PAPER

Long term effects of intensity of upper and lower limb training after stroke: a randomised trial

G Kwakkel, B J Kollen, R C Wagenaar

J Neurol Neurosurg Psychiatry 2002;**72**:473–479

See end of article for authors' affiliations

Correspondence to: Dr G Kwakkel, Department of Physical Therapy, University Hospital Vrije Universiteit, Universiteit Department of Physiotherapy, PO Box 7057, 1007 MB Amsterdam, The Netherlands; g.kwakkel@vum.nl

Received 24 July 2001
In revised form 29 October 2001
Accepted 8 November 2001

Objective: To assess long term effects at 1 year after stroke in patients who participated in an upper and lower limb intensity training programme in the acute and subacute rehabilitation phases.
Design: A three group randomised controlled trial with repeated measures was used.
Method: One hundred and one patients with a primary middle cerebral artery stroke were randomly allocated to one of three groups for a 20 week rehabilitation programme with an emphasis on (1) upper limb function, (2) lower limb function or (3) immobilisation with an inflatable pressure splint (control group). Follow up assessments within and between groups were compared at 6, 9, and 12 months after stroke.
Results: No statistically significant effects were found for treatment assignment from 6 months onwards. At a group level, the significant differences in efficacy demonstrated at 20 weeks after stroke in favour of the lower limb remained. However, no significant differences in functional recovery between groups were found for Barthel index (BI), functional ambulation categories (FAC),action research arm test (ARAT), comfortable and maximal walking speed, Nottingham health profile part 1(NHP-part 1), sickness impact profile-68 (SIP-68), and Frenchay activities index (FAI) from 6 months onwards. At an individual subject level a substantial number of patients showed improvement or deterioration in upper limb function (n=8 and 5, respectively) and lower limb function (n=19 and 9, respectively). Activities of daily living (ADL) scores showed that five patients deteriorated and four improved beyond the error threshold from 6 months onwards. In particular, patients with some but incomplete functional recovery at 6 months are likely to continue to improve or regress from 6 months onwards.
Conclusions: On average patients maintained their functional gains for up to 1 year after stroke after receiving a 20 week upper or lower limb function training programme. However, a significant number of patients with incomplete recovery showed improvements or deterioration in dexterity, walking ability, and ADL beyond the error threshold.

Recently, small but significant overall effect sizes were found in favour of higher intensity of a stroke rehabilitation programme after pooling the findings of nine controlled trials.[1]. In a recent randomised controlled trial, Kwakkel *et al* provided more evidence for larger effect sizes as a result of higher intensity of upper and lower limb training in terms of activities of daily living (ADL), walking ability, and dexterity.[2] They attributed these favourable effects to factors within the design—that is, (1) increased treatment contrast between control and experimental treatment, (2) reduced heterogeneity of included patients with regard to neurological diagnosis and disability, and (3) optimal use of scaling properties of assessment instruments.[2] In addition, effects of rehabilitation seemed to be more pronounced within the first months after stroke, whereas little recovery took place thereafter. However, the question whether reported differences in treatment efficacies could still be discerned at 1 year after stroke was not addressed in this study.

The findings of several studies suggest that most patients maintain their achieved gains of rehabilitation in terms of ADL,[3–7] walking ability,[5] and dexterity[7] 6 months after stroke. Others indicated small but significant continuation of functional recovery up to 2 years after stroke,[8] particularly in response to a task oriented treatment programme.[9–16] However, some studies reported deterioration in disability, especially when patients were discharged home without adequate rehabilitative support.[17 18] In addition, it was found that severity of neurological impairments and disabilities in the first 6 months were indicative of the long term prognosis at 1 or 2 years after stroke.[7 11]

The objectives of the present study were (1) to determine if treatment effects are maintained within and between treatment groups from 6 months to 1 year after stroke, and (2) to identify those patients who are likely to show significant improvement or deterioration in ADL, walking ability, and dexterity from 6 months onwards.

SUBJECTS AND METHODS

Patients

The patients with stroke participating in the present study (1) had had a primary, first ever stroke in the territory of the middle cerebral artery (MCA) as shown by CT or MRI, (2) were between 30 to 80 years of age, (3) had an impaired motor function of upper as well as lower limbs, (4) were unable to walk at first assessment, (5) had no complicating medical history such as cardiac, pulmonary, or other neurological disorders, (6) had no severe deficits in communication, memory, or understanding, and (7) gave written or verbal informed consent, and were sufficiently motivated to participate in the research project. Stroke was defined clinically according to the World Health Organisation criteria[19] and classified according to the Bamford classification using clinical

Abbreviations: SAN, Dutch Foundation aphasia test; MMSE, mini mental state examination; OPS, Orpinton prognostic scale; BI, Barthel index; FAC, functional ambulation categories; ARAT, action research arm test; NHP, Nottingham health profile; SIP, sickness impact profile; FAI, Frenchay activities index; ADL, activities of daily living

Table 1 Documented frequencies of selected goals for treatment

Training of activities	Frequency of applied treatment goals during first 20 weeks			
	CT	UL	LL	p Value*
Air splint application	2504	0	0	0.000
Lower limb training:				
Impairments (for example, muscle strength and ROM)	517	434	655	0.475
Transfers	361	310	484	0.291
Sitting balance, sitting up from lying position	576	531	604	0.690
Standing balance	716	656	669	0.449
From sitting to standing/standing up from lying position	592	692	676	0.436
Gait: coordination, stability, symmetry, and velocity	1130	1225	1649	0.324
Climbing stairs, walking over uneven surfaces and doorsteps	366	332	703	0.069
Outdoor walking	215	168	367	0.185
Learning to use a walking aid	219	123	367	0.235
Other lower limb functions	278	129	351	0.164
Upper limb training:				
Impairments (for example, muscle strength and range of motion)	1778	1280	1991	0.164
Postural reactions and weight bearing	821	1346	871	0.580
Reaching, grasping activities	489	1054	724	0.189
Personal hygiene (for example, dressing, cooking, washing, and combing)	431	829	585	0.441
Application of sling or orthosis	11	26	19	0.808
Other functions	379	583	257	0.279

*χ^2 test.
UL, upper limb; LL, lower limb; CT, control group.

features to determine the size and site of infarct.[20] These subtypes are total anterior circulation infarcts (TACI), partial anterior circulation infarcts (PACI), and lacunar infarcts (LACI).[20]

Within 24 hours after stroke onset, patients were assessed by a neurologist to confirm the clinical diagnosis of stroke and to record clinical symptoms such as level of consciousness (assessed with the Glasgow coma scale (GCS)).[21] A speech therapist assessed the ability to communicate, and accepted a cut off of 50 percentile corrected for age on the Dutch Foundation aphasia test (SAN).[22] The mini mental state examination (MMSE) was applied to screen the orientation in time and place. Only patients with an MMSE score of 24 points or higher were included in the trial.[23]

In addition, sitting balance were assessed with the trunk control test.[24] Homonymous hemianopia was identified by confrontation and visual inattention was assessed by the letter cancellation task.[25] Conjugate gaze deficit was diagnosed when there was a failure of conjugate gaze towards the paretic body side. Finally, social support was defined as having a healthy partner willing and able to support the patient in care. To control for the heterogeneity of the stroke population, muscle strength, balance, proprioception, and cognitive function were assessed following the Orpinton prognostic scale (OPS).[26]

Design

Within 14 days of stroke, 101 patients with a primary, first ever stroke in the territory of the middle cerebral artery were randomly assigned to one of the three treatment groups.[2] The control group was designed for patients subjected to immobilisation of the paretic arm and leg by means of an inflatable pressure splint.[27] The splint (Svend Andersen, plastic industrials,Haarlev, Denmark ®) was applied to the supine patient for 30 minutes each day, 5 days a week for 20 weeks.[27 28] The two experimental groups received 30 minutes lower limb or upper limb training, 5 days a week for 20 weeks.

In addition, all three groups received 15 minutes of lower limb rehabilitation, 15 minutes of upper limb rehabilitation, and 1.5 hours of weekly ADL training. The ADL training was carried out by an occupational therapist. After finishing the treatment protocol, from 20 weeks onwards, decisions about type of treatment and its intensity were made by the stroke management team taking care of the individual patient. Ethical approval was given by each participating hospital.[2]

Treatment conditions

The treatment programme was based on a protocol comprising evidence based guidelines. A task oriented therapeutic approach was advocated. Upper limb treatment was focused on improvement in disabilities involving the hemiplegic arm (for example, grasping, reaching, leaning, clothing), whereas lower limb treatment was focused on the functional recovery of balance (for example, sitting, standing balance), transfers such as turning over, and gait (for example, performance and climbing stairs). The treatment goals were registered daily by predefined codes in a diary. The frequency of applied treatment goals is summarised in table 1. Differences in treatment duration are presented elsewhere.[2]

Assessments

Primary outcome variables included the Barthel index (BI), functional ambulation categories (FAC) and the action research arm test (ARAT). The Dutch version of the BI is a reliable and valid measurement that represents a patient's ability to perform 10 ADL tasks (bladder and bowel control, toilet use, dressing, feeding, ambulation, personal toilet, transfer activities, bathing, and stair climbing).[29] The FAC measures six levels of walking ability and documents personal support needed during walking with or without aid, and has been described as a reliable and valid measurement.[30] Functional recovery of the upper limbs was monitored with the ARAT.[31] This test consists of 19 functional movement tasks which are divided into four domains (grasp, grip, pinch, and gross movement). The BI, FAC, and ARAT were reassessed for their within observer reliability in 15 patients with stroke using a 1 week interval between measurements. Spearman rank correlation coefficients (r_s) were 0.97 for BI and FAC, and 0.99 for the ARAT test ($p<0.001$).

Secondary variables of outcome included comfortable and maximal walking speeds by means of a 10 m timed walking test.[32] The tests showed high test-retest reliability ($r_s=0.97$, $p<0.001$ and $r_s=0.96$, $p<0.001$, respectively). In addition, the number of applied walking devices were monitored. Part 1 of the Nottingham health profile (NHP-part 1)[33] and a short generic version of the sickness impact profile (SIP-68)[34 35] were used to assess quality of life. The first part of the NHP consists of 38 items (yes/no questions) describing health related behaviour in six dimensions (or domains of daily life; energy, physical mobility, sleep, pain, emotional reactions, and social isolation).[33] High scores indicate a poor health status.

Table 2 Baseline characteristics of patients

	Control treatment (n=37)	UL training (n=33)	LL training (n=31)
Demography:			
M/F	14/23	16/17	13/18
Age (y)*	64.1 (15.0)	69.0 (9.8)	64.5 (9.7)
Stroke characteristics:			
Left/right	13/24	16/17	13/18
TACI	25	19	17
PACI	9	11	13
LACI	3	3	1
Clinical characteristics:			
Glasgow coma scale (0–15)†	15 (15–15)	15 (15–15)	15 (15–15)
MMSE (0–30)†	26 (24–28)	27 (24–29)	27 (26–29)
Urinary incontinence (0/1)	19 (51%)	19 (58%)	11 (35%)
Sitting balance (0/1)	26 (70%)	23 (70%)	25 (81%)
Visual gaze deficit (0/1)	12 (32%)	8 (24%)	5 (16%)
Hemianopia (0/1)	15 (41%)	11 (33%)	7 (23%)
Visual inattention (0/1)	20 (54%)	17 (51%)	14 (45%)
TFT score (0–3)†	1 (0.5–2)	1 (0–2)	1 (0–2)
OPS (1.6–6.8)†	4.8 (4.0–5.0)	4.4 (3.6–5.2)	4.2 (3.6–4.8)
Social support	14 (38%)	15 (45%)	11 (35%)
Outcome variables at baseline:			
ADL ability (BI)†	5.5 (3–7)	5 (3–7)	6 (3–8)
Walking ability (FAC)†	0 (0–1)	0 (0–1)	1 (0–2)
Dexterity (ARAT)†	0 (0–0)	0 (0–1)	0 (0–6)
Walking velocity (m/s)*	0 (0)	0 (0)	0 (0)
Frenchay activities index*	26.8 (6.8)	26.5 (6.1)	27.1 (7.0)
Nottingham health profile*	16.5 (6.7)	17.5 (9.3)	14.5 (6.4)
Sickness impact profile*	41.2 (11.7)	38.6 (10.9)	42.5 (6.5)
Time from stroke onset to start of treatment (days)*	7.5 (2.9)	7.2 (2.8)	7.0 (2.5)

*Mean (SD); †median (IQR).
(0/1), binary scored;UL, upper limb; LL, lower limb; M/F, male/female; TACI, total anterior cerebral infarct; PACI, partial anterior cerebral infarct; LACI, lacunar infarct; MMSE, mini mental state examination; TFT, thumb finding test; OPS, Orpington prognostic scale.

Test-retest reliability of the Dutch version of the NHP-part 1 has been demonstrated by Erdman *et al*.[33] The SIP-68 evaluates six domains of health related functional status (somatic autonomy, mobility control, psychological autonomy, communication, social behaviour, emotional stability, and mobility range), explaining 94% of the total variance of the original SIP-136.[34] A high score indicates poor health related functional status. Post *et al* have demonstrated its high validity and reliability.[34] Extended ADLs were assessed with the Frenchay activities index (FAI).[35] The first part of the FAI evaluates the frequency of performance of 10 activities (preparing meals, washing up, washing clothes, light and heavy housework, social outings, local shopping, walking outside (>15 minutes), actively pursuing a hobby, and driving a car or travelling by bus) during the last 12 weeks, whereas five activities (outings and car rides, gardening, household maintenance, reading books, and gainful working) performed in the last 26 weeks are evaluated in the second part. Schuling *et al*[36] have demonstrated its reliability and validity.

All primary and secondary outcome variables were assessed at 6, 9, and 12 months after stroke. Within the first 6 months all measurements were carried out by one investigator (GK) who was blinded for treatment assignment. However, 6 months after stroke the blinding procedure was released. Depending on stroke severity, the test battery took about 45 to 75 minutes to complete.

Statistics

Group level

The Kruskal-Wallis test was applied to evaluate the differences between the three groups at 9 and 12 months after stroke for BI, FAC, ARAT, comfortable and maximal walking velocity, number of walking devices, SIP-68, and NHP-part (SPSS version 9.0.) The same tests were applied to evaluate possible differences between groups for changes on FAI from baseline to 6 months and from 6 to 12 months after stroke. When significant differences between three groups were found a post hoc analysis was performed using the Mann-Whitney *U* test to demonstrate which group differed significantly from the other.

To establish any significant improvement or deterioration from 6 months onwards in the complete group as well as within each group, changes in BI, FAC, ARAT, SIP-68, and NHP part 1 scores were tested with a Friedman two way analysis of variance (ANOVA) by ranks. If significant findings were obtained, a post hoc Wilcoxon matched pairs signed ranks test for non-continuous outcome variables was applied to evaluate the differences in outcomes at 6, 9, and 12 months. Outcome in FAI was tested at 6 and 12 months by applying a Wilcoxon matched pairs signed ranks test. After testing interval scaled measurements for normality with the Kolomogorov-Smirnov test, a paired sample *t* test was used to demonstrate differences in comfortable and maximal walking speeds.

Subject level

To show whether patients showed significant recovery or deterioration in functional status from 6 months onwards, measurement errors (error thresholds) were calculated and compared to the actual changes in BI, FAC, ARAT, comfortable and maximal walking speed. The error threshold was calculated on the basis of two independent measurements taken at 9 and 10 weeks after stroke. Based on the assumption that the errors of the two measurements are independent from each other, the within subject variance was determined. Subsequently, the standard error of measurement (SEM) was calculated from the square root of the within subject variance assuming that the difference between two independent measurements should be at least $1.96\sqrt{2}\times SEM$ to meet the criterion of a 95% confidence level of a real difference between the true scores.[37 38]. Finally, the error threshold for each variable of outcome was rounded off and the number of patients who improved or deteriorated beyond the error threshold after 6 months was determined.

Table 3 Primary outcomes

	Median (IQR) value		
	Control group (n=37)	UL training group (n=33)	LL training group (n=31)
ADL ability (Barthel index):			
Week 26	17 (10.5–19)	17 (11.75.20)	19 (15–20)
Week 38	17 (12.5–18.25)	17 (10.5–20)	17.5 (15.25–20)
Week 52	17 (14–20)	15 (12.5.20)	18 (14.5–20)
Change beyond ET after 6 months (n=86):			
Number improved≥4 points	3	1	0
Number deteriorated≥4 points	1	2	2
Walking ability (functional ambulation categories):			
Week 26	4 (2–5)	4 (3–5)	5 (4–5)
Week 38	4 (3–5)	4 (3–5)	5 (4–5)
Week 52	4 (3–5)	4 (3–5)	5 (4–5)
Change beyond error threshold after 6 months (n=86):			
Number improved≥1 point	11	4	4
Number deteriorated≥1 point	2	6	1
Dexterity (action research arm test):			
Week 26†	0 (0–2.25)	4 (0–38)**	3 (0–56)*
Week 38	0.5 (0–20.5)	5 (0–38.5)	5 (0–51.5)
Week 52	1 (0–28.5)	6 (0–42.25)	6 (0–52.75)
Change beyond error threshold after 6 months (n=86):			
Number improved≥5 points	2	4	2
Number deteriorated≥5 points	0	3	2

*p<0.05; **p<0.01 for differences between experimental and control group; †p<0.01 for significant difference among groups (Kruskal-Wallis ANOVA test).
UL, upper limb; LL, lower limb.

Table 4 Secondary outcomes

	Mean (SD) value		
	Control group (n=37)	UL training group (n=33)	LL training group (n=31)
Comfortable walking speed (m/s):			
Week 26	0.44 (0.44)	0.55 (0.44)	0.63 (0.47)
Week 38	0.52 (0.46)	0.59 (0.44)	0.65 (0.45)
Week 52	0.53 (0.44)	0.59 (0.43)	0.64 (0.46)
Change at individual level >6 months:			
Number improved≥0.16 m/s	6	2	2
Number deteriorated≥0.16 m/s	2	2	6
Maximal walking speed (m/s):			
Week 26	0.57 (0.60)	0.73 (0.62)	0.85 (0.65)
Week 38	0.67 (0.61)	0.76 (0.58)	0.86 (0.62)
Week 52	0.71 (0.62)	0.88 (0.67)	0.85 (0.63)
Change at individual level after 6 months:			
Number improved≥0.18 m/s	8	6	4
Number deteriorated≥0.18 m/s	2	3	7
Used walking aids:			
Week 26	17 (49%)	17 (57%)	14 (53%)
Week 38	21 (60%)	17 (61%)	16 (69%)
Week 52	20 (59%)	19 (68%)	15 (63%)
Sickness impact profile*			
Week 26	32.9 (12.0)	27.9 (13.1)	25.7 (12.7)
Week 38	32.0 (12.2)	28.5 (13.7)	24.2 (14.3)
Week 52	31.2 (11.6)	26.9 (13.1)	26.1 (14.1)
Nottingham health profile*:			
Week 26	11.5 (7.9)	9.5 (5.9)	9.8 (8.1)
Week 38	11.8 (7.4)	10.6 (7.4)	10.4 (8.5)
Week 52	11.7 (8.4)	9.0 (6.0)	11.6 (9.6)
Frenchay activities index:			
Week 26	8.2 (7.8)	10.9 (8.3)	13.7 (9.5)
Week 52	12.0 (8.3)	12.7 (9.1)	15.7 (11.7)

*High scores indicate poor status.
UL, upper limb; LL, lower limb.

RESULTS

Eighty six (85%) out of 101 patients were reassessed at 9 and 12 months after stroke onset. During the first year follow up period four patients dropped out from the control group, five in the upper limb, and six in the lower limb group. Twelve out of these patients dropped out before week 20 (three control group, four upper limb group, and five lower limb group).[2] Recurrent stroke (n=6), comorbidity (for example, cancer) (n=2), and death from cardiac failure (n=2) were the most common reasons.

In total 1750 (96.3%) of the intended 1818 measurements were performed. The amount of upper limb training administered during the 20 week treatment protocol in the upper limb group (3860 minutes) was about 2250 minutes and 2080

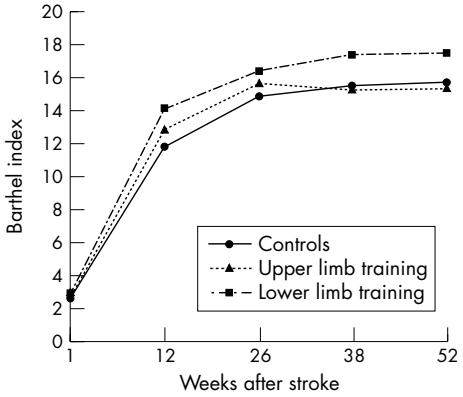

Figure 1 Recovery patterns for patients as measured by the Barthel index.

minutes in excess of upper limb function training provided to the controls and lower limb group, respectively. The lower limb group received about 3660 minutes of lower limb training, which was about 2270 and 2320 minutes more than the lower limb function training provided to the control group and upper limb group, respectively. After 6 months, 68% of the patients (n=59) were discharged home, whereas 52.5% (n=53) were still ADL dependent (BI<19). They received one to three weekly treatment sessions of 30 minutes, depending on their personal needs. Almost all rehabilitation services were performed at the institution of discharge. For patients who were considered to be ADL independent, rehabilitation was stopped. At 1 year after stroke, patients included in the trial were not receiving any type of physical or occupational therapy.

Group level

The results of the primary and secondary outcomes at baseline, 6, 9, and 12 months are shown in tables 2, 3, and 4, respectively. The mean pattern of functional recovery in BI for patients receiving control group, upper limb, and lower limb treatment is presented in figure 1. Visual inspection of the mean functional recovery in BI suggests that the increased outcome as the result of higher intensity of rehabilitation carried over to 9 and 12 months after stroke. However, no significant differences in functional recovery between groups were found for BI, FAC, ARAT, comfortable and maximal walking speed, NHP-part 1, SIP-68, and FAI from 6 months onwards.

Within the included (total) patient group no significant changes between outcomes at 6 months and 12 months were found within the included (total) patient group in BI ($\chi^2_{n=2}$=2.50; p=0.29), FAC ($\chi^2_{n=2}$=3.88; p=0.14), ARAT ($\chi^2_{n=2}$=4.01; p=0.13), comfortable ($\chi^2_{n=2}$ =3.31; p=0.19) and maximal walking speed ($\chi^2_{n=2}$=4.92; p=0.09), NHP-part 1 ($\chi^2_{n=2}$=2.41; p=0.30), and SIP-68 ($\chi^2_{n=2}$ =3.12; p=0.21). Only the FAI score at 12 months was significantly higher (about 2 points) compared with the score obtained at 6 months after stroke (Z=5.17; p<0.001).

Comparing the outcomes at 6 months and 12 months after stroke, no significant changes were found within the three patient groups for primary and secondary variables of outcome. Only maximal walking speed in the control group showed a significant improvement from 6 months onwards (t=2.29; p=0.03).

Subject level

The responsiveness of the primary outcome assessments (BI, FAC, ARAT) and secondary outcome assessments (comfortable and maximal walking speed) are shown in tables 3 and 4. The calculated error thresholds for BI, FAC, and ARAT were 4, 1, and 5 points, respectively. In tables 3 and 4 the number of patients improving or deteriorating significantly from 6 months to 1 year is presented. Four out of 86 patients continued to improve in BI score (median five points; range 5–7), 19 in FAC score (mean 1 point; range 1–3), and eight in ARAT score (median 8.5, range 6–24). Most of the patients improving in FAC score were participating in the control group (n=11), however, the differences between groups were not statistically significant. At 6 months, median scores for patients who improved in BI, FAC, and ARAT were 9.5 (IQR: 9–10.75), 2 (IRQ: 1–4), and 21 (IQR: 1.5–45.75) points, respectively.

Five patients showed significant deterioration from 6 months to 1 year in BI (mean five points; range 4–6), nine patients in FAC score (median 1; range 1–3) and five patients in ARAT score (mean 11; range 6–13). No significant differences were found between the three treatment groups. However, the median scores and interquartile ranges (IQR) for patients who deteriorated corresponded to incomplete functional recovery on BI (16; IQR 9–17), FAC (4; IQR 2–4) and ARAT (41; IQR 19.5–54), 6 months after stroke.

The error thresholds for comfortable (0.16 m/s) and maximal (0.18 m/s) walking speeds are presented in table 3. From 6 months to 1 year, 10 patients (six controls, two upper limb, and two lower limb) improved significantly from 0.38 to 0.64 m/s in comfortable walking speed, whereas during the same period 18 patients (eight controls, six upper limb, and four lower limb) improved from 0.60 to 0.73 m/s in maximal walking speed (table 3). Ten patients deteriorated in comfortable walking speed (two controls, two upper limb, and six lower limb) and 12 patients in maximal walking speed (two controls, three upper limb, and seven lower limb).

DISCUSSION

The first objective of this follow up study was to determine the long term effects of an intensive rehabilitation programme for upper and lower limb function training during the first year after stroke. With the exception of a significant recovery of maximal walking speed in the control group, no significant between and within group differences were found for ADL, extended ADL, walking ability, dexterity, comfortable walking speed, and health related functional status between 6 and 12 months after stroke. The significant recovery in maximal walking speed in the control group may have been due to a slow and late recovery as a result of immobilisation of an upper and lower limb during the first 20 weeks after stroke onset. The ability of the stroke management teams to make their own decisions about individual patient care after ending the 20 week intense treatment programme may have contributed to improvements, in particular for those who were immobilised.

The present findings confirm the results of other studies indicating that higher intensity of upper and lower limb function training during the first 6 months after stroke did not result in significant gains at 1 year, even though this training accelerated speed of functional recovery[4 6 7] and improved health related functional status during the first 3 months after stroke.[2] However, the absence of functional recovery at group level does not imply that no changes occurred at an individual subject level. Therefore, the second objective of the present study was to identify those patients who showed functional changes beyond the error threshold after 6 months.

Although the present findings suggest that most functional levels achieved after stroke were maintained after 6 months, individually some patients tended to improve or regress in their functional ability beyond the critical 95% level of measurement error. All patients who changed significantly from 6 months onwards showed some but incomplete functional recovery at 6 months after stroke. For example, patients who improved or regressed at least 4 points or more in BI score after 6 months (n=9) showed a median score of 11

points on the BI at 6 months, whereas 28 patients (33%) who showed further improvement or deterioration on the FAC score were only able to walk under supervision (median of 3 points on FAC). Moreover, some of these patients showed significant changes in comfortable (23%) and maximal (34%) walking speeds. In agreement with the deteriorations in FAC scores, most patients showed low comfortable (0.38 (SD 0.41) m/s) and maximal (0.53 (SD 0.44) m/s) walking speeds at 6 months. Finally, 13 patients (15%) showed further changes of at least five points in the ARAT score. Again, patients with incomplete functional recovery of the upper limb on the ARAT test (median of 37 points) are likely to change beyond the error threshold.

The presented findings for BI and FAC indicated that most of these patients were not able to get dressed, take a bath, transfer, walk and climb stairs independently. Most likely, the present findings reflect the long term instability of achieved gains, in particular for those patients who have regained some, but still incomplete functional activity at 6 months after stroke. Several randomised controlled studies have shown that those with an incomplete functional recovery are able to improve walking ability,[10 16], dexterity,[12 14–16] and ADL[13 39 40] when those tasks are included in their therapeutic programme. In addition, proper instruction to patient and caregiver to prevent overprotection at home,[17 18 41], participation in recreational sports, and application of strategies to improve the self care and self efficacy[42] may be important elements in a rehabilitation programme for establishing further recovery and preventing learned non-use after discharge. It may be hypothesised that the implementation of the intensive, task oriented exercise programme beyond the first 20 weeks results in further improvements in functional recovery, in particular for those with an incomplete recovery. However, more than half of the patients did not receive physical or occupational therapy more than 6 months after stroke. With the exception of one patient, intensity of therapy was less compared with the treatment intensity during the first 20 weeks after stroke in the group of patients that did continue therapy after 6 months. At 1 year, none of the patients with stroke received any rehabilitation services. Most likely this finding reflects the general assumption among healthcare providers that individual changes more than 6 months after stroke will be limited and not clinically relevant. Due to a lack of systematic manipulation and control for intensity and content of rehabilitation services provided after 6 months, we were unable to demonstrate the long term effects of intensity of treatment on the individual patterns of functional recovery between 6 and 12 months after stroke. In addition, we cannot rule out possible observation bias due to elimination of blinding of the observer 6 months after stroke.

Future studies may be directed towards finding predictive factors of functional recovery more than 6 months after stroke. In addition, the effects of dose-response relations of task oriented treatment programmes in these patients with stroke showing an incomplete, but slow and persistent functional recovery should be investigated. Being able to identify these patients will allow for the administration of better individually tailored therapeutic interventions with regard to intensity, task specificity, and treatment frequency. Although, presently adequate identification of these patients is not possible, continuity in monitoring functional outcome will help therapists and physicians to decide the type and intensity of treatment needed to prevent further deterioration or to enhance improvement.[43]

ACKNOWLEDGMENTS

We acknowledge all students of the Department of Physical Therapy of the Hogeschool of Amsterdam for their participation, and A Zuidgeest for his supervising activities of students in research projects within the trial. Finally, we thank Els van Deventer (Department of Neurology, VU Medical Centre) for collecting and copying relevant references. This is part of a research project supported by a grant from The Netherlands Heart Foundation (reference No 93.134).

Authors' affiliations

G Kwakkel, University Hospital Vrije Universiteit, Department of Physical Therapy and Research Institute for Fundamental and Clinical Human Movement Sciences, Amsterdam, The Netherlands
B J Kollen, Isala clinics, site Sophia, Department of Physiotherapy, Zwolle, The Netherlands
R C Wagenaar, Boston University, Sargent College of Health and Rehabilitation Sciences, Department of Physical Therapy, Boston, Massachusetts, USA

REFERENCES

1 **Kwakkel G**, Wagenaar RC, Koelman TW, *et al*. Effects of intensity of stroke rehabilitation: a research synthesis. *Stroke* 1997;**28**:1550–6.
2 **Kwakkel G**, Wagenaar RC, Twisk JWR, *et al*. Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *Lancet* 1999;**354**:191–6.
3 **Andrews K**, Brocklehurst JC, Richards B, *et al*. The rate of recovery from stroke and its measurement. *Internal Rehabilitation Medicine* 1981;**3**:155–61.
4 **Sivenius J**, Pyorala K, Heinonen OP, *et al*. The significance of intensity of rehabilitation of stroke: a controlled trial. *Stroke* 1985;**16**:928–31.
5 **Davidoff GN**, Keren O, Ring H, *et al*. Acute stroke patients: long-term effects of rehabilitation and maintenance of gains. *Arch Phys Med Rehabil* 1991;**72**:869–73.
6 **Indredavik B**, Bakke F, Slørdahl SA, *et al*. Stroke Unit treatment 10 year follow-up. *Stroke* 1999;**30**:1524–7.
7 **Sunderland A**, Fletcher D, Bradley L, *et al*. Enhanced physical therapy for arm function after stroke: a one year follow up study. *J Neurol Neurosurg Psychiatry* 1994;**57**:856–8.
8 **Katz S**, Ford AB, Chinn AB, *et al*. Prognosis after stroke: long term outcome of 159 patients. *Medicine* 1966;**45**:236–46.
9 **Tangeman PT**, Banaitis DA, Williams AK. Rehabilitation of chronic stroke patients: changes in functional performance. *Stroke* 1990;**71**:876–90.
10 **Wade DT Collen FM**, Robb GF, *et al*. Physiotherapy intervention late after stroke and mobility. *BMJ* 1992;**304**:609–13.
11 **Dam M**, Tonin P, Casson S, *et al*. The effects of long-term rehabilitation therapy in poststroke hemiplegic patients. *Stroke* 1993;**24**:1186–91.
12 **Taub E**, Miller NE, Novack TA, *et al*. Technique to improve chronic motor deficit after stroke. *Arch Phys Med Rehabil* 1993;**74**:347–54.
13 **Werner RA**, Kessler S. Effectiveness of an intensive outpatient rehabilitation program for postacute stroke patients. *Am J Phys Med Rehabil* 1996;**75**:114–20.
14 **Dean CM**, Shepherd RB. Task related training improves performance of seated reaching tasks after stroke: a randomized controlled trial. *Stroke* 1997;**28**:722–8
15 **Lee van der JM**, Wagenaar RC, Lankhorst GJ, *et al*. Forced use of the upper extremity in chronic stroke patients. *Stroke* 1999;**30**:2369–75.
16 **Dean CM**, Richards CL, Malouin F. Task-related circuit training improves performance of locomotor tasks in chronic stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2000;**81**:409–17.
17 **Andrews K**, Stewart J. Stroke recovery: He can but does he? *Rheum Rehabil* 1979;**18**:43–8.
18 **Ungern-Sternberg AV**, Küthmann M, Weimann G. Stroke: evaluation of long-term rehabilitation effects. *J Neural Transm* 1991;**33**(suppl):149–55.
19 **WHO Special report**. Stroke: 1989: recommendations on stroke prevention, diagnosis, and therapy. *Stroke* 1989;**20**:1407–31.
20 **Bamford J**, Sandercock P, Dennis M, *et al*. Classification and natural history of clinical identifiable subtypes of cerebral infarction. *Lancet* 1991;**337**:1521–6.
21 **Teasdale G**, Murray G, Parker L, *et al*. Adding up the Glasgow coma scale. *Acta Neurochir (Wien)* 1979;**28**:13–6.
22 **Deelman BG**, Liebrand WBG, Koning-Haanstra, *et al*. SAN test: an aphasie test for language comprehension and linguistic usage. *Construction and standards*. Lisse: Swets and Zeitlinger BV, 1981.
23 **Folstein MF**, Folstein SE, McHugh PR. Mini-mental state: a practical method for grading the cognitive state of patients for clinician. *J Psychiatr Res* 1975;**12**:189–98.
24 **Collin C**, Wade DT. Assessing motor impairment after stroke: a pilot reliability study. *J Neurol Neurosurg Psychiatry* 1990;**53**:576–80
25 **Beers KA**. *The cancellation test, report*. Hoensbroeck: Rehabilitation Centre Hoensbroeck, 1986.
26 **Kalra L**, Crome P. The role of prognostic scores in targeting stroke rehabilitation in eldery patients. *J Am Geriatr Soc* 1993;**41**:396–400.
27 **Robichaud JA**, Agostinucci J, Van der Linden DW. Effects of air-splint application on soleus muscle motorneuron reflex excitability in non-disabled subjects and subjects with cerebrovascular accidents. *Phys Ther* 1992;**72**:176–81.
28 **Poole JL**, Whitney SL, Hangeland N, *et al*. The effectiveness of inflatable pressure splints on motor function in stroke patients. *Occupational Therapy Journal of Research* 1990;**10**:360–5.
29 **Haan de R**, Limburg M, Schuling J, *et al*. Klinimetrische evaluatie van de Barthel-Index, een maat voor beperkingen in het dagelijks functioneren. *Ned Tijdschr Geneeskd* 1993;**137**:917–21.

30 **Collen FM**, Wade DT, Bradshaw CM. Mobility after stroke: reliability of measures of impairment and disability. *Int Disabil Studies* 1990;**12**:6–9.
31 **Lyle RC**. A performance test for assessment of upper limb function in physical rehabilitated treatment and research. *Int J Rehabil* 1981;**4**:483–92.
32 **Hunt SM**, McKenna SP, Williams J. Reliability of a population survey tool for measuring perceived health problems: a study of patients with osteoarthrosis. *J Epidemiol Community Health* 1981;**35**:297–300.
33 **Erdman RAM**, Passchier J, Kooijman M, *et al*. The Dutch version of the Nottingham health profile: investigations of psychometric aspects. *Psychological Reports* 1993;**72**:1027–35.
34 **Post MWM**, DeBruin A, DeWitte L, *et al*. The SIP68: a measure of health related functional status in rehabilitation medicine. *Arch Phys Med Rehabil* 1996;**77**:440–5.
35 **Holbrook M**, Skilbeck CE. An activities index for use with stroke patients. *Age Ageing* 1983;**12**:166–70.
36 **Schuling J**, DeHaan M, Limburg, *et al*. The Frenchay activities index: assessment of functional status in stroke patients. *Stroke* 1993;**24**:1173–7.
37 **Guyatt G**, Walter S, Norman G. Measuring change over time: assessing the usefulness of evaluation instruments. *J Chron Dis* 1987;**40**:171–8.
38 **Beckerman H**, Vogelaar TW, Lankhorst GJ, *et al*. A criterion for stability of the motor function of the lower extremity in stroke patients using the Fugl-Meyer assessment scale. *Scand J Rehabil Med* 1996;**28**:3–7.
39 **Walker WF**, Drummond AER, Lincoln NB. Evaluation of dressing practice for stroke patients after discharge from hospital: a crossover design study. *Clin Rehabil* 1996;**10**:23–31.
40 **Drummond AER**, Walker MF. A randomised controlled trial of leisure rehabilitation after stroke. *Clin Rehabil* 1995;**9**:283–90.
41 **Morris DM**, Crago JE, DeLuca SC, *et al*. Constraint-induced movement therapy for motor recovery after stroke. *Neurorehabilitation* 1997;**9**:29–43.
42 **Robinson-Smith G**, Johnston MV, Allen J. Self-care self-efficacy, quality of life, and depression after stroke. *Arch Phys Med Rehabil* 2000;**81**:460–4.
43 **Kwakkel G**, van Dijk GM, Wagenaar RC. Accuracy of physical and occupational therapists' early predictions of recovery after middle cerebral artery stroke. *Clin Rehabil* 2000;**14**:28–41.