Mobility Activity of Stroke Patients During Inpatient Rehabilitation

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Abstract: The purposes of this study were to quantify the actual upright activity of inpatient stroke patients in order to investigate the influence of disability, physiotherapy contact time, and time since stroke on the amount of activity recorded. Forty-one inpatients from three Glasgow stroke units were monitored during one therapeutic day. Measurements were made using an instrumented recording device which quantified (i) the proportion of time spent upright, and (ii) the frequency of transitions to upright. The results were compared to a global measure of disability, the Barthel Index, a functional mobility scale, the Rivermead Mobility Index (RMI) and walking speed. Results were also compared to time spent in physiotherapy and the time since their stroke. The patients spent an average of 8.3% of the therapeutic day upright. They transitioned to upright an average of 2.6 times/hour. There were significant correlations between upright activity (proportion of time) and Barthel Index score ($r=0.79, p<0.01$), RMI score ($r=0.77, p<0.01$), walking speed ($r=0.48, p=0.02$), and physiotherapy time ($r=0.43, p=0.01$). Physiotherapy contact time was independently related to activity, indicating that physiotherapy directly influences quantity of mobility activity during inpatient rehabilitation. The patients spent a small proportion of the therapeutic day upright despite being in dedicated stroke rehabilitation units, and each patient’s activity level was dependent upon both their level of disability and the amount of physiotherapy input they received.

Key words: activity, mobility, physiotherapy, stroke

Introduction

Mobility practice is a key component of post-stroke rehabilitation. Thus, measurement of actual mobility of stroke patients is of increasing relevance to researchers and clinicians [1]. Whilst strong evidence now exists that management of stroke patients in specialized stroke units reduces patient morbidity and improves the likelihood of returning home [2], the specific components of stroke unit care that improve outcome are as yet unknown [3]. There is some suggestion that early intensive mobility facilitation contributes to the success of stroke unit care [4]. This may be due, in part, to a reduced risk of complications attributed to immobility [5]. In addition, there is emerging evidence that greater mobility practice improves outcome [6]. Understanding the nature of the relationship between exposure to mobility activity and the outcomes of rehabilitation is an important step in the development of appropriate post-stroke interventions. This can only be achieved through the measurement of actual activity. At present however, the amount of mobility activity undertaken by stroke patients in any type of care has rarely been reported [7,8] and the factors that influence the amount of activity are not known. Thus, there is a lack of data with which to compare different services, and to help inform development of services with enhanced mobility practice.

There are many factors that may influence how active a patient is on any one day, including the severity of their disability, their age, health, motivation, the time since their stroke occurred, and the amount of mobility-focused therapy to which they had access [9]. Thus, the

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Received: 7 March 2006 Accepted: 22 September 2006

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The purpose of this study was to measure the actual mobility activity of patients undergoing inpatient rehabilitation in representative United Kingdom stroke unit settings, in order to explore the relative influence of some of these factors.

There are three main methods of recording activity: (i) self-rating through diary entry, which is reliant on recall and open to bias and inaccuracies; (ii) observational methods, which are more accurate and can give highly detailed information, but are extremely resource expensive, can miss data as recordings are generally made in blocks, suffer from interobserver differences, and are subject to bias due to the awareness of the patients and staff of the monitoring; and (iii) instrumented methods. Although instrumented methods may also cause similar bias due to awareness of being monitored, if the device is unobtrusive and worn for long periods of time, this bias is reduced. In addition, instrumented methods enable cost-efficient, continuous, and long-term activity data collection. Previous studies reporting activity of inpatient stroke patients have utilized observation methods [7,8]. This study utilized a simple instrumented method, which was developed for the purpose of categorizing activity into either non-upright postures (sitting and lying) or upright postures (standing, transferring and walking), and calculating the number of transitions from non-upright to upright.

The specific objectives of this study were: (1) to record the amount of time spent upright and the frequency of transitions from a non-upright to upright position in a sample of patients undergoing inpatient rehabilitation in three dedicated stroke units; and (2) to investigate the relationship between the actual upright activity recorded and three different measures of disability, (the Barthel Index [10], the Rivermead Mobility Index (RMI) [11] and walking speed [12]), plus the amount of time spent in direct physiotherapy contact, and the time since stroke onset.

**Methods**

**Participants**
The subjects were 41 stroke patients undergoing rehabilitation at three stroke units in Glasgow. Subjects were a subgroup of the participants recruited as part of a larger, Stroke Association funded trial, where half the patients were given extra physiotherapy input [1]. The study protocol aimed to provide the “augmented” group with double the standard duration of physiotherapy sessions. In practice, this level of contact time was not achieved, resulting in a wide range of physiotherapy contact times across the groups. North Glasgow Hospitals University NHS Trust granted ethical approval for the main trial including this study, and eligible patients were required to give informed consent. The criteria for inclusion into the trial were: recent, first stroke (diagnosis confirmed by computed tomography scan) and admitted for rehabilitation; independent functional sitting balance (at least 1 minute unassisted); no major comorbidities (no recent myocardial infarct, significant surgery within 3 months, angina, chronic obstructive airflow disease, peripheral vascular disease or arthritis limiting ability to exercise, carcinoma or poorly controlled diabetes); no major communication or cognitive impairment (Abbreviated Mental Test [13] score ≤ 8); independent prior to their stroke (pre-stroke Rankin score [14] > 2); and considered safe to exercise by medical staff and thus able to tolerate mobility rehabilitation. Patients were transferred to the stroke rehabilitation units from general medical wards when considered medically stable and fit for active physiotherapy. The time from stroke to inclusion in trial therefore varied considerably.

**Outcome measures**
The recording device consisted of a thin, plastic, open-ended, oil-filled tube with a commercially available, miniature pressure transducer at one end (the sensor). This was taped along the lateral aspect of the unaffected leg with the same length of tubing above as below the knee (Figure 1). The output from the sensor is proportional to the vertical distance between the pressure transducer and the open end of the tube. For example, when the subject is standing, the whole tube is straight and vertical; but when the subject is sitting with the knee flexed, the tube bends in the middle with the upper half horizontal and only the lower half vertical. Thus, during standing, twice as much of the tube length is vertical than for sitting, which effectively halves the oil pressure and the transducer output. The output was recorded on a data logger [Biomedical Monitoring Ltd., Glasgow, UK], which was attached to a belt worn around the subject’s waist. The signal was sampled at 10 Hz. The data were downloaded to a PC for calculation of the output quantities using custom developed software algorithms. The transducer...
from medical records.

data including hospital admission date were gathered
ity recording day to the nearest 5 minutes. Demographic
ment as close as possible to the assessment day.
the recording so as not to influence
activity, but a maximum of 3 days apart. The recording
An activity of interest was used to measure the patients’
interfaces were all permitted). The Barthel Index,
and walking speed were used to measure the patients’
degree of mobility disability. The Barthel Index [10] is a
widely used disability scale. Originally designed to mea-
ure “dependency”, this questionnaire is commonly used
as an indication of activity limitation. It ranges from 0 to
a maximum score of 20. The Rivermead Mobility Index
(RMI) was developed as a measure of functional mobility
of neurologically impaired patients [11]. It consists of
14 questions and one observation, giving a total ranging
from 0 (immobile) to 15 (mobile). It has established mea-
urement properties and has been shown to be reliable
within 2 points [17]. Self-selected walking speed was
measured over a 10-metre walkway from a standing start.
Only those patients who could walk without physical
assistance could perform the test (walking aids, orthoses
and supervision were all permitted). The Barthel Index,
RMI and walking speed assessments were scored on a
different day to the activity recording so as not to influence
activity, but a maximum of 3 days apart. The recording
day was chosen to suit availability of staff and equip-
ment as close as possible to the assessment day.

Physiotherapy staff recorded the amount of time they
spent in direct contact with the patients during the activ-
ity recording day to the nearest 5 minutes. Demographic
data including hospital admission date were gathered
from medical records.

Procedure
The monitoring was conducted in their third week of
the main trial (approximately third week after admis-
sion to the stroke unit), with the system being applied
eyly in the morning and removed just before bedtime.
The single day represented a snapshot of the subject’s
activity status as an inpatient undergoing subacute reha-
bilitation. The patients were informed that the device
would measure the amount of time they spent standing
up but were instructed to be as active as they would
normally be. A member of the physiotherapy staff applied
the sensor between 8.30 am and 9.30 am and nursing
staff removed the system in the evening at their discre-
tion. As there was a wide variation in the time of removal,
data from after 4.30 pm was excluded from this analy-
sis. The recording period of between 7 and 8 hours until
4.30 pm represented the therapeutic day.

Data analysis
For the first objective of recording and describing the
mobility activity of stroke unit patients, upright time
and frequency of transitions to upright were presented
as means and standard deviations (SD), medians and
ranges, and 95% confidence intervals (CI) of the means.
Spearman’s Rank test for correlation, a nonparametric
statistic, due to the ordinal nature of the Barthel Index
and RMI and non-normal distribution of the walking
speed and activity results, was used to test for associa-
tion between the activity recordings, proportion of time
upright and transitions per hour, and the factors that may
influence upright time. A significance level of 0.05 was
used for all correlation analyses. In order to test whether
time upright was affected independently by physiother-
apy contact time, a multiple linear regression model was
then applied relating proportion of time spent upright
(transformed to a normal distribution by calculating the
log of the activity recordings as determined by a Box-
Cox transformation [18]) as a function of the significant
factors. Backward elimination was used to select the
final model.

Results
Activity was recorded for 41 patients. A total of 708
patients were admitted to the units during the data col-
collection period, of which 83 met the inclusion criteria.
Of those, 13 did not give consent, 12 were discharged
before their third week in the unit, one died before
their mobility behaviour was recorded, and 16 patients
were not recorded due to incorrect or missed application,
incorrect logger set up or other technical problems. Thus,
6% of all patients admitted to the stroke units were
recorded. The low proportion of stroke patients eligible
reflects the prevalence of comorbidities of this population
and cognitive/communication problems affecting ability
to give informed consent. Of the 41 patients recorded,
23 were able to complete the walking speed test. The
tested subjects spent an average of 52.3 ± 22.9 minutes
(range, 0–110 minutes) per day in physiotherapy. Time
since stroke averaged 46.4 ± 16.6 days (range, 28–89 days).
Although there was a wide range in amount of time since
stroke, they represented the subacute inpatient phase of
rehabilitation and all patients were in their third week of
stroke unit care. All demographic data are shown in
Table 1.
This sample of patients spent an average of 8.3% (95% CI, 5.6–11.0%) of their time in upright activities during the therapeutic day (equivalent to less than 5 minutes every hour). They averaged 2.6 transitions per hour (95% CI, 2.0–3.1). It can be seen from the descriptive data (Table 1) that there was a very large variation in amounts of activity between individual patients. For example, one patient spent virtually no time in an upright position, whereas another was standing or walking for nearly half of the recording period (43.0%).

Table 2 shows the results from the correlation analyses between activity recordings and other mobility measures, direct physiotherapy contact time and number of days since stroke onset. Scatter plots (Figures 2–5) were used to examine the relationships. There was a significant and moderate correlation between transitions per hour and all three disability scales, a significant and moderate correlation between proportion of time spent upright and walking speed, and a significant and strong correlation between the proportion of time spent upright and both Barthel Index and RMI. Patients who were unable to walk the 10 metres unassisted required to complete the walking speed test were allocated a speed of 0.0 m/s for the scatter plot in Figure 4 (but not for the correlation analysis), which illustrated the floor effect of walking speed measurement in comparison to actual activity measurement. There was a weaker but statistically significant correlation between both proportion of time spent upright and transitions per hour, and direct physiotherapy contact time, but no association between the activity outcomes and time since stroke onset.

The final regression model retaining only statistically significant terms \( p < 0.05 \) suggested the RMI score \( (t_{33} = 7.567, p < 0.0001) \) plus physiotherapy contact time \( (t_{33} = 3.055, p = 0.0044) \) explained 67% of the variation in upright activity (adjusted \( R^2 = 0.67 \)). The 95% CIs for regression coefficients for RMI and physiotherapy contact time were 0.149–0.257 and 0.003–0.015 respectively. The regression analyses showed that Barthel Index, RMI and walking speed had multicolinearity or similar relationships with proportion of time spent upright and in combination did not add to the model.

### Table 1. Demographic data and results from disability measures and activity recordings \( (n = 41, \text{ except } *n = 23) \)

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender (male)</strong></td>
<td>22</td>
</tr>
<tr>
<td><strong>Side affected (left)</strong></td>
<td>26</td>
</tr>
<tr>
<td><strong>Sensory impairment</strong></td>
<td>25</td>
</tr>
<tr>
<td><strong>Vision affected</strong></td>
<td>13</td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
<td>68.2 ± 11.3</td>
</tr>
<tr>
<td><strong>Time since onset of stroke (d)</strong></td>
<td>46.4 ± 16.6</td>
</tr>
<tr>
<td><strong>Direct physiotherapy contact time (min)</strong></td>
<td>52.3 ± 22.9</td>
</tr>
<tr>
<td><strong>Barthel Index (1–20)</strong></td>
<td>13.6 ± 3.1</td>
</tr>
<tr>
<td><strong>Rivermead Mobility Index (1–15)</strong></td>
<td>6.0 ± 2.6</td>
</tr>
<tr>
<td><strong>Walking speed (m/s)</strong></td>
<td>0.56 ± 0.33</td>
</tr>
<tr>
<td><strong>Proportion of time spent upright (%)</strong></td>
<td>8.3 ± 8.5</td>
</tr>
<tr>
<td><strong>Transitions to upright per hour</strong></td>
<td>2.6 ± 1.7</td>
</tr>
</tbody>
</table>

SD = standard deviation.

### Table 2. Spearman’s Rank correlation scores \( (p \text{ values}) \) comparing activity recordings to other measures of mobility (Barthel Index, Rivermead Mobility Index, walking speed), direct physiotherapy contact time and number of days since stroke onset

<table>
<thead>
<tr>
<th>BI ( (n = 41) )</th>
<th>RMI ( (n = 41) )</th>
<th>WS ( (n = 23) )</th>
<th>Direct PT contact time ( (n = 41) )</th>
<th>Days since stroke onset ( (n = 41) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of time spent upright</td>
<td>0.79 (&lt; 0.01)</td>
<td>0.77 (&lt; 0.01)</td>
<td>0.48 (0.02)</td>
<td>0.43 (0.01)</td>
</tr>
<tr>
<td>Average number of transitions to upright per hour</td>
<td>0.56 (&lt; 0.01)</td>
<td>0.51 (&lt; 0.01)</td>
<td>0.52 (0.01)</td>
<td>0.34 (0.04)</td>
</tr>
</tbody>
</table>

BI = Barthel Index; RMI = Rivermead Mobility Index; WS = walking speed; PT = physiotherapy.
Both RMI and physiotherapy contact time showed a positive relationship with proportion of time upright. Residual diagnostic plots and tests did not support curvilinear relationships.

**Discussion**

This study examined the actual upright activity of a sample of inpatient stroke unit patients. They spent an average of 8.3% of the therapeutic day upright and made an average of 2.6 transitions each hour. There was a wide variation in activity even for this modest sample of patients and in general, activity levels seemed low despite undergoing rehabilitation in specialized stroke units. What constitutes acceptable levels of activity is presently unknown because of the lack of evidence for optimal dosage in stroke rehabilitation; however, there is evidence that mobility levels do influence recovery and this is an important area for future research [4].

These results can be compared to two previous studies of activity of stroke patients. In 1996, Lincoln et al [8] carried out an observational recording of stroke unit patients in Nottingham, UK. Their method involved patients being observed in blocks and activity recorded in broad categories, which included standing, sitting,
lying, and “other” positions. They found that the stroke unit patients were standing during 2.3% of their observations during the waking day. Bernhardt et al (2004) [7] similarly used an observational methodology. Patients were observed at scheduled 1-minute time intervals, 10 minutes apart between 8.00 am and 5.00 pm for 2 days at five stroke units in Melbourne, Australia. Broad categories of degree of physical work from 0 (no activity) to 4 (therapeutic, high), and 11 positions/activities were recorded. They found that their 58 patients spent 12.8% of the recordings either transferring or walking.

The results from both these studies differ from the present study where upright time was found to be 8.3% of the therapeutic day (95% CI, 5.6–11.0%). One found that patients spent longer times upright, and the other found that patients were upright less. A number of factors may explain the differences. Firstly, differences in the environment within the units, and therapy and nursing staff input available. The extra physiotherapy may have advantaged some of the patients in the present study, but other local influences such as staffing levels and staff training may also affect activity. Major differences in

Figure 4. Plot of proportion of time spent upright versus walking speed (n=41). The plot includes subjects who were unable to complete the walking speed test. They were allocated a walking speed of 0.0 m/s.

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Figure 5. Plot of proportion of time spent upright versus time spent in direct physiotherapy contact (n=41).
staffing between stroke units in different parts of the country were not expected to be substantial, but there may be differences between countries. Secondly, the inclusion criteria for participants in the studies differed. Patients in the present study represent the more medically fit and cognitively able of stroke unit patients, and those with a predominance of sensorimotor impairment. Patients in the Lincoln et al [8] study were similarly monitored after transfer to a stroke unit. They were also medically fit and able to tolerate active rehabilitation. Their sample represented 5% of all patients admitted to the hospital with stroke in the time frame. In contrast, both of these studies’ subjects were in a later stage of rehabilitation compared to the Bernhardt et al trial, which included all admitted patients, who were observed less than 14 days from onset of stroke. However, it would be expected that this difference would result in the patients of this trial being more, rather than less, active than the patients of the Bernhardt et al study. Finally, the differences in method of recording activity may have affected the results. Observational methods that record activity and positions in blocks of 10 minutes may be a poor record of actions, which typically last only a few minutes or even seconds. The recording device used in this study samples positional data 10 times per second. Monitoring is also continuous so that activity between periods of observation is not missed. In addition, Bernhardt et al recorded the highest level of activity that occurred during the 1-minute observation. That meant that if during a 60-second period, the subject stood even briefly, activity would be recorded as standing for that observation. This would lead to a bias toward higher levels of activity, which could explain the greater activity of their patients.

Both observational methods and the recording system used in this study may have resulted in bias due to the awareness of the patients and staff of the monitoring. It is not possible to know if or how much patients in any of the studies modified their behaviour due to the monitoring. However, a relatively small and discrete monitor was chosen in this study to minimize subject awareness of the monitoring process, the recording system used was far less noticeable than a person observing, and patients and staff frequently reported they forgot the device was on. Bias from the methods used in this study was therefore expected to be minimal.

Scores of both the RMI mobility scale and the Barthel Index disability scale were strongly associated with upright activity. There was also a statistically significant association with walking speed; however, the association was weaker than with the more global scores. This may be due to the lower numbers of subjects that were able to walk 10 metres and were thus included in the correlation analysis. Walking speed is easy to measure clinically and has been used as a predictor of function as well as an indicator of motor recovery. Walking speed suffers from a “floor” effect (patients who cannot walk 10 metres unassisted cannot be tested), which can clearly be seen in Figure 4 and may also have influenced the correlation results. There were 18 patients (44% of the sample) who were unable to walk the 10 metres required for the walking speed test, yet most of these patients still demonstrated measurable upright activity.

Some patients in the study had extra time in physiotherapy resulting in a wide range of physiotherapy contact times. In addition, the methods in this study controlled the physiotherapy contact time to a large extent so that contact time was not controlled by other factors such as patient motivation, therapist availability etc. This allowed investigation of the relationship between physiotherapy contact time and upright activity. The existence of a small relationship between physiotherapy contact time and upright activity suggested a link between the amounts of physiotherapy available and the mobility activity exposure that occurred. Further, the regression model indicated that physiotherapy contact time influenced upright time independently of the subjects’ level of disability.

A limitation to the study is that this activity recording device provided data on limited aspects of mobility (proportion of time spent upright and the frequency of stands or transfers), but it allowed relatively inexpensive, continuous, objective recording for a long period of time, and the results relate well to disability scores despite being difficult to compare to results from the other published observational studies. The patient sample in this study was small and select, from stroke units in only one region. Therefore, it may not be reasonable to generalize from these results, although the stroke units are likely to be fairly similar to other units throughout the UK National Health Service at this time.

**Conclusion**

Upright activity (standing and walking) constitutes an important and relevant goal for many stroke patients, and time spent upright during rehabilitation may contribute to better outcomes [4]. This study illustrated the amount of physical activity patients are exposed to whilst being managed in specialized stroke rehabilitation units at this time. Significant, positive correlations were demonstrated between actual mobility behaviours and the Barthel Index, RMI and walking speed, and a weak relationship between the amount of time spent in direct contact with a physiotherapist and the amount of time spent upright was shown. This study indicates that an increase in physiotherapy contact time can contribute to an increase in the time the patient spends upright. Quantification of actual activity, such as in this study, provides an important step towards understanding the role of mobility activity exposure in rehabilitation and, ultimately, the provision of optimal management for stroke survivors.
Acknowledgements

This project was part of the Glasgow Augmented Physiotherapy after Stroke (GAPS) study, which was funded by the Stroke Association. We are grateful to the physiotherapy and nursing staff of Kintyre Ward, Drumchapel Hospital; Ward 47, Stobhill Hospital; and Ward 1, Lightburn Hospital, who assisted in this study.

References