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Effect of Static versus Cyclical Stretch on Hand Motor Control in Subacute Stroke

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Abstract

Background and Purpose: The purpose of this study was to investigate the impact of passive static and cyclical stretching of the fingers on hand function in subacute stroke survivors.

Participants: Thirteen stroke survivors, 2-5 months post-incident, with moderate to severe hand impairment took part in the study.

Method: Each participant completed three separate sessions, separated by at least one week, consisting of 30 minutes of: static stretch of the digits, cyclical stretch, or rest. Stretching was performed by a powered glove orthosis (X-Glove). Outcome measures, comprised of three timed hand-specific tasks from the Graded Wolf Motor Function Test (GWMFT-Time), grip termination time (GTT), grip strength, and lateral pinch strength, were assessed at the beginning and end of each session. Change in outcome score during each session was used for analysis.

Results: Data suggested a trend for improvement following stretching. Reduction in mean completion time for the GWMFT-Time after the cyclic stretching was 5 times greater than for the rest condition (P = 0.010). After the static stretching, GTT was 31% faster than the mean pre-test times (P = 0.055). Improvements in grip and pinch strength were also evident following the stretching interventions, although these changes did not reach statistical significance.

Discussion and Conclusion: While more study is needed, cyclically stretching the finger muscles in the stroke hand appears to be a promising treatment for stroke survivors in the subacute phase of recovery. It may prove especially effective as an adjuvant therapy facilitating subsequent performance of active movement therapy. Future studies exploring the neural correlates of improvement are warranted.

Keywords: Hand; Stretching; Stroke; Subacute; EMG

Introduction

Hemiparesis, involving the hand in particular, is a common consequence of cerebrovascular stroke [1,2]. Stretching is typically prescribed as treatment, often with the intent of preventing contracture [3-6]. The consequences of this stretching, however, have not been fully described. While elongation of the musculotendon unit is naturally thought to impact biomechanical properties, stretching may affect neuronal excitability as well.

Passive movement of the digits has been shown to result in activity in sensory cortices S1 and S2 [7]. In addition, passive movement of the elbow produces activity in supplementary motor area [8]. Stinear et al. [9] reported that movement of the affected wrist in stroke survivors, as driven by the less affected side, was associated with an increase in ipsilesional excitability, an increase in interhemispheric inhibition from the ipsilesional to the contralesional side, and an increase in intracortical inhibition within the contralesional primary motor cortex [9]. Thus, neurological changes induced by stretching may impact stroke rehabilitation. The aforementioned passive wrist movement, for example, potentiated subsequent upper extremity therapy [9]. Somatosensory stimulation, such as that produced by peripheral nerve stimulation, has been associated with improved hand motor control in stroke survivors [10,11].

In a previous study with stroke survivors with chronic hemiparesis we observed better performance of motor tasks after a single session of stretching the digits of the hand [12]. This improved performance seemed to result, in part, from a reduction in hyperexcitability of long finger flexor muscles, which can manifest as spasticity [13,14], excessive co-activation [15], and prolonged relaxation times [16]. Cyclical stretching, involving movement of the digits back and forth from a relaxed flexed posture into an extended neutral posture repeatedly, proved to be more effective than static stretching for this stroke survivor population in the chronic phase of recovery.

The effectiveness of this treatment in earlier stages of recovery has yet to be determined, despite the fact it is more likely to be performed during the acute and subacute phases of recovery, when the stroke survivor has greater clinical access. The changes observed in muscle conduction velocity [17], motoneuronal excitability [18,19], and spasticity [20] across the subacute phase raise the possibility that the impact of stretching during this time period could differ from that seen in chronic hemiplegia. Thus, in this study, we examined the impact of three different experimental conditions-static stretch, cyclic stretch, and rest-on stroke survivors in the subacute phase of recovery. We hypothesized that stretching would affect hand performance, and that cyclic stretching would be more effective for improving motor control of the hand.

Methods

Participants

A convenience sample of 13 stroke survivors in the subacute phase of recovery (2-6 months post-injury) subsequent to a single cerebrovascular incident took part in this study in our research

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laboratory to evaluate the effectiveness of passive stretching on hand motor control in the early months following stroke. Subjects were screened to confirm that they had severe to moderate hand impairment, as indicated by the rating of 3 or 4 on the Stage of Hand section of the Chedoke-McMaster Stroke Assessment (CMSA) [21]. Thus, participants displayed some active finger (and/or thumb) flexion or extension but very limited or no individuated movement or other fine motor control of the fingers. Exclusion criteria included: 1) presence of contractures limiting passive joint extension beyond 20 degrees of flexion; 2) use of antispasticity medications and/or injections such as Baclofen or Botox®; and 3) inability to follow simple one-step commands. Participants ranged in age from 20 to 70 years old (Table 1). Written, informed consent was obtained from all subjects in accordance with the Institutional Review Board of Northwestern University prior to involvement in the study.

Experimental protocol

Stroke survivors participated in three experimental sessions spaced at least one week apart. During each session the subject underwent passive cyclical or static stretching of the muscles of the digits or rested for 30 minutes. All subjects participated in all three sessions and the order of treatments was randomly chosen. Outcome measures were recorded before and immediately after the 30 minutes of stretching or rest.

Both stretching methods incorporated use of an actuated glove orthosis, the eXtension glove (X-glove), developed in our laboratory to passively extend the digits of the hand [12] (Figure 1). For the static stretching, the X-Glove moved the digits from the resting posture to a fully open posture (digits extended), which was maintained for the duration of the stretch. For the cyclical stretching, the X-Glove moved the digits from the resting (flexed) position into the fully open posture and then allowed the digits to passively close; this cycle was repeated at a rate of roughly 0.05 Hz [12]. Subjects were encouraged to relax completely throughout the stretching period. For the rest session, subjects did not wear the X-Glove, as the device itself could have provided some measure of stretch, but were instructed to keep the arm and the hand in a resting posture.

Outcome measures

Primary outcome measures, collected before and after the 30-minute stretching/rest intervention, consisted of evaluations of dexterity, strength, and neurological state. Namely, the four measures were: 1) the summed completion time for three components of the Graded Wolf Motor Function Test (GWMFT-Time) [22] which specifically focuses on grasp and release; 2) power grip strength (GS) as recorded with a dynamometer (JAMAR 5030J1 Hand Dynamometer); 3) lateral pinch strength (LPS) as quantified with a pinch gauge (PG-60, B & L Engineering); and 4) grip termination time (GTT), as measured by the delay in transitioning from voluntary activation to relaxation of flexor digitorum superficialis (FDS), a primary finger flexor. For the GWMFT-Time, participants performed each of the three tasks a total of three times for each evaluation session, and the mean values were used to calculate the sum. The time to complete each task was recorded with a stopwatch, and a maximum allowable time (120 s) was assigned to any unsuccessful trials. For the GTT, subjects were instructed to generate maximal grip force upon hearing an auditory tone and to relax grip force as soon as the tone ended [12,23]. FDS EMG activity was monitored using a bipolar active surface electrode (Bagnoli; Delsys, Inc., Boston, Massachusetts) placed over the muscle belly on the forearm about halfway between the medial epicondyle of humerus to the styloid process of the ulna.

Data processing

For the GWMFT-Time, the sum of the three timed components was then used as the outcome measure. In accordance with previous studies, a logarithmic transformation of the completion time was performed to improve the data distribution [24]. Grip relaxation time was evaluated by monitoring changes in FDS EMG activity [12,23]. EMG data were recorded during the entire 30 s trial at 500 Hz using a Delsys amplifier and data acquisition system (NI PCI-MIO-16XE-10 and Lab VIEW, National Instruments, Austin, TX). Envelopes of muscle activity were created by rectifying the data and digitally low-pass filtering the signal forwards and backwards at 10 Hz with a 30th-order FIR filter. GTT was specified as the delay between the cue for the subject to relax (end of the audible tone) and the point at which average FDS EMG activity in a 0.5 s moving window dropped below a predetermined threshold, based upon mean + 3 standard deviations of the baseline EMG activity, or when the 95% confidence interval of this moving window overlapped the baseline. A maximum termination time of 20 s was assigned to trials unable to meet these criteria.

Subject	Age, years	Gender	Time post stroke months	Impaired side	(CMSA) Hand Score
SA1	46	F	3	R	3
SA2	20	M	4	L	3
SA3	53	F	3	L	4
SA4	53	M	3	L	4
SA5	44	F	3	L	3
SA6	51	M	2	R	4
SA7	49	F	5	R	3
SA8	53	M	3	R	3
SA9	66	F	4	R	4
SA10	70	M	3	L	3
SA11	51	F	5	R	3
SA12	58	M	2	L	3
SA13	55	F	5	R	3
Mean ± *SD*	51 ±12	7F/6M	3 ± 1	7R/6L	3 ± 0.5

Note: SD = standard deviation; CMSA= Chedoke-McMaster Stroke Assessment; M = male; F = female; L = left; R = right

Table 1: Characteristics of the stroke survivors (n=13).

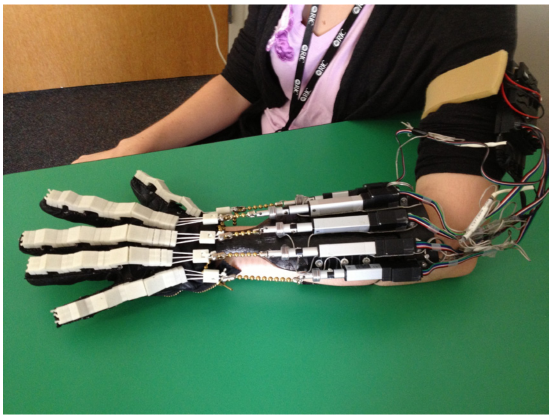

Figure 1: The X-Glove. The hand is shown with the digits in the fully retracted (open) posture. Linear actuators located on the forearm pull cables that traverse the dorsal side of the digits, thereby producing extension. The plastic pieces connected to the glove serve to guide the cables and to prevent joint hyperextension.

Statistical analysis

For this repeated measures study, a non-parametric Wilcoxon Signed-Rank Test was performed using SPSS software (SPSS Inc, Chicago, IL) for each of the 4 chosen outcome measures (GWMFT-Time, GS, LPS, and GTT) comparing pre and post values to examine the impact of stretching method/rest. Comparison between the three treatment conditions for each outcome was performed with the Freidman Test using the pre-post difference as the dependent variable. Significance was set for an α-level of 0.06.

Results

The benefits of passively stretching the digits of the hand, in either a static or cyclic fashion for 30 minutes were assessed in 13 subacute stroke survivors with moderate to severe hand motor impairment. There were no significant differences in the Pre-test values for the different conditions of rest, static stretch, and cyclical stretch for any of the four outcome measures according to the Freidman Test (P > 0.5).

Stretching, specifically cyclical stretching impacted performance of hand tasks (Table 2). Mean decrease for the sum of completion times for all 3 tasks of the GWMFT-Time after cyclical stretching was at least five times greater than what was observed after the resting (control) condition (Figure 2). Cyclical stretching resulted in a reduction in time to perform these tasks of 14.6 ± 22.0 s (*P* = 0.010), while static stretching and resting exhibited minimal reductions of 0.9 ± 40 s (*P* = 0.209), and 2.5 ± 4.7 s (*P* = 0.099), respectively.

The data also showed a trend for the stretching to impact force production. Grip strength tended to increase following both static and cyclical stretching. Normalized to the average strength for all 3 pre conditions, subjects increased maximum voluntary GS by 10 %or 5.7 ± 17.0 N (*P* = 0.308) following the cyclical stretching regime and by 15 % or 8.5 ± 22 N (*P* = 0.209) following the static stretching, compared to only 2 %or 0.9 ± 13.7 N (*P* = 0.463) for the rest condition (Figure 3). Only the cyclical stretching condition, however, showed a trend for improvement for LPS, as the lateral pinch force increased by 18% or 4.9 ± 22 N (*P* = 0.650) from pre-cyclical stretch to the post-cyclical stretch. In contrast, LPS actually decreased by 7% or 1.6 ± 8.0 N (*P* = 1.000) for the static stretching protocol and significantly decreased by 11% or 2.9 ± 4.4 N (*P* = 0.041) for the rest condition.

GTT also displayed a greater reduction trend after both stretching conditions than after rest (Figure 4). Time for FDS activation to return to baseline levels after stretching was diminished by 0.8 ± 2.8 s (*P* = 0.055) for the static case and by 0.6 ± 3.7 s (*P* = 0.972) for the cyclical case, whereas after rest it was reduced by only 0.2 ± 2.3 s (*P* = 0.552). This improvement after stretching, when normalized to the average termination time of the three pre-conditions, equated to a 31% (static stretch) and 24% (cyclical stretch) decrease in termination time compared to the 8% reduction for rest. These changes in GTT after stretching were readily apparent through visual inspection for some subjects (Figure 5).

	GWMFT-Time (s)	LPS (N)	GS (N)	GTT (s)
Cyclical stretch				
Pre	*138.5(133.2)**	26.3(11.1)	57.4(31.0)	2.2(3.1)
Post	*123.8(135.3)**	31.2(22.7)	63.1(34.0)	1.5(2.0)
Δ	*14.6(22.0)**	4.9(22.0)	5.7(17.0)	0.6(3.7)
Static stretch				
Pre	128.5(122.4)	29.6(9.8)	55.1(32.7)	*3.3(3.2)**
Post	127.7(124.4)	28.6(11.1)	64.2(32.1)	*2.5(3.1)**
Δ	0.9(40)	-1.6(8.0)	8.5(22.0)	*0.8(2.8)**
Rest				
Pre	137.5(122.4)	*26.0(9.2)**	60.4(29.8)	2.4(2.6)
Post	135.0(120.4)	*23.1(9.6)**	61.3(33.6)	2.2(2.2)
Δ	2.5(4.7)	*-2.9(4.4)**	0.9(13.7)	0.2(2.3)

Note: Values are mean (SD). GWMFT-Time: Graded Wolf Motor Function Test Time; LPS: lateral pinch strength; GS: grip strength; GTT: grip termination time. Positive Δ indicates improvement following treatment. outcomes shown in italics were significantly different according to the Wilcoxon Test for α < 0.06.

Table 2: Outcome measures.

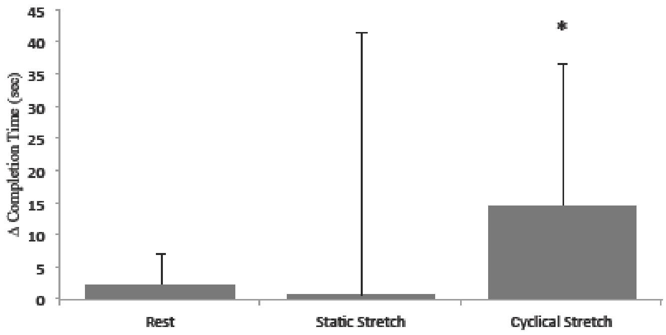

Figure 2: GWMFT-Time change in completion time for the sum of tasks. A significant reduction in completion time was observed after the cyclical stretching.

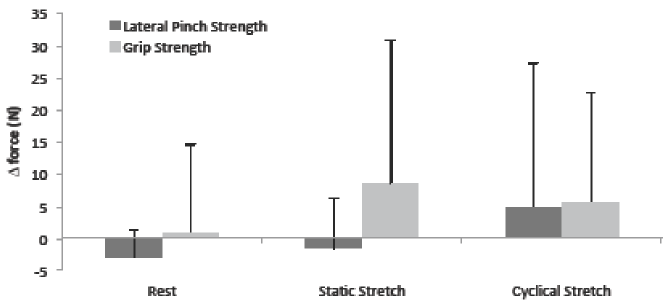

Figure 3: Change in force production for grip strength (GS) and lateral pinch strength (LPS). The cyclical stretch condition was the only one for which the mean force increased after the 30 minutes for both grip strength and lateral pinch strength.

While trends were apparent, the differences in effects across the three different treatments did not reach statistical significance according to the Freidman Test for any of the outcome measures: GWMFT-Time (*p* = 0.472), GS (*p* = 0.368), LPS (*p* = 0.383) and GTT (*p* = 0.232).

Discussion

This study examined the effectiveness of two distinct passive stretching regimens on improving hand motor control and strength in individuals with moderate to severe hand impairment during the subacute phase of recovery. The stretching routines consisted of 30 minutes of passive stretching, either statically maintaining an open hand posture or cycling between the relaxed (flexed) and open postures. In both cases subjects expressed satisfaction with the procedure; they enjoyed the sight and feeling of the hand opening.

Intriguingly, while, as expected, the 30 minutes of rest produced little improvement in task performance or strength (mean positive

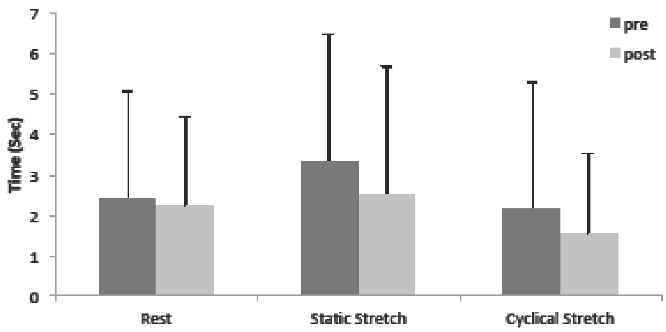

Figure 4: Grip termination time (GTT) as measured by voluntary FDS EMG relaxation following maximum voluntary contraction.

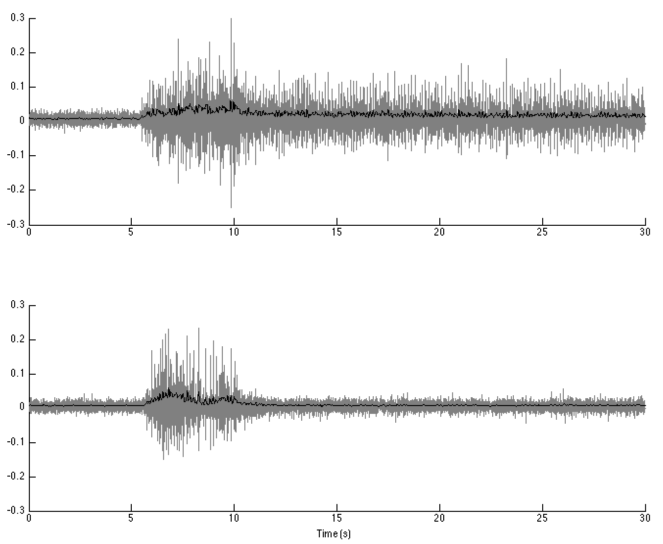

Figure 5: Sample of FDS EMG activity during a single trial before (top) and after (bottom) the cyclical stretching condition. The dark line indicates the EMG envelope. Note how the envelope remains elevated prior to stretching (top curve). The shaded box shows the duration of the audible tone signaling the subject to maximally contract.

change across subjects of less than 2% of the initial value for GWMFT-Time, GS, or LPS), trends in improvement were readily apparent after a single stretching session. Improvements of 10-18% were observed for GWMFT-Time, GS, and LPS.

The changes in the grip termination time suggest that the stretching may have helped to reduce flexor hyper excitability. The mean decrease in GTT following stretching was 3-4 times larger than the change seen after rest. This is in accordance with previous studies that described a reduction in spasticity following stretching [25-27]. The reductions in GTT were smaller than those we previously reported for stroke survivors in the chronic phase of recovery (greater than 7 months), who achieved a mean reduction of 2.3 s. However, the values before stretching were also smaller than for the chronic subjects. Interestingly, the post-stretching absolute values for all three conditions for these subacute subjects were in fact quite similar to the values attained with the chronic group implying we may have been experiencing a floor effect.

In contrast to results in stroke survivors with chronic hemiparesis [12], the advantages of cyclical over static stretching were not as readily apparent. Cyclical stretching was the only treatment to result in an average improvement of at least 10% across all four of the outcome measures. Notably there was a statistically significant reduction in GWMFT-Time. Static stretching, however, resulted in an average improvement of at least 10% in two of the outcome measures and a significant reduction in GGT.

The exact neural sites at which the stretching is exerting influence remain unknown, but cortical pathways are likely impacted. As noted, passive movement of the upper extremity has been shown to produce cortical excitation, including in S1 and S2 [7], and in SMA [8]. This activity may impact relative levels of inhibition and disinhibition in the brain and spinal cord. Indeed, in stroke survivors, movement of the paretic wrist, as driven by the non-paretic wrist, led to improved balance in interhemispheric inhibition [9,28,29]. The trend toward reduced relaxation time after stretching, as seen in this as well as previous studies [12,16], suggest a partial restoration of normal inhibition, such as on the reticulospinal pathways, which favor excitation of the flexor muscles in the upper extremity [30].

Although the stretching interventions showed overall trends for improvements in strength and functional abilities, there were several limitations to the present study that should be noted. First, these data represent trends from a small convenience sample at variable stages of recovery (months post stroke ranged from 2 to 5 months). Second, since data were collected over a period of two weeks, the possibility of spontaneous recovery or improvements from concurrent therapy cannot be excluded. We attempted to minimize these confounding factors through study design with each person serving as his or her own control (pre-post) and by randomizing treatment order. Finally, we only looked at activity from FDS to quantify muscle hyperexcitability. EMG activity of other finger flexors, such as flexor digitorum profundus (FDP), or extensors, such as extensor digitorum communis (EDC), may also be of interest.

While more study is needed, stretching of the finger muscles in the stroke hand appears to be a promising treatment for stroke survivors in the subacute phase of recovery. It may prove especially effective as an adjuvant therapy facilitating subsequent performance of active movement therapy. Future studies exploring the neural correlates of improvement are warranted.

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