ORIGINAL ARTICLE

The Effects of Constraint-Induced Therapy on Kinematic Outcomes and Compensatory Movement Patterns: An Exploratory Study

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ABSTRACT. Massie C, Malcolm MP, Greene D, Thaut M. The effects of constraint-induced therapy on kinematic outcomes and compensatory movement patterns: an exploratory study. Arch Phys Med Rehabil 2009;90:571-9.

Objective: To determine changes in kinematic variables and compensatory movement patterns of survivors of stroke completing constraint-induced therapy (CIT).

Design: Pre-post, case series.

Setting: Clinical rehabilitation research laboratory.

Participants: Men (n=7) and women (n=3) with unilateral stroke occurring at least 9 months prior to study entry with moderate, stable motor deficits.

Intervention: Participants completed 10 consecutive weekdays of CIT for 6 hours a day comprised of trainer-supervised, functionally based activities using massed practice.

Main Outcome Measures: Kinematic measures included movement time, average velocity, trajectory stability, shoulder abduction, and segmental contribution. Functional measures included Wolf Motor Function Test (WMFT) performance time and functional ability scores and Motor Activity Log (MAL) "how-well" scores. All measures were administered before and after the 2-week CIT intervention.

Results: Movement time, average velocity, and trajectory stability significantly improved after CIT. Participants used more shoulder flexion to reach after CIT, but also demonstrated increased compensatory shoulder abduction. Functional scores also significantly improved, including WMFT performance time and functional ability and MAL scores. There was no change in trunk movement or amount of elbow extension.

Conclusions: CIT improved motor capacities in the hemiparetic arm as reflected in the functional outcomes and in some kinematic measures. Participants' reliance on common compensatory movements was not beneficially affected by CIT. The results of this study demonstrate that while functional capacity and some movement strategies in the hemiparetic arm improve after CIT, participants may not overcome their reliance on common compensatory movement patterns. Based on these findings, this study suggests that CIT may encourage subjects to generate movement through compensatory and/or synergy-dominated movement rather than promote the normalization of motor control. This outcome highlights the need to develop CIT further as an intervention that improves functional capacity and more normative movement strategies.

Key Words: Rehabilitation; Stroke.

STROKE IS THE LEADING cause of adult long-term disability in the United States, often resulting in reaching impairments that may limit autonomy in activities of daily living and quality of life.[1] After a stroke, the capacity for central control of movement is typically severely compromised because of damage to neural mechanisms that control voluntary movement.[2] This damage leads to weakness, abnormal muscle tone, and stereotypical movement synergies that collectively limit functional reach. Consequently, survivors of stroke often rely on compensatory movement strategies to accomplish reaching tasks.[3-6] Compensatory strategies are considered maladaptive and are often detrimental to recovery of necessary movement capacities (eg, use of elbow extension or shoulder flexion).[5] Although neurorehabilitation research has recently demonstrated that structured, specific, and intensive training protocols increase the amount of hemiparetic limb use, less attention has been given to normalizing movement strategies poststroke.[7]

CIT is a more recently developed intervention designed to restore motor skill capacity through massed practice of functional activities with the stroke-affected upper extremity.[8,9] Training concepts of CIT focus on re-establishing basic limb use by increasing attention to and use of the affected side. The signature protocol of CIT is well supported as an intervention of 6 hours of therapy a day for 10 consecutive weekdays while wearing a restraining mitt on the less affected extremity for up to 90% of waking hours.[10-14] The efficacy of the signature CIT intervention was demonstrated in the recently completed EXCITE trial,[11] which investigated over 200 survivors of stroke in a randomized controlled design. Along with other smaller CIT trials, findings from the EXCITE project demonstrated a substantial and lasting increase in amount of hemiparetic arm use. With the success of CIT, considerable efforts have also been made to develop modified CIT protocols.[10,15-18] There is, however, no consensus on the most efficacious form of modified CIT.[19] Although evidence supports modified CIT protocols, Sterr et al[10] found that 6 hours a day of training is superior to

List of Abbreviations

CIT	constraint-induced therapy
EXCITE	Extremity Constraint Induced Therapy Evaluation
MAL	Motor Activity Log
WMFT	Wolf Motor Function Test

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3 hours a day. This finding suggests that intensity may be the main factor that differentiates modified and the signature CIT protocol.[19] Given the limited consistency across modified CIT protocols and a greater amount of evidence supporting signature CIT protocol, the current study employed the standard, 6 hours a day of intervention.

The bulk of CIT outcomes have focused on functional measures of change including the WMFT and the MAL. However, inconsistencies in the quality of movement ratings using the WMFT functional ability scale are reported in CIT literature.[11,20] The MAL is a participant-rated quality of movement scale based on different activities of daily living, and reported outcomes indicate real-world improvements after CIT.[11] Kunkel et al[13] have suggested that while subject ratings of quality of movement on the MAL substantially improved after CIT, movement still exhibited a substantial deficit. One method that has been proposed to clarify movement deficits after CIT is kinematic motion analysis because it can objectively and quantitatively describe the geometry of movement in clinically relevant outcome measures.[7] Furthermore, postintervention changes in motor control strategies involving range of motion, multijoint control, movement velocity, and timing are readily detected through kinematic analyses. Outcomes that rely on subject ratings or therapist perceptions of movement validly demonstrate improvements in functional capacity but are limited in revealing specific changes in poststroke movement strategies.

To our knowledge, such specific assessment of postintervention kinematics has not been reported on the signature CIT protocol. A limited number of studies, however, have employed kinematic motion analysis to objectively and quantitatively measure changes after modified CIT protocols.[15,16,18,21] These studies reported spatiotemporal measures such as movement duration, reaction time, normalized movement units, and normalized jerk scores. Caimmi et al[15] demonstrated improvements in normalized jerk scores and movement duration but did not include assessment of any change in motor strategy in the context of compensatory or synergy-driven movement. Similarly, Wu et al[18] reported significant improvement in normalized movement time after CIT. In contrast, Wu et al[21] found no significant improvement in movement time when comparing a modified CIT protocol with traditional rehabilitation. Based on commonly reported outcome measures (both functional and kinematic), movement deficits that remain after signature or modified implementation of CIT protocol, and the extent to which such changes in movement capacities depend on compensatory motor strategies, are unclear.

Carr and Shepherd[6] suggest that compensatory strategies are the result of using available movements given the poststroke state of the central nervous system, which leads to long-term functional limitations. Because CIT is an intervention focused on overcoming learned nonuse by massed practice of available movement strategies, limited attention may be directed to the quality of movements being performed. Therefore, distinguishing between recovery of normalized movement patterns and compensatory movement patterns is critical to understand the mechanisms underlying functional improvements after CIT (ie, overcoming learned nonuse).[7,22] To clarify further the role of CIT on motor recovery in the chronic stage of stroke, this study employed a detailed kinematic motion analysis to determine how CIT influenced movement patterns, including compensatory strategies and spatiotemporal parameters of movement. We hypothesized that participants would exhibit changes in movement strategies after CIT that may or may not change the extent to which survivors of stroke rely on compensatory reaching strategies. A secondary hypothesis was that participants would demonstrate significant improvement in spatiotemporal parameters of reach and in functional outcome measures (ie, WMFT and MAL).

Table 1: Demographic Characteristics of Participants

Participant	Sex	Age (y)	Time Since Stroke (y)	Side of Stroke
1	F	81	1.00	RCVA
2	F	62	2.75	LCVA
3	F	70	5.30	LCVA
4	M	38	1.67	LCVA
5	M	64	1.00	LCVA
6	M	77	7.00	RCVA
7	M	66	2.08	RCVA
8	M	45	1.75	LCVA
9	M	42	3.41	RCVA
10	M	67	0.83	RCVA
Range	3 F;7 M	38–81	0.83–5.30	5 RCVA; 5 LCVA
Mean ± SD	NA	61.2±14.7	2.68±2.04	NA

Abbreviations: F, female; LCVA, left cerebral vascular accident; M, male; NA, not applicable; RCVA, right cerebral vascular accident.

METHODS

Participants

A convenience sample of participants enrolled in a separate randomized controlled CIT study was used for this study. Ten participants (3 female; 5 left cerebral vascular accident) with a mean age ± SD of 61±14.7 years participated and gave written consent in accordance with the policies of the local institutional review board. Table 1 summarizes participant demographics. Participants were recruited from the community and met the following inclusion criteria: at least 9 months poststroke of unilateral clinical presentation; at least 10° of active wrist extension and 10° of extension in at least 2 fingers and thumb; approximately 30° of active shoulder flexion; at least half the normative passive range of motion at all upper-extremity joints; ability to follow simple instructions and multistep commands; endurance to complete 6 hours of training; a score of 24 or higher on the Mini-Mental State Examination[23]; the ability to sit independently without back or arm support for 5 minutes; and the ability to stand with or without the assistance of a cane, quad cane, or hemiwalker for 2 minutes. Exclusion criteria included the following: any health problems judged by the screening physician to put the client at significant risk of harm during the study, other neurologic conditions (eg, multiple sclerosis, Parkinson disease), drugs or injections treating spasticity within 3 months of participation, significant stroke-affected arm use during daily living (MAL "amount-of-use" score≥2.5), and a pain score greater than 5 on the McGill Pain Scale. These are typical selection criteria in CIT studies.[11] Participants were required to obtain a medical release from their primary physicians.

Intervention

Participants completed 2 weeks of CIT training based on the recently published EXCITE multicenter clinical trial.[11] During 10 consecutive weekdays, participants completed a daily 6-hour on-site trainer-supervised program of functionally based activities using massed practice. Task parameters (eg, spatial and/or temporal) were manipulated in each successive period of task practice requiring increased control of the affected arm and hand.[24] Global feedback was provided at the end of a training task, and during task practice if performance substan-