Disorders of Upper Limb Speed and Accuracy Following Stroke

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Objectives: The primary aim of this investigation was to quantify disorders of movement speed, accuracy and motor function in the upper limb following stroke. A further aim was to examine variability in upper limb performance in elderly stroke subjects over a 24-hour period.

Subjects: Eighteen subjects with a mean age of 76.4 (s.d. 8.7) years and a history of a unilateral stroke (post stroke 8-52 days) were tested.

Methods: Upper limb movement speed and movement accuracy were measured using discrete Fitts’ aiming tasks (1, 2). Ten discrete aiming movements consisting of moving a metal stylus from the starting point to a target were performed at three indices of difficulty (IDs) according to Fitts’ protocol: 4.32, 5.32 and 6.32 (2). Upper limb function was quantified using the Action Research Arm Test (ARA) (3) and the advanced hand component of the Motor Assessment Scale (MAS) (4).

Results: Sixteen subjects repeated the speed and accuracy tasks on the second day. Movement times increased as a function of ID although the subjects with strokes were considerably slower than previously reported for both unimpaired adults and younger stroke patients. The mean score for the ARA was 47.3 (s.d. 8.5) whilst the median score for the MAS was 2 (IQR 2), indicating moderate upper limb disability. Although individuals showed moderate within-session variability in performance of the Fitts’ tasks, there were high correlations between repeat measures of movement speed over the 24-hour period (ICCs were 0.89 at ID 4.32; 0.95 at ID 5.42, and 0.74 at ID 6.32).

Conclusion: The subjects with strokes had disorders of upper limb movement speed and accuracy that were moderately disabling yet remained consistent from one day to the next.

Key Words: stroke, upper limb, movement disorders, neurolgy, measurement, ageing.

Introduction

Movement disorders affecting the upper limb are a common and disabling consequence of cerebrovascular accidents. Common impairments include weakness (5), spasticity (6), sensory disturbance (7) and lack of dexterity (8). These impairments limit the stroke patient’s capacity for fast and accurate performance of functional tasks such as reaching and grasping (9) and dressing (10). Clinically it appears that a trade-off occurs between the speed and accuracy of movement, so that patients with strokes are very slow to move their affected hand to a small target, whereas they can move more quickly when the target is large.

Studies on upper limb aiming tasks in unimpaired individuals have repeatedly demonstrated that movements performed as fast and as accurately as possible show a trade-off between the speed of a movement and its precision (1, 2, 11, 12). The relationship between movement accuracy and movement time (MT) is linear so that as the requirement for accuracy increases, the speed of the movement decreases. A useful measure of movement accuracy was proposed by Fitts (1, 2) and is known as the index of difficulty (ID). According to Fitts, ID = \log_{2} A/W, where A refers to the amplitude from a starting point to a target and W refers to the width of the target (1, 2). As the width of the target decreases, the difficulty of the task increases and the person slows down more. An increased distance to the target increases the ID and lengthens the time taken to reach the target.

In people with strokes, several studies have demonstrated that Fitts’ law also predicts the performance of aiming movements, although there is a steeper increase in MT as the ID increases for these patients than for age-matched controls (13, 14). Ada and colleagues (8) have shown that...
stroke subjects reduce their speed and accuracy of movement when performing tracking tasks, particularly when there is a dual requirement for moving both quickly and accurately. The extent to which this reduction in speed and accuracy is due to weakness, spasticity, peripheral mechanical changes in muscle, or higher order cognitive and perceptual problems remains under investigation.

Similar to patients with strokes, a marked speed-accuracy trade-off has been demonstrated in the performance of aiming movements in elderly people (15-17). Older people appear to place greater emphasis on achieving a high degree of accuracy at the expense of movement speed, having learned the consequences of speed-related errors (18). The accuracy bias in older people results in a steeper speed-accuracy gradient for Fitts' law (1) than for age-matched controls. It is likely that in most elderly patients with strokes, the speed-accuracy trade-off is not only affected by the motor and perceptual disorders that occur following an infarct or hemorrhage, but also by the ageing process. Previous stroke studies have been restricted to samples of younger subjects and hence have not investigated this interaction. For example, in the study by Ryan et al (13), the mean age of stroke subjects was 58.2 years and in that of Turton and Fraser (14), the mean age was only 52.4 years.

Given these considerations, the purpose of this experiment was to explore the relationship between upper limb movement speed and accuracy in elderly stroke subjects performing a discrete timed aiming task. A further aim was to examine variability in upper limb performance in stroke subjects over a 24-hour period, thus providing clinicians with a measure of stability of performance over the short-term. In order to confirm the criterion-related validity of Fitts' test, we concurrently measured stroke subjects' performance on two tests of upper limb disability, the Action Research Arm Test (ARA) (3) and the advanced hand component of the Motor Assessment Scale (Section 8) (MAS) (4).

Methods

Design Eighteen geriatric subjects with strokes participated in a single group repeated-measures study that examined performance of the affected upper limb on discrete Fitts' aiming tasks at three levels of difficulty. The tasks were repeated 24 hours later in 16 of the subjects with strokes to investigate variability of performance over a short time interval, during which recovery processes could be assumed to be minimal. On day 1 subjects also completed the ARA and section 8 of the MAS. The project was approved by the respective Human Ethics Committees of the hospitals concerned and La Trobe University.

Subjects Eight male and ten female subjects with strokes with a mean age of 76.4 (s.d. 8.7) years were recruited for the study. The mean duration of stroke was 24.2 days (s.d. 13.9, range 8-52). Participants were only included if they were: (i) diagnosed with a cerebrovascular accident not more than 8 weeks previously; (ii) aged 60 years or more; (iii) medically stable as determined by a neurologist; (iv) able to hold a pencil; and (v) willing and able to provide informed consent. Subjects were excluded if they had a history of previous stroke that prevented full participation in a rehabilitation program. At the time of data collection, all subjects were undergoing inpatient rehabilitation. The subject characteristics are detailed in Table 1.

Table 1. Subject characteristics.

<table>
<thead>
<tr>
<th>Subject no.</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Days since stroke</th>
<th>Affected side</th>
<th>Site of stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>85</td>
<td>F</td>
<td>19</td>
<td>L</td>
<td>Parietal</td>
</tr>
<tr>
<td>2*</td>
<td>81</td>
<td>F</td>
<td>20</td>
<td>R</td>
<td>No CT done</td>
</tr>
<tr>
<td>3</td>
<td>73</td>
<td>M</td>
<td>13</td>
<td>R</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>F</td>
<td>13</td>
<td>L</td>
<td>Parietal</td>
</tr>
<tr>
<td>5</td>
<td>76</td>
<td>M</td>
<td>8</td>
<td>L</td>
<td>Occipitoparietal</td>
</tr>
<tr>
<td>6</td>
<td>81</td>
<td>F</td>
<td>14</td>
<td>R</td>
<td>Sub-cortical</td>
</tr>
<tr>
<td>7</td>
<td>84</td>
<td>F</td>
<td>24</td>
<td>L</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>8</td>
<td>90</td>
<td>F</td>
<td>21</td>
<td>L</td>
<td>Pons</td>
</tr>
<tr>
<td>9</td>
<td>79</td>
<td>F</td>
<td>21</td>
<td>R</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>10</td>
<td>76</td>
<td>M</td>
<td>17</td>
<td>R</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>M</td>
<td>15</td>
<td>R</td>
<td>No CT done</td>
</tr>
<tr>
<td>12</td>
<td>76</td>
<td>F</td>
<td>18</td>
<td>R</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>13</td>
<td>60</td>
<td>M</td>
<td>25</td>
<td>R</td>
<td>Basal ganglia</td>
</tr>
<tr>
<td>14</td>
<td>61</td>
<td>F</td>
<td>57</td>
<td>R</td>
<td>Corona radiata</td>
</tr>
<tr>
<td>15</td>
<td>79</td>
<td>M</td>
<td>60</td>
<td>L</td>
<td>Temporal</td>
</tr>
<tr>
<td>16</td>
<td>73</td>
<td>M</td>
<td>30</td>
<td>L</td>
<td>Internal capsule</td>
</tr>
<tr>
<td>17</td>
<td>87</td>
<td>F</td>
<td>28</td>
<td>L</td>
<td>No CT done</td>
</tr>
<tr>
<td>18</td>
<td>63</td>
<td>M</td>
<td>32</td>
<td>R</td>
<td>Thalamus &amp; internal capsule</td>
</tr>
</tbody>
</table>

* denotes subjects who were not assessed on the second day.

Procedure After giving informed consent and following explanation of the project, participants performed 10 trials of the Fitts' discrete aiming task at each of the three levels of difficulty (ID). The three IDs for the experiment were 4.32, 5.32, and 6.32, which corresponded with target widths of 20, 10 and 5 mm respectively. The order of tests were counterbalanced across subjects to minimize series effects. The same procedure was followed at the same time on the following day to control for diurnal variation.

The procedure for data collection for the Fitts' task was as follows. Subjects were seated at a table holding an insulated
metal pointer in the affected hand and in contact with the starting point of a target board. On the command “Ready, go!” they moved the pointer as fast as possible to a target on the board positioned lateral to the starting point. This closed a circuit enabling the purpose-designed electronic timer to measure the movement time in thousandths of a second. The starting point of the target board was positioned directly in front of the affected shoulder. Subjects were instructed to move the pointer as fast as they could to hit the target. All targets were 190mm lateral to the start; thus ID was varied only by the different target widths.

Administration of the ARA followed the author’s guidelines (3). Four sections representing different aspects of arm movement were assessed: grasp, grip, pinch and gross movement. The nineteen items comprising the ARA were graded from 0 (unable) to 3 (performed normally), enabling a maximum score of 57. The most difficult item in each section was tested first. A score of 3 in that item obviated the need to try the less advanced items because of the demonstrated scaling qualities of the test (3). Concurrent validity of the ARA as a measure of functional recovery with motor recovery as evaluated by the Brunnstrom-Fugl-Meyer assessment (FMA) (19) has been established (20).

The advanced hand activities section of the MAS (4) comprised of 6 functional activities: picking up a pen top, taking a small sweet out of a cup, drawing horizontal lines and dots on paper within a time limit, taking a dessertspoon of liquid to the mouth and combing the hair on the back of the head. Testing began at item 1 and ceased at the first item that could not be performed. Each activity was scored 0 (unable) or 1 (successful), for a possible maximum of 6. The MAS also has concurrent validity with the FMA (21). Both the ARA and MAS have inter-rater and intra-rater reliability of >0.98 (3, 4, 21).

Statistical Analysis After visual inspection of each subject’s Fitts’ data for each ID on the two days, intra-individual variability of performance during each set of 10 trials was quantified, using the coefficients of variation (COV = (s - μ/100 (22).

The effects of ID and test day on mean MT were examined using a two factor repeated-measures Analysis of Variance (ANOVA, ID x Day). Post-hoc multiple comparisons were used to establish whether significant differences existed between each of the three IDs (Tukey’s HSD tests; (22)).

The degree to which movement time on Day 1 could predict MT on Day 2 at each ID was examined by linear and multiple regression procedures. Stability of MTs from Day 1 to Day 2 at each ID was also considered using intraclass correlation coefficients (ICCs) (23). Predictive equations and 95% confidence intervals were developed to enable clinicians to compare MTs of an individual patient with expected MTs and know with 95% confidence whether observed changes represent a real departure from the norm.

As the ARA data were normally distributed, parametric methods of analysis were used to compare them with the Fitts’ data. Linear and multiple regression procedures examined the ability of scores on the ARA to predict MT at each ID. The ordinal MAS data was correlated with the ARA and Fitts’ data using Spearman rho correlation coefficients to examine their relationships.

Results

The speed-accuracy trade off in stroke

As predicted by Fitts’ law, the results of this experiment showed that mean MTs for this stroke group increased with the degree of difficulty of the aiming task (refer to Figure 1). For an ID of 4.32, when the target width was 20 mm, the mean MT was only 0.79s, increasing to 0.97s when the target width was 10 mm (ID 5.32). The mean MT further increased to 1.1s with reduction of target width to 5 mm at ID 6.32. The main effect for ID was statistically significant (F(2,30) = 42.84, p < 0.001; Greenhouse-Geisser correction). Post-hoc tests confirmed that the mean MTs at each ID were significantly different from each other (ID 4.32; difference between means 0.19 > minimum significant difference (MSE) of 0.058, p < 0.001; ID 5.32; difference between means 0.31 > MSE 0.082; p < 0.001; ID 6.32; difference between means 0.12 > MSE 0.082, p < 0.001).

The degree of difficulty of the aiming task (ID) predicted a small yet significant proportion of the variability for the raw

![Figure 1 Movement time for each index of difficulty](image)

movement times for individuals (n = 540; r² = 0.11, p < 0.001) and slightly more of the variability for the mean movement times for group as a whole (n = 18; r² = 0.16, p < 0.001). This means that 16% of the variance in mean MT could be accounted for by the ID (accuracy requirements) of the task. Post-hoc division of the group results showed that
the strength of the ID to MT relationship differed according to age and level of disability. Movement time was less strongly related to ID in the older subgroup (n = 10, mean age 81.0 (s.d. 4.76) years), where \( r = 0.34 \), than for the younger subgroup (n = 6, mean age=66.7 (s.d. 3.3) years) for whom \( r = 0.46 \). \( t_{(6)} = 2.14, p < 0.001 \). Moreover, subjects in the “low disability” group who scored more than 50 on the ARA (mean score = 53.75; s.d. 2.12) demonstrated a stronger relationship between MT and ID \( (r = 0.44) \) than subjects who were more disabled (mean ARA = 42.10; s.d. 8.14), \( r = 0.18 \). \( t_{(58)} = 4.44, p < 0.001 \).

Figure 2 depicts box-plots for the distribution of coefficient of variation values on Day 1 and Day 2 for the three IDs. These illustrate that intra-test or trial to trial variability was wide but with an almost identical median for each level of difficulty on Day 1 when the task was new. On Day 2, the amount of variability decreased for the two easier IDs, reflecting the effect of practice, remaining high for the most precise task.

**Variability of performance on Fitts’ tasks**

![Figure 2 Variability of performance](image)

No main effect for day of testing was found in the two-factor repeated-measures ANOVA described above. In addition, linear regressions of mean MTs for Day 1 on those for Day 2 showed a moderately high degree of consistency of results (Table 2). Multiple regression incorporating additional factors of age and the number of days since the stroke showed stronger predictive ability of the MT results for Day 1 (refer to Table 3) with significant coefficients of determination of \( R^2_{adj} = 0.54 \) at ID 4.32 and 0.81 at ID 5.32. The \( R^2_{adj} \) of 0.26 at ID 6.32 which did not reach statistical significance.

Intraclass correlation coefficients also indicated moderate to high degrees of consistency in MT performance from Day 1 to Day 2. For an ID of 4.32 the ICC for MT was 0.88. For an ID of 5.32 the ICC was 0.95 and for an ID of 6.32 it was 0.72. Thus repeatability of performance was greatest for the easier two tasks and less for the most difficult task.

<p>| Table 2 Linear regression of Day 2 movement times on those for Day 1. |</p>
<table>
<thead>
<tr>
<th>Index of difficulty</th>
<th>( R^2 )</th>
<th>( Y ) intercept</th>
<th>Slope</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.32</td>
<td>0.580</td>
<td>0.139</td>
<td>0.820</td>
<td>0.001</td>
</tr>
<tr>
<td>5.32</td>
<td>0.775</td>
<td>0.178</td>
<td>0.800</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6.32</td>
<td>0.302</td>
<td>0.634</td>
<td>0.466</td>
<td>0.027</td>
</tr>
</tbody>
</table>

**Relationships between Fitts’ tasks performance and upper limb disability**

The ARA data were normally distributed and showed a high coefficient of scalability. Inspection of the scattergrams for the mean ARA scores for the group as a whole at each ID showed weak to moderate associations between MT and ARA scores, with the strongest association found at ID 5.32 where \( r = 0.54, p = 0.02 \) (Table 4). However, post-hoc division of the ARA results into a severe disability group (scores < 50) and mildly disabled group (scores \( \geq 50 \)) revealed higher correlations. For the less disabled group, \( r = 0.64 \) at ID 4.32, \( r = 0.54 \) at ID 4.32 and \( r = 0.47 \) at ID 6.32. When subject age and days since stroke were included in the regression analysis, almost all of the variability in the ARA scores could be predicted by mean MT for the mildly disabled group of subjects (\( R^2_{adj} = 0.95 \) at ID 4.32; \( R^2_{adj} = 0.70 \) at ID 5.32; \( R^2_{adj} = 0.74 \) at ID 6.32). (\( R^2_{adj} \) figures were used because they provide a less optimistic estimate of the population figures from small sample sizes than \( R^2 \)).

For the MAS, scores on the advanced hand activities section were unevenly distributed, with all except three subjects failing to pass item 3. Item 3 involves drawing 10 horizontal lines to end at a vertical line (4). Most subjects could perform the task, but not within the required 20 second time limit. Spearman’s rank-order correlation showed low and non-significant correlation between the MAS and mean MT for ID 4.32, \( rho = -0.27 \). The higher IDs demonstrated moderate correlation with MAS scores (ID 5.32 \( rho = -0.57 \) \( p =

<p>| Table 3 Multiple regression for movement time on Day 2. |</p>
<table>
<thead>
<tr>
<th>Index of difficulty</th>
<th>( R^2_{adj} )</th>
<th>IC</th>
<th>Day 1 MT coefficient</th>
<th>Age CE</th>
<th>*DSS CE</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.32</td>
<td>0.54</td>
<td>-0.048</td>
<td>0.765</td>
<td>0.004</td>
<td>-0.002</td>
<td>0.100</td>
</tr>
<tr>
<td>5.32</td>
<td>0.81</td>
<td>-0.040</td>
<td>0.685</td>
<td>0.920</td>
<td>-1.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6.32</td>
<td>0.26</td>
<td>0.094</td>
<td>0.425</td>
<td>0.008</td>
<td>-0.003</td>
<td>0.100</td>
</tr>
</tbody>
</table>

*\( DSS \) denotes number of days since stroke. IC = intercept; CE = coefficient

<p>| Table 4 Correlation of ARA to movement times on Day 1. |</p>
<table>
<thead>
<tr>
<th>Index of difficulty</th>
<th>Pearson r</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.32</td>
<td>0.269</td>
<td>0.280</td>
</tr>
<tr>
<td>5.32</td>
<td>0.542</td>
<td>0.020</td>
</tr>
<tr>
<td>6.32</td>
<td>0.469</td>
<td>0.049</td>
</tr>
</tbody>
</table>

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Discussion

Deficits in accuracy of upper limb aiming

The results of this study support the clinically observed difficulty with aiming movements seen after stroke by demonstrating that FITTS’ law holds for the relationship between movement speed and movement accuracy in elderly patients with strokes in the early stages of rehabilitation. In agreement with Ryan et al (13), our investigation showed that ID only predicted 16% of the variance in MT. In contrast, Turton and Fraser (14) found that the ID predicted 34% of the variance in MT in their subjects. The weaker predictions in our study may have been related to the increased age of subjects in the sample. High variability is a characteristic feature of motor performance in elderly subjects (15, 16, 25) and greater variance in data sets results in reduced statistical ability to detect differences (22). Lending support to the notion of age weakening the MT to ID relationship, our older subgroup (aged 75 years or more) demonstrated a weaker association (r = 0.34) between MT and ID than the younger subjects with strokes (r = 0.46). Clinically, this may suggest that older subjects with strokes have more difficulty in achieving consistent levels of performance on motor tasks requiring both speed and accuracy.

The strength of the speed-accuracy relationship can also be affected by the degree of within-subject variability in movement performance. In this investigation there was a moderate degree of within-subject variability in performance over the 10 trials performed by each subject for each ID. The older age of the sample has already been mentioned as a possible cause of this variability. Stroke itself commonly results in variable motor performance (28, 29), especially in the early phase of recovery. Our subjects were still in early rehabilitation, with a mean number of 3.5 weeks ± 2 since the stroke, compared with a mean of 7.3 weeks in the study by Ryan et al (13). No data on time elapsed since stroke was reported by Turton and Fraser (14) but at least some testing occurred after 6 months, suggesting a more chronic stroke sample. There are many possible contributing factors to increased variability of motor performance following stroke. Among them are peripheral factors such as weakness or inability to activate adequate numbers of motor units (30), decreased inability to modulate EMG activation (6), increased muscle stiffness (31) or changes in muscle length which alter the length-tension relationship (32), as well as central changes such as possible differences in movement strategy (13). Any or all of these factors may impact the speed and accuracy of movement.

Variability in motor performance is frequently considered to represent low levels of skill or noise within the motor control system (33). Many previous investigations have examined the variability in endpoint accuracy or spatial error (17) rather than temporal variability as in the current project. However, Newell and co-workers utilized a space-time model to allow them to consider the variability of normal subjects in both dimensions. They found that the amount of error or variability in space and in time was comparable, both for movements up to 400 ms (33) and for those up to three seconds (34). Contrary to the predictions of FITTS’ law, however, their results showed that shorter movement durations actually resulted in reduced variability, both temporally and spatially i.e. shorter MTs demonstrated greater accuracy. As they used young normal subjects and a different experimental paradigm, it is difficult to compare their results with those of the present study. The current project measured MT on the closure of an electronic circuit but did not evaluate near-misses or poor contacts, so that the degree of similarity between spatial and temporal variability in this group cannot be examined. Further, our data did not demonstrate a statistically significant association between movement speed and movement variability at any ID, although variability increased significantly with increasing task difficulty on the second day of testing. Further investigation is required to determine whether Newell’s results (34) can be replicated in the elderly and stroke populations.

So far, variability has been discussed as a negative aspect of motor control, associated with lower levels of skill. An alternative explanation would be that the inter-trial variability observed in this study was due to subjects’ trialling different strategies as an exploratory learning technique to improve motor performance. For example, in an electromyographic and kinematic analysis of reaching in chronic subjects with strokes, Trombley (35) noted that patients experimented with different strategies throughout the study. Some of these strategies met with less success but overall progress was made throughout the project. Although this possibility cannot be excluded in the current project because practice trials were not included in the protocol, it has been noted above that there were no significant correlations between individuals’ speed of movement and the COV of their trials at any ID. This suggests that the variability was not due to trying different strategies. More extensive kinematic examination of early subjects with strokes is necessary to establish the role of variability of performance as a motor learning strategy.

The particular nature of the discrete aiming task used in the current investigation may have accentuated the trial to trial variability of performance. Whereas upper limb measurement tools such as the ARA (3), Fugl-Meyer (19), Motor Club (36) and Frenchey (37) assessments allow patients to complete tasks at their own rate, the FITTS’ tasks require subjects to move as quickly as possible. It has previously been noted that when a timed component is incorporated into an upper limb test (such as the advanced section of the MAS hand battery), subjects with strokes have greater difficulty in performing dexterous movements (21, 38). For example,
Ada and colleagues showed that movement speed and strength were both adequate for the performance of an upper limb tracking task but dexterity diminished at higher speeds (8). Variability of step length and step width is minimised at subjects’ preferred walking speed (39) and it is likely that demanding maximum speed for a movement increases the variability of that movement.

**Effects of ageing on movement time**

These results suggest that it is difficult to assess motor performance accurately in subjects with strokes without considering the effects of age related changes in motor performance. Age was found to be a significant factor affecting movement time and upper limb disability for the vast majority of results. This is consistent with the increased slope of the Fitts’ law equation that has been noted in older subjects (40). Slower total reaction time (i.e. the sum of reaction time and movement time) is a well-recognised consequence of normal ageing (41). Although changes occur at every level of the motor response – sensory input, central processing and motor output – the greatest delays occur in central processing and response selection (41, 42). The long movement times seen in this study would be due to some degree to the age of the participants.

In addition, for the tasks which had greater requirements for precision (high IDs), temporal performance was more variable in the older subjects with strokes than younger individuals. Increased spatial and temporal variability of movement is commonly associated with ageing (41-43). For this investigation, the variability in movement time may have been due in part to the need for greater visual acuity to locate a target only 5 mm wide, providing particular difficulty for older subjects. Alternatively variability might be related to other age-related changes, such as: decreased accuracy of visual or proprioceptive input (26, 44), delayed information processing (45) or less effective selection and programming of motor responses (41). These factors may be compounded by peripheral changes in the structure and functioning of muscles and tendons such as a lower and more variable motor unit discharge rate (46) or the greater atrophy of fast-twitch muscle fibres (47) that are associated with ageing. Clinically, it is important to note that the impact of age would be still more marked if subjects were performing a test using fast repetitive movements, such as a finger tapping test or the repetitive version of Fitt’s task. This is because fast repetitive movements exaggerate age differences in behavioural speed (41).

**Consistency of performance on Fitts’ tasks**

Although geriatric subjects with strokes had disorders of upper limb movement speed and accuracy that were moderately disabling, group performance remained consistent from one day to the next. Despite high correlations between consecutive days’ performance, confidence intervals were large, reflecting the wide inter-subject variability within the group. For clinicians, this suggests that repeated measurement of an individual over time is more likely to demonstrate progress (or otherwise) than comparison of an initial and one subsequent test. The same recommendation has been made in regard to walking after stroke (48, 49).

Goldie and colleagues found that the progress in gait velocity made by subjects with strokes over an eight-week rehabilitation period was predicted by confidence intervals ranging from 8.3 m/min to 14.4 m/min for the group. However, this varied between a deterioration of -4.6 m/min to gains of 38.4 m/min, highlighting the variability amongst individuals with stroke. The wide variability in our study is in keeping with that found by Goldie et al (49) and Hill et al (48) and reinforces the need for clinicians to use repeated measures when charting an individual patient’s progress.

**Relationships between Fitts’ tasks performance and upper limb disability**

The results of this investigation showed a close relationship between performance on the aiming task and results on the ARA test of upper limb disability. In fact, when subjects’ age and days since stroke were included in the regression analysis, more than 95% of the variability in the ARA scores could be predicted by the mean MT for the mildly disabled group of subjects. This suggests that measuring speed and accuracy of movement may be of greater relevance to those whose motor function is approaching normal levels. Other studies have found that many chronic subjects with strokes continued to find the limb slow and clumsy despite good performance on clinical tests (50) and even that they may cease to use their affected arm because it is quicker and easier to perform unilaterally (51). It follows that an emphasis on assessing and treating the more subtle impairments of speed and accuracy is particularly relevant to this patient group.

Although this study is the first to document the relationship between movement speed and accuracy for a discrete aiming task in elderly patients with strokes, there are a number of limitations that need to be taken into consideration. Foremost, the sample was restricted to elderly patients recruited whilst undergoing active rehabilitation. The findings might not be applicable to those still in the acute hospital or in chronic settings. The comparatively small sample of 18 subjects also reduces the ability to consider it as fully representative of the aged stroke population. Awareness of the wide inter- and intra-subject variability associated with both age and stroke further suggests that larger sample numbers are needed in future projects to enable more confident interpretation of results.

**Conclusions**

Following stroke, individuals typically have disorders of upper limb movement speed and accuracy that are moderately disabling yet remain consistent from one day to the next.
The relationship between movement speed and accuracy in geriatric subjects with strokes is linear and conforms to Fitts’ law. These results support the inclusion of measures of movement speed and accuracy as an integral part of the neurological assessment of subjects with stroke. For valid measures of performance, the effects of ageing and level of functional disability on movement control also need to be taken into consideration.

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References


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Erratum

In the March 2001 issue of Physiotherapy Singapore, Vol 4 (1), the author’s name for the research report ‘Effect of Unilateral and Bilateral Knee Immobilisation on the Energy Cost of Walking’, has been erroneously printed. It should be GYF Ng. The issue year printed at the header should be 2001 instead of 2000. We apologise for the errors.