What is the functional outcome for the upper limb after stroke?

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The Motor Assessment Scale (MAS) and the Functional Independence Measure (FIM) are commonly used in Australian rehabilitation centres but there have been few systematic studies using them to measure recovery after stroke, especially with regard to upper limb function. The aims of this study were to provide a profile of upper limb recovery in a non-surgical stroke population using measures of impairment and disability. The records of 153 subjects were audited for upper limb MAS sub-scores, the FIM sub-score for upper body dressing, and the total FIM score at admission and discharge from rehabilitation. Significant improvement occurred for all outcome measures. There was no relationship between the MAS scores and the functional task of upper body dressing. The results emphasize the importance of using outcome measures that assess both impairment and disability, and indicate that substantial improvements in upper limb function frequently occur after stroke. Although the MAS has limitations, it is a valuable tool for measuring upper limb outcome after stroke because it provides a more accurate profile of true upper limb recovery than the FIM. **[Williams BK, Galea MP and Winter AT (2001): What is the functional outcome for the upper limb after stroke? *Australian Journal of Physiotherapy* 47: 19-27]**

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Introduction

Stroke affects an estimated 37,000 people a year in Australia, and half of the long-term survivors of stroke are handicapped (Anderson et al 1993). A common component of handicap after stroke is an inability or reduced ability to use the affected upper limb. The general assumption is that the outcome of the upper limb after stroke is poor, however, there have been relatively few studies which focus on the recovery of motor function in the upper limb after stroke (Dean and Mackey 1992). Moreover, the outcome measures used and the outcomes reported vary considerably (Duncan et al 1992, Heller et al 1987, Olsen 1990, Nakayama et al 1994a). It is critical to distinguish between outcome tools that measure changes in impairment, that is, the motor recovery and function of the hemiplegic upper limb, and those that measure changes in disability. Disability is the functional consequence of impairment that occurs at a personal level, and measures of disability potentially record the degree of compensation achieved with the non-hemiplegic upper limb. Impairment is the loss of function as result of organic abnormality or pathology (World Health Organisation 1980).

The Functional Independence Measure (FIM) (Hamilton et al 1987) is used as the primary outcome tool in many Victorian rehabilitation centres and assesses a person's need for assistance or their burden of care. The FIM has demonstrated reliability (Dodds et al 1993, Hamilton et al 1987, Hamilton et al 1991, Hamilton et al 1994, Kidd et al 1995, Ottenbacher et al 1996) and validity (Dodds et al 1993, Granger et al 1992, Kidd et al 1995, Ocskowski and Barreca 1993). However, as a measure of disability, the FIM does not provide detailed information about neurological recovery and it is possible to achieve a full score of 126 on the FIM and still have significant neurological impairment.

Another measure commonly used in Australian rehabilitation centres is the Motor Assessment Scale (MAS), which combines elements of impairment and disability (Carr et al 1985, Loewen and Anderson

1988). To date there have been few systematic studies utilising the MAS to measure recovery after stroke, especially in regard to upper limb function. It is a reliable (Carr et al 1985, Loewen and Anderson 1988) and valid (Poole and Whitney 1988) outcome measure that can be used for most stroke patients when recording their level of impairment and capacity to perform functional tasks.

At Caulfield General Medical Centre (CGMC) both FIM and MAS scores are collected as part of a standardised assessment of stroke patients. We retrospectively audited these outcome measures over a two year period in order to examine the outcome for upper limb function following stroke and the relationship, if any, between the two measures.

The aims of this study were:

- To examine the difference between the admission and discharge MAS scores on the sub-tests: Upper Arm Function, Hand Movements and Advanced Hand Activities, and the FIM score for upper body dressing
- To examine the relationships between the admission, discharge and change MAS scores for the upper limb and the FIM score for upper body dressing to determine the degree to which recovery of movement of the hemiplegic upper limb is reflected in performance of functional tasks.

Methodology

This study was granted ethical approval by The Alfred Ethics Committee which is responsible for all research at The Alfred and CGMC.

Subjects The subjects for this study were selected from the population of unilateral first stroke patients (n = 228) admitted to the Neurological Rehabilitation Unit at CGMC during a two year period between February 1996 and January 1998. Subjects were admitted to CGMC for rehabilitation if, in the opinion of the admitting rehabilitation consultant, they demonstrated potential for improvement. Patients were diagnosed as having suffered a stroke after clinical examination and review of brain CT scans. Subjects were excluded if they had incomplete records (n = 28) or had neurosurgical intervention (n = 47), as data for these patients was only available for the second 12 months during the period of audit. For nine of the subjects with incomplete records, the MAS was not completed because the subjects were performing at a high level and had no apparent motor impairment. One hundred and fifty-three subjects were therefore suitable for inclusion in this study.

Measurement tools and procedures The MAS comprises eight items of motor function, with each item scored hierarchically on a seven point scale from 0 to 6 (Carr et al 1985). The three items concerned with upper limb function, Items 6 (Upper Arm Function), 7 (Hand Movements) and 8 (Advanced Hand Activities) were scored within one week of admission, and on the day prior to, or day of, discharge. The subject's treating therapist performed the assessment, and results were recorded in the subject's physiotherapy records. A score of 0 indicated that a subject was unable to perform any of the tests for that item. A higher score indicated that a subject adequately performed the test corresponding to that score as well as the preceding tests. Problems have been noted with the hierarchical scoring of Item 8 (Advanced Hand Activities: Dean and Mackey 1992, Poole and Whitney 1988). In clinical practice, physiotherapists in many Australian rehabilitation centres do not rate Item 8 hierarchically, instead determining the score by counting the number of tasks the subject is able to perform. However, this approach is problematic as the reliability of Item 8 has only been established by hierarchical ranking and further research is required to establish a valid ranking of Advanced Hand Activities. In this study, therefore, Item 8 was scored hierarchically. All physiotherapists who collected the MAS data had demonstrated good inter-rater reliability after undergoing the procedure described by Carr and Shepherd (1998).

The FIM consists of 18 items which include a person's continence level and physical and his or her cognitive abilities. Each item was scored on a seven point scale, dependent upon the level of assistance required. The total FIM score, including the FIM sub-score for upper body dressing, was recorded for all subjects within one week of admission and prior to, or just after, discharge. The task of upper body dressing involves dressing and undressing above the waist, and may involve one or more item of clothing depending on the subject's choice of outfit (Uniform Data Systems 1993). A subject who required total assistance with dressing would score 1, while a subject who could dress the upper body completely

Table 1. Subject demographics
(SD = standard deviation, IQR = interquartile range
* indicates non-normal distributions).

Age:		
Mean (SD)	70.1	(13.2)
Range	36-96	
Sex:		
Male	98	(64.1%)
Female	55	(35.9%)
Pre-admission accommodation:		
Home alone	73	(47.7%)
Home with family	73	(47.7%)
Special accommodation/Hostel	5	(3.3%)
Nursing home	2	(1.3%)
Type of stroke:		
Infarct	123	(80.4%)
Haemorrhage	30	(19.6%)
Side of pathology:		
Right	71	(46.4%)
Left	82	(53.6%)
Time to rehabilitation admission (days):		
Median (IQR)	16	(21)*
Range	2-218	
Discharge destination:		
Home alone	47	(30.2%)
Home with family	80	(52.4.%)
Special accommodation/hostel	11	(7.3%)
Nursing home	10	(6.7%)
Deceased	5	(3.4%)
Length of stay in rehabilitation (days):		
Mean (SD)	51	(30.6)
Range	1-170	
Total admission FIM score:		
Mean (SD)	83.3	(20.6)
Range	32-123	
Total discharge FIM score:		
Median (IQR)	112	(15)*
Range	33-126	
Change in FIM score:		
Mean (SD)	23.6	(15.3)
Range	-20-59	

independently would score 7. All staff were trained in the use of FIM and most were tested for reliability. Not all staff at CGMC undertook FIM reliability testing because it was only carried out once for rehabilitation staff during the two year data collection period. However, all staff members underwent extensive training in the FIM by qualified FIM instructors and the FIM scoring was performed in the context of the team meeting during which more experienced staff provided supervision.

All patients were assessed by the rehabilitation team and then participated in a routine therapy program according to their needs. This included one or two physiotherapy sessions per day with their treating physiotherapist. Physiotherapists working in the Neurological Rehabilitation Unit used an eclectic approach to treatment, drawing on the principles of the Bobath treatment approach (Davies 1985) and the Movement Science approach (Carr and Shepherd 1987). No attempt was made to standardise treatment during the two year data collection period.

Data analysis Records were audited retrospectively and prospectively and data was entered into a computer spreadsheet. The length of time between stroke and admission to rehabilitation and the length of stay for each subject were calculated. The MAS and FIM scores for each subject were recorded along with the total admission and discharge FIM scores. Change scores for each of the outcome measures were calculated.

Statistical analysis was undertaken using Statview SE + Graphics (Abacus Concepts Inc. 1988-1991) statistical software package. Descriptive statistics were used to describe the sample characteristics. Means, standard deviations, medians and modes were also calculated for admission and discharge scores on the MAS Items 6-8, FIM score for upper body dressing and the total FIM. Wilcoxon's signed rank test was used to determine if there was a significant change in these scores during rehabilitation. Scatter plots were drawn to examine the changes that had occurred. Spearman's correlation co-efficient was used to determine if there was a relationship between the scores on the MAS upper limb subtests, Items 6, 7 and 8, and the FIM sub-score for upper body dressing. Scatter plots were drawn to examine these relationships further. For each statistical test, the alpha value was set at 0.05.

Table 2. Number of subjects with scores of 0 or 6 on admission whose scores did not change during the period of rehabilitation.

MAS Item Number	Subjects scoring 0 on admission and discharge	Subjects scoring 6 on admission and discharge
Item 6	17	60
Item 7	25	47
Item 8	31	46
Items 6-8	15	40

Table 3. Relationships between the MAS scores for Items 6, 7 and 8 and the FIM score for upper body dressing (UBD) on discharge.

Relationship	Spearman's rho	*p*
Item 6: UBD	0.61	0.0001
Item 7: UBD	0.53	0.0001
Item 8: UBD	0.53	0.0001

Results

Subject demographics are summarised in Table 1.

Changes in MAS and FIM scores during rehabilitation Significant improvement occurred during rehabilitation for both MAS and FIM scores from admission to discharge ($p < 0.05$). Figure 1 shows the scatter plots for the admission and discharge scores on the MAS and the FIM for upper body dressing. Once the subjects who had perfect scores initially were excluded, the median change score for MAS Items 6-8 was 1.

Figure 1A-C shows a triangular shift towards the upper left half of the scatter plot, indicating an improvement in most subjects during rehabilitation. A cluster effect was observed to a varying extent in all three scatter plots with numerous subjects scoring either 0 or 6 on both admission and discharge for Items 6-8 of the MAS). At discharge from rehabilitation, a total of 60 (39.2%) subjects scored 6 on all three items. Few patients scored in the middle range of the scale for Item 8, in particular scores 4 and 5. Table 2 shows the number of subjects who scored 6 on all three items at admission and on discharge from rehabilitation.

Most subjects improved their score on the upper body dressing item of the FIM (Figure 1D). Eighty per cent of subjects scored either 6 or 7 on discharge. Clustering in this instance occurred for those subjects who scored 7 on admission and discharge ($n = 28$) and those who scored 4 on admission and 7 on discharge ($n = 28$).

Relationship between the MAS and FIM scores Table 3 shows the relationship between the MAS scores for upper limb function on discharge and the FIM score for upper body dressing on discharge. These results indicated a moderate relationship between the outcome measures based on the guidelines in Portney and Watkins (1993, p. 442). However, inspection of the scatter plots (example shown in Figure 2) suggested that because the majority of scores were high, and the relationship of the other scores was diffuse, this correlation index was not a useful one. In general, the scatter plots showed that there was only a diffuse pattern of agreement and a clustering at score 6 for the MAS items and score 7 for the FIM sub-score for upper body dressing, indicating that no true relationship existed.

Discussion

In our sample, significant improvement was demonstrated in some subjects for all upper limb outcome measures during inpatient rehabilitation after stroke, although the median change for the group indicated that this improvement might not be clinically significant. It is one of the largest audits of upper limb recovery that has been conducted in Australia, involving 153 subjects over a two year period. The results emphasize the importance of using outcome measures that take into account both movement and function, and support the suggestion

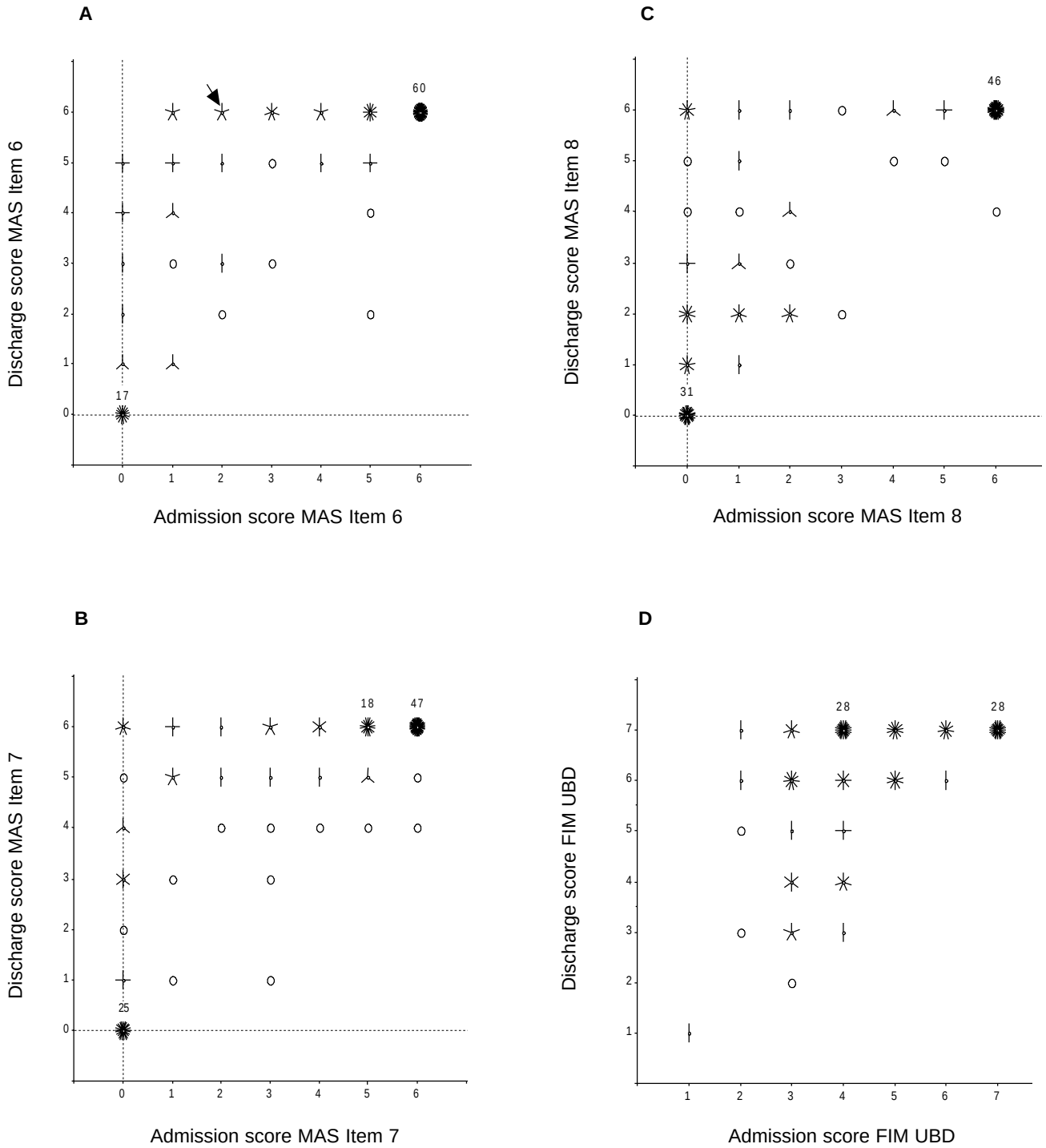

Figure 1. Scatter plots showing relationship between initial and discharge scores for MAS and FIM measures. Circles denote a single subject. The number of "petals" on each "flower" denote the number of subjects. For example, the arrowed co-ordinate in A indicates that five people who scored 2 on admission scored 6 on discharge. Numbers refer to the number of subjects arrowed achieving those scores. UBD, upper body dressing.

of Dean and Mackey (1992) that a non-functional upper limb should not be accepted as the norm after stroke; some return of arm function is possible, but this can only be demonstrated using appropriate outcome measures. Dean and Mackey (1992) noted significant improvement on all items of the MAS in 70 stroke patients between admission and discharge from rehabilitation. Full scores on the upper limb sub-tests were achieved by 48% of patients on Item 6 Upper Arm Function, by 46% on Item 7 Hand Movements and by 53% on Item 8 Advanced Hand Activities on discharge.

Item 6 of the MAS indicates the ability of the subject to perform movements at the shoulder and elbow. Seventy-three per cent of subjects scored at least 5 on this item, indicating they had the ability to lift the extended arm to 90 degrees of forward flexion and to maintain the position for 10 seconds. This degree of upper limb movement would allow a subject to reach forward to position the hand for a functional activity such as turning on a light switch, picking up an object or opening a cupboard. The level of functional activity possible is ultimately dependent on the amount of wrist and hand movement available.

To fulfill the criterion for a full score on Item 6 of the MAS, a subject must be able to stand and hold their arm against a wall while they move their body. This item tests not only upper arm control but also the ability to stand independently. One problem with this MAS item is that if a subject is unable to stand, then they will not be able to record a full score. Nonetheless, 61.4% of the 153 subjects in the study achieved a score of 6 on Item 6.

Item 7 of the MAS measures the subject's ability to move the wrist, forearm and hand, and the ability to incorporate these movements into functional activities such as picking up a ball with both hands or moving a polystyrene cup from one side of the table to the other. The former activity is the only test in the MAS that involves bilateral arm function. On discharge, 74% of subjects were able to perform this gross bimanual task: picking up a 14cm diameter ball (Criterion 4). The MAS does not test fine, manipulative bimanual hand activities and assessment of the hemiplegic upper limb may therefore need to be supplemented by a test such as the Upper Extremity Performance Test for the Elderly (TEMPA; Desrosiers et al 1993) which includes five bimanual tasks.

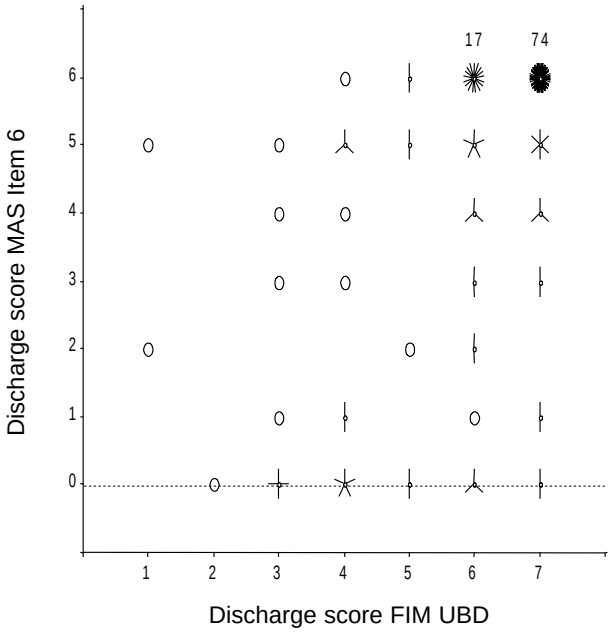

Figure 2. Relationship between the MAS score for Item 6, Upper Arm Function, and the FIM score for Upper Body Dressing (UBD) at discharge. Grids denote a single subject. Refer to legend in Figure 1 for key.

A full score for Item 7 was achieved by 58.2% of the subjects on discharge, and 68.7% of subjects scored at least 5, indicating that they were able to pick up a polystyrene cup and put it down on the other side of the table. It is encouraging that a large percentage of the subjects in this study were able to perform a motor skill integral to everyday life: moving an object from one place to another in the horizontal plane. These results compare favourably with those of other studies that have used the MAS. Dean and Mackey (1992) reported that 47.7% scored 6, 60% scored 5 or more (n = 65) and Kilbreath and Heard (1997) reported 39% scored at least 5 (n = 218).

Item 8 of the MAS reflects a subject's ability to perform fine motor skills with the hand, such as picking up a pen cap, as well as the ability to perform activities involving the whole upper limb such as taking a spoon to the mouth and combing hair. Time taken to perform activities is taken into account. The activities tested involve a high level of co-ordination and the integration of component movements and being able to perform any activity in Item 8 indicates

that a subject has some degree of functional use of the upper limb. A polarisation of scores for Item 8 at 0 and 6, similar to that identified by Dean and Mackey (1992), also occurred in this study.

The rates of improvement on Item 8 reported in both this study and that by Dean and Mackey (1992) provide further support for the idea that it is possible for recovery of upper limb function to occur to an advanced level after stroke. However, the clustering of results for this item emphasises that the hierarchical ranking of Item 8 must be reviewed to determine whether stroke patients who are able to perform the fine manipulation required to retrieve a jelly bean from a cup, but cannot draw lines or make dots with the speed required to fulfill a score of 3 or 4, can in fact perform a task that is crucial to independence, ie lifting a spoon to the mouth.

It should be reiterated that patients who had neurosurgical intervention were not included this study, which means the results are only representative of the patient population at CGMC with stroke who did not require surgery. Differences in results between this and other studies using the MAS (Dean and Mackey 1992, Kilbreath and Heard 1997) may be attributed to differences in the sample populations, as these studies appear to have included stroke patients who had neurosurgical intervention for management of subarachnoid haemorrhage or intracerebral haemorrhage.

In this study, 28 subjects had to be excluded from the final data analysis because of incomplete data. Thirty-two per cent of these subjects had not had MAS testing performed because they were at a high level of motor functioning and had no apparent motor deficits. They were admitted to rehabilitation for cognitive and language therapy. However, 40 (26.1%) of the subjects included in this study recorded full upper limb MAS scores on admission and discharge. These subjects may have had subtle deficits that were not detected by the MAS or may not have had any motor deficits.

The MAS incorporates active movement, speed of performance and functional ability to provide a thorough assessment of the affected upper limb. However, it does not measure high level upper limb function. Subjects may have a full score on Items 6, 7 and 8 but still have limited ability to use their affected arm. They may not be able to perform high level skills such as writing and touch typing, gardening, carpentry, driving with normal controls, or sporting activities such as golf, tennis and swimming. These activities, though not as essential to daily living as bathing and dressing, are important for leisure and work and an inability to perform them may severely diminish a person's quality of life. Nevertheless, a person recording a full score of 6 on each of the upper limb items of the MAS would be deemed to have a high level of recovery of the hemiplegic upper limb. Thirty nine per cent of subjects fulfilled these requirements for a full recovery. Only 9.8% of subjects had no movement in the affected upper limb on discharge from rehabilitation and scored 0 on all three upper limb items of the MAS. The MAS data in this study has provided a useful indication of the degree of upper limb recovery after stroke. It is a relatively easy test to perform, using equipment that would normally be available in any physiotherapy department.

Significant improvement occurred in upper body dressing from admission to discharge, and 80% of subjects in this study scored 6 or 7 on discharge from rehabilitation, indicating modified independence or independence in upper body dressing. The mean scores at admission and discharge compare favorably with those of other studies (Hamilton and Granger 1994, Keith et al 1995, Wilson et al 1991). However, it must be noted that patients who required neurosurgical intervention were excluded from this study.

No relationship was found at discharge between the FIM score for upper body dressing and the scores for each of the upper limb sub-tests of the MAS. Movement of the hemiplegic upper limb was not related to ability to perform a functional task involving the upper limb. It was also apparent that some subjects were able to score 6 or 7 for upper body dressing, indicating complete or modified independence in dressing, but had a low score on the MAS. It was not necessary to have full upper limb function, as measured by the MAS, to be able to dress the upper body independently.

The sub-tests of the MAS used in this study provide a clearer profile of the recovery of the affected upper limb than the upper body dressing score of the FIM. Previous studies have used items of the Barthel Index, such as upper body dressing, grooming and feeding, to measure upper limb recovery after stroke

(Anderson et al 1995, Nakayama et al 1994a and 1994b, Olsen 1989 and 1990, Parker et al 1986, Shah et al 1991). If their example is followed and the FIM score for upper body dressing is used to measure recovery after stroke, then in this study 58.2% of subjects would have been deemed to have made a very good recovery of upper limb function. However, this proportion is much higher than the 39.2% of subjects who scored 6 on all three upper limb sub-tests of the MAS, indicating a good recovery of upper limb function. If the upper body dressing score is used as a measure of affected upper limb recovery then, as these results show, a misleading level of recovery is recorded, with the inference that upper limb recovery after stroke is better than the reality.

The FIM is widely used in Australian hospitals because it has been shown to be both valid and reliable and takes only a short time to administer. However this measure may provide a distorted view of a patient's ability in terms of upper limb function. Despite the increased time the MAS takes to perform, this study shows that the MAS provides valuable qualitative information about recovery after stroke, which is not available when measures of disability, such as the FIM, are used in isolation. It is vital that physiotherapists use standardised measures of impairment, such as the MAS, to obtain information about recovery after stroke. This will enable them to best predict and optimise patient outcome and allocate resources appropriately.

Further research could address the fact that outcome measures in this study were collected at admission and discharge from rehabilitation and not at set times after stroke, so that it was not possible to systematically examine the pattern of recovery occurring over time. In addition the effects of pain, passive range of movement, tone, sensation, neglect, dyspraxia and hand dominance on upper limb recovery and MAS performance after stroke need further investigation.

Conclusion

Significant improvements were identified for all the upper limb outcome measures used in this study and the results were encouraging when compared with previous studies. Recovery of the upper limb, although variable, is possible after stroke. Furthermore, a non-functional arm can no longer be considered typical in the general non-surgical stroke population in a rehabilitation facility. Although the MAS has limitations, it remains a valuable tool for measuring upper limb outcome after stroke because it provides information at both upper and lower limits of recovery, and a more accurate profile of true upper limb recovery than the FIM. The MAS is recommended as a standard physiotherapy outcome measure after stroke.

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References

Anderson CS, Linto J and Stewart-Wynne EG (1995): A population based assessment of the impact and burden of care-giving for long-term stroke survivors. *Stroke* 26: 843-849.

Anderson CS, Jamrozik KD, Burvill PW, Chakera TMH, Johnson GA and Stewart-Wynne EG (1993): Ascertaining the true incidence of stroke: experience from the Perth Community Stroke Study, 1989-1990. *Medical Journal of Australia* 158: 80-84.

Carr JH and Shepherd RB (1998): Neurological Rehabilitation: Optimizing Motor Performance. Oxford: Butterworth-Heinemann, pp. 49.

Carr JH and Shepherd RB (1987): A Motor Relearning Program for Stroke. (2nd ed.) London: William Heinemann.

Carr JH, Shepherd RB, Nordholm L and Lynne D (1985): Investigation of a new motor assessment scale for stroke patients. *Physical Therapy* 65: 175-180.

Davies PM (1985): Steps to Follow. A Guide to the Treatment of Adult Hemiplegia. Berlin: Springer-Verlag.

Dean C and Mackey F (1992): Motor assessment scale scores as a measure of rehabilitation outcome following stroke. *Australian Journal of Physiotherapy* 38: 31-35.

Desrosiers J, Hebert R, Dutil E and Bravo G (1993): Development and reliability of an upper extremity function test for the elderly: the TEMPA. *Canadian Journal of Occupational Therapy* 60: 9-16.

Dodds TA, Martin DP, Stolov WC and Deyo RA (1993): A validation of the Functional Independence Measurement and its performance among rehabilitation in-patients. *Archives of Physical Medicine and Rehabilitation* 74: 531-536.

Duncan PW, Goldstein LB, Matchar D, Divine GW and Fussner J (1992): Measurement of motor recovery after stroke: Outcome assessment and sample size requirements. *Stroke* 23: 1084-1089.

Granger CV, Hamilton BB and Fiedler R (1992): Discharge outcomes after stroke rehabilitation. *Stroke* 23: 978-82.

Hamilton BB and Granger CV (1994): Disability outcomes following inpatient rehabilitation for stroke. *Physical Therapy* 74: 494-503.

Hamilton BB, Laughlin JA, Fiedler RC and Granger CV (1994): Interrater reliability of the 7-level Functional Independence Measure (FIM) *Scandinavian Journal of Rehabilitation Medicine* 26: 115-119.

Hamilton BB, Granger CV, Sherwin FS, Zielezny M and Tashman JS (1987): A uniform national data system for medical rehabilitation. In Fuhrer M (Ed.): Rehabilitation Outcomes: Analysis and Measurement. Baltimore: Paul H Brookes Publishing Inc, pp. 137-147.

Hamilton BB, Laughlin JA Granger CV and Kayton RM (1991): Interrater agreement of the seven-level Functional Independence Measure (FIM). *Archives of Physical Medicine and Rehabilitation* 72: 790.

Heller A, Wade DT, Wood VA, Sunderland A, Langton Hewer R and Ward E (1987): Arm function after stroke: measurement and recovery over the first three months. *Journal of Neurology, Neurosurgery and Psychiatry* 50: 714-719.

Keith RA, Wilson DB and Gutierrez P (1995): Acute and subacute rehabilitation for stroke: a comparison. *Archives of Physical Medicine and Rehabilitation* 76: 495-500.

Kidd D, Stewart G, Baldry J, Johnson J, Rossiter D, Petruckevitch A and Thompson AJ (1995): The Functional Independence Measure: a comparative validity and reliability study. *Disability and Rehabilitation* 17: 10-14.

Kilbreath SL and Heard R (1997): Upper and lower limb function in stroke patients following task-specific training. Proceedings of the Australasian Faculty of Rehabilitation Medicine 5th Annual Scientific Conference. Perth, pp. 22-23.

Loewen SC and Anderson BA (1988): Reliability of the Modified Motor Assessment Scale and the Barthel Index. *Physical Therapy* 68: 1077-108.

Nakayama H, Jørgensen HS, Raaschou HA and Olsen TM (1994a): Recovery of upper extremity function in stroke patients: The Copenhagen Stroke Study. *Archives of Physical Medicine and Rehabilitation* 75: 394-398.

Nakayama H, Jørgensen HS, Raaschou HA and Olsen TM (1994b): Compensation in recovery of upper extremity function after stroke: The Copenhagen Stroke Study. *Archives of Physical Medicine and Rehabilitation* 75: 852-857.

National Health and Medical Research Council (1997): Prevention of Stroke: The Role of Anticoagulants, Antiplatelet Agents and Carotid Endarterectomy. Canberra: National Health and Medical Research Council.

Olsen TS (1989): Improvement of function and motor impairment after stroke. *Journal of Neurological Rehabilitation* 3: 187-192.

Olsen TS (1990): Arm and leg paresis as outcome predictors in stroke rehabilitation. *Stroke* 21: 247-251.

Ottenbacher KJ, Hsu Y, Granger CV and Fiedler RC (1996): The reliability of the Functional Independence Measure: a quantitative review. *Archives of Physical Medicine and Rehabilitation* 77: 1226-1232.

Parker VM, Wade DT and Langton Hewer R (1986): Loss of arm function after stroke: measurement, frequency, and recovery. *International Rehabilitation Medicine* 8: 69-73.

Poole JL and Whitney SL (1988): Motor Assessment Scale for stroke patients: concurrent validity and interrater reliability. *Archives of Physical Medicine and Rehabilitation* 69: 195-197.

Portney LG and Watkins MP (1993): Foundations of Clinical Research. Applications to Practice. Connecticut: Appleton and Lange, pp. 439-455.

Shah S, Vanclay F and Cooper (1991): Stroke rehabilitation: Australian patient profile and functional outcome. *Journal of Clinical Epidemiology* 44: 21-28.

Uniform Data System for Medical Rehabilitation (1993): Guide for the uniform data set for medical rehabilitation (Adult FIM) Australian Version 4.0, effective 1 April 1994. UB Foundation Activities Inc.

Wilson DB, Houle DM and Keith RA (1991): Stroke rehabilitation: a model predicting return home. *Western Journal of Medicine* 154: 587-590.

World Health Organisation (1980): International Classification of Impairments, Disabilities and Handicaps. Geneva: World Health Organisation.