



CHAPTER 5

Unilateral Versus Bilateral
Upper Limb Training After Stroke:
The Upper Limb Training After Stroke
Clinical Trial

5 Unilateral versus bilateral upper limb training after stroke: The Upper Limb TRaining After stroke clinical trial

Abstract

Background and purpose: Unilateral and bilateral training protocols for upper limb rehabilitation after stroke represent conceptually contrasting approaches with the same ultimate goal. In a randomized controlled trial, we compared the merits of modified constraint-induced movement therapy, modified bilateral arm training with rhythmic auditory cueing, and a dose-matched conventional treatment. Modified constraint-induced movement therapy and modified bilateral arm training with rhythmic auditory cueing targeted wrist and finger extensors, given their importance for functional recovery. We hypothesized that modified constraint-induced movement therapy and modified bilateral arm training with rhythmic auditory cueing are superior to dose-matched conventional treatment.

Methods: Sixty patients, between 1 to 6 months after stroke, were randomized over 3 intervention groups. The primary outcome measure was the Action Research Arm test, which was conducted before, directly after, and 6 weeks after intervention.

Results: Although all groups demonstrated significant improvement on the Action Research Arm test after intervention, which persisted at 6 weeks follow-up, no significant differences in change scores on the Action Research Arm test were found between groups post-intervention and at follow-up.

Conclusions: Modified constraint-induced movement therapy and modified bilateral arm training with rhythmic auditory cueing are not superior to dose-matched conventional treatment or each other in improving upper limb motor function 1 to 6 months after stroke.

Clinical Trial Registration: www.trialregister.nl. Unique identifier: NTR1665

Introduction

In post-stroke upper limb rehabilitation, unilateral training protocols such as constraint-induced movement therapy²⁹ stand in stark contrast to bilateral training protocols such as bilateral arm training with rhythmic auditory cueing.⁸ A recent meta-analysis revealed that both types of training are similarly effective in patients in the early and the chronic phase after stroke.⁷¹

The present single-blinded randomized controlled trial, called the Upper Limb Training After Stroke trial, is the first to compare the merits of both unilateral and bilateral training to each other and an equally intensive, dose-matched conventional treatment (DMCT) in patients starting the intervention between 1 and 6 months after stroke. In the unilateral and bilateral training protocols, emphasis was placed on the increase of control of wrist and finger extensors, given its importance for functional recovery.³⁶ Patients were divided into 3 intervention groups: modified constraint-induced movement therapy (mCIMT), modified bilateral arm training with rhythmic auditory cueing (mBATRAC), and DMCT. We hypothesized that both mCIMT and mBATRAC would significantly improve upper limb function when compared with DMCT.

Methods

A detailed description of the methods (including stratification in subgroups) is presented in Supplement I and elsewhere.⁷³

Sixty patients with an upper limb paresis, and at least minimal distal control were recruited from the Reade rehabilitation center in Amsterdam between 1 to 6 months after a first ever stroke.

After obtaining informed consent, a pretest of outcome variables was performed. Next, patients were randomized in permuted blocks and allocated to 1 of the 3 intervention groups. Concealed allocation was effectuated online using the minimization method.

After randomization, there was a 6-week intervention period. The posttests were conducted during the week after intervention. Follow-up tests were conducted 6 weeks after the posttests.

The mCIMT therapy involved repetitive task practices and shaping of the desired movements,^{7,29} with an emphasis on the increase of control of wrist and finger extensors. Patients were encouraged to wear a mitt on the nonparetic hand for 6 hours each weekday. The mBATRAC therapy involved a modification of the original bilateral arm training with rhythmic auditory cueing protocol,⁸ which targeted rhythmic flexion and extension movements about the wrist rather than movements of proximal parts of the upper limb. The DMCT was an exercise therapy on the basis of existing guidelines for upper limb rehabilitation after stroke, discarding specific elements of mCIMT and mBATRAC. All patients received 60-minute therapy sessions, 3 days a week for 6 consecutive weeks. They were also instructed to practice outside of therapy hours and encouraged to perform activities of daily living according to the concept of their allocated treatment.

The Action Research Arm test served as primary outcome measure. Secondary outcome measures are described in Supplement I.

We tested for differences between the groups on baseline values, change scores from pretests to posttests, and from posttests to follow-up tests. We also tested for significant changes within groups after the intervention and at follow-up (see Supplement I).

Results

Sixty patients were assigned to the mCIMT, mBATRAC, or DMCT groups, with 55 patients being tested after intervention and 52 patients at follow-up (Figure 5.1). Baseline data, patient characteristics, and therapy compliance are presented in Table 5.1. There were no significant differences between groups.

No significant differences in change scores were obtained on the primary and secondary outcome measures between the groups at posttest and follow-up. Tabulated change-score data are presented in Supplements III and IV.

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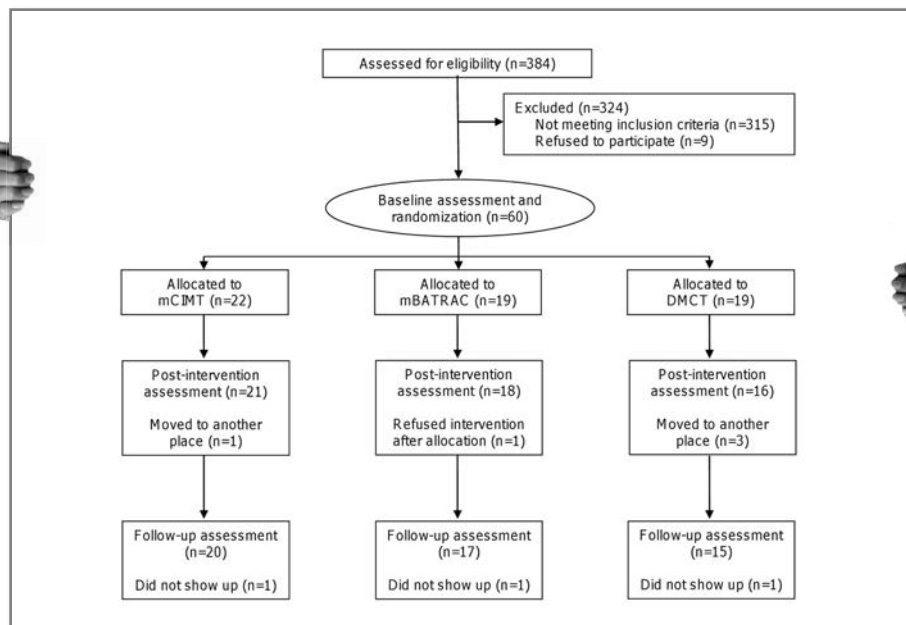
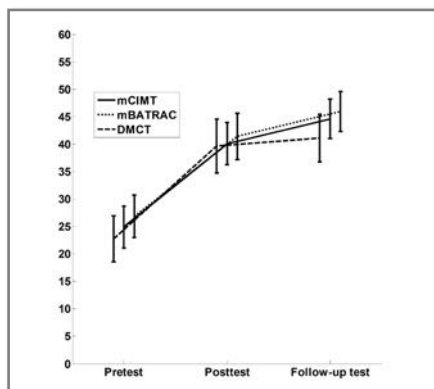


Figure 5.1 Flow chart. DMCT indicates dose-matched conventional treatment; mBATRAC modified bilateral arm training with rhythmic auditory cueing; and mCIMT, modified constraint-induced movement therapy.

Demographics	mCIMT (N=22)	mBATRAC (N=19)	DMCT (N=19)	Between-Group <i>p</i>
Age, years*	59.8 (13.8)	62.6 (9.8)	56.9 (12.7)	0.37
Time since stroke, weeks*	9.2 (6.8)	7.8 (4.9)	11.1 (6.8)	0.28
Female/male	8/14	8/11	3/16	0.18
Arm affected, left/right	12/10	11/8	11/8	0.97
Affected dominant side, yes/no	11/11	9/10	7/12	0.68
Pretests				
Action Research Arm Test*	23.8 (16.8)	25.8 (16.1)	23.3 (15.4)	0.93
Grasp*	7.1 (5.9)	8.2 (6.3)	7.6 (5.9)	0.88
Grip*	4.5 (3.8)	4.7 (3.9)	4.6 (3.6)	0.99
Pinch*	5.3 (5.8)	6.2 (5.5)	5.8 (5.6)	0.76
Gross Movement*	6.7 (2.7)	6.7 (2.4)	5.4 (2.2)	0.06
Motricity Index*	65.4 (13.6)	63.9 (12.1)	61.9 (14.1)	0.51
Fugl-Meyer Arm Assessment*	43.0 (14.7)	42.7 (12.4)	39.0 (10.3)	0.38
9 Hole Peg Test*	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.40
Erasmus mod. Nottingham Sensory Assessment*	33.3 (12.8)	31.4 (14.3)	38.2 (2.8)	0.75
Motor Activity Log				
Amount of Use*	1.4 (0.9)	1.5 (1.1)	1.5 (1.1)	0.97
Quality of Movement*	1.0 (0.7)	1.1 (0.9)	1.2 (1.2)	0.95
Stroke Impact Scale				
Strength*	55.1 (16.7)	49.7 (15.4)	52.5 (14.2)	0.41
Memory*	88.1 (16.6)	85.9 (16.1)	83.8 (16.4)	0.67
Emotion*	78.4 (18.0)	78.1 (16.0)	83.0 (14.3)	0.45
Communication*	88.1 (14.6)	90.2 (13.6)	87.2 (14.2)	0.80
ADL*	56.5 (16.0)	56.4 (19.1)	61.4 (17.1)	0.63
Mobility*	70.5 (23.4)	56.0 (28.9)	68.9 (22.1)	0.22
Hand Function*	22.7 (20.0)	27.4 (27.2)	33.7 (26.6)	0.34
Social Participation*	38.1 (20.1)	37.8 (22.6)	44.6 (17.5)	0.45

*Mean (SD).

Table 5.1 Baseline Characteristics



All groups demonstrated significant improvement on the Action Research Arm test after intervention, which lasted or improved further during the 6-week follow-up period (Figure 5.2).

Figure 5.2

Mean Action Research Arm test scores (and SEs) over time per group. Group-lines are shifted to enhance clarity. DMCT indicates dose-matched conventional treatment; mBATRAC modified bilateral arm training with rhythmic auditory cueing; and mCIMT, modified constraint-induced movement therapy.

Discussion

This is the first trial that emphasized training of distal extensors of the paretic limb in a direct comparison of unilateral and bilateral upper limb training after stroke. The results indicate that mCIMT and mBATRAC are not superior to DMCT or each other in improving upper limb motor function 1 to 6 months after stroke when provided with comparable intensity. Hence, the results suggest that the intensity of active exercise of the paretic upper limb may be more important than specific features that distinguish the training approaches, such as unilateral and bilateral training.^{54,71}

A limitation of this trial is the small sample size because of the eligible criteria for applying mCIMT or mBATRAC. However, on the basis of the obtained difference of 1.6 points on the Action Research Arm test between mBATRAC or mCIMT on the one hand and DMCT on the other hand, we calculated that 265 patients are required per group to achieve a significant difference between these interventions.⁷³ Moreover, such a small difference is deemed clinically irrelevant.¹⁵⁷ Second, there was considerable variation in the starting moment of the intervention after stroke. Given the nature of the interventions, we recruited patients with at least minimal distal motor control (i.e., the possibility to actively extend wrist, thumb, and 2 fingers for 10°). Some patients showed this ability at intake in the rehabilitation center and others some time later. Given the randomized allocation within 6 months after stroke, it may be expected that all 3 groups benefitted from certain spontaneous mechanisms of recovery, such as restored neuronal networks in reperfused cerebral tissue and alleviation of diaschisis,⁷ which would imply that any differences in effect are related to differences between the interventions. Furthermore, self-practice and mitt-compliance were inconsistently documented. Hence, the assumptions of equivalent self-practice between groups and mitt-compliance for the mCIMT group relied on verbal staff reports. Nonetheless, this was the first trial comparing unilateral and bilateral upper limb training with patients starting the intervention between 1 to 6 months after stroke (i.e., the time-window in which most patients receive therapy).

As it stands, the relative contributions of actual (re)learning and spontaneous recovery to the improvement of upper limb function after stroke are unknown, and the same applies to the time evolution of these processes. For a better understanding of motor recovery, longitudinal studies with repeated kinematic measures in time combined with neuroimaging studies are required.

Sources of funding

this study was funded by the Dutch Scientific College of Physiotherapy of the Royal Dutch Society for Physical Therapy.

SUPPLEMENT I

Detailed methods

The ULTRA-Stroke trial was approved by the Medical Ethical Reviewing Committee of VU University Medical Center (protocol number 2008/296, Dutch Central Committee on Research Involving Human Subjects, CCMO, protocol number NL20456.029.08). The design of the trial was published around the time of its initiation.⁷³

Participants

The 60 recruited patients met the following criteria within 6 months after stroke onset: (I) first-ever stroke in one of the hemispheres, as verified by CT and/or MRI scan; (II) upper limb paresis, however with minimal control of the paretic wrist and fingers (i.e., able to execute at least 10° of active wrist extension, 10° of active thumb abduction/extension, and 10° active extension in at least 2 additional digits); (III) Action Research Arm Test (ARAT) score lower than 53 points; (IV) between 18 and 80 years of age; (V) informed consent; (VI) motivated to participate; (VII) no upper-limb orthopedic limitations; (VIII) ability to communicate (i.e., more than 3 points on the Utrecht Communication Observation¹⁹⁶); and (IX) a minimum score of 23 points on the Folstein Mini-Mental State Examination.

Design

After the pretests, participants were stratified into a higher-functioning group (i.e., able to execute more than 10° of each metacarpophalangeal and interphalangeal joint of all digits and more than 20° of wrist extension) or a lower-functioning group (i.e., unable to meet the aforementioned criteria).⁷ After stratification, participants were randomized in permuted blocks and allocated to 1 of the 3 intervention groups, resulting in 6 subgroups (i.e., mCIMT-Low, mCIMT-High, mBATRAC-Low, mBATRAC-High, DMCT-Low and DMCT-High). Concealed allocation was effectuated online, using the minimization method.¹⁹⁸

Interventions

The interventions (described in greater detail elsewhere⁷³) were applied by trained physical and/or occupational therapists. In brief, the three interventions were as follows.

Modified CIMT

The mCIMT therapy involved repetitive task practices and shaping of the desired movements using successive approximation. Emphasis was placed on the increase of control of wrist and finger extensors. During supervised exercise the participants received continuous verbal feedback and stimulation and, if necessary, hands-on facilitation of movements. The exercises followed a quasi-hierarchical bottom-up approach from more easy applied gross motor functions to more complex in-hand manipulations. Participants were encouraged to wear a padded safety mitt on the non-paretic hand for 6 hours each weekday.

Modified BATRAC

The modification of the original BATRAC protocol⁸ entailed the involvement of distal rather than proximal parts of the upper limb. The apparatus used for mBATRAC was mounted on a chair with arm rests. At the distal end of each arm rest a manipulandum with a handgrip and a potentiometer were fitted. The hands were vertically fixated to the handgrips and the lower arms were fixated to the arm rests. The rotation axis of the wrist was aligned with that of the manipulandum. Treatment was applied in 3-minute movement periods interspersed with 5-minute rest periods. During exercise bimanual in-phase (i.e., mirror symmetric) and anti-phase (i.e., alternating) flexion and extension movements about the wrist in the horizontal plane were paced by an auditory metronome at an individually selected tempo. Movement feedback (left-hand position by right-hand position) and the desired movement trajectory were provided on a laptop screen. Over the course of training the tempo was adjusted in response to improvement in task performance.

DMCT

The DMCT is an exercise therapy based on existing guidelines for upper limb treatment as presented by the Royal Dutch Society of Physical Therapy²⁰⁶ and the Dutch Society of Occupational Therapy.²⁰⁵ However, specific elements of mCIMT and mBATRAC were discarded.

For each group, content and duration of each treatment session were recorded in patient-logs. Mitt-compliance and self-practice were monitored by staff and patients were asked to record these in their patient-logs. However, self-practice and mitt-compliance turned out to be inconsistently documented, and only the amount of supervised treatment sessions were properly recorded.

Assessments

Outcome Measures

We aimed to cover all 3 levels of the International Classification of Functioning, Disability and Health. We chose the ARAT as primary outcome measure to assess upper limb function. The ARAT shows excellent clinimetric properties^{159,208} and high concurrent validity with the Wolf Motor Function Test.¹⁵⁵

The secondary outcome measures were: (I) Motricity Index (MI) to measure strength in the upper limbs;²⁰⁹ (II) Fugl-Meyer motor assessment of the arm (FMA) to measure upper limb impairment;²¹¹ (III) Nine Hole Peg Test (NHPT) to measure manual dexterity;²¹³ (IV) Erasmus modification of the Nottingham Sensory Assessment (EmNSA) to measure the sense of touch, pressure, proprioception, and sharp-blunt discrimination in the upper limb;²¹⁴ (V) Motor Activity Log (MAL) to measure how well (5-point Quality of Movement [QOM] scale) and how much (5-point Amount of Use [AOU] scale) the paretic upper limb was used spontaneously to accomplish 26 activities of daily living outside the laboratory;^{215,216} and (VI) Stroke Impact Scale (SIS; version 3.0) to evaluate changes in 8 impairments, function and quality-of-life subdomains.^{217,218} All secondary outcome measures show satisfactory validity and reliability.⁷³

Statistical analyses

Power Analysis

Based on a statistical power of 80% (preventing Type II error) with an alpha of 5% (preventing Type I error) for detecting a difference of 6 points (i.e., > 10%) on the ARAT, the required number of participants was 20 per group, including an expected percentage of 15% drop-outs.⁷³ In total 60 participants were needed for the trial.

Data Analysis

We tested for differences between the (sub)groups regarding baseline values, change scores from pretests to posttests, and from posttests to follow-up tests, using Chi-square tests for nominal outcomes (e.g. female/male), Kruskal-Wallis H tests for ordinal outcomes (e.g., ARAT), and ANOVAs for continuous outcomes (e.g., age). Significant change-score differences between the (sub)groups were analyzed further using post-hoc Mann-Whitney U tests with a Holm-Bonferroni correction for multiple comparisons. Wilcoxon signed-rank tests were used to determine significant changes within (sub)groups after the intervention and at follow-up. All tests were applied with a preset two-tailed significance level of $p < 0.05$.

SUPPLEMENT II

Baseline Characteristics and Therapy Compliance for Subgroups

	mCIMT-Low (N=10)	mBATRAC-Low (N=8)	DMCT-Low (N=6)	Between-Group <i>p</i>	mCIMT-High (N=12)	mBATRAC-High (N=11)	DMCT-High (N=13)	Between-Group <i>p</i>
Age, years*	57,5 (16,1)	59,8 (11,8)	65,8 (9,4)	0,50	61,7 (12,1)	64,6 (8,0)	52,8 (12,1)	0,03†
Time since stroke, weeks*	10,7 (7,4)	9,0 (5,6)	10,3 (3,9)	0,83	8,0 (6,3)	6,9 (4,3)	11,5 (8,0)	0,21
Female/male	5/5	4/4	1/5	0,36	3/9	4/7	2/11	0,50
Arm affected, left/right	2/8	1/7	0/6	0,50	1/11	0/11	1/12	0,57
Affected dominant side, yes/no	4/6	5/3	1/5	0,23	7/5	4/7	6/7	0,63
Action Research Arm Test*	11,2 (8,8)	11,3 (10,6)	11,3 (9,6)	0,93	34,3 (14,6)	36,5 (9,8)	28,8 (14,6)	0,43
Grasp*	2,6 (2,8)	2,8 (3,5)	2,3 (2,6)	1,00	10,9 (5,2)	12,2 (4,6)	10,1 (5,4)	0,68
Grip*	1,7 (1,9)	1,4 (2,1)	3,2 (4,5)	0,70	6,8 (3,5)	7,1 (3,1)	5,2 (3,2)	0,18
Pinch*	1,3 (1,9)	2,1 (4,2)	1,7 (2,3)	0,89	8,6 (5,8)	9,2 (4,2)	7,8 (5,7)	0,61
Gross Movement*	5,5 (3,0)	5,0 (2,7)	4,2 (1,3)	0,61	8,0 (2,0)	8,0 (1,2)	6,0 (2,3)	0,02‡
Motricity Index*	59,2 (13,7)	53,9 (11,9)	56,8 (9,5)	0,43	70,5 (11,7)	71,3 (5,0)	64,2 (15,6)	0,45
Fugl-Meyer Arm Assessment*	33,9 (13,1)	32,3 (10,4)	31,2 (6,2)	0,86	50,6 (11,6)	50,4 (6,9)	42,4 (10,2)	0,06
9 Hole Peg Test*	0,0 (0,0)	0,0 (0,0)	0,0 (0,1)	0,10	0,1 (0,0)	0,1 (0,1)	0,1 (0,1)	0,34
Erasmus mod. Nottingham	32,2 (15,7)	36,6 (6,9)	38,7 (2,8)	0,80	34,3 (10,4)	27,6 (17,2)	38,0 (2,8)	0,73
Sensory Assessment*								
Motor Activity Log								
AOU*	1,4 (0,9)	0,7 (0,8)	0,8 (0,4)	0,09	1,5 (1,0)	2,1 (1,0)	1,8 (1,1)	0,44
QOM*	0,8 (0,5)	0,4 (0,6)	0,6 (0,4)	0,27	1,2 (0,8)	1,6 (0,8)	1,5 (1,3)	0,50
Stroke Impact Scale								
Strength*	56,3 (18,2)	55,5 (16,2)	47,5 (11,7)	0,54	54,2 (16,1)	45,5 (14,0)	54,8 (15,1)	0,21
Memory*	94,6 (7,2)	89,3 (15,0)	79,2 (21,6)	0,24	82,7 (20,3)	83,4 (17,1)	85,9 (13,9)	0,93
Emotion*	83,9 (15,4)	76,7 (14,0)	85,2 (14,3)	0,29	73,8 (19,4)	79,0 (18,0)	82,1 (14,7)	0,42
Communication*	96,4 (4,1)	90,6 (17,5)	88,1 (14,9)	0,88	81,3 (16,8)	89,9 (10,9)	86,8 (14,5)	0,40
ADL*	58,5 (10,0)	60,0 (17,7)	57,5 (7,9)	0,95	54,9 (14,6)	53,9 (20,5)	63,3 (20,1)	0,49
Mobility*	68,6 (27,4)	72,2 (25,2)	74,1 (19,7)	0,87	72,0 (20,7)	44,2 (26,4)	66,5 (23,5)	0,03§
Hand Function*	17,5 (19,8)	15,0 (20,9)	13,3 (11,3)	0,92	27,1 (20,1)	36,4 (28,6)	43,1 (26,5)	0,27
Social Participation*	34,4 (18,7)	40,6 (20,2)	47,9 (14,1)	0,26	41,1 (21,5)	35,8 (24,9)	43,0 (19,1)	0,47
Treatment Compliance	(N=9)	(N=7)	(N=5)		(N=11)	(N=10)	(N=10)	
Supervised hours in 6 Weeks*	17,0 (1,2)	17,3 (1,3)	16,4 (0,5)	0,42	17,3 (1,7)	17,2 (1,0)	17,1 (1,3)	0,96

* Mean (SD).

† Post-hoc test: mBATRAC-High group was older than the DMCT-High group.

‡ Post-hoc test: mCIMT-High scored higher than DMCT-High.

§ Post-hoc test: mCIMT-High scored higher than mBATRAC-High.

SUPPLEMENT III

Comparison of Changes for the 3 Intervention Groups

Measure	Posttest			Between-Group <i>p</i>	Follow-up			Between-Group <i>p</i>
	mCIMT (N=21)	mBATRAC (N=18)	DMCT (N=16)		mCIMT (N=20)	mBATRAC (N=17)	DMCT (N=15)	
	Change	Change	Change		Change	Change	Change	
ARAT	14,6 (12,0)†	14,1 (12,2)†	15,9 (12,5)†	0,81	4,5 (7,1)†	4,5 (5,7)†	1,5 (9,2)	0,25
Grasp	5,3 (5,1)†	4,2 (4,9)†	4,2 (4,0)†	0,64	1,3 (2,9)*	2,1 (3,1)*	0,4 (3,2)	0,22
Grip	3,9 (3,5)†	4,9 (3,7)†	4,6 (3,5)†	0,65	1,4 (2,7)*	0,5 (3,4)	0,6 (2,5)	0,16
Pinch	4,4 (5,0)†	4,3 (4,2)†	5,1 (5,5)†	0,94	1,8 (3,8)*	1,3 (1,7)*	0,2 (4,0)	0,57
Gross Movement	1,0 (1,7)*	0,8 (1,6)*	1,9 (1,9)†	0,15	0,0 (0,3)	0,3 (1,0)	0,3 (1,2)	0,51
MI	6,2 (11,2)*	8,2 (11,8)†	9,3 (10,4)†	0,78	4,4 (7,9)*	2,8 (7,5)	3,9 (6,4)	0,72
FMA	7,8 (9,4)†	9,8 (7,9)†	9,2 (7,3)†	0,73	2,4 (4,0)†	4,3 (8,0)*	7,1 (11,0)†	0,67
NHPT	0,2 (0,2)†	0,1 (0,1)†	0,1 (0,1)†	0,86	0,0 (0,1)	0,0 (0,1)	0,1 (0,1)†	0,57
EmNSA	0,5 (2,6)	3,2 (6,4)*	0,7 (3,7)	0,36	0,6 (2,1)	0,6 (2,6)	-0,7 (3,9)	0,77
MAL								
AOU	1,3 (1,3)†	0,8 (1,4)*	1,0 (0,8)†	0,33	-0,1 (0,5)	0,4 (0,7)	0,4 (0,7)	0,06
QOM	1,3 (1,0)†	0,8 (1,2)*	0,8 (0,6)†	0,23	0,1 (0,7)	0,4 (0,6)*	0,4 (0,7)*	0,08
SIS								
Strength	8,3 (14,8)*	13,5 (18,3)*	0,5 (19,1)	0,13	6,3 (15,4)	-1,1 (13,1)	11,7 (13,1)*	0,04‡
Memory	-3,6 (17,1)	-3,2 (13,9)	4,5 (12,3)	0,26	3,6 (13,3)	0,2 (9,6)	-0,9 (8,2)	0,45
Emotion	-1,0 (17,0)	4,9 (10,5)	1,0 (13,9)	0,62	5,8 (18,1)	-7,2 (11,0)	3,9 (11,7)	0,03‡
Communication	1,9 (9,4)	-2,4 (9,8)	2,5 (8,1)	0,33	-0,7 (7,1)	2,3 (11,9)	3,1 (12,8)	0,38
ADL	14,8 (13,0)†	15,4 (16,6)†	15,5 (15,8)†	0,99	4,0 (12,5)	2,8 (13,5)	0,0 (12,7)	0,78
Mobility	13,0 (16,8)†	23,3 (21,8)†	20,8 (18,3)†	0,29	4,3 (9,9)	1,8 (7,3)	3,1 (10,4)	0,87
Hand Function	32,6 (12,3)†	27,5 (30,1)†	23,8 (23,6)†	0,44	0,3 (19,2)	11,5 (22,8)	9,7 (22,6)	0,31
Social Participation	15,3 (23,7)†	1,5 (26,11)*	21,5 (19,3)†	0,47	15,9 (22,4)†	6,8 (19,3)	3,1 (20,5)	0,28

Values are mean (SD).

* $p < 0.05$ for within-group changes.

† $p < 0.01$ for within-group changes.

‡ Post-hoc tests: mBATRAC scored lower than DMCT ($p = 0,01$).

SUPPLEMENT IV

Comparison of Changes for the 6 Subgroups

Measure	Posttest						Between-Group <i>p</i>
	mCIMT		mBATRAC		DMCT		
	Low (N=10)	High (N=11)	Low (N=8)	High (N=10)	Low (N=6)	High (N=10)	
Change	Change	Change	Change	Change	Change		
ARAT	16.3 (15.2)†	13.0 (8.5)†	18.6 (16.2)*	10.5 (6.8)†	13.7 (14.1)*	17.3 (12.0)†	0.88
Grasp	6.4 (6.5)*	4.4 (3.5)†	6.5 (6.2)*	2.4 (2.6)*	4.2 (4.8)	4.2 (3.8)*	0.62
Grip	3.8 (3.9)†	3.9 (3.2)†	5.8 (4.6)*	4.2 (2.8)†	3.3 (3.1)*	5.3 (3.6)*	0.71
Pinch	4.4 (5.8)*	4.5 (4.4)*	5.4 (5.0)*	3.5 (3.4)*	3.8 (5.3)	5.8 (5.7)*	0.94
Gross Movement	1.8 (2.0)*	0.3 (0.9)	1.0 (1.9)	0.7 (1.4)	2.3 (2.0)	1.6 (1.9)*	0.15
MI	6.0 (13.5)	6.4 (9.2)	12.0 (13.4)*	5.2 (9.9)	9.3 (7.8)*	9.3 (12.2)*	0.74
FMA	11.1 (11.3)*	4.8 (6.6)*	13.8 (8.2)*	6.7 (6.4)*	8.3 (6.8)*	9.7 (7.9)†	0.21
NHPT	0.1 (0.1)*	0.2 (0.2)†	0.1 (0.2)	0.2 (0.1)†	0.1 (0.1)*	0.2 (0.1)†	0.03‡
EmNSA	-0.1 (1.3)	1.1 (3.4)	1.1 (3.2)	5.0 (7.9)*	0.0 (4.0)	1.1 (3.4)	0.34
MAL							
AOU	0.8 (1.3)	1.7 (1.2)†	1.1 (1.6)	0.5 (1.3)	0.9 (0.7)*	1.0 (0.9)*	0.32
QOM	0.8 (0.7)†	1.7 (1.0)†	1.1 (1.4)*	0.6 (1.1)	0.7 (0.6)*	0.8 (0.7)*	0.16
SIS							
Strength	11.9 (12.3)*	5.1 (16.7)	8.6 (23.1)	17.5 (13.4)*	1.5 (15.7)	0.0 (21.7)	0.30
Memory	-1.1 (11.3)	-5.8 (21.4)	-4.9 (18.5)	-1.8 (9.6)	7.7 (7.6)	2.5 (14.4)	0.46
Emotion	1.9 (18.6)	-3.8 (15.8)	4.9 (10.7)	5.0 (10.9)	2.3 (12.7)	0.3 (15.1)	0.90
Communication	2.1 (4.5)	1.6 (12.5)	-4.0 (12.4)	-1.1 (7.5)	1.8 (8.1)	2.9 (8.6)	0.68
ADL	9.3 (11.0)*	19.8 (13.2)†	12.8 (19.6)	17.5 (14.5)†	6.7 (9.4)	20.8 (16.9)*	0.22
Mobility	19.2 (16.6)†	7.3 (15.5)	15.3 (24.1)	29.7 (18.5)†	13.9 (16.3)	25.0 (19.0)*	0.10
Hand Function	31.0 (13.1)†	34.1 (12.0)†	28.1 (32.3)*	27.0 (29.9)*	24.2 (18.3)*	23.5 (27.3)*	0.84
Social Participation	14.1 (21.2)	16.5 (26.7)	9.0 (20.6)	20.6 (29.9)	17.7 (20.8)	23.8 (19.2)*	0.76

Values are mean (SD).

* $p < 0.05$ for within-group changes.

† $p < 0.01$ for within-group changes.

‡ Kruskal-Wallis $H = 12.5$, $p = 0.03$; however, the post-hoc Mann-Whitney U tests with a Holm-Bonferroni correction for multiple comparisons were non-significant (smallest $p = 0.01$).

	Follow-Up						Between-Group <i>p</i>
	mCIMT		mBATRAC		DMCT		
	Low (N=9)	High (N=11)	Low (N=7)	High (N=10)	Low (N=5)	High (N=10)	
	Change	Change	Change	Change	Change	Change	
	8.9 (8.5)*	0.9 (2.6)	6.6 (8.1)	3.1 (3.1)*	1.2 (16.7)	1.6 (2.5)	0.10
	2.3 (4.0)	0.5 (1.2)	2.7 (3.1)	1.6 (3.1)	1.0 (5.7)	0.1 (1.0)	0.32
	2.9 (3.5)*	0.2 (0.4)	1.6 (3.3)	-0.2 (3.4)	1.8 (4.4)	0.9 (2.0)	0.12
	3.6 (5.1)	0.4 (1.4)	1.6 (2.1)	1.1 (1.4) *	-1.2 (6.6)	0.6 (0.8)	0.72
	0.1 (0.3)	-0.1 (0.3)	0.1 (1.2)	0.4 (1.0)	-0.4 (1.5)	0.0 (0.0)	0.14
	4.4 (7.0)	4.4 (8.9)	3.9 (8.2)	2.1 (7.3)	0.8 (10.1)	5.4 (3.4)†	0.90
	1.9 (2.1)*	2.8 (5.2)*	2.7 (2.1)*	5.4 (10.3)	6.0 (3.7)*	7.6 (13.5)	0.68
	0.0 (0.1)	0.0 (0.1)	0.1 (0.1)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)*	0.78
	0.0 (1.9)	1.0 (2.2)	-0.3 (0.8)	1.2 (3.3)	-1.4 (5.9)	-0.4 (2.8)	0.73
	0.0 (0.5)	-0.1 (0.6)	0.6 (0.3)*	0.2 (0.8)	0.2 (0.4)	0.4 (0.8)	0.07
	0.3 (0.6)	0.0 (0.7)	0.5 (0.2)*	0.3 (0.8)	0.5 (0.2)*	0.4 (0.9)	0.15
	-0.7 (15.5)	11.9 (13.5)*	-0.9 (10.5)	-1.3 (15.3)	7.5 (13.5)	13.8 (13.1)*	0.06
	4.0 (9.5)	3.2 (16.2)	-2.0 (7.1)	1.8 (11.1)	0.7 (8.9)	-1.8 (8.1)	0.69
	2.5 (10.5)	8.6 (22.8)	-9.5 (14.3)	-5.6 (8.5)	1.1 (11.7)	5.3 (12.0)	0.19
	-1.2 (2.5)	-0.3 (9.5)	4.1 (9.8)	1.1 (13.6)	-0.7 (3.0)	5.0 (15.4)	0.76
	-0.6 (9.6)	7.7 (13.7)	4.3 (9.4)	1.8 (16.2)	1.5 (12.4)	-0.8 (13.4)	0.73
	3.1 (10.3)	5.3 (10)	0.0 (7.5)	3.1 (7.3)	0.0 (8.1)	4.7 (11.4)	0.64
	2.2 (21.2)	-1.4 (18.3)	15.0 (25.0)	9.0 (22.1)	17.0 (5.7)*	6.0 (27.2)	0.43
	13.9 (22.3)	17.6 (23.4)*	14.7 (19.1)	1.3 (18.4)	-2.5 (18.1)	5.9 (22.0)	0.42