, Rushna Ali, MD⁵, Michael W. O'Dell, MD⁶, David Pierce, MSEE², Cecilia N. Prudente, PhD², Jessica Redgrave, MD⁷, Wuwei Feng, MD⁸, Charles Y. Liu, PhD⁹, Gerard E. Francisco, MD¹⁰, Benjamin L. Brown, MD¹¹, Anand Dixit, MD¹², Jen Alexander, MSc¹, Louis DeMark, DPT¹³, Vibor Krishna, MD¹⁴, Steven A. Kautz, PhD¹⁵, Arshad Majid, MD¹⁶, Brent Tarver, MSEE², Duncan L. Turner, PhD¹⁷, and Teresa J. Kimberley, PhD¹⁸

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“The response was similar across subgroups examined. The findings suggest that the effects of paired VNS observed in the VNS-REHAB trial are likely to be consistent in wide range of stroke survivors with moderate to severe upper extremity impairment.”

Transauricular VNS (taVNS): DoC

Transcutaneous Vagus Nerve Stimulation in Patients With Severe Traumatic Brain Injury: A Feasibility Trial

Jakob Hakon, MD, PhD*^{†1} ; Melika Moghiseh, MD*¹;
Ingrid Poulsen, RN, PhD*[‡] ; Christoffer M.L. Øland, MSc*;
Christian P. Hansen, MD, Med.Sc.D*[§]; Anne Sabers, MD, PhD[§]

Objectives: Preclinical studies have shown that surgically implanted vagus nerve stimulation (VNS) promotes recovery of consciousness and cognitive function following experimental traumatic brain injury (TBI). The aim of this study is to report the feasibility and safety of a noninvasive transcutaneous vagus nerve stimulation (tVNS) in patients with persistent impairment of consciousness following severe TBI.

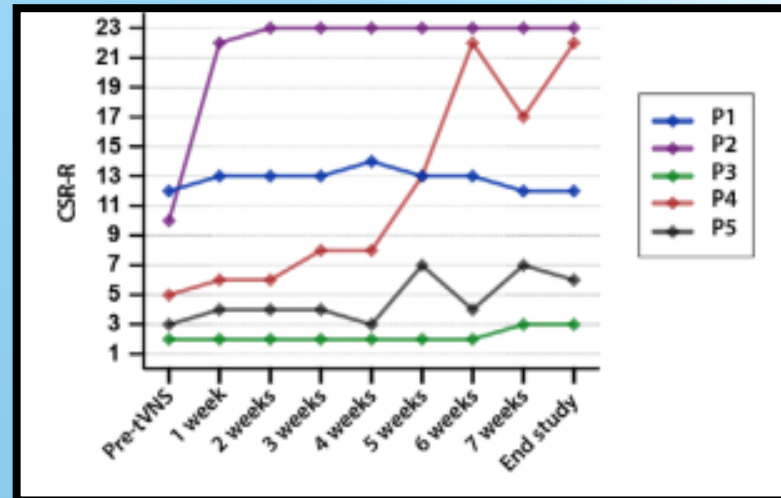
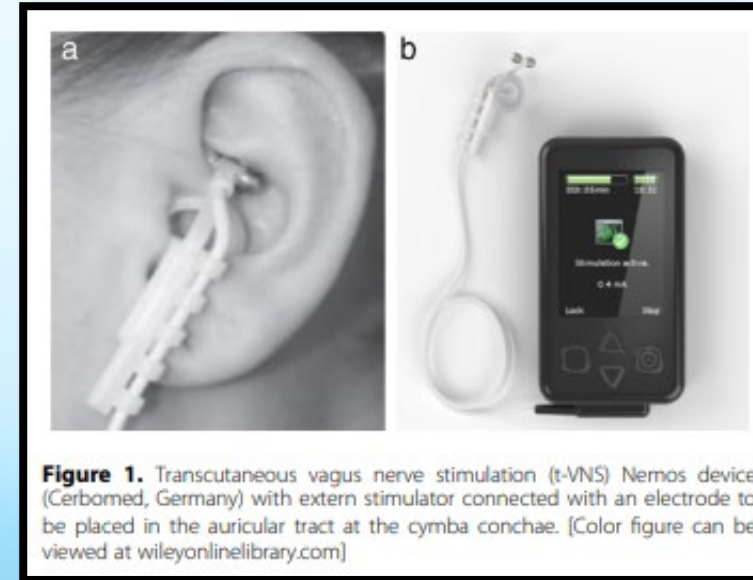
Materials and Methods: The feasibility of tVNS was evaluated in five patients presenting with diffuse axonal injury and reduced dominant EEG activity one month following severe TBI. tVNS was applied to the left cymba conchae of the external ear using a skin electrode four hours daily for eight weeks. Possible effects of tVNS on physiological parameters and general side effects were recorded. In addition, we report the rate of recovery using coma recovery scale revised (CRS-R).

Results: The tVNS regime of four hours daily for eight weeks was feasible and well tolerated with little side effects and no clinically relevant effects on physiological parameters. Three patients showed improvements (>3 points) in the CRS-R following eight weeks tVNS.

Conclusion: We demonstrated that tVNS is a feasible and safe VNS strategy for patients following severe TBI. Controlled studies are needed to clarify whether tVNS has a potential to promote recovery of consciousness following severe TBI.

Keywords: vagus nerve stimulation, Transcutaneous vagus nerve stimulation, traumatic brain injury, feasibility study

Conflict of Interest: Anne Sabers has received consultancy or lecture fees from Eisai Denmark and UCB Nordic. There are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. The remaining authors have no conflicts to disclose.



N=5 DOC

4 hours/day X 8 weeks

No adverse events

>3 point improvement on CRS-R

Transauricular VNS (taVNS): UE Function

Research Article

NEURAL REGENERATION RESEARCH
www.nrronline.org

Efficacy and safety of transcutaneous auricular vagus nerve stimulation combined with conventional rehabilitation training in acute stroke patients: a randomized controlled trial conducted for 1 year involving 60 patients

<https://doi.org/10.4103/1673-5374.332155>

Date of submission: April 19, 2021

Date of decision: September 11, 2021

Date of acceptance: October 23, 2021

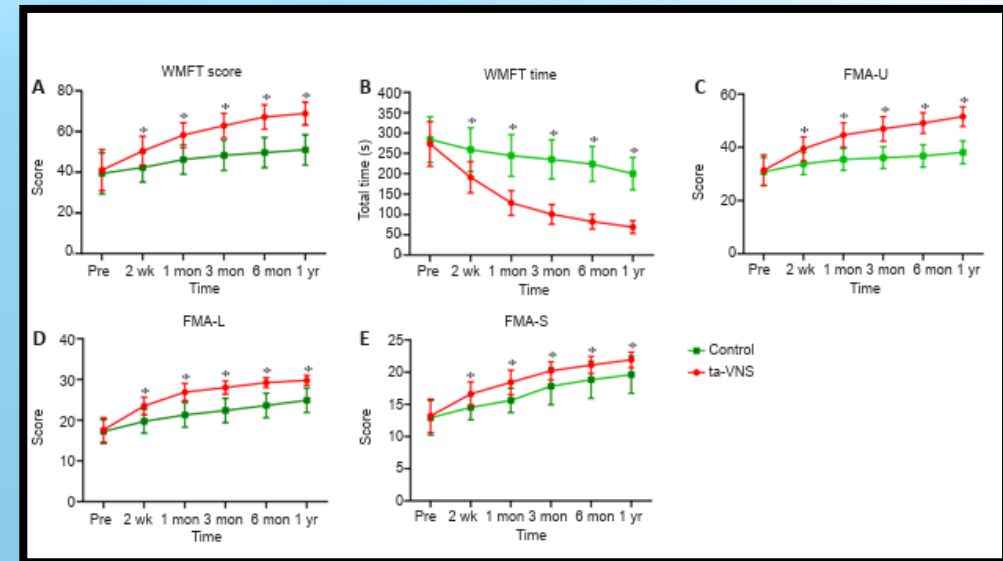
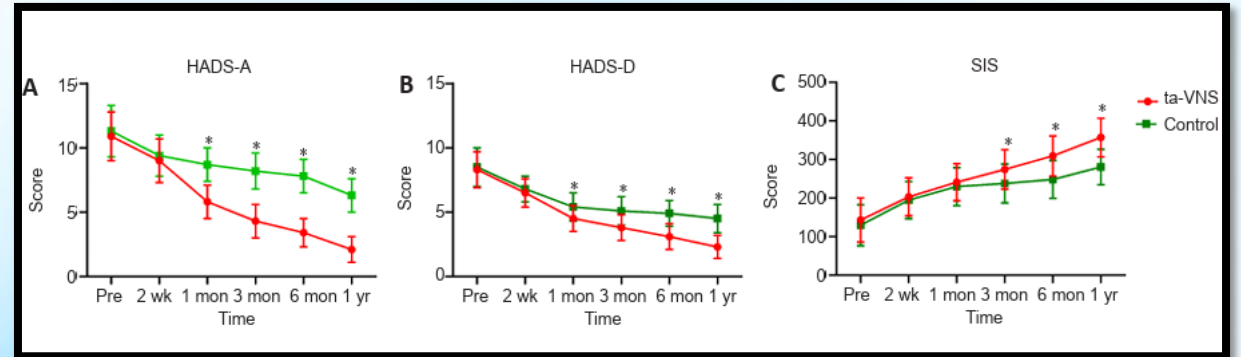
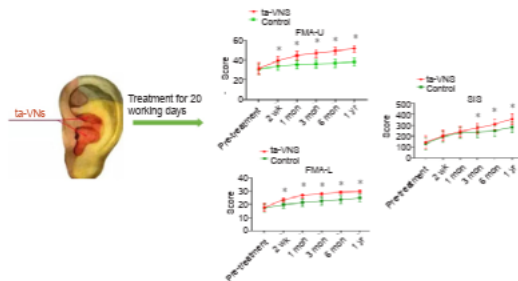
Date of web publication: January 7, 2022

Jia-Ni Li¹, Chen-Chen Xie¹, Chang-Qing Li¹, Gui-Fang Zhang², Hao Tang¹, Chuan-Na Jin¹, Jing-Xi Ma^{2,3}, Lan Wen⁴, Ke-Ming Zhang⁵, Ling-Chuan Niu^{1,*}

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Graphical Abstract Transcutaneous auricular vagus nerve stimulation (ta-VNS) combined with conventional rehabilitation therapy leads to great recovery of neurological function in acute stroke patients






Subacute Stroke

Research Article

Effect and Safety of Transcutaneous Auricular Vagus Nerve Stimulation on Recovery of Upper Limb Motor Function in Subacute Ischemic Stroke Patients: A Randomized Pilot Study

Dandong Wu ¹, Jingxi Ma,^{2,3} Liping Zhang,⁴ Sanrong Wang ¹, Botao Tan,¹ and Gongwei Jia ¹

Transcutaneous Auricular Vagus Nerve Stimulation with Upper Limb Repetitive Task Practice May Improve Sensory Recovery in Chronic Stroke

Sheharyar Sajjad Baig BM BCh ^{*}, Konstantinos Falidas MSc [†], Peter J. Laud MSc [‡], Nicola Snowdon MSc [†], Muhammad Umar Farooq MD [§], Ali Ali MSc [¶], Arshad Majid MD, FRCP [¶]  , Jessica N. Redgrave DPhil [¶]  

Neural Plasticity

5

TABLE 2: Outcome mean differences in change from baseline.

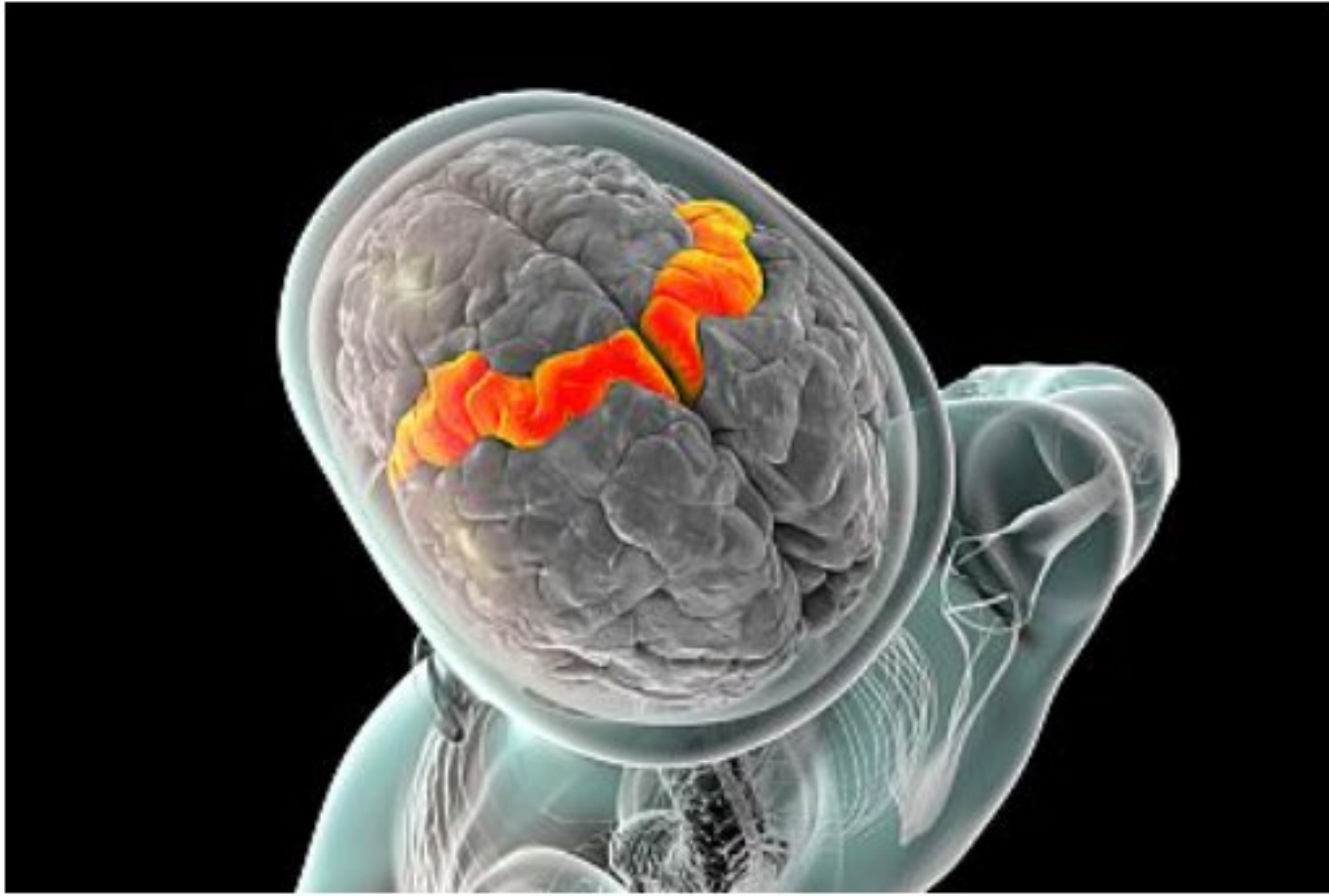
| Variable | Baseline | | Endpoint | | Between-group difference | |
|---|--------------|------------------|------------------------------|----------------------------|--------------------------|--------|
| | taVNS group | Sham-taVNS group | taVNS group | Sham-taVNS group | Mean* (95% CI) | P |
| n | 10 | 11 | 10 | 11 | | |
| FMA-U | 17.50 ± 4.91 | 16.82 ± 3.89 | 24.40 ± 4.62 | 20.00 ± 3.58 | | 0.024 |
| FMA-U mean change from baseline (95% CI) | | | 6.90 ± 1.85 (5.57 to 8.23) | 3.18 ± 1.17 (2.40 to 3.97) | -3.72 (-5.12 to -2.32) | ≤0.001 |
| WMFT | 20.60 ± 4.62 | 20.45 ± 3.93 | 27.10 ± 3.81 | 23.36 ± 3.78 | | 0.036 |
| WMFT mean change from baseline (95% CI) | | | 6.50 ± 2.37 (4.81 to 8.20) | 2.91 ± 1.14 (2.15 to 3.67) | -3.59 (-5.27 to -1.92) | ≤0.001 |
| FIM | 91.80 ± 6.03 | 88.82 ± 6.13 | 102.3 ± 5.77 | 95.45 ± 5.72 | | 0.013 |
| FIM mean change from baseline (95% CI) | | | 10.50 ± 4.93 (6.98 to 14.02) | 6.64 ± 2.58 (4.90 to 8.37) | -3.86 (-7.41 to -0.32) | 0.034 |
| Brunnstrom | 2.50 ± 1.08 | 2.64 ± 0.81 | 3.20 ± 0.92 | 3.27 ± 0.90 | | 0.857 |
| Brunnstrom mean change from baseline (95% CI) | | | 0.70 ± 0.67 (0.22 to 1.18) | 0.64 ± 0.67 (0.18 to 1.09) | -0.06 (-0.68 to 0.55) | 0.831 |

* Mean difference between groups in change from baseline scores. Data expressed as mean ± SD. FMA-U: upper limb Fugl-Meyer assessment; WMFT: Wolf motor function test; FIM: Functional Independence Measurement.

N= 12

- **Repetitive training (300 reps) with tVNS**
- **18 sessions (6 weeks)**
- **Significant improvements in UE sensory and motor function**

Spinal Stimulation: Intent-Driven



Abnormal Corticospinal Excitability in Traumatic Diffuse Axonal Brain Injury

[Montse Bernabeu](#),^{1,*} [Asli Demirtas-Tatlidede](#),^{2,*} [Eloy Opisso](#),¹ [Raquel Lopez](#),¹ [Jose M^a Tormos](#),¹ and [Alvaro Pascual-Leone](#)^{1,2}

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[Abstract](#)

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► [Brain Stimul.](#) 2013 Mar;6(2):130-7. doi: 10.1016/j.brs.2012.03.010. Epub 2012 Apr 18.

Corticospinal excitability in patients with anoxic, traumatic, and non-traumatic diffuse brain injury

[Natallia Lapitskaya](#)¹, [Sofie Kirial Moerk](#), [Olivia Gosseries](#), [Joergen Feldbaek Nielsen](#), [Alain Maertens de Noordhout](#)

[Affiliations](#) + [expand](#)

PMID: 22542389 DOI: 10.1016/j.brs.2012.03.010

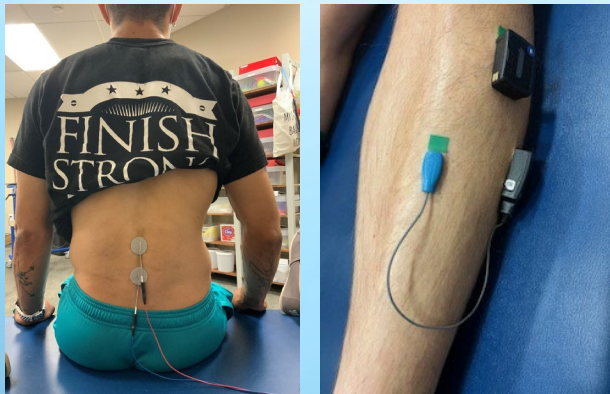
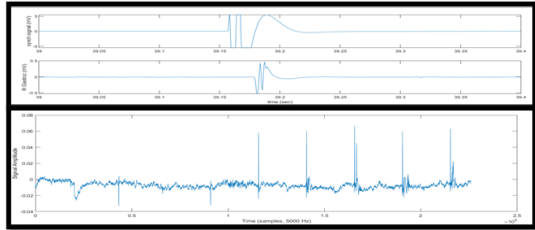
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Spinal Stimulation

Open Access Article

Characterization of Motor-Evoked Responses Obtained with Transcutaneous Electrical Spinal Stimulation from the Lower-Limb Muscles after Stroke

by Yaejin Moon^{1,2,†}, Taylor Zuleger^{3,†}, Martina Lamberti^{4,†}, Ashir Bansal², Chaithanya K. Mummidisetty¹, Kelly A. McKenzie¹, Lindsey Yingling¹, Sangeetha Madhavan⁵, Elliot J. Roth^{1,2}, Richard L. Lieber^{1,2,6} and Arun Jayaraman^{1,2,7}



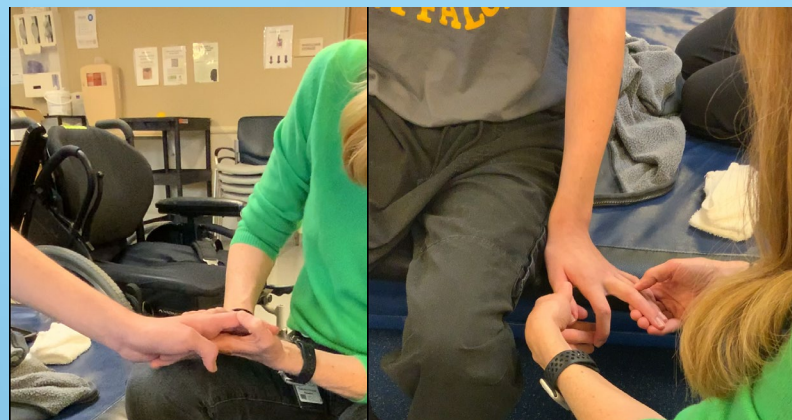
- Decreased corticospinal excitability of the tibialis anterior and medial gastrocnemius muscles in chronic stroke survivors → **downregulation of spinal circuitry poststroke.**
- Thus, **upregulation of spinal circuitry** could be a treatment target for individuals poststroke.

RESEARCH ARTICLE

Spinal motor evoked responses elicited by transcutaneous spinal cord stimulation in chronic stroke: Correlation between spinal cord excitability, demographic characteristics, and functional outcomes

Nicole C. Veit^{1,2}, Chen Yang², Shreya Aalla², Ameen Kishta², Kelly McKenzie², Elliot J. Roth^{2,3}, Arun Jayaraman^{2,3*}

- Desired neurophysiological outcome after a tSCS intervention in **stroke may involve decreasing spinal cord excitability in the paretic side, unlike in pathologies such as SCI where enhancement is sought.**
- Additionally, it raises the question of whether **electrode placement in tSCS interventions for stroke should be adjusted, possibly towards lateral positioning**, to selectively target one side over the other.



Spinal Cord Stimulation for Poststroke Hemiparesis: A Scoping Review

Jonathan R. Allen, Swathi R. Karri, Chen Yang, Mary Ellen Stoykov

Importance: Spinal cord stimulation (SCS) is a neuromodulation technique that can improve paresis in individuals with spinal cord injury. SCS is emerging as a technique that can address upper and lower limb hemiparesis. Little is understood about its effectiveness with the poststroke population.

Objective: To summarize the evidence for SCS after stroke and any changes in upper extremity and lower extremity motor function.

Data Sources: PubMed, Web of Science, Embase, and CINAHL. The reviewers used hand searches and reference searches of retrieved articles. There were no limitations regarding publication year.

Study Selection and Data Collection: This review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist. The inclusion and exclusion criteria included a broad range of study characteristics. Studies were excluded if the intervention did not meet the definition of SCS intervention, used only animals or healthy participants, did not address upper or lower limb motor function, or examined neurological conditions other than stroke.

Findings: Fourteen articles met the criteria for this review. Seven studies found a significant improvement in motor function in groups receiving SCS.

Conclusions and Relevance: Results indicate that SCS may provide an alternative means to improve motor function in the poststroke population.

Plain-Language Summary: The results of this study show that spinal cord stimulation may provide an alternative way to improve motor function after stroke. Previous neuromodulation methods have targeted the impaired supraspinal circuitry after stroke. Although downregulated, spinal cord circuitry is largely intact and offers new possibilities for motor recovery.

Allen, J. R., Karri, S. R., Yang, C., & Stoykov, M. E. (2024). Spinal cord stimulation for poststroke hemiparesis: A scoping review. *American Journal of Occupational Therapy*, 78, 7802180220. <https://doi.org/10.5014/ajot.2024.050533>

- Epidural SCS (5), transcutaneous spinal stimulation (4), transcranial direct current stimulation (5).
- 14 studies included in this review, 12 reported significant improvements in at least one neurophysiological or behavioral outcome
- 4/6 studies pairing SCS with training saw significant motor improvement
- Reduced spasticity in comparison to control or sham groups
- Improvements in gait speed and endurance
- Stimulation parameters variable
- No adverse events were reported in these studies

Evidence-based clinical practice guidelines provide a foundation for upper and lower extremity motor rehabilitation after brain injury.

TBI is a chronic condition, requiring rehabilitation strategies that target long-term recovery and adaptation.

Motor rehabilitation should be informed by a neural network perspective, recognizing dynamic interactions across cortical, subcortical, and spinal circuits.

Aerobic exercise is a promising adjunct intervention that can influence motor, cognitive, and neurophysiological outcomes after TBI.

fNIRS offers a noninvasive window into treatment-related brain activity and may help characterize neural mechanisms underlying motor recovery.

Rigorous comparative effectiveness studies are needed to clarify the role of vagus nerve stimulation and other neuromodulation approaches in TBI rehabilitation.

How to Claim Credit

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