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Improved quality of life following constraint-induced movement therapy is associated with gains in arm use, but not motor improvement.

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Abstract

Background.—Constraint-induced movement therapy (CI therapy) is one of few treatments for upper extremity (UE) hemiparesis that has been shown to result in motor recovery and improved quality of life in chronic stroke. However, the extent to which treatment-induced improvements in motor function versus daily use of the more affected arm independently contribute to improved quality of life remains largely unexplored.

Objective.—The objective of this study is to identify whether motor function or daily use of a hemiparetic arm has a greater influence on quality of life after constraint-induced movement therapy.

Methods.—Two cohorts of participants with chronic stroke received either in-person CI therapy (n=29) or video-game home-based CI therapy (n=16). The two cohorts were combined and the motor-related outcomes (Wolf Motor Function Test, Action Research Arm Test, Motor Activity Log) and quality of life (Stroke Specific Quality of Life) were jointly modeled to assess the associations between outcomes.

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Disclosure of Interest

Authors Borstad and Gauthier are shareholders of Games That Move You, PBC, a company that commercialized the technology utilized in the gaming cohort. Conflict management plans have been put in place by the University to ensure the integrity of the research. Authors Kelly and Kline report no conflicts of interest.

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Results.—The only outcome associated with improved quality of life was the Motor Activity Log. Improvements in quality of life were not restricted to motor domains, but generalized to psychosocial domains as well.

Conclusions.—Results suggest that improved arm use during everyday activities is integral to maximizing quality of life gains during motor rehabilitation for chronic post-stroke UE hemiparesis. In contrast, gains in motor function were not associated with increases in quality of life. These findings further support the need to implement techniques into clinical practice that promote arm use during daily life if improving quality of life is a main goal of treatment.

Keywords

Constraint-induced movement therapy; quality of life; transfer package; behavior change; motor recovery; chronic stroke; hemiparesis

Introduction

Patient-centered health care demands attention to patient-centered outcomes. Rightly, increasing emphasis has been placed on the importance of measuring quality of life outcomes. These outcomes capture the patient perspective, which is important when evaluating the effectiveness of an intervention.^{1–3} Quality of life is a multifactorial construct and while there is no one agreed-upon definition, it is generally accepted that physical functioning plays a role in how people perceive their quality of life.² Upper extremity (UE) weakness has been reported as one of the most common results of a stroke with incidence up to 77%⁴ and impaired UE motor function has significantly correlated to lower quality of life.^{5–8} It has therefore been suggested that improvement in this area of physical functioning should improve a person's quality of life.^{9,10} However, not all therapeutic techniques that are recommended for promoting UE motor recovery¹¹ also improve quality of life¹² and there is often a mismatch between subjective and objective reports.^{13–15}

Constraint-induced movement therapy (CI therapy) is one of the few interventions that have been shown to result in UE motor recovery¹¹ and improved quality of life.¹² The neural mechanisms underlying motor improvements seen after CI therapy remain elusive. Imaging studies investigating patterns of structural change, cortical activation, and lateralization for the ipsilesional and contralesional hemispheres have produced inconsistent findings.^{16–18} Accelerometry data have shown that the use of both arms increases during CI therapy, with the affected arm showing greater increases than the unaffected arm.¹⁹ Taken together with results indicating that use of the restraint mitt on the unaffected side contributes minimally to the therapeutic effect,^{18,20,21} one can infer that the therapeutic benefit of CI therapy results from increased use of the more affected upper extremity. Improvements in use following CI therapy are achieved through two main components of the intervention: 1) its intensive practice schedule and 2) its specific incorporation of a transfer package, which is a set of behavioral techniques to enhance carry-over of motor gains into daily activities.²² It was initially thought that high-repetition massed motor practice was the critical component that yielded better outcomes compared to standard care.²³ However, many studies that have used dosages similar to CI therapy have not seen significant change in daily life arm use despite showing significant improvements in objective motor measures.^{24–29} In addition,

improved arm use during daily activities appears to be independent of type of motor practice, but instead depends upon whether the intervention incorporates the transfer package (i.e., contracting, daily self-assessment, targeted home-practice of functional activities, problem-solving).^{30–33} Furthermore, intensive interventions that did not promote carry-over to daily activities via transfer package techniques failed to produce significant gains in quality of life³⁴ or yielded significantly poorer gains in quality of life than CI therapy.^{28,35} Taken together, these studies indicate that while intensive motor practice facilitates improved motor function, the transfer package is instrumental to improving daily life arm use. However, the extent to which CI therapy-induced improvements in motor function versus daily use of the more affected UE independently contribute to improved quality of life remains largely unexplored.

CI therapy provides a good model for testing which elements of motor recovery may be most critical to quality of life improvement because it is the only intervention to consistently show clinically meaningful improvements in both motor function on standardized laboratory-based tests and use of the more affected UE for daily activities.¹¹ In addition, these two elements are not highly correlated with one another^{15,36–38} and so are thought to measure different constructs. Therefore, the aim of this study is to identify which CI therapy motor-related outcomes are most associated with quality of life. We hypothesize that improved arm use during daily activities (Motor Activity Log), will be more strongly correlated to improved quality of life than will improvements in objective motor function (Wolf Motor Function Test, Action Research Arm Test). Gaining a better understanding of which elements of motor performance relate best to improved quality of life would provide further guidance in implementing treatment strategies that can maximize meaningful outcomes during stroke rehabilitation.

Methods

Participants:

Twenty-nine participants with chronic stroke aged 24–84 years (mean 58.98 ± 12.85 years) were recruited for a study examining neuroplastic response to in-person CI therapy between November 2012 and June 2016. Sixteen participants with chronic stroke aged 14–68 years (mean 45.69 ± 20.54 years) were recruited for another study examining a therapist-as-consultant model of providing CI therapy in-home through use of a video-game platform between July 2012 and December 2014.³⁹ Data utilized in this paper reflects a retrospective analysis of data acquired during these two prior studies. Participant characteristics are provided in Table 1. These studies were approved by the Institutional Review Board for human research at [Institution removed for blinding], all patients provided signed informed consent to participate, and all data has been de-identified to ensure participant anonymity.

Potential participants were community-dwelling individuals who met the following study criteria that are used in other CI therapy trials: 1) stroke of any etiology with greater than 6 months chronicity, 2) preserved ability to understand English, 3) passive range of motion of at least 90 degrees of shoulder flexion and abduction, 45 degrees of external rotation, 150 degrees of elbow extension, 145 degrees of MCP extension, and 10 degrees of thumb extension or abduction, and 4) active range of motion of at least 10 degrees of finger

extension and thumb extension or abduction, 20 degrees of elbow extension, and 45 degrees of shoulder flexion and abduction. Exclusion criteria included: 1) Botox injection in the more affected upper extremity in the 12 weeks prior to participation, 2) minimal non-use (Motor Activity Log score of > 2.5), 3) preserved dexterity (9-hole Peg Test score above the 10th percentile), 4) concurrent upper extremity rehabilitation, and 5) medical concerns that would prevent safe performance of the intervention at the intensity required.

Interventions and Equipment:

All interventions were provided in a one-on-one setting supervised by a physical therapist. The in-person CI therapy protocol involved 30 hours (3 hours/day, 10 weekdays over a 2 week period) of intensive motor training focusing on both functional tasks and shaping, plus behavioral techniques for 0.5 hours per day (transfer package) that promote carry over of therapeutic gains into everyday activities. The gaming CI therapy protocol involved a target of 30 hours in-home game play over 2 weeks. Movements made by the participant were detected via the Microsoft Kinect® and were designed to be intuitive, minimize reinforcement of compensatory movement, and progress in difficulty (automated shaping) based on patient-specific performance. Patients received 4 in-home visits totaling 5 hours to deliver the transfer package. Performance of everyday activities as encouraged by the transfer package emphasized independent completion, regardless of motor strategy utilized. Details on shaping methods and transfer package techniques can be found elsewhere.²² Patients in both protocols were asked to wear a padded mitt restraint on their less affected hand for a target of 90% of waking hours daily; compliance was measured through motion tracking hardware inserted into the mitt. Compliance to in-home CI therapy was monitored through the video game software.

Outcome Measures:

Testing was performed by independent assessors; effort was made to blind the testers to pre/post-treatment condition. The Motor Activity Log (MAL), Wolf Motor Function Test (WMFT), Action Research Arm Test (ARAT), and Stroke Specific Quality of Life Scale (SSQoL) were administered. The MAL is a semi-structured interview to assess the amount of use (AOU) and quality of movement (QOM) of the upper extremity in 28 common daily activities; it measures spontaneous real-world arm use during functional tasks. It is rated on a 6-point ordinal scale (score range, 0-5) where higher scores indicate more or better use, respectively; the test score is the mean of the item scores. It has been shown to be valid and reliable in the stroke population with a minimal detectable change (MDC) for the QOM of 0.5 points.^{30,40} Due to the high correlation previously reported between AOU and QOM,³⁰ only the QOM is used in analysis to avoid redundancy.

The WMFT is a valid and reliable in-laboratory measure of upper extremity motor performance containing 15 timed functional tasks.^{41,42} The performance time of each item was natural-log-transformed to reflect the relative nonlinearity of potential performance time improvement (i.e., an improvement from 4 seconds to 2 seconds is greater than an improvement from 100 to 102 seconds). The WMFT summary score reflects the mean of the natural-log-transformed item scores; a higher score reflects poorer performance.⁴³ The reported MDC for the WMFT time score is 4.36 seconds⁴⁴.

The ARAT assesses motor function on 19 items grouped into 4 subscales (grasp, grip, pinch, and gross movement) with a maximum score of 57 where higher scores indicate better function. It is one of the more widely used outcome measures in upper extremity rehabilitation literature and has reported strong psychometric properties. Reported minimal clinically important difference (MCID) for the ARAT is 5.7 points, or 10% of the measure's total range; MDC is 3.5 points, or 6% of the measure's total range.^{38,45–49} The WMFT and ARAT were included because each addresses a different aspect of motor function; the WMFT captured the speed of movement while the ARAT captured the quality of movement.

The SSQoL is a quality of life self-report measure with 49 items comprising 12 subscales representing domains commonly affected by stroke; each item is scored using a 5-point ordinal scale (score range, 1-5) with higher scores representing better quality of life.⁵⁰ It has demonstrated acceptable psychometric properties,^{51,52} has been shown to represent multiple International Classification of Functioning, Disability, and Health categories and components,⁵³ and, being a condition specific instrument, is more appropriate to use in capturing quality of life than generic measures.^{54,55}

Data Analysis:

Our primary aim is to assess the association between the ARAT, WMFT, MAL, and SSQoL post intervention. To do so, we fitted a joint multivariate normal model on the outcome vector containing ARAT, WMFT, MAL, and SSQoL. In this model, we included a cohort indicator in each marginal mean to capture differences between the cohorts. We also assumed a common covariance matrix across cohorts. Each marginal mean was adjusted for baseline and other clinical and patient characteristics, including gender, cognition (via the Montreal Cognitive Assessment (MoCA)), touch sensation (as measured by the Semmes Weinstein Monofilament Test), affected side, handedness, and concordance. Gender, affected side, handedness, and concordance were entered as indicators of male, right side affected, right handedness, and presence of concordance, respectively. Cognition and touch sensation were categorized as impaired or unimpaired using cutoff points of less than 26/30 on the MoCA⁵⁶ and greater than or equal to 0.16 grams on the Semmes-Weinstein Monofilament Test⁵⁷ to indicate impairment. We fitted the model in the Bayesian paradigm using Markov Chain Monte Carlo (MCMC) implemented through JAGS⁵⁸ in R.⁵⁹ All prior distributions were weakly informative and the covariance matrix was modeled as in Daniels (2002).⁶⁰ Missing data were assumed to be missing at random⁶¹ given the other outcomes and covariates in the model, and imputation was seamlessly incorporated into the MCMC algorithm.^{62,63} One participant had missing data for the post-test ARAT, MWFT, and MAL, 8 participants had missing data for the pre-test SSQoL, and 11 participants had missing data for the post-test SSQoL. A complete case analysis was also conducted to assess differences in the results from assuming data were missing completely at random. Full model details are included in the supplemental material. The content of this manuscript conforms to STROBE guidelines.

Results

Participants showed significant gains in both motor function and arm use during daily activities after the intervention. MDCs were exceeded for the MAL (1.07 points mean change) and WMFT (7.08 seconds mean change). However, neither the MDC nor MCID were reached for the ARAT (2.41 points mean change). The mean change in total SSQoL was 16.60 points. Improvements in quality of life were not limited to motor domains of the SSQoL, but generalized to other domains as well (Figure 1).

The primary goal of this analysis was to assess the associations among ARAT, WMFT, MAL, and SSQoL scores post intervention after baseline scores and other patient characteristics (the covariates) have been adjusted for. Table 2 presents the effects of included covariates on the means of each of the four outcomes. We saw evidence that each outcome is positively associated with its baseline value. We also saw that ARAT and MAL scores differ for patients in the gaming study relative to the traditional CI therapy protocol. Finally, there was a positive association between touch sensation and ARAT. Each of these significant associations is represented with an asterisk in Table 2.

After accounting for the Table 2 covariates, we examined the residual correlation between the motor outcomes and SSQoL. This is graphically depicted in Figure 2. The only motor outcome significantly correlated with SSQoL was the MAL with posterior mean correlation of 0.74 with 95% credible interval of (0.48, 0.89). The posterior mean change in SSQoL for a one point increase in MAL was 33.19 with 95% credible interval of (17.13, 49.34). The posterior mean and 95% credible interval for the correlation between ARAT and SSQoL was -0.09 ($-0.63, 0.50$) and for WMFT and SSQoL was -0.27 ($-0.72, 0.32$).

Discussion

A strong relationship^{64–66} was observed between improved daily life arm use and improved quality of life, whereas improvements in objective measures of motor function had no association with quality of life. These findings indicate that focus on translating motor skills into daily life is paramount to improving patient quality of life after stroke. This has implications for rehabilitation practice. Given previous findings that incorporation of the transfer package results in greater improvements in daily life arm use,^{30,31,33} this component of CI therapy may be integral to the treatment plan for maximizing quality of life in people with mild to moderate hemiparesis. Without it, patients may not achieve their potential for improved quality of life regardless of motor function gains made during rehab.

The strong relationship between arm use and quality of life (amongst our sample of individuals with some use of the distal upper extremity) may be a result of greater independence with daily activities once non-use is overcome.⁶⁷ Autonomy with daily activities has been shown to positively affect quality of life.^{68–72} Successfully completing daily activities, which was the focus of the transfer package, and thus increasing overall engagement and participation, does not require “normal” movement of the more affected upper extremity.^{73,74} Rather, the repertoire of activities that a person can accomplish independently may depend more strongly on cooperative use of both upper extremities,

regardless of whether the chosen strategy represents a return to “normal” movement. Treatments focused on attaining more “normal” performance may inadvertently discourage attempted use of the more affected upper extremity by conveying that tasks should be completed in a specific way, which may adversely affect self-efficacy and contribute to reduced quality of life.^{75,76}

As part of the transfer package of CI therapy, participants received guided problem-solving on daily activities.²² Those that were able to apply this approach in their daily lives, as evidenced by greater increases on the MAL, showed the most pronounced improvement in quality of life. Ability to problem-solve has previously been shown to improve self-efficacy^{70,77} and quality of life.^{77,78} It may also promote on-going recovery in absence of continued therapy.^{30,31,78} By teaching clients how to monitor use of the more affected upper extremity and collaboratively engaging them in developing strategies to enable successful completion of tasks, they may generalize the approach to untrained tasks.⁷⁹ Consistent with the negligible relationship between motor improvement and daily arm use observed here, carry-over of motor gains into daily activities does not innately occur as motor function improves.^{29–31,34,80} The client’s ability to change the habit of non-use in response to the transfer package appears critical to enhancing carry-over to daily activities and, subsequently, quality of life.

In the current study, improved use of the weaker upper extremity was associated with improved quality of life in both motor and non-motor domains. There have been frequent associations made between physical, mental, social, and emotional status in post-stroke patients;^{69,81–85} consequently, an improvement in ability to perform daily tasks more effectively would likely lead to improvement in one or more other areas. Previous studies investigating whether quality of life improvements following CI therapy generalize past the motor domain have produced inconsistent findings. Some studies have reported improved social participation and communication^{35,86} following CI therapy whereas others have found improvements only in motor domains (e.g. hand function, ADLs, strength, mobility), which was thought to be a direct response to motor training.^{28,87,88} This discrepancy could be due to varying implementation of the transfer package, which despite its apparent importance to quality of life outcomes, has often been diluted or excluded in studies of CI therapy.^{18,30}

While our findings are generally consistent with previous studies that have shown a weak relationship between objective (therapist-evaluated) and self-report measures,^{13–15} this study expands upon those findings in several ways. For one, the current analysis includes psychosocial domains of quality of life, where others included only the hand function domain.^{13,14} Thereby, this study considers the patient more holistically and recognizes that our interventions, if they are truly patient-centered, should and can address other domains of quality of life. Associations found in the literature between psychosocial factors and physical impairment reinforce that these connections exist and provide another therapeutic target to account for in a plan of care.^{81,82} Additionally, through recent work that has delved into the independent effects of different components of CI therapy, we now know that the transfer package element is related to the greatest improvements in arm use;³⁰ this knowledge in combination with the current analysis allows us to relate a specific intervention component to quality of life outcomes, which enhances the evidence for use of

the transfer package as a highly patient-centered solution with multidimensional motor and psychosocial impact.

There are two main limitations of this study. It is a correlational study and so direct causal relationships cannot be confirmed, only inferred. In addition, the sample size is relatively small with some missing data that we assume to be missing at random. Despite these limitations, we have shown a strong positive association between rehabilitation-induced improvements in arm use and quality of life. Furthermore, a complete case analysis (not shown) reached the same conclusions as the primary analysis presented above. Overall, this work highlights the importance of emphasizing carry-over of motor gains into daily activities in upper extremity treatment plans for individuals with mild-moderate upper extremity impairment. Future definitive randomized controlled trials should examine the quality of life impact associated with adding components of the CI therapy transfer package to other upper extremity motor training paradigms. More research is also needed to determine whether these findings would generalize to those with more severe motor impairment.

Conclusion

The current study suggests that improving carry-over through promoting use of a hemiparetic arm during daily activities is integral to maximizing quality of life gains during motor rehabilitation post stroke. In contrast, gains in motor function were not independently associated with improvements in quality of life. A treatment approach that incorporates behavioral techniques to promote carry-over of motor gains into daily activities is known to bolster patient outcomes^{30–33} but is not standard practice at this time. The findings reported here further support the need to emphasize carry-over in standard clinical practice if improving quality of life is a main goal of treatment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Score change per question in SSQoL for 1-point increase in MAL by Domain:

Improvements in quality of life were not limited to motor domains and appear to generalize to other domains.

Figure 2.

Scatterplots showing the posterior mean residual for ARAT, WMFT, and MAL plotted against the posterior mean residual of SSQoL. Least squares regression line and 95% confidence bands are shown on each plot. A strong linear relationship exists between the MAL and SSQoL while no relationship exists between either the WMFT or ARAT and the SSQoL.

Table 1.

Participant characteristics and Baseline Values, means and standard deviations unless otherwise noted.

	In-person CI Therapy (n=29)	Gaming CI Therapy (n=16)
Age, years	58.98 (12.85)	45.69 (20.54)
Gender, % Male	79.31%	62.50%
Chronicity, years	3.43 (4.00)	2.72 (1.42)
Affected Side, % Right	41.38%	56.25%
Touch Sensation of Affected Side, grams of force	45.84 (105.09)	23.47 (83.09)
MoCA	24.38 (3.82)	22.81 (5.50)
MAL-QoM	1.22 (0.85)	1.54 (0.98)
WMFT	2.38 (1.13)	1.98 (0.95)
ARAT	21.90 (16.18)	33.94 (17.91)
SSQoL	173.00 (29.39)	189.92 (31.14)

Table 2.

Posterior mean (95% credible interval) for each estimated covariate effect from joint multivariable regression for each outcome. The category in parentheses indicates the variable in the model. Cells marked with an * indicate an association between the covariate and the outcome. All covariates were adjusted for in the multivariable model.

	ARAT	WMFT	MAL	SSQoL
Intercept	8.01 (−2.99, 18.73)	0.71 (−1.26, 2.76)	0.58 (−0.96, 2.17)	18.05 (−72.55, 112.32)
Study (Gaming)	−3.61 (−7.19, −0.14)*	0.36 (−0.03, 0.74)	−0.75 (−1.25, −0.24)*	1.44 (−23.49, 26.75)
Baseline ARAT	1.05 (0.92, 1.19)*	n/a	n/a	n/a
Baseline WMFT	n/a	0.91 (0.71, 1.11)*	n/a	n/a
Baseline MAL	n/a	n/a	0.94 (0.72, 1.16)*	n/a
Baseline SSQoL	n/a	n/a	n/a	0.67 (0.36, 0.99)*
Gender (Male)	−1.58 (−5.27, 2.11)	0.34 (−0.09, 0.76)	−0.45 (−1.00, 0.09)	−17.14 (−43.85, 9.38)
Cognition (Impaired)	−0.28 (−0.67, 0.14)	−0.02 (−0.06, 0.03)	0.04 (−0.02, 0.09)	2.59 (−0.03, 5.13)
Touch Sensation (Impaired)	4.02 (0.48, 7.59)*	−0.29 (−0.69, 0.11)	0.25 (−0.26, 0.76)	2.16 (−24.68, 28.56)
Affected Side (Right)	−1.45 (−5.81, 2.86)	−0.19 (−0.69, 0.34)	−0.15 (−0.79, 0.50)	8.31 (−21.25, 38.22)
Handedness (Right)	−0.62 (−5.32, 4.30)	0.24 (−0.33, 0.78)	−0.04 (−0.75, 0.68)	−4.46 (−37.43, 28.58)
Concordance (Present)	0.04 (−4.91, 5.11)	−0.46 (−1.01, 0.10)	0.33 (−0.40, 1.07)	−0.51 (−33.07, 33.32)