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Stroke patients and long-term training: is it worthwhile? A randomized comparison of two different training strategies after rehabilitation

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Objective: To find out if there were any differences in improvement and maintenance of motor function, activity of daily living and grip strength between patients with first-ever stroke receiving two different strategies of physical exercise during the first year after stroke.
Design: A longitudinal randomized controlled stratified trial.
Setting: Rehabilitation institutions, community, patients' homes and nursing homes.
Subjects: Seventy-five male and female first-time-ever stroke patients: 35 in an intensive exercise group and 40 in a regular exercise group.
Intervention: The intensive exercise group received physiotherapy with focus on intensive exercises in four periods during the first year after stroke. The regular exercise group patients were followed up according to their subjective needs during the corresponding year.
Main outcome measures: Motor Assessment Scale, Barthel Index of Activities of Daily Living, and grip strength.
Results: Both groups improved significantly up to six months when function stabilized. The groups did not differ significantly on any test occasions. The difference of improvement from admission to discharge was significant in favour of the intensive exercise group, in the Motor Assessment Scale total score (intensive exercise group 7.5; regular exercise group 1.7, $P = 0.01$), and in the Barthel Index of Activities of Daily Living total score (17.4 versus 8.9, $P = 0.04$).
Conclusion: Motor function, activities of daily living functions and grip strength improved initially and were maintained during the first year after stroke in all patients irrespective of exercise regime. This indicates the importance of motivation for regular exercise in the first year following stroke, achieved by regular check-ups.

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Introduction

Stroke is a major cause of disability, and its long-term effects often lead to a need of rehabilitation services. It has been shown that intensive stroke unit care and functional exercises are beneficial in the acute rehabilitation of stroke patients. The length of stay at rehabilitation units for stroke patients is decreasing, leaving patients with incomplete recovery at discharge and in need of follow-up services.[1–5]

Investigations concerning interventions in the longer perspective after stroke are not so common. However, stroke patients have been found to benefit from exercises after stroke.[6–9] Studies of stroke patients after the acute phase have often focused on specific functions such as gait or arm movements. The duration of treatment has varied, for example from three weeks to six months, and often the treatment does not start until one year or longer after the stroke.[10–14] Some studies have focused on rehabilitation in the home, but the follow-up therapy has had a short duration, and the intensity of the programmes has been submaximal.[15–23] One of our previous studies, in which stroke patients were followed up for four years after the acute event, revealed a change from the intensive treatment in the acute phase to little or no physiotherapy or other rehabilitation activities after this period.[24]

The same study confirmed what other studies had shown, that a deterioration of activities of daily living and motor function and increased dependence on relatives were apparent at one year and critical after four years of follow-up.

It is yet to be established what kind of rehabilitative care after stroke is needed to enhance motor function and what contributes to a more independent life for a longer period of time, and to be determined whether deterioration is a natural development of the disease. If the latter is the case, strategies in primary care need to be altered to meet an increased demand for help.

There is a general assumption that physical exercises are beneficial at all stages of stroke, but it is questionable whether these benefits are sustained after the treatment ends.[8,23] To our knowledge, there have been no longitudinal studies of the effects of uninterrupted regular physical exercises in stroke patients from the acute phase up to one year after stroke.

The present study was undertaken to find out if there were any differences in motor function, function of activities of daily living and grip strength between two groups of patients with first-time-ever stroke treated in a stroke unit in the initial phase and given different follow-up treatments during the first year after the onset.

The main research question was: Will there be a difference in how first-time-ever stroke patients improve and maintain their motor function, as measured with the Motor Assessment Scale, independence in activities in daily living measured with the Barthel Index of activities of daily living, and grip strength, measured with a Martin vigorimeter, if they receive continued intensive training compared with treatment only when required?

A further aim was to determine whether there were any differences in the numbers of patients who lived in their own homes after one year, who used community services, or received help from relatives between the groups receiving the two different types of training regimes.

It was hypothesized that patients undergoing the intensive treatment programme would have better motor function, be more independent in daily living and have better grip strength at one year of follow-up compared with those who received training when needed.

Methods

Design

This study was a longitudinal randomized controlled stratified trial conducted on male and female patients with first-ever stroke during the first year after the onset. At discharge from the acute hospital, patients were randomized to one of two different groups by a person not involved with the patients or the treatment in the ward. Randomization was performed with a die: patients with uneven numbers went to group 1, an intensive exercise group, and those with even numbers to group 2, a regular exercise group.

Stratification was according to gender and hemisphere lesion: the first male patient with a right hemisphere lesion and with an uneven number was allocated to the intensive exercise group, and the next male patient with a right hemisphere lesion was allocated to the regular exercise group. The procedure with the die was then used when the third male patient with a right hemisphere lesion entered the stroke unit and so on. A corresponding procedure was followed for female patients. The protocol was sealed for 1.5

years from the start of the study until the last patient included was tested at one year of follow-up. The study was an intention-to-treat trial with the aim of being double-blind; that is, neither the investigator nor the patients knew to which group the patients were allocated.

On the basis of an earlier study[4] a power calculation was made and it was estimated that 29 participants were required in each group to detect a difference in motor function with a significance level of 0.05 and a power of 80%.

Subjects

The patients were all admitted to the primary hospital covering a geographical area with a population of 140 000. Patients with stroke were consecutively screened for inclusion as they were admitted to the hospital. Participation in the study was voluntary. All participants and their families were informed about the tests and the use of the test results, and were asked to sign a written statement in which they formally consented to inclusion in the study. The informed consent was obtained by methods approved by the Regional Committee of Medical Research Ethics of Norway. The information, given in writing and verbally, was that the participants would be randomized to one of two groups at discharge, one of which would be given intensive physical therapy regularly with special emphasis on endurance, strength and balance during four periods, with a total treatment period of at least 80 hours, in the following year after discharge from the hospital. The exercises in this group were compulsory in that the therapy was initiated and planned throughout the first year by the physiotherapist regardless of the evaluated need. The other group would have physical therapy exercises in accordance with the routines in the community, if required. In some cases this means no follow-up treatment.

Inclusion criteria were first-time-ever stroke with neurological signs, computer tomography-confirmed stroke and voluntary participation. Exclusion criteria were more than one stroke incident, subarachnoid bleeding, tumour, other serious illness, and brainstem or cerebellar stroke. Seventy-five patients fulfilled the inclusion criteria and were randomized to one of the two groups after the first test occasion 3–5 days after admission. The randomization was put into effect as the patients were discharged from the hospital and did not interfere with the treatment at the hospital.

Outcome measures

A test protocol for evaluation of motor function, activities of daily living and grip strength was set up, consisting of well-known clinical measurements that could be implemented anywhere without laboratory equipment. The Motor Assessment Scale and the Barthel Index of Activities of Daily Living are both functional measurements that can be said to represent measurements on the activity level according to the World Health Organization's International Classification of Functioning.[25] Grip strength, on the other hand, is a test on the body organ and body structure level, according to the same classification.[25] These tests would give an overall, thorough impression of motor function from different levels and activities, throughout the first year after stroke.

The patients were tested on admission, at discharge, and three months, six months and one year after stroke by an experienced investigator, blinded to group allocation. The tests were performed in the general hospital, in the patients' homes and in community service centres.

The Motor Assessment Scale

The Motor Assessment Scale is a test of motor function developed by Carr and Shepherd.[26] Each item scores from 0 to 6. Hence the total scores range between 0 and 48. The test has been shown to have high inter- ($r = 0.89$–0.99) and intra-reliability ($r = 0.87$–0.98) and high construct cross-sectional validity ($r = 0.88$ and $r = 0.96$).[27] The Motor Assessment Scale scores in this study were also dichotomized into lower scores (0–35) and higher scores (36–48). The lower Motor Assessment Scale scores were estimated with a cut-off point of score 4 on all the subscores, scores below the cut-off indicating a lower level of motor function.

The Barthel Index of Activities of Daily Living

The Barthel Index of Activities of Daily Living is a test of primary activities of daily living developed by Mahoney and Barthel[27] for the purpose of measuring functional independence in personal care and mobility. The items are weighted differently. The scores reflect the amount of time and assistance required by a client. A score of 0 (complete dependence), 5, 10 or 15 is assigned to each level, with a possible total score of 100. The test has high scores for inter- ($r = 0.70$–0.88), and intra-reliability ($r = 0.84$ and $r = 0.98$) and construct cross-sectional validity ($r = 0.73$–0.77).[27,28] The

scores of the Barthel Index of Activities of Daily Living were also dichotomized into lower (0–59) and higher scores (60–100) in this study. This estimation was based on the clinical guideline of a cut-off point of 60, scores below which indicate a need for institutional care.[29]

Grip strength

Grip strength was measured with a Martin vigorimeter,[30] consisting of a manometer with rubber tubing and three different-sized rubber balls: male, female/young and child size. The manometer gives the respective reading in bars (1 bar = 100 kPa = 1.019 atm = 1.019 kp/cm^2). When taking the test, the patient has to squeeze the vigorimeter three times with all possible strength without seeing the gauge. The mean of the three squeezes is then used. Normal values of healthy people are: male adult 0.8–1.3 bar and for female adult 0.7–1.2 bar.[31–33] Validity has been compared between the Jamar dynamometer and the Martin vigorimeter and Pearson's product-moment correlation was $r = 0.89$ for the right hand and 0.90 for the left hand.[31] Test–retest reliability showed an intraclass correlation coefficient of 0.96 for the mean of three measures on the dominant hand and of 0.98 on the other.[34]

In addition, housing, help from the community and/or relatives, time from admission to discharge and civil status were recorded through the documentation at the stroke unit/rehabilitation centre and at the interviews with patients and relatives on the test occasions. Patients and relatives were also encouraged to keep track of the incidence of falls and pain. Falls were recorded by the patients and their relatives in a diary as they occurred. Pain was recorded likewise, as present or not between test occasions and was reported at the interviews, when the patients were asked about occurrences of falls and pain. The answers were noted by the investigator in the protocol. This recording was monitored in order to see whether the input of exercises could be related to pain or falls.

Treatment

During the acute phase of rehabilitation at the hospital both groups received functional task-oriented training tailored to their specific needs. The amount of training was equal in the two groups, with two periods per day, the two periods comprising a total of 1 hour of physiotherapy in combination with other specialized therapies according to the patients' needs. At discharge the patients were randomized into two separate groups, an intensive exercise group and a regular exercise group, as described above.

The subsequent training for the intensive exercise group included a functional exercise programme with emphasis on high intensity of endurance, strength and balance. The individualized training programmes were aimed at functional improvements but with variations, for example: getting up from a chair, walking indoors, Nordic walking outdoors, stationary bicycling, and stair walking, where the physiotherapist monitored the levels of intensity through Borg's Scale or through the pulse rate. A protocol with suggestions of types of exercises and levels of intensity was developed in discussion with all physiotherapists involved. This protocol was intended as a guideline. The goal of these exercises was to improve and maintain motor function, activities of daily living and grip strength. Patients in the intensive exercise group were also encouraged to maintain a high activity level apart from that in the training sessions.

If the patients in the regular exercise group were considered to be in need of follow-up treatment or rehabilitation they were assigned to that, but not on a regular basis. No specific treatment was recommended to this group. On the other hand, the same encouragement to maintain a high activity level besides the training, if any, was given to the regular exercise group.

In order to standardize the follow-up treatment and exercises given to the patients in the intensive exercise group, physiotherapists in the two communities to which the patients were transferred from the local hospital were contacted in advance of the study. A group of physiotherapists in the rehabilitation departments, homes for the elderly /community home services, and physiotherapists in private practices, agreed to receive the patients allocated to the intensive exercise group and treat them according to the training principles described in the protocol.

Arrangements were made for patients allocated to the intensive exercise group to have physiotherapy during four periods, with a minimum of 20 hours every third month, in the first year after the stroke (see Figure 1). The intervention sessions started immediately after discharge, two or three times a week if the patient was at home or attending a private physiotherapy practice, and daily if he or she was in a rehabilitation ward. This intervention was repeated after three months, six months and one year.

The regular exercise group patients were given follow-up treatment according to their needs, as considered by the rehabilitation staff at the stroke unit/rehabilitation department and by the rehabilitation team in the community after discharge. A simplified description of these exercises and of what was actually done in the intensive and regular exercise groups is given in Table 1a and b.

Compliance to the training programmes was recorded by the physiotherapists in charge of the

Table 1a Numbers of patients in the intervention group (IG) and the regular training group (RG) who practised different types of exercise with a physiotherapist (PT) or self-training

	Acute ward		Discharge		3 months		6 months		12 months	
	IG	RG	IG	RG	IG	RG	IG	RG	IG	RG
Intensive with PT	12	13	20	18	16	11	12	10	12	7
Intensive self-training				1	5	14	6	14	6	15
Submaximal with PT	19	14	11	14	7	6	6	2	5	3
Minimal with PT and/or self-training	3	10	1	5	3	2	5	4	4	2
No training					1	2	3	1	5	4
Death/withdrawal	1	2	3	2	3	5	3	9	3	9
Total (*n*)	35	40	35	40	35	40	35	40	35	40

Table 1b Suggested components of the intervention programme (time 45 minutes)

Endurance	
Intensity	
High	70–80%, calculated from maximal pulse: 208 – 0.7 × age (Tanaka 2001) or 15–17 (hard to very hard) on Borg's rating scale of perceived exertion. At least two pulse peaks when training
Medium	50–60% calculated from maximal pulse: 208 – 0.7 × age (Tanaka 2001) or 12–14 (hard to very hard) on Borg's rating scale of perceived exertion. At least two pulse peaks when training
Proposal exercises	Walking Bicycling on stationary bike (arm-, leg- or combined) Treadmill Step Working with balls or balloons
Strength	
Intensity	50–60% calculated from 1RM (repetition maximum), dynamic, concentric and eccentric with preference for the latter
Proposed exercises (repetition 10 × 3)	Extension of back: pulley, pull-down, 'walking stick', prone- extension Stomach: ordinary sit-ups with fixation of pelvis if necessary Arms: push-ups in chair, weight–lifting, water bottles, pulley Hips–legs: ordinary knee flexion/extension, walking stairs, steps Legs–feet: toe and heel rise on the floor, step, Airex mat, with or without support
Balance	Maximal level on Borg's scale: Varied with increasing difficulty: more or less visual input, visual or auditory 'disturbances', obstacles
Proposal exercises	Walking on even/uneven surface Walking in 8, keeping borders Walking on a line Dual task Obstacles Dancing Tai chi
If not possible with any of the above:	Sitting**:** senior dance, balls, balloons
Note:	Use breathing techniques; take breaks - especially with heart and lung problems. Do light stretching of large muscles after the end!

follow-up treatment. In the intensive exercise group compliance was considered high if the patients did the exercises in all four exercise periods in the year after the stroke and at least twice a week. In the patients of the regular exercise group any follow-up treatment after the acute rehabilitation was considered as high compliance, since the expectations of follow-up were minimal in this group, according to previous experiences.[24] The participants of both groups were also interviewed informally on each test occasion concerning their own training habits, their motivation for exercise, and whether and how they were doing exercises. Motivation was considered high if the participants did the exercises regularly, if they complied with the tests at different times during the follow-up year and if they verbally expressed a positive opinion of the importance of exercise. In order not to compromise blinding and disclose group allocation, the project leader made notes during these interviews so as to keep track of information and to be able to compare these notes on training habits with the actual training information given by the physiotherapists, as the seal of blinding was broken at the end of the study. This procedure was meant to be a double-check on the training habits and compliance by allowing comparison between subjective and objective information.

Statistical analysis

The results were analysed in an SPSS program version 13. Descriptive statistics were used to summarize demographic, stroke and baseline characteristics. All analyses were performed on an intention-to-treat basis. Means, medians and standard deviations (SD) were calculated for each clinical test. A general linear model, with a univariate analysis of variance (ANOVA) was used, with baseline to one year change in the respective scores of the Motor Assessment Scale, Barthel Index of Activities of Daily Living, and grip strength as a dependent variable and with treatment group as a primary factor and age and gender as covariates. In addition differences in improvement were calculated for total score on the Motor Assessment Scale, Barthel Index of Activities of Daily Living and grip strength and analysed in the same manner. A subgroup analysis on the dichotomized values of the Motor Assessment Scale and Barthel Index of Activities of Daily Living was also performed. The significance level was set at < 0.05.

Results

A total of 185 patients with a diagnosis of stroke according to the International Classification of Diseases 10 were registered during the period 1 September 2003 to 1 September 2004. After close screening, 75 were found to have a first-time-ever stroke and were consecutively included in the study: 35 in the intensive exercise group and 40 in the regular exercise group. Of these 75 initially included in the study, four died and four withdrew during the acute stage (Figure 1).

Reasons for withdrawal were: new diagnosis = 1; anxiety = 1; cognitive status/dementia = 1; advanced age (98 years) = 1; did not want to participate = 1.

Demographic data are presented in Table 2. There were no significant differences between the groups regarding age, hemisphere lesion, marital status at baseline, or admission to the stroke unit. The overall cause of the stroke was thrombosis or embolism with 29 such cases in the intensive exercise group and 36 in the regular exercise group, the other 10 being haemorrhages.

Outcomes

Both groups improved significantly in motor function (Motor Assessment Scale), activities of daily living (Barthel Index of Activities of Daily Living) and grip strength (vigorimeter) from admission to three months (Tables 3–5). Between the three-month and six–month follow-up this improvement had stabilized and there were no significant further improvements in either of the groups. At one-year of follow-up there was a tendency to a reduction of performance in the Motor Assessment Scale and Barthel Index of Activities of Daily Living in both groups, whereas grip strength still seemed to be improving (Table 5).

There were significant differences in improvement from admission to discharge in favour of the intensive exercise group, regarding the Motor Assessment Scale total score and subscores for turning in bed, standing up, upper extremity function and hand function, and also for the Barthel Index of Activities of Daily Living total score and subscores for dressing, transfer from bed to chair, walking capacity, and walking up and down stairs (Table 6). There were also significant group differences in improvement of grip strength in the paretic hand from the three- to six-month scores, and of the Motor Assessment Scale total scores from the six-month to the one-year scores (Table 6).

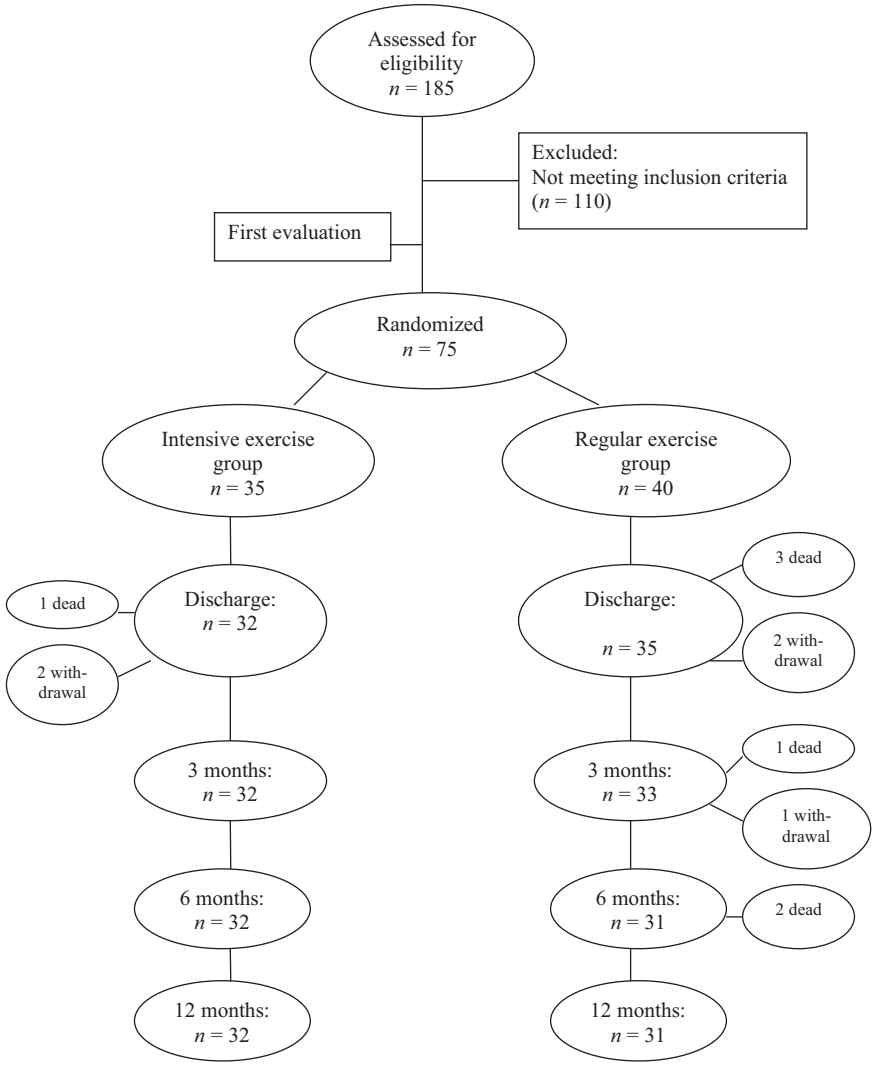

Figure 1 Flowchart for stroke patients included in the study 2003–2005: on admission, at discharge, and at 3, 6 and 12 months.

The mean motor function at baseline, as assessed by the Motor Assessment Scale, was higher in the regular exercise group ($m = 31.4$) than in the intensive exercise group ($m = 26.7$) (Table 3). The regular exercise group also had higher baseline values for activities of daily living, as measured by the Barthel Index of Activities of Daily Living (regular exercise group $m = 66$; intensive exercise group $m = 56.6$) (Table 4) and for grip strength, as assessed with the vigorimeter (regular exercise group 0.41 and 0.65 bar; intensive exercise group 0.37 and 0.55 bar) (Table 5). The differences were not significant, however.

The patients were also divided into those with lower Motor Assessment Scale scores (0–35) and those with higher scores (36–48) and the results confirmed the observed differences between the two exercise groups, although they were not significant. Fifty-four per cent of the patients in the intensive exercise group and 45% of those in the regular exercise group scored low on admission.

Table 2 Baseline demographic data for patients included in the two different groups and significance levels at $P<0.05$ for differences between the groups

	Intensive exercise group ($n=35$)	Regular exercise group ($n=40$)	*P*-values
Hemisphere lesion			
Right (*n*)	19	19	0.56
Left (*n*)	16	21	
Age mean (SD)	76 (12.7)	72 (13.6)	0.23
Medication Y/N (*n*)	33Y/2N	37Y/3N	0.89
Assistive devices (*n*)	5	4	0.5
Self-reported health status before stroke			
Good (*n*)	17	25	0.66
Minor problems (*n*)	17	11	
Moderate problems (*n*)	0	3	
Major problems (*n*)	1	1	
Occupation			
Retired (*n*)	28	27	0.37
Working (*n*)	7	13	
Civil status			
Married (*n*)	17	24	0.42
Widow/-er (*n*)	13	11	
Divorced (*n*)	3	2	
Single (*n*)	2	1	
Living together	0	2	
Children Y / N (*n*)	27Y/8N	25Y/15N	0.39
Days in the hospital (mean)	22	16	0.03*
SD	13	10	
Assistance with home services, shopping, cleaning, transport Y/N (*n*)	6Y/29N	4Y/36N	$P=0.29$

This difference had levelled out at discharge, when 40% and 42%, respectively, scored low. At the three-month follow-up the levelling had ceased and 38% in the intensive exercise group versus 30% in the regular exercise group had low scores. At the one-year follow-up 34% of the intensive exercise group patients and 19% of those in the regular exercise group had low scores. None of these differences were significant, however.

The same development was observed regarding activities of daily living when the scores were divided into low scores of 0–59 and high scores of 60–100 for analysis. At discharge, 26% in the intensive exercise group and 28% in the regular exercise group scored low on the Barthel Index of Activities of Daily Living. At the one-year follow-up 28% of the intensive exercise group and 10% of the regular exercise group had low scores. None of these differences were significant.

The patients in both groups were highly motivated for training and 25 patients in the intensive exercise group (71%) and 26 patients in the regular exercise group (65%) stated spontaneously on the test occasions that they found the exercises vital for their function and well-being. Compliance to the training programmes was high in 28 patients (80%) in the intensive exercise group and in 31 patients (78%) in the regular exercise group. The intensity of the programme was high in both groups, with a tendency to therapeutically steered training in the intensive exercise group and more self-initiated training in the regular exercise group (Table 1). Between the three-month and the 12-month follow-up the mean number of occasions of supervised exercise in the intensive exercise group was 2.1 times per week and in the regular exercise group 2.2 times per week. This amounts to approximately 40 weeks of exercise per year in both groups, which represents the 80 hours we initially aimed at in the intensive exercise group.

All patients included in the study came from their own homes in the local communities when admitted to the hospital. At discharge 15 patients in the in-

Table 3 Motor Assessment Scale (MAS): subscores 1–8 and total score on admission, at discharge, and 3, 6 and 12 months post stroke

	Admission $n=35$ *m* (Md) SD	Discharge $n=32$ *m* (Md) SD	3 months $n=32$ *m* (Md) SD	6 months $n=32$ *m* (Md) SD	1 year $n=32$ *m* (Md) SD
Intensive exercise group					
Turning in bed	3.6 (5)	4.6 (6)	4.9 (6)	5 (6)	4.9 (6)
	2.6	2.0	1.8	1.8	2
Sitting up	3.8 (5)	4.7 (6)	4.9 (6)	5.1 (6)	4.9 (6)
	2.4	1.8	1.6	1.5	1.8
Sitting	3.9 (4)	4.9 (6)	5.1 (6)	5.3 (6)	5.1 (6)
	2.1	1.6	1.4	1.1	1.5
Standing up	3.1 (2)	4.3 (5)	4.6 (5)	4.7 (6)	4.5 (6)
	2.4	1.99	1.8	1.8	2.1
Walking	2.8 (2)	3.9 (4)	4.2 (5)	4.3 (5)	4.2 (5.5)
	2.4	2.1	1.9	1.9	2.1
Upper arm function	3.5 (5)	4.5 (6)	4.7 (6)	4.8 (6)	4.8 (6)
	2.6	2.2	2	1.8	1.9
Wrist function	3.4 (4)	5.8 (5)	4.6 (5.5)	4.8 (6)	4.7 (5)
	2.6	8.8	2.1	1.9	1.9
Hand function	2.4 (2)	3.0 (2)	3.4 (3)	3.7 (5.5)	3.6 (4)
	2.5	2.4	2.5	2.5	2.5
MAS total	26.7 (29)	34.2 (42)	36.4 (42)	37.9 (43.5)	36.7 (43.5)
	18.2	14.9	13.9	12.8	14.3
Regular exercise group					
Turning in bed	4.5 (6)	4.7 (6)	5.1 (6)	5.4 (6)	5.4 (6)
	2.4	2.1	1.7	1.4	1.4
Sitting up	4.6 (6)	4.9 (6)	5.5 (6)	5.6 (6)	5.7 (6)
	2.1	1.9	1.3	1.1	1.1
Sitting	4.5 (6)	4.97 (6)	5.3 (6)	5.4 (6)	5.5 (6)
	2.0	1.6	1.2	1.2	1.2
Standing up	4.9 (5)	4.2 (5)	4.96 (6)	5.1 (6)	5.3 (6)
	5.4	2.1	1.7	1.5	1.3
Walking	3.5 (4)	4.1 (5)	4.8 (6)	4.9 (6)	5.0 (6)
	2.6	2.1	1.7	1.6	1.5
Upper arm function	4.3 (6)	4.5 (6)	4.7 (6)	4.9 (6)	5.2 (6)
	2.4	2.3	2.0	1.8	1.5
Wrist function	4.1 (5)	4.3 (5)	4.7 (6)	4.7 (6)	4.9 (6)
	2.4	2.4	2.2	2.2	2.2
Hand function	3.1 (3)	3.1 (2)	3.9 (6)	3.9 (6)	4.2 (6)
	2.6	2.6	2.6	2.5	2.5
MAS total	31.4 (41) 17.1	33.8 (42) 15.5	38.9 (46) 12.7	39.8 (47) 12.1	41.2 (48) 11.5

Mean (median) and SD are given for the two study groups. There were no significant differences between the groups. MAS subscore values range from 0 to 6 and the total score has a maximum of 48 points.

tensive exercise group and 19 in the regular exercise group were discharged to their own homes, and at the one-year follow-up 24 and 29 patients in these two groups, respectively, were living at home. There were no significant differences in this respect (Table 7).

There was a significant difference in the length of stay at the acute hospital. The mean stay of the patients in the intensive exercise group was 22 days, as compared to 16 days in the regular exercise group ($P=0.03$).

The patients of the intensive exercise group were receiving more help from relatives and the community on all test occasions. These differences were significant only at one year of follow-up ($P=0.04$).

Pain was being experienced by 15 of the intensive exercise group patients and by 13 of the regular

Table 4 Mean (median) and SD for Barthel Index of Activities of Daily Living (BI) subscores and total scores on admission, at discharge and 3 months, 6 months and 1 year after stroke in the two study groups

	Intensive exercise group					Regular exercise group				
	Admission *n* = 35 *m* (Md) SD	Discharge *n* = 32 *m* (Md) SD	3 months *n* = 32 *m* (Md) SD	6 months *n* = 32 *m* (Md) SD	1 year *n* = 32 *m* (Md) SD	Admission *n* = 40 *m* (Md) SD	Discharge *n* = 35 *m* (Md) SD	3 months *n* = 33 *m* (Md) SD	6 months *n* = 31 *m* (Md) SD	1 year n = 3 1 m (Md) SD
Feeding 0–10	6.6 (10) 4.2	7.6 (10) 3.5	8.3 (10) 2.4	8.6 (10) 2.3	8.3 (10) 2.7	7.1 (10) 3.9	7.9 (10) 3.2	8.8 (10) 2.5	8.9 (10) 2.4	8.8 (10) 2.7
Bathing self 0–5	1.9 (0) 2.5	2.4 (0) 2.5	3.2 (5) 2.4	3.3 (5) 2.4	3.3 (5) 2.4	2.5 (2.5) 2.5	2.6 (5) 2.5	3.2 (5) 2.4	3.8 (5) 2.2	3.9 (5) 2.0
Personal hygiene 0–5	2.6 (5) 2.5	3.7 (5) 2.2	4.4 (5) 1.7	4.4 / 5 1.7	3.9 (5) 2.1	3.4 (5) 2.4	3.9 (5) 2.1	4.4 (5) 1.7	4.7 (5) 1.2	4.7 (5) 1.0
Dressing 0–10	4.7 (5) 4.5	8.1 (10) 9.1	7.8 (10) 3.8	7.96 (10) 3.3	7.7 (10) 3.8	6.0 (10) 4.6	6.9 (10) 4.0	8.3 (10) 3.2	8.8 (10) 2.8	8.8 (10) 2.7
Bowel control 0–10	6.0 (10) 4.5	8.1 (10) 3.2	8.6 (10) 2.9	8.6 (10) 2.9	8.8 / 10 2.8	6.9 (10) 4.0	7.9 (10) 3.5	9.2 (10) 2.2	9.1 (10) 2.6	9.1 (10) 2.5
Bladder control 0–10	6.1 (5) 4.03	7.6 (10) 3.5	8.4 (10) 3.2	7.96 (10) 3.3	7.7 (10) 3.6	6.8 (10) 4.2	7.6 (10) 3.5	8.9 (10) 2.4	9.1 (10) 2.6	8.9 (10) 2.9
Toilet transfer 0–10	6.3 (5) 4.1	7.7 (10) 3.1	8.6 (10) 2.6	8.9 (10) 2.1	8.4 (10) 2.7	6.9 (10) 4.0	7.9 (10) 3.2	9.2 (10) 2.2	9.6 (10) 1.9	9.3 (10) 2.4
Transfer bed– chair 0–15	9.3 (10) 5.3	12.4 (15) 4.3	13.3 (15) 3.5	13.3 (15) 3.5	12.8 (15) 3.8	10.5 (15) 5.5	12.2 (15) 4.4	13.8 (15) 2.8	14.2 (15) 2.2	14.1 (15) 2.99
Walking 0–15	8.4 (10) 6.8	11.7 (15) 4.8	12.8(15) 3.8	13.3 (15) 3.0	12.3(15) 4.8	10.1 (15) 6.5	11.9 (15) 4.7	13.3 (15) 3.5	14.1 (15) 2.9	13.7 (15) 3.9
Walking stairs 0–10	4.7 (5) 4.99	7.3 (10) 3.7	7.8 (10) 3.3	7.96 (10) 3.3	7.7 (10) 3.8	6.0 (10) 4.8	6.9 (10) 4.2	8.5 (10) 3.2	9.1 (10) 2.6	9.7 (10) 2.6
BI total	56.6 (60) 38.9	75.5 (90) 30.6	82.96 (100) 26.4	84.5 (100) 23.9	80.8 (100) 29.5	66.0 (87.5) 39.0	75.8 (87.5) 30.4	87.6 (100) 21.5	91.2 (100) 19.9	87.7 (100) 27.8

There were no significant differences between the groups.
Barthel Index (BI) subscores range from 0 to 5, 0 to 10 or 0 to 15 depending on the item and the total score has a maximum of 100 points.
Md, median; SD, standard deviation.

Table 5 Grip strength (bar), measured with a Martin vigorimeter, in the two study groups; mean (*m*) and standard deviation (SD). There were no significant differences between the groups. Normative values of healthy people are: male adults 0.8–1.3 bar, and female adults 0.7–1.2 bar

	Intensive exercise group					Regular exercise group				
	Admission $n=35$ *m* (SD)	Discharge $n=32$ *m* (SD)	3 months $n=32$ *m* (SD)	6 months $n=32$ *m* (SD)	1 year $n=32$ *m* (SD)	Admission $n=40$ *m* (SD)	Discharge $n=35$ *m* (SD)	3 months $n=33$ *m* (SD)	6 months $n=31$ *m* (SD)	1 year $n=31$ *m* (SD)
Grip strength paretic hand	0.37 (0.36)	0.40 (0.34)	0.46 (0.34)	0.55 (0.42)	0.63 (0.46)	0.41 (0.26)	0.48 (0.29)	0.54 (0.39)	0.55 (0.41)	0.67 (0.43)
Grip strength non-paretic hand	0.55 (0.35)	0.62 (0.28)	0.68 (0.29)	0.77 (0.35)	0.87 (0.40)	0.65 (0.29)	0.73 (0.27)	0.79 (0.31)	0.81 (0.31)	0.99 (0.32)

exercise group at the end of the one-year follow-up period. Three patients in the intensive exercise group and one in the regular exercise group reported having had a fall during the whole period.

Discussion

This study is, to our knowledge, the first randomized controlled trial in which an intensive exercise programme is compared with regular treatment in first-time-ever stroke patients during the first year after the period in the acute stroke unit. Other similar studies have concerned patients with chronic stroke[6–7,9–14] and patients with mixed first- and second-time stroke[5–7,9–14] with interventions for shorter periods. The improved function in these studies could also be seen as a reduction of secondary complications and inactivity after stroke and not as a prolonged recovery after stroke. The benefit of treating a group of patients with first-time stroke for a longer period, such as one year in our study, is that the secondary complications in connection with inactivity are minimized. The improvement and maintenance of function can then be attributable to the spontaneous recovery and rehabilitation.

Our main findings were that the improvements in motor function, activities of daily living and grip strength during the acute rehabilitation period continued and were maintained during the first year after stroke. These observations were made in both the intensive exercise group and regular exercise group, contrary to our hypothesis. However, the exercise levels were high in both groups in this study, higher than anticipated from earlier experience.[24] This was unintentional but probably due to high motivation of all participants regardless of group allocation. We believe this high motivation was triggered by the test occasions and regular contact with a physiotherapist initiating higher exercise levels in the regular exercise group, identical to those of the intensive exercise group.

In this study, the improvements in the scores of the Motor Assessment Scale and the Barthel Index of Activities of Daily Living, in both groups, were larger at three months and one year than were found in a previous follow-up study of stroke patients who received little or no treatment in the after-stroke period.[24] These improvements and the maintenance of motor function, activities of daily living and grip strength in

Table 6 The mean difference and SD in improvement of total scores between different test occasions, for the Motor Assessment Scale, Barthel Index of Activities of Daily Living and grip strength measured in bar in the paretic and non-paretic hand, with *P*-values for significant differences between the groups

	Intensive exercise group ($n=35$)	Regular exercise group ($n=40$)	*P*-values
Motor Assessment Scale			
adm–dis	7.5 (10.7)	1.7 (4.6)	0.01*
dis–3 months	2.2 (5.1)	4.6 (4.2)	0.54
3–6 months	1.5 (4.6)	0.9 (3.1)	0.61
6 months–1 year	1.2 (3.9)	−0.7 (2.4)	0.02*
Barthel Index			
adm–dis	17.4 (24.6)	8.9 (13.6)	0.04*
dis–3 months	7.5 (12.2)	11.8 (12.9)	0.91
3–6 months	1.5 (11.4)	3.6 (10.4)	0.44
6 months–1 year	−3.7 (9.8)	−3.5 (13.1)	0.71
Grip strength, paretic hand			
adm–dis	0.03 (0.2)	0.07 (0.2)	0.67
dis–3 months	0.05 (0.1)	0.06 (0.2)	0.86
3–6 months	0.01 (0.2)	0.01(0.1)	0.04*
6 months–1 year	0.08 (0.2)	0.12 (0.2)	0.16
Grip strength, non-paretic hand			
adm–dis	0.07 (0.2)	0.08 (0.1)	0.76
dis–3 months	0.06 (0.1)	0.06 (0.2)	0.90
3–6 months	0.09 (0.2)	0.02 (0.1)	0.11
6 months–1 year	0.1 (0.3)	0.18 (0.2)	0.61

adm, admission; dis, discharge.
*$P<0.05$.

Table 7 Living conditions in patients with stroke in the intensive exercise group (IG) and the regular exercise group (RG) on different test occasions

	Admission		Discharge		3 months		6 months		12 months	
	IG	RG	IG	RG	IG	RG	IG	RG	IG	RG
Own home	35	40	15	17	18	21	24	28	24	29
Rehabiltation			10	15	8	9	1	2	0	0
Service home			0	0	0	0	0	0	1	0
Short-term nursing home			7	2	5	2	1	1	1	0
Long-term nursing home			0	1	1	1	6	2	6	2
Withdrawal			2	2	2	3	2	3	2	3
Death			1	3	1	4	1	4	1	6

IG, intensive exercise group; RG, regular exercise group.

firs-time-ever stroke patients have not, to our knowledge, been shown in any other study.

In our opinion, these positive results are due to the regular exercise programmes and the regular follow-ups three, six and twelve months following the acute stroke (Table 1).

We did not find any significant differences in motor function, activities of daily living or grip strength between the intensive exercise and regular exercise group on any test occasion. This might be explained by several factors. One is that the motor function and activities of daily living were slightly better in the regular exercise group than in the intensive exercise group at the first test on admission. This difference should not, however, have had an impact on the patients' reactions to the rehabilitative input, since even

the most severely affected patients may experience meaningful improvement during early rehabilitation.[35–40]

Regarding the different degrees of improvement in the two groups, there was significantly greater improvement in the intensive exercise group in the total Motor Assessment Scale score and the total Barthel Index of Activities of Daily Living score, during the first rehabilitation period between admission and discharge (Table 6). Grip strength of the paretic hand showed the same tendency between the three- and six-month tests (Table 6). It might seem that the poorer function in the intensive exercise group on admission was compensated for by a more sensitive and rapid reaction to therapy in the early rehabilitation stage. It may be speculated whether brain plasticity is perhaps more pronounced in patients with severe damage than in those with less damage, since the therapy was equally distributed at that time in the two groups.[41] It has been proposed that the adult brain might be most plastic in the period immediately following an injury, offering a window of opportunity for therapeutic intervention.[41–45] It has also been suggested that the brain insult induces transient hyperexcitability of the unaffected motor cortex, mainly reflecting corticospinal excitability changes, but that this might also induce some degree of brain plasticity. The fact that the patients in the intensive exercise group had lower scores on admission than the regular exercise group but displayed more rapid improvement, especially in the acute setting at the stroke unit, might be an indication of a larger injury to the brain, and therefore higher susceptibility to therapy, since they improved and maintained this improvement during the year of follow-up.[46] Another explanation for the more rapid improvement in the intensive exercise group in the first six-month period might be that the stay in the hospital, which was significantly longer in that group than in the regular exercise group, was very beneficial for this group of patients. On the other hand, more patients from the regular exercise group were transferred directly to rehabilitation units in the community compared with patients in the intensive exercise group (Table 7). The length of acute stroke rehabilitation has not been discussed in the literature as much as the question of when to start the process of rehabilitation and the importance of adherence to guidelines.[7,47–50] Indirectly, however, this issue has been addressed by studies of extended stroke services and home programmes. The intervention part of these extended services varied in time from 4 to 44 weeks, and the type of intervention varied from exercises conducted by physio-, occupational and speech therapists to nurses' visits for delivery of medicine.[21] These extended services after early discharge have been proven to reduce long-term dependency and transfer to institutional care as well as to shorten hospital stays, indicating that exercises and follow-up are beneficial in combination with early rehabilitation in stroke units.[3–5,15–22] Our results support these findings.

The training levels, compliance and motivation in the two groups were equally high. There was no difference in training habits or follow-ups between the groups on any of the test occasions (Table 1). The intensive training that was compulsory in the intensive exercise group was compensated for by an extensive self-training programme in the regular exercise group. This latter was carried out in private physiotherapy practices or at home or in outdoor areas together with relatives or alone. This result was somewhat surprising. Our earlier study had revealed little or no physical activity in the first year after stroke.[24] This high compliance and training could have been triggered by the regular test occasions, which all patients of both groups were informed would take place three months, six months and one year after the stroke. The test occasions in themselves were strong motivators for training and seemed to make the participants, irrespective of group allocation, aware of their own need for exercise. This supportive role of supervision or of inclusion in a social group has also been noted in a study by Olney *et al.*[51]

Some of the participants in the intensive exercise group did not comply with the intended intensive exercise because of cognitive difficulties and lack of motivation. The relative numbers of patients with cognitive reduction and lack of motivation, however, were equal in the two groups, which levelled out the impact of this non-participation.

One of the weaknesses of the study is the fact that for different reasons the two groups were equally active in doing physical exercises. We did not have a true control with which to compare our findings. However, the results of these groups at the end of the year were better than those previously presented from comparable studies.[24,51] All the patients had kept their motor, hand and activities of daily living functions reasonably intact, which must be said to be an excellent achievement.

Another weakness is the fact that the intensive exercise group did not comply 100% with the proposed interventions. This of course must be seen in the light of the fact that stroke is a complex disease with a heterogeneous population and development. In that respect we had a representative stroke population in our study.

One fact that might be considered a weakness was that some therapists administered a submaximal programme to patients whom they had volunteered to exercise maximally. The reason for this was explained by the therapists involved as being a practical adaptation to pathological conditions such as heart failure, pain and a poor cognitive status, which inhibited a maximal effort. In order to carry out the exercises, adjustments were made so that routines could be maintained through the study period. This is probably also one of the reasons why so many patients complied with the exercise programmes.

Conclusion

Our main finding in this study was that the general improvement in motor function, activities of daily living and grip strength from the acute stage of the stroke continued to some extent and was maintained during the year of follow-up. This was observed in both the intensive exercise group and the regular exercise group, contrary to our hypothesis. A high positive impact of training on compliance to and motivation for exercises in the year after the stroke in both groups probably contributed to the results. The Motor Assessment Scale and the Barthel Index of Activities of Daily Living scores were higher at three months and one year than had been found in a previous study of function in stroke patients.[24] Grip strength improved in both groups and showed no decline at the one-year follow-up. Thus, the overall results of this study were positive, indicating that a more intensive follow-up programme during the first year after stroke is highly favourable.

A follow-up programme on a consultative basis is as beneficial as a compulsory exercise programme. However, these exercises need to be instituted and encouraged by medical staff with knowledge of and an interest in intensive functional exercise programmes individually tailored for stroke patients.

Clinical messages

- After initial rehabilitation following stroke, planned regular exercise continued over one year leads to a greater improvement in motor function than treatment ‘as required’.
- Many patients continue regular exercises after stroke rehabilitation even if not planned by a therapist.
- Concurrent other illnesses reduce the potential for exercise.

References

1 Asplund K, Berman P, Blomstrand C *et al.* How do stroke units improve patient outcomes? A collaborative systematic review of the randomized trials. *Stroke* 1997; **28**: 2139–44.

2 Indredavik B, Bakke F, Slordahl SA, Rokseth R, Haheim LL. Stroke unit treatment – 10-year follow-up. *Stroke* 1999; **30**: 1524–27.

3 Indredavik B, Bakke F, Slordahl SA, Rokseth R, Haheim LL. Treatment in a combined acute and rehabilitation stroke unit – Which aspects are most important? *Stroke* 1999; **30**: 917–23.

4 Langhammer B, Stanghelle JK. Bobath or Motor Relearning Programme? A comparison of two different approaches of physiotherapy in stroke rehabilitation: a randomized controlled study. *Clin Rehabil* 2000; **14**: 361–69.

5 Winstein CJ, Rose DK, Tan SM, Lewthwaite R, Chui HC, Azen SP. A randomized controlled comparison of upper-extremity rehabilitation strategies in acute stroke: a pilot study of immediate and long-term outcomes. *Arch Phys Med Rehabil* 2004; **85**: 620–28.

6 Dean CM, Richards CL, Malouin F. Task-related circuit training improves performance of locomotor tasks in chronic stroke: a randomized, controlled pilot trial. *Arch Phys Med Rehabil* 2000; **81**: 409–17.

7 Duncan PW, Horner RD, Reker DA *et al.* Adherence to afteracute rehabilitation guidelines is associated with functional recovery in stroke. *Stroke* 2002; **33**: 167–77.

8 Green J, Forster A, Bogle S, Young J. Physiotherapy for patients with mobility problems more than 1 year after stroke: a randomised controlled trial. *Lancet* 2002; **359**: 199–203.

9 Macko RF, Ivey FM, Forrester LW *et al.* Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke – a randomized, controlled trial. *Stroke* 2005; **36**: 2206–11.

10 McClellan R, Ada L. A six-week, resource-efficient mobility program after discharge from rehabilitation improves standing in people affected by stroke: Placebo-controlled, randomised trial. *Aust J Physiother* 2004; **50**: 163–67.

11 Peurala SH, Tarkka IM, Pitkanen K, Sivenius J. The effectiveness of body weight-supported gait training and floor walking in patients with chronic stroke. *Arch Phys Med Rehabil* 2005; **86**: 1557–64.

12 Salbach NM, Mayo NE, Robichaud-Ekstrand S, Hanley JA, Richards CL, Wood-Dauphinee S. The effect of a task-oriented walking intervention on improving balance self-efficacy afterstroke: a randomized, controlled trial. *J Am Geriatr Soc* 2005; **53**: 576–82.

13 Taub E, Lum PS, Hardin P, Mark VW, Uswatte G. AutoCITE – automated delivery of CI therapy with reduced effort by therapists. *Stroke* 2005; **36**: 1301–304.

14 Macko RF, Ivey FM, Forrester LW. Task-oriented aerobic exercise in chronic hemiparetic *stroke*: training protocols and treatment effects. *Top Stroke Rehabil* 2005; **12**: 45–57.

15 Holmqvist LW, von Koch L, Kostulas V *et al.* A randomized controlled trial of rehabilitation at home after stroke in southwest Stockholm. *Stroke* 1998; **29**: 591–97.

16 von Koch L, Pedro-Cuesta J, Kostulas V, Almazan J, Holmqvist LW. Randomized controlled trial of rehabilitation at home after stroke: one-year follow-up of patient outcome, resource use and cost. *Cerebrovasc Dis* 2001; **12**: 131–38.

17 Thorsen AM, Holmqvist LW, Pedro-Cuesta J, von Koch L. A randomized controlled trial of early supported discharge and continued rehabilitation at home after stroke – five-year follow-up of patient outcome. *Stroke* 2005; **36**: 297–302.

18 Indredavik B, Fjaertoft H, Ekeberg G, Loge AD, Morch B. Benefit of an extended stroke unit service with early supported discharge – a randomized, controlled trial. *Stroke* 2000; **31**: 2989–94.

19 Askim T, Rohweder G, Lydersen S, Indredavik B. Evaluation of an extended stroke unit service with early supported discharge for patients living in a rural community. A randomized controlled trial. *Clin Rehabil* 2004; **18**: 238–48.

20 Monger C, Carr JH, Fowler V. Evaluation of a home-based exercise and training programme to improve sit-to-stand in patients with chronic stroke. *Clin Rehabil* 2002; **16**: 361–67.

21 Langhorne P, Taylor G, Murray G *et al.* Early supported discharge services for stroke patients: a meta-analysis of individual patients' data. *Lancet* 2005; **365**: 501–506.

22 Leroux A. Exercise training to improve motor performance in chronic stroke: effects of a community-based exercise program. *Int J Rehabil Res* 2005; **28**: 17–23.

23 Duncan P, Studenski S, Richards L *et al.* Randomized clinical trial of therapeutic exercise in subacute stroke. *Stroke* 2003; **34**: 2173–80.

24 Langhammer B, Stanghelle JK. Bobath or Motor Relearning Programme? A follow-up one and four years after stroke. *Clin Rehabil* 2003; **17**: 731–34.

25 World Health Organization. *International Classification of Functioning, Disability and Health*. Accessed 30 January 2006, from http://www3.who.int/icf/icftemplate.cfm.

26 Carr J, Shepherd R. Modified Motor Assessment Scale. *Phys Ther* 1989; **69**: 780.

27 Finch E, Brooks D, Stratford PW, Mayo NE. MAS, Berg Balance Scale, Barthel ADL Index. In *Physical rehabilitation outcome measures*. Lippincott Williams & Wilkins, 2002: 169–172, 93–94, 87–90.

28 Wyller TB, Sveen U, BautzHolter E. The Barthel ADL Index one-year after stroke – comparison between relatives and occupational therapists scores. *Age Ageing* 1995; **24**: 398–401.

29 Granger CV, Sherwood CC, Greer DS. Functional status measures in a comprehensive stroke care program. *Arch Phys Med Rehabil* 1977; **58**: 555–61.

30 Solgaard S, Kristiansen B, Jensen JS. Evaluation *of* instruments *for* measuring grip strength. *Acta Orthop Scand* 1984; **55**: 569–72.

31 Desrosiers J, Hebert R, Bravo G, Dutil E. Comparison of the Jamar dynamometer and the Martin vigorimeter for grip strength measurements in a healthy elderly population. *Scand J Rehabil Med* 1995; **27**: 137–43.

32 Desrosiers J, Bravo G, Hebert R, Dutil E. Normative data for grip strength of elderly men and women. *Am J Occup Ther* 1995; **49**: 637–44.

33 Merkies ISJ, Schmitz PIM, Samijn JPA, Van der Meche FGA, Toyka KV, Van Doorn PA. Assessing grip strength in healthy individuals and patients with immune-mediated polyneuropathies. *Muscle Nerve* 2000; **23**: 1393–401.

34 Jones E, Hanly JG, Mooney R *et al.* Strength and function in the normal and rheumatoid hand. *J Rheumatol* 1991; **8**: 1313–18.

35 Jorgensen HS, Nakayama H, Raaschou HO, Olsen TS. Acute stroke: prognosis and a prediction of the effect of medical treatment on outcome and health care utilization – The Copenhagen Stroke Study. *Neurology* 1997; **49**: 335–42.

36 Kwakkel G, Wagenaar RC, Kollen BJ, Lankhorst GJ. Predicting disability in stroke – a critical review of the literature. *Age Ageing* 1996; **25**: 479–89.

37 Paolucci S, Antonucci G, Pratesi L, Traballesi M, Lubich S, Grasso MG. Functional outcome in stroke inpatient rehabilitation: predicting no, low and high response patients. *Cerebrovasc Dis* 1998; **8**: 228–34.

38 Black-Schaffer RM, Winston C. Age and functional outcome after stroke. *Top Stroke Rehabil* 2004; **11**: 23–32.

39 Paolucci S, Antonucci G, Grasso MG *et al.* Functional outcome of ischemic and hemorrhagic stroke patients after inpatient rehabilitation a matched comparison. *Stroke* 2003; **34**: 2861–65.
40 Ergeletzis D, Kevorkian RG, Rintala D. Rehabilitation of the older stroke patient – Functional outcome and comparison with younger patients. *Am J Phys Med Rehabil* 2002; **81**: 881–889.
41 Ward NS, Cohen LG. Mechanisms underlying recovery of motor function after stroke. *Arch Neurol* 2004; **61**: 1844–1848.
42 Dobrossy MD, Dunnett SB. Optimising plasticity: environmental and training associated factors in transplant-mediated brain repair. *Rev Neurosci* 2005; **16**: 1–21.
43 Ward NS, Brown MM, Thompson AJ, Frackowiak RSJ. Neural correlates of motor recovery after stroke: a longitudinal fMRI study. *Brain* 2003; **126**: 2476–2496.
44 Connor BB, Appelman J, Hardy JA *et al.* Older adults successfully use and benefit from a novel brain-plasticity-based training program. *Arch Clin Neuropsychol* 2005; **20**: 855.
45 Delvaux V, Alagona G, Gerard P, De Pasqua V, Pennisi G, de Noordhout AM. After-stroke reorganization of hand motor area: a 1-year prospective follow-up with focal transcranial magnetic stimulation. *Clin Neurophysiol* 2003; **114**: 1217–25.
46 Wiese H, Stude P, Sarge R, Nebel K, Diener HC, Keidel M. Reorganization of motor execution rather than preparation in afterstroke hemiparesis. *Stroke* 2005; **36**: 1474–79.
47 Musicco M, Emberti L, Nappi G, Caltagirone C. Early and long-term outcome of rehabilitation in stroke patients: the role of patient characteristics, time of initiation, and duration of interventions. *Arch Phys Med Rehabil* 2003; **84**: 551–58.
48 Langhorne P, Wagenaar R, Partridge C. Physiotherapy after stroke: more is better? *Physiother Res Int* 1996; **1**: 75–88.
49 Astrom M. Generalized anxiety disorder in stroke patients – a 3-year longitudinal study. *Stroke* 1996; **27**: 270–75.
50 Schepers VP, Visser-Meily AM, Ketelaar M, Lindeman E. Prediction of social activity 1 year after stroke. *Arch Phys Med Rehabil* 2005; **86**: 1472–76.
51 Olney SJ, Nymark J, Brouwer B *et al.* A randomized controlled trial of supervised versus unsupervised exercise programs for ambulatory stroke survivors. *Stroke* 2006; **37**: 476–81.