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Training Grip Control with a Fitts' Paradigm: A Pilot Study in Chronic Stroke

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ABSTRACT:
Study Design: A clinical measurement study.
Purpose: To test the applicability of Fitts' paradigm to grasping tasks in individuals with chronic stroke.
Introduction: Fitts' Law relates the time of target achievement to task difficulty in repetitive motor tasks.
Methods: Six male chronic stroke patients performed repetitive actuation of a grip force dynamometer with their affected hands for 12 sessions over four to six weeks.
Results: Movement times followed Fitts' behavior with correlations of $R^2 > 0.8$ for all subjects. Grasp control improved during training, as indicated by an average decrease in Fitts' slope of 26% at high difficulty levels ($p < 0.05$), and decreases in the number of force corrections and in jerkiness, both at $p < 0.001$ level.
Conclusions: The Fitts' grip force targeting protocol provides an objective standardized instrument for grasp proficiency quantification and a potentially efficacious platform for hand training for persons with stroke.
Level of Evidence: N/A.

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The ability to finely adjust grasp strength appropriate to the task is fundamental to dexterity and is generally lost in conditions of neurological impairment, including chronic stroke.[1] Because grasping is closely interdependent with arm reaching, its proficiency determines, to a large extent, overall functional recovery of the poststroke arm.[2,3] Accordingly, grasp training is a high priority for rehabilitation of the upper limb (UL).[4–7]

A primary UL functional deficit in neurologically impaired persons pertains to grasp control, expressed mainly as slowness in grasp formation and inconsistent application of grip force.[8] Recovery can sometimes be achieved through repetitive structured hand exercises, especially when integrated with sensory feedback.[9–12] Herein, we tested a repetitive grasp-and-release protocol that elicited precise isometric grip forces across a set of alternating force targets. The protocol was adapted from the well-established Fitts' test of speed versus accuracy in a kinematic reaching task.[13] This paradigm has been extensively used in behavioral studies of reaching movements in unimpaired individuals[14,15] and its applicability to neurologically impaired subjects has been explored.[10,16–19]

Fitts' Law is a physiologically valid and widely used descriptor of reaching motions and human—computer interactions.[20–24] Mathematically, it relates the movement time (MT) required to move between a pair of stationary targets with a particular index of difficulty (ID), both defined as:

$$\mathrm{MT} = a + b \cdot \mathrm{ID} \qquad (1)$$

where the ID, expressed in bit units, depends on the distance, d, between targets of height, h:

$$\mathrm{ID} = \log_2(2d/h) \qquad (2)$$

The purpose of this pilot study was to test the hypotheses that for persons with chronic stroke 1) the

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Fitts' paradigm will apply to dynamic force targeting similar to that observed in kinematic movement tasks and 2) grasp proficiency will improve after 12 sessions of dynamic training. In addition to Fitts' parameters, two independent measures of motor proficiency were also calculated: smoothness of grip force application, as measured by the average force trace jerk, and the number of changes in the direction of the force velocity, an index of the corrective adjustments required to reach the force target. To clarify terminology, we operationally use *grasp* to represent the prehensile activity of the hand, and *grip* to represent its forceful output. Here, we report our findings on the assumption of Fitts-type behavior in the isometric grasp of persons with compromised motor function because of chronic stroke and also the potential for neurologic restoration via a grip force targeting (GFT) task.

METHODS

Human Subjects

Six right-handed, right-side affected male stroke patients (age 63.6 ± 8.8 yr; 7.3 ± 7.6 mo poststroke) were recruited from the outpatient population at JFK Johnson Rehabilitation Institute, Edison, NJ, (see Table 1). Inclusion was based on moderate impairment in the affected hand, having scores between 3 and 5 on the hand inventory of the Chedoke—McMaster test (scale between 1 and 7),[25] or Fugl-Meyer test score (upper body section) less than20.[26] Additionally, subjects had visual acuity screened according to a Snellen level less than 1.2, and demonstrated full understanding of all instructions in English. All of the above tests were administered by an occupational therapist before training. Subjects were monitored throughout the training period for their ability to complete a full series of alternating grip cycles without rest or assistance and without fatigue. All subjects signed a consent form approved by the institutional review board (IRB) of Rutgers University and University of Medicine and Dentistry of New Jersey (UMDNJ).

Hand Dynamometry

To measure grip force, a custom grip force dynamometer (GFD) was modified from a previous design (Figure 1).[27] To accurately register true cylindrical grip force, the GFD was designed to maximize the radial contact between the five metacarpal bones and the sensors. GFD output was linearized over the range 0—60 lbs and calibrated for each subject in terms of his maximum voluntary contraction (MVC). Total weight of the GFD was 40 g.

Protocol

Subjects were seated comfortably in front of a computer screen with their test arms placed in the Mechanical Arm Support and Tracker (MAST) device.[28] The MAST fixes the arm in a horizontal plane with the wrist in neutral (working) position while supporting the arm against gravity. Each subject grasped the GFD with their affected hand, as in Figure 1 (*Left*). To correct for baseline force before testing, subjects were asked to grasp the GFD by wrapping their fingers and thumb around it with their wrist in neutral position, completely relaxed, with a minimal force just sufficient to hold the GFD. To scale for maximum force, subjects were then asked to maximally perform their full cylindrical grasp, and target magnitudes were then adjusted according to %MVC.

The GFT protocol was delivered via a custom LabVIEW (*National Instruments*) interface that displayed a vertical blue tank with a pair of force targets representing high and low grip forces as shown in Figure 1 (*Right*). Actual ID values in bits, shown in Table 2, were selected to adequately cover the whole individual MVC levels, and optimal target size and positions were calculated from those selected ID values. The two targets within the display tank, were of constant equal size (height), *h*, and separated by a variable distance, *d*, according to each ID. Thus, exact numerical values for ID's were specified by the distances between target pairs, whereas the target size, *h,* and hence accuracy requirements, remained constant over all force levels. Task difficulty was progressively increased by incrementally increasing target pair distance, thereby increasing grip force demands. Thus, targets were offset from the mid-tank level (50% MVC) by ±5%, ±12%, ±22%, ±32%, and ±40% MVC, corresponding to target positions of ±3.5, ±4.9, ±9.5, ±13.5, and ±18.0 cm from mid-tank level. Subjects were instructed to hold the GFD with comfortable force while waiting for a "ready" cue to begin alternately hitting the targets as quickly

TABLE 1. **Demographics of Stroke Subjects**

Subject No.	*Gender*	*Age*	*Number of Months Poststroke*	*Handedness*	*Side Affected*
1	M	77	34	R	R
2	M	79	6	R	R
3	M	60	11	R	R
4	M	45	8	R	R
5	M	73	13	R	R
6	M	65	6	R	R

M = Male; R = right-side.

Follow this cue ~

Hit the target !

FIGURE 1. *GFD (Left); Interface display for cyclic GFT exercise (Right). Target height, H, and separation distance d_1 at the lowest ID level (ID 1) are indicated. Target blocks remained gray until target range was achieved for 200 milliseconds, whence the block would change to a bright red color, and an audible tone would sound, indicating a "hit" had been registered. Target height was set to 6% of user MVC. Abbreviations: GFD = grip force dynamometer; GFT = grip force targeting; ID = index of difficulty; MVC = maximum voluntary contraction.*

as possible, by applying the correct forces in sequence. A successful target achievement, hereafter a "target hit," was recorded when the user force level remained within the target boundary for 200 milliseconds. Feedback for successful target hit was given as a visual blink of the target, with a color change from gray to bright red, along with an audible tone.

In each 75-second test set, target pairs were presented for 15 seconds each, totaling $T = 75$ seconds for all five IDs; five sets were performed over a single session. The protocol involved 12 sessions over four to six weeks because a flexible 2-day or 3-day-per-week schedule was offered. Four of the subjects trained twice weekly for six weeks and two other subjects trained three times per week for four weeks. To account for task and strategy learning and also to establish each subject's competence at the task, a familiarization session ("session 0") was conducted but not included in the performance evaluation (sample result shown in Figure 2). The primary study protocol thereafter involved 11 sessions.

TABLE 2. **IDs for Dynamic GFT Test**

	ID 1	*ID 2*	*ID 3*	*ID 4*	*ID 5*
d (target distance in cm)	3.5	4.9	9.5	13.5	18.0
d (target distance in %MVC, i.e., force range)	±5	±12	±22	±32	±40
ID values (bits)	2.5	3.0	4.0	4.5	5.0

IDs = indices of difficulty; GFT = grip force targeting; MVC = maximum voluntary contraction.
Note: Target height, *h*, was uniformly equal to 1.2 cm = 6% MVC.

Extraction of Fitts' Parameters

Average movement time (MT) per hit for each ID level was calculated according to the total number of target hits achieved for a given ID level: *MT = 15 seconds (time given per ID level) ÷ total # of hits per ID level*. Once MTs were acquired for all ID levels, a scatter plot of average MT across five IDs was fitted to a regression line m, such that

$$m = a + b \cdot \mathrm{ID}, \qquad (3)$$

where m represents the MT predicted at a given ID. Constants, a and b, represent the intercept and the slope of the regression fit line: slope conveys grasp proficiency in terms of the decrease in targets achieved with an increase in ID and intercept reflects response time.

Grasp Proficiency Metrics

To determine the proficiency of task completion, the speed and consistency of force application were extracted from the GFD data. Two separate metrics of grasp performance were calculated. Firstly, the

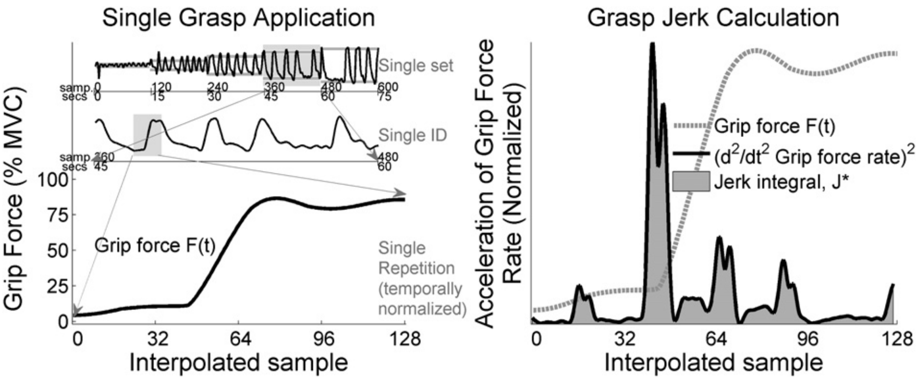

FIGURE 2. Calculation of the jerk integral for grasp. At left, top, force traces for all five IDs are shown in sequence. Middle traces are expanded from ID 4. Bottom shows one grasp, F(t), temporally normalized to 128 time points to eliminate bias in jerk calculation. At right, F(t) is differentiated three times (acceleration profile of the grip force rate) and squared, and the integral of this (area under the curve) yields modified jerk, J. Abbreviation: ID = index of difficulty.*

smoothness of the force trace from each target hit event was evaluated using the parameter, jerk:

$$J = \int_0^T \left(\frac{d^3}{dt^3} F(t) \right)^2 dt \tag{4}$$

where $\frac{d^3}{dt^3}F(t)$ is the rate of change of acceleration of the grip force application over time $0 \leq t \leq T$, integrated over a single grasp cycle. The standard jerk integral, used in the assessment of motor performance in a wide variety of tasks, was adapted here to quantify the spontaneous accelerative behaviors in the grip force profile, *F(t)*. This modified jerk metric, *J**, conveys task proficiency as a positive scalar value for which an ideally performed grasp would incur $J^* = 0$. To eliminate bias associated with possible differences in movement speed, each repetition was temporally normalized to $T^* = 128$ data points, and the integral itself was normalized to average force velocity $\overline{\dot{F}(t)}$; the sign was discarded to allow for direct comparison between application and release of grasp:

$$J^* = \frac{1}{\overline{\dot{F}(t)}} \int_0^{T^*=128} \left(\frac{d^3}{dt^3} F(t) \right)^2 dt \tag{5}$$

The process of calculating the normalized jerk is depicted in Figure 2. Within the set, the grip force trace *F(t)* is separated into its five ID levels, lasting 15 seconds ($15\,\text{sec} \times 80\,\text{Hz} = 120$ samples) each. Next, within each ID, single target hit event vectors (grip force records spanning two target achievements) were extracted and processed according to Eq. (5), yielding normalized grasp jerk, *J**.

Ideally, each grasp application or release will be executed with either a steadily increasing or declining force, with no overshoots or undershoots. Thus, the ideal grip force profile should increase and decrease monotonically from baseline to the higher and lower targets, respectively. In cases where grasp control is not perfect, there will be target over- and undershoots. To quantify these, the number of target crossovers (changes of sign), $S(t)$, calculated from the first time derivative of grip force vector is summed at each ID level as a secondary measure of smoothness in targeting execution and defined as the number of force modulations, Δ:

$$\Delta = \sum \frac{d}{dt} S(t) > 0 \tag{6}$$

where $S(t) = \pm 1$:

$$S(t) = \text{sign}\left(\frac{d}{dt} F(t) \right) \tag{7}$$

is a binary record of the signs, that is, ±1 of the first derivative of grip force. In the case of ideal force targeting with smooth force trajectory, the Δ performance limit converges to 1.

Statistical Analysis

To test the hypothesis that the Fitts' task training benefited the subjects, a Wilcoxon's rank-sum hypothesis test was applied to each grasp performance metric. For each measure, the profile of scores of each subject over the 11 sessions was normalized to unity scale to compensate for the large variability expected between subjects' raw performance. These data were subsequently fit to a first-order polynomial, obtaining a linear trend of performance at a given ID level. The slope of this fit was extracted and averaged over all subjects yielding a measure of percent change-per-session in a given performance measure; a negative slope in any metric implies an improvement in task performance. To quantify the improvement in grasp response time, the change in Fitts' intercept, Δa, was also calculated, with performance improvement determined by a Wilcoxon rank-sum hypothesis test

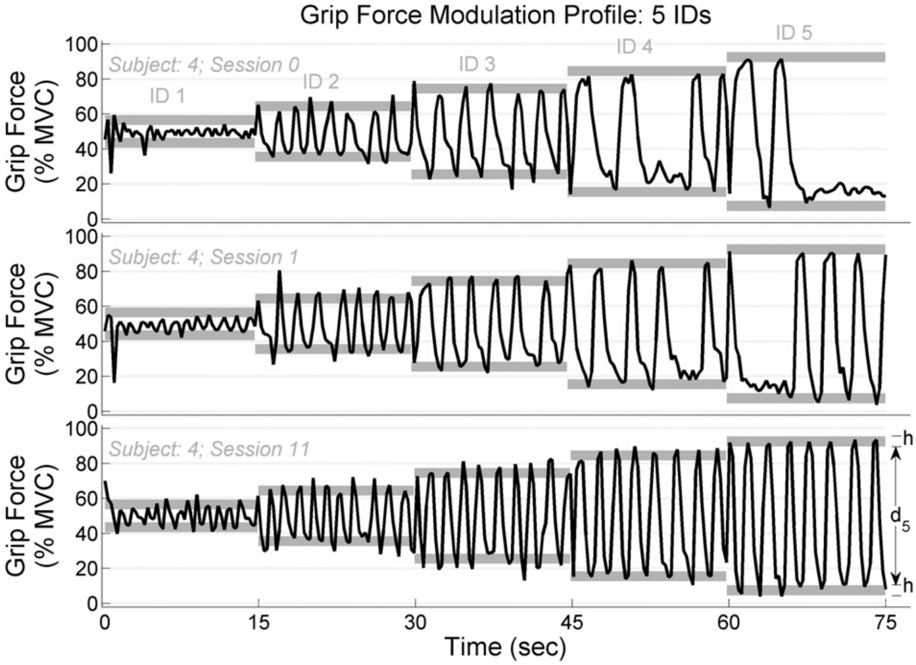

FIGURE 3. Typical force profile of GFT sessions performed by a single subject across five ID levels: session 0 (Top), session 1 (Middle), and session 11 (Bottom). The horizontal gray bars denote target levels. Target height h, and separation distance at the highest ID level d_5 are indicated. Abbreviations: GFT = grip force targeting; ID = index of difficulty.

on $\Delta a < 0$. As stated earlier, early phase training represents the first three sessions after the initial ''familiarization'' session.

RESULTS

GFT Test

Typical grip force waveforms are shown in Figure 3, spanning all five ID levels for a single subject, captured at the familiarization period (session 0), and at the first and last sessions. As shown, targets were reached when the thick black trace, *F(t)*, stayed within the horizontal gray bars (targets of height *h*, separated by distance *d*); when the trace traversed outside the gray bars, corrective movements were evident. It can be seen that, as training progressed, grip force appeared faster and smoother.

Figure 4 reports the raw performance scores, averaged over all subjects at each ID (*Left*), and the change in performance as measured by the average percentage decrease in this score per session (*Right*). In this way, a ''session-wise decrease'' in a given metric is akin to the slope of the linear trends fitted to the

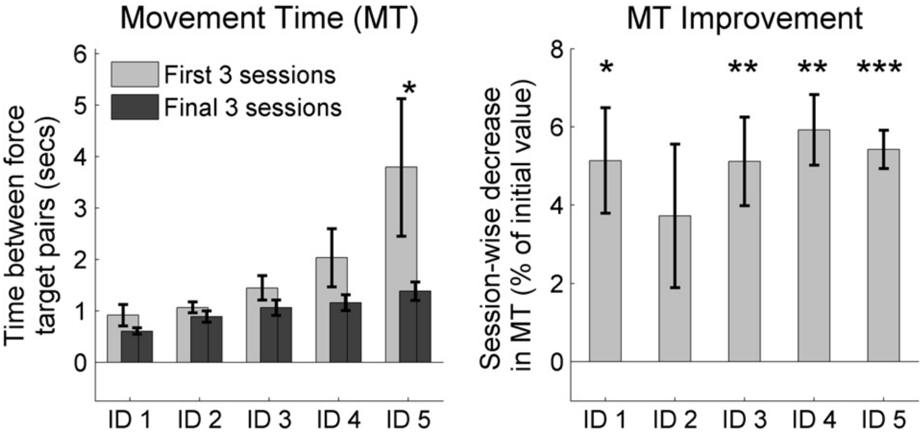

*FIGURE 4. Average MT per ID level (Left). Note that MT increased with ID level, as expected according to Fitts' Law. After training, MTs decreased at all IDs, significantly so at IDs 1, 3, 4, and 5 (Right); improvement is measured as the session-wise decrease in MT, that is, the average slope of linear trends fitted to the scatter of raw score versus session. Bar plots show cohort mean ± SEM; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Abbreviations: MT = movement time; ID = index of difficulty; SEM = standard error of the mean.*

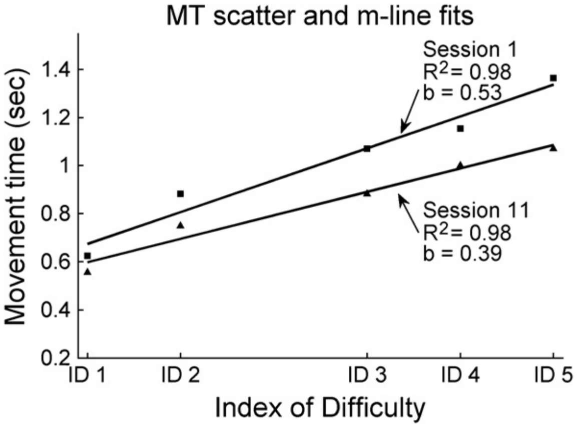

FIGURE 5. Sample scatter plots of average MT against ID for a single subject during 1st and 11th sessions. Actual ID values in the abscissa, displayed in Table 2, are manually selected for optimal placement as target pairs to cover the whole individual MVC levels, resulting noninteger values in bits. Abbreviations: MT = movement time; ID = index of difficulty; MVC = maximum voluntary contraction.

scatter of raw performance over 11 sessions. As seen, MTs between targets initially ranged from MT = 0.92 ± 0.21 to 3.79 ± 1.34 (sec/hit; mean ± standard error of the mean) at IDs 1 and 5, respectively. MTs decreased after training with all subjects performing faster grasp-release cycles at all IDs (Figure 4, *Left*). The decreases in MTs over time were significant showing improvement at IDs 1, 3, 4, and 5 (Figure 4, *Right*).

Changes in Fitts' Parameters After Training

MTs correlated linearly with ID, indicating a close match to Fitts' behavior, as seen in Figure 5. In the early sessions, the correlation of the MT scatter data to its linear trend was $R^2 = 0.84 \pm 0.02$ and this increased after training to $R^2 = 0.91 \pm 0.02$, $p < 0.05$.

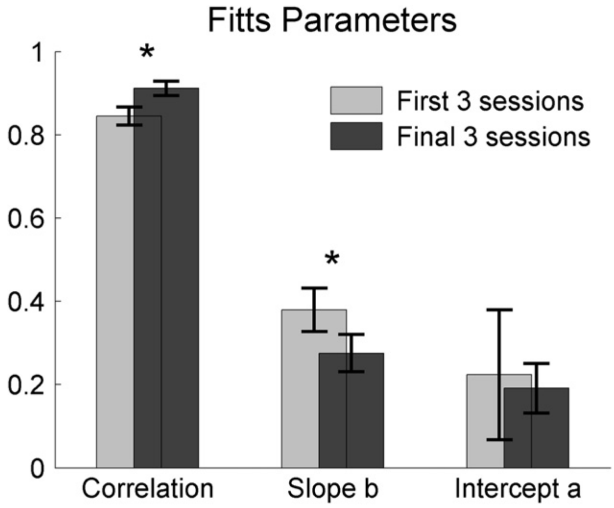

FIGURE 6. Average goodness-of-fit, Fitts slope, and intercept are shown, averaged over all subjects. Correlation increased from 0.85 to 0.91 after training and Fitts slope, b, decreased from 0.38 ± 0.05 to 0.28 ± 0.4 after training. Fitts intercept, a, showed improvement, but this effect was not significant at the p < 0.05 level.

Fitts' slope decreased in all subjects after training, by an average of 26% from 0.38 ± 0.05 to 0.28 ± 0.05 bit/sec (Figure 6; $p < 0.05$), with the largest decrease occurring at the highest IDs. Grasp response time, seen as the intercept, *a*, decreased slightly but not significantly.

Force Corrective Adjustments

In addition to improving speed between target pairs, subjects became considerably more proficient at reaching force targets after training, as depicted in Figure 7. Here, consistency in grip force application was measured by grasp modulation according to the number of corrective changes in the direction of force, Δ and analysis was similar to that in Figure 4. In early stage training, average corrective behaviors ranged from 1.37 ± 0.09 Δ/hit at ID level 2, to 4.47 ± 1.55 Δ/hit at ID level 5. At the end of 12 sessions' practice, however, the number of corrective behaviors reduced to near unity at all ID levels. In other words, subjects reached each force target directly without correcting. This improvement was most prominent at high ID levels at ID 4 and 5 ($p < 0.001$). The changes were incremental, with approximately 5% improvement per session. The slight increase in corrections at ID 2 was not significant and relates to the fact that performance at this intermediate level was already nearly ideal at baseline.

Force Trace Smoothness

Training resulted in a nearly tenfold reduction in grasping jerk between targets, as seen in Figure 8. Integrated jerk, *J*, is a standard measure of motor proficiency for which spontaneous accelerations in the signal trace are considered indicative of highly ''unsmooth'' behavior. The modified formulation used here, *J**, incorporates a temporal normalization and a normalization for average velocity. The decrease in *J** occurred gradually at a rate of 5–8% per session across all IDs and after training completion, this was significant at all IDs except ID5; the greatest jerk decrease occurred at ID2.

DISCUSSION

Validity of Study

This pilot study tested the clinical applicability of a GFT task by motor-impaired individuals with chronic stroke. We adapted the traditional Fitts' cyclic targeting protocol for reaching to a dynamic test of handgrip force control. Six individuals with moderate residual motor function were selected from a pool

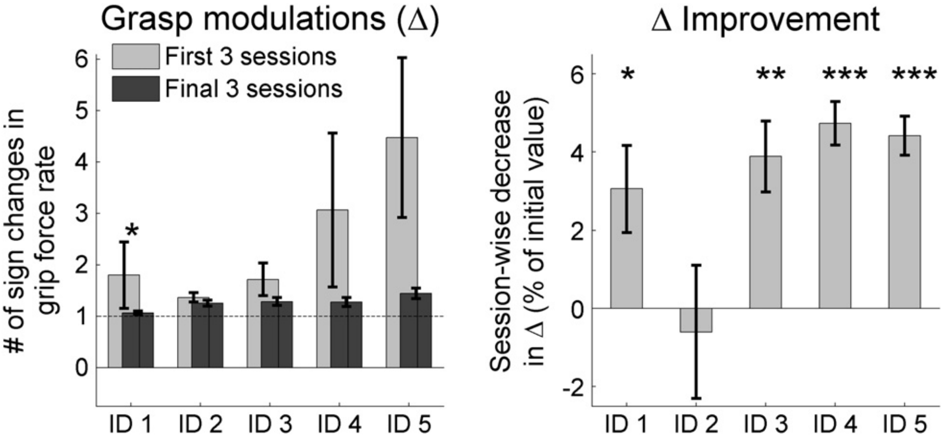

FIGURE 7. *Number of sign changes in grip force trace normalized to total number of hits (Left), and the relative improvement in grasp modulation over six weeks' training (Right). After training, average grasp fluctuations approached unity for all ID levels, indicating few or no corrective movements were required. These improvements were significant at IDs 1, 3, 4, and 5; improvement is measured as the session-wise decrease in MT, that is, the average slope of linear trends fitted to the scatter of raw score versus session. Bar plots show cohort mean ± SEM;* $*p < 0.05$, $**p < 0.01$, $***p < 0.001$. *Abbreviations: ID = index of difficulty; MT = movement time; SEM = standard error of the mean.*

of candidates recently discharged from supervised outpatient stroke therapy to directly test the hypothesis that MT between targets increases with task difficulty in a way that is predicted by Fitts' Law (Eqs. 1 & 2). Furthermore, a longitudinal training study was done to determine whether Fitts' parameters and other measures of motor proficiency would improve after repetitive training with the cyclic GFT protocol.

The ID represented a pair of targets of specific size (height) and separation distance that can be reached by alternating high and low application of force, with MT being the dependent variable (Eq. 1). Each subject was tested on his affected hand with the arm supported against gravity and wrist in neutral position.

Grip force was registered by a GFD, calibrated to the User's MVC, recording the time course of isometric grasp in response to visual prompts for targeted grasp modulation in the presence of instantaneous audio and visual feedback. The cylindrical shape of the GFD used herein enabled full radial contact between the entirety of the five digits and the sensor element.

Although subjects were asked to generate their MVC in hand grip force at each session, comparison of MVC changes between early and later days of the training was not performed in this study because the main purpose of this pilot study was to improve their hand grasp proficiency focusing on their ability to control along their entire MVC range, as opposed to increasing their strength.

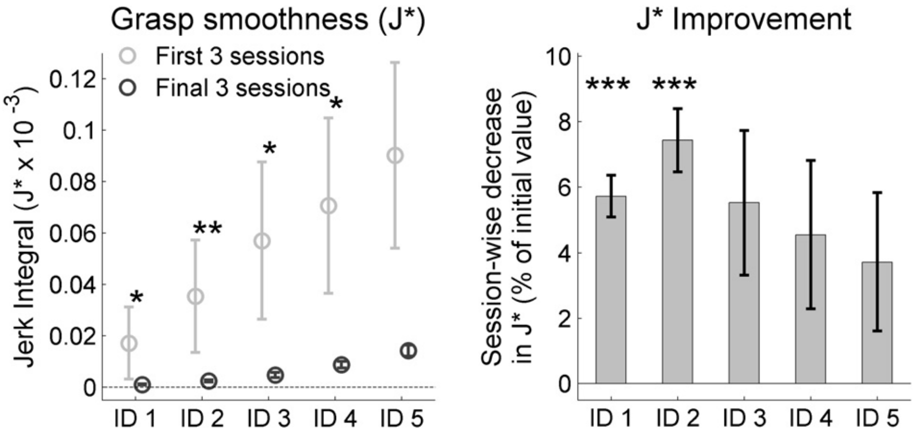

FIGURE 8. *Average rate of change of the acceleration of force application (jerk integral, J*, Left), and the relative improvement in grasp jerk over time (Right). Profile J* between targets increased linearly with ID, as expected, and jerk decreased in all subjects over all IDs with training. Improvement is measured as the session-wise decrease in MT, that is, the average slope of linear trends fitted to the scatter of raw score versus session. Bar plots show cohort mean ± SEM;* $*p < 0.05$, $**p < 0.01$, $***p < 0.001$. *Abbreviations: ID = index of difficulty; MT = movement time; SEM = standard error of the mean.*

In addition to validating Fitts' parameters as clinical measures of grasp proficiency, two additional measures were applied, relating to consistency and smoothness. Consistency was based on the number of corrective adjustments to the force target; smoothness was assessed by modified integrated jerk. Integrated jerk is a standard measure of motor proficiency for which spontaneous accelerations in the signal trace are considered indicative of highly ''unsmooth'' behavior. The modified formulation used here, J^* (Eq. 5), normalizes for time and for average velocity to account for the wide variability (and concomitant potential for bias in J) observed in motor-impaired individuals.[28–30]

Primary Findings

Foremost, it was determined that the grip force applications of the six stroke patients in this study adhered strictly to a Fitts-type profile, with correlations of $R^2 = 0.84 \pm 0.02$ at baseline, and improving to 0.91 ± 0.02 over 12 sessions of training (averages over first and last three test days, familiarization session discarded). Over the course of training, the significant decreases in Fitts' slope revealed an increase in intertarget grasping speed: MTs decreased at all IDs for all subjects, as determined by a secondary slope-fit analysis of each parameter.

Consistency of grip force application also improved, as measured by a decrease in corrective behaviors. For example, at ID5, Δ/hit initially was 3.79 ± 1.34 and declined progressively approximately 5% per session to 1.39 ± 0.18 at the last session, a 63% improvement (Figure 7). Force smoothness also improved, as indicated by the modified jerk, J^*, which decreased for all subjects at all IDs with the largest decreases seen at IDs 1 and 2 ($p < 0.001$, Figure 8).

Clinical Implications

Objective measures of hand function are prerequisite to evidence-based practice, particularly because standard clinical measures do not always correlate well with hand dysfunction.[7,31] Speed and consistency of grasp, in particular, are two factors considered essential to grasp proficiency and are primary deficits in stroke subjects.[8] Our subjects' outcome measures reported in this study significantly improved in both these skills, as measured by MT, integrated force jerk, and corrective adjustments, across various IDs. These changes are likely veridical indicators of motor improvement, as opposed to nonspecific learning of the test because they continued gradually over the training period; simple task learning would be expected to plateau after the first few sessions. Our results therefore suggest the potential of the GFT training protocol to effect collateral improvements beyond merely speed of task completion as applied to dynamic grasp.

Our results further imply that the new metrics can possibly differentiate between abilities at separate difficulty levels. For example, Figures 4 and 7 show that movement speed and consistency have improved across all IDs except for ID2. This range includes force pairs from 45–55% to 10–90% but not 48–62% (see Table 2). Because Fitts' paradigm trains specifically for speed and accuracy, these improvements are not surprising and the lack of improvement at ID2 may relate to the relatively high baseline performance at this level (Figure 7). It may be that ID2, being an intermediate level, was more commonly practiced by the subjects. With regard to smoothness, in contrast, improvement was highest at ID2. This implies that the GFT protocol can benefit functions beyond just speed and accuracy; thus, smoothness is a separable quality of grasp, which may be independently targeted in therapeutic protocols. It may be fruitful to test modifications to the targeting protocols, such as force target tracking at various speeds, selecting more restricted force ranges for tasks and including reaching-to-grasp paradigms.

It remains to be seen whether our subjects' improvement within the objective measures of motor control have permanence beyond the several week training period and whether these skills impact more complex and integrated manual skills. At present, a neuroimaging study is underway using near-infrared spectroscopy as a complementary measurement modality to monitor metabolic activity by detecting brain oxygenation consumption level changes and total blood volume changes during GFT. Previous studies have shown that blood oxygenation level and total volume changes during motor skill training can be used as an assessment of learning.[32,33] It would be useful to see how an improved outcome measure would manifest in the brain activity levels. This future study will test the use of modified Fitts' paradigms on learning retention, applicability to activities of daily living, and possible neuromotor rehabilitation of the hand.

Summary

Two conclusions are drawn: 1) Fitts' Law can be applied to the dynamic force application of stroke subjects' affected hand, with its parameters yielding robust indices of motor performance and 2) cyclic force targeting protocols may extend the results of manual therapies, with only a minimally intensive regimen. Training involved 12 sessions lasting approximately 20 min each, summing to a total of less than 10 min of active force generation per session. This protocol is efficacious and stimulating and minimizes the opportunity for subject fatigue. It is suggested that the GFT test adapted from Fitts can quantify grasp control abilities in stroke-impaired persons and become a potentially powerful strategy for their rehabilitation.

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#1. The primary testing instrument was a
   a. soft rubber ball with pressure sensors imbedded in its core
   b. grasp force dynamometer using a blood pressure bulb
   c. standard Jamar dynamometer
   d. cylindrical custom made grasp force dynamometer

#2. The primary purpose of the training methodology was to
   a. test the protocol for its validity
   b. test the protocol for its reliability
   c. increase hand grasp proficiency
   d. increase hand grasp power

#3. The grasp targets were intended to alternate
   a. rapidly between a high and low application of force with the involved hand
   b. slowly/deliberately between a high and low application of force with the involved hand
   c. rapidly high applications of force between the involved and uninvolved hands
   d. slowly/deliberately high applications of force between the involved and uninvolved hands

#4. In this study the authors use the term Fitt's paradigm to suggest the relationship between the following two factors
   a. speed vs. power
   b. speed vs. accuracy
   c. power vs. accuracy
   d. accuracy vs. long time intervals

#5. The authors present data to strongly suggest a carry-over from the GFT testing protocol to improved ADL performance
   a. true
   b. false

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