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Effect on arm function and cost of robot-assisted group therapy in subacute patients with stroke and a moderately to severely affected arm: a randomized controlled trial

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Abstract

Objective: To evaluate the effectiveness and efficiency of robot-assisted arm group therapy (RAGT) versus individual arm therapy (IAT) to restore motor function in the moderately to severely affected patient after stroke.

Design: Single blind randomized controlled trial.

Setting: Two in-patient neurological rehabilitation centers.

Participants: Fifty first time subacute patients with stroke and a non-functional hand.

Intervention: The patients practiced either 30 minutes of RAGT + 30 minutes of IAT (group A) or 2x30 minutes of IAT (group B), per workday for four weeks. The RAGT consisted of six workstations enabling repetitive practice of finger, wrist, forearm and shoulder movements. Patients practiced according to their impairment level on at least two workstations per session. The IAT followed the Motor Relearning Programme, enriched by elements of the impairment-oriented training.

Main outcome measure: Changes of the Fugl Meyer Score (FM, 0-66) between baseline and after 4 weeks, incremental cost effectiveness.

Results: Patients were homogeneous at study onset. All patients improved their upper limb motor function over time, but there were no between group differences. The initial (terminal) FM scores were 14.6±9.4 (25.7±16.5) in group A and 16.5±9.8 (31.1±19.1) in group B. The treatment of a single patient with RAGT cost 4.15 €, compared to 10.00 € for a patient to receive IAT.

Conclusion: RAGT in combination with IAT was equally effective as a double session of IAT regarding the restoration of upper limb motor functions in moderate to severely affected subacute patients with stroke. The treatment costs for RAGT were less.

Keywords

Stroke, robot-assisted devices, randomized controlled trial, rehabilitation intervention, neurological rehabilitation

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Introduction

Stroke is the leading cause of persisting disability in the industrialized world.[1] A third of the surviving patients present with a severe arm paresis, meaning the hand is non-functional, and the prognosis to regain a meaningful hand activity six months later is regarded poor. [2,3]

In case of a severe arm paresis and limited staff resources, early rehabilitation after stroke rather focuses on the compensatory use of the non-affected upper extremity in daily activities instead of intensively practising the non-functional arm. [3]

The intensity of therapy is known to be an important factor relating to outcome after stroke, but staff costs are a limiting factor. In this climate, robots may offer an alternative intervention to increase the intensity of the upper limb rehabilitation. [4–9]

Recently, Buschfort et al. developed an arm studio, which combined four end-effector-based machines to enable robot-assisted group therapy with six different workstations.[10] The machines enabled the repetitive practice of 1- or 3-degree of freedom movements of the shoulder, elbow, wrist and fingers. It required input from one supervised therapy assistant, who was responsible for three to four patients at the same time. One treatment session lasted 30 minutes, and a median of 35 patients frequented the arm studio every workday. An open study reported high acceptance of the concept both among patients and therapists. [10]

Building on this proof-of-concept study, we undertook a randomised controlled, single-blinded, two-centre trial (www.clinicaltrials.gov/NCT006080610) to compare the effect of the robot-assisted group therapy + individual arm therapy with individual arm therapy of the same intensity in subacute patients with stroke and a moderate to severe upper limb paresis.

The individual arm therapy followed the task-oriented Motor Relearning Programme in combination with elements of the impairment-oriented training in the most severely affected patients.[11,12] Both approaches had been positively evaluated in subacute stroke rehabilitation.[13,14]

The hypothesis was that at least the combined therapy approach, robot-assisted group therapy + individual arm therapy, was equally effective as the individual arm therapy of double intensity in the recovery of upper limb motor control in subacute patients with stroke. Additionally, efficiency questions, calculating the actual treatment costs per individual patient receiving robot-assisted group therapy and individual arm therapy, were evaluated.

Methods

Patients from two in-patient stroke rehabilitation units participated in the study, the recruitment period lasted 18 months. The responsible study physician screened all admitted patients with stroke and contacted those who fulfilled the below mentioned inclusion criteria and explained the content and goal of the study. Inclusion criteria were:

- First-time supratentorial stroke (hemorrhagic or ischemic), lesion interval < eight weeks.
- Age 18 – 90 years.
- Able to get out of bed and mobilised in a wheelchair or were able walk.
- Participating in an in-patient rehabilitation program of at least six weeks.
- Non-functional or minimally functional upper limb (Fugl-Meyer Score,(0-66) < 19, or Fugl-Meyer Score 19 – 35).[15]
- No severe arm spasticity, i.e. scored 3 or less on the modified Ashworth Scale score (0-5, 12) when tested for the passive hand and finger extension while supine.[16]
- No hemiparetic shoulder pain requiring physical therapy or pain medication.
- No swollen hand impeding closing of the fist.
- No other neurological or orthopedic arm impairments requiring physical therapy or pain medication.
- Able to give informed consent (approved by the local ethical committee) in the study.

The power calculation made the following assumptions: beta was 0.8, alpha was 0.05, with a mean (SD) improvement of + 9.0 (10) for the primary variable, the Fugl-Meyer Score (0-66). A clinically meaningful difference between groups was 9.0 Fugl-Meyer Score points.[17] The power calculation

arrived at 20 patients per group, 25 patients per group were recruited to allow for drop-outs.

Each participant, who signed the informed consent, was assigned to one of two groups, either the robot-assisted group therapy or individual arm therapy by restricted randomisation pooled for center.

The allocation of patients to the two groups (robot-assisted group therapy or individual arm therapy) was conducted online by using a web-based randomization tool (http://www.randomizer.at).

Patients in group A received a 30 min session of robot-assisted group therapy + a 30 min individual arm therapy per workday for four weeks, i.e. a total of 20 days. Patients in group B received 2x30 min individual arm therapy sessions per workday for four weeks, i.e. also a total of 20 days.

The robot-assisted group therapy was delivered in an arm studio, and was guided by one supervised therapy assistant, followed previously described principals.[10]. The studio comprised six devices, namely the computerized arm trainer Bi-Manu-Track,[18] the electromechanical finger trainer Reha-Digit,[19] and two mechanical arm trainers, the Reha-Slide,[20] and Reha-Slide duo. Each patient practiced for 15 min each with two of the devices during one robot-assisted group therapy session. For a more detailed description of the devices see the references, Table 1 and the online Appendix. (Supplementary Material Table 1) All implemented devices were following the endeffector-based approach, i.e. the devices' manipulators acted on the fingers or hands as the most distal parts of the arm.

The devices were selected as they shared a common purpose, namely passive mobilisation to prevent immobilzation-related muscle shortenings,[21] and repetitive training of isolated movements.[22]

The responsible clinician categorized the patients into three groups, I, II, and III - based on their impairment level. In group I: the hand was plegic with no palpable movement of the wrist and finger extensors, the patients could, at most, move the shoulder and/or the elbow in a synergistic manner. In group II, the patient showed some selective movements proximally and/or distally. For shoulder elevation and abduction a visible movement with gravity eliminated, corresponding to a Medical Research Council grade of 2 (0-5, 0=plegic, 5 = normal strength), was required.[16] In group III, patients were able to grasp, reposition and release a tennis ball placed on a table within a therapeutic situation. In those patients, whose group assigning was a matter of debate within the therapeutic team, the Fugl-Meyer Score[15] served as another criterion. Patients with a score < 12 were assigned to group I, > 12 were assigned to group II, and those with a Fugl-Meyer Score ≥ 34 were assigned to group III.

In every session the patients of group I practised with the Bi-Manu-Track (in passive – passive and active – passive modes) and the Reha-Digit. Patients of group II used the Bi-Manu-Track (in all three modes) and the Reha-Slide, while patients of group III used the Bi-Manu-Track (in active – active mode) and the Reha-Slide duo. In cases of elevated finger stiffness, patients of group II and III started their session with the Reha-Digit for 10 minutes to lessen the muscle tone.

The therapy assistant was responsible for positioning the patients in the machines, attaching their paretic hands, turning the machines on and off, attending to the patients, and helping them to move from one workstation to the other after 15 minutes. One session lasted 30 minutes net, positioning, attaching and removing the hand from the devices took another 10 minutes. During one session three to four patients practised in the arm studio at the same time. The supervising therapist worked in a room next to the studio, and was available in case help was needed.

The individual upper limb therapy followed the same principles in both groups, it was conducted by a therapist with at least 5 years of experience in stroke rehabilitation, in each center. They applied an eclectic approach consisting of the task-oriented motor relearning programme at its core, supplemented by elements of the impairment-oriented arm ability training (repetitions of movements and shaping) in the most severely affected patients.[11] Those patients were not yet able to perform reaching, grasping, holding, manipulation and finger dexterity tasks. A prestudy workshop with participants from both centers had been organized to agree on therapy contents and to bring the application into line.

In both centres, the robot-assisted group therapy was delivered in the morning and the individual

Table 1. Content of the arm lab.

Device	Movement	Unilateral	Bilateral	Number of repetitions practiced per session	Mode			
					Passive	Active	Assistive	Restrictive
Bi-Manu-Track	Wrist flexion/ extension		X	400	X	X	X	X
	Forearm pro- and supination		X	400	X	X	X	X
Reha-Digit	Finger flexion/ extension Vibration of finger tips	X		300	X			
Reha-Slide	Shoulder anteversion and abduction/ adduction Elbow and wrist flexion/extension		X	300	X	X		X
Reha-Slide duo	Shoulder anteversion Elbow and wrist flexion/extension	X	X	200		X		X

arm therapy in the afternoon, or in the control group one session of individual arm therapy in the morning and the other one in the afternoon.

In addition to the trial interventions both groups participated in a comprehensive rehabilitation programme. It included physiotherapy to improve mobility but not arm function, an equipment-mediated locomotor training (each five times a week), physical therapy (three times a week) and an early morning training of basic activities of daily living (every workday for two to three weeks). Speech and neuropsychological therapies were administered on an individual basis as required.

The primary variable was the change in the blinded Fugl-Meyer arm Score (0-66).[15] The valid and reliable Fugl-Meyer Score assesses reflexes and motor tasks according to presumed stages of recovery, with each motor subtest being composed of one to seven items. The test was videographed with a mirror placed behind the patient to ensure later blind rating by an external experienced therapist.

Secondary outcomes were the disability-based Action Research Arm Test, [23] the disability-based Box & Block Test,[24] upper limb muscle strength, upper limb muscle tone, and the independence in the basic activities of living.

The upper limb muscle strength was assessed with the help of Medical Research Council grades[16] (0-5, 0 = plegic, 5 = full power as compared to unaffected side) tested for shoulder elevation, elbow, wrist, finger flexion and extension and thumb abduction and adduction. Upper limb muscle tone was assessed using the Modified Ashworth Scale score (0-5; 0 = no increase in muscle tone, 5 = affected part(s) rigid in flexion or extension) tested for the same passive joint movement as the assessment of strength. [16] A sum score for both the Medical Research Council and the Modified Ashworth Scale score was calculated (0-45). The Barthel Index (0-100) assessed independence in the basic activities of daily living. [16]

The parameters were assessed at baseline assessment, after the four-week intervention and three months after study end for follow-up. The assessment of the primary outcome was blind, an experienced therapist rated the patients with the help of videographs. The assessment of the secondary parameters was not blinded. By experience, concealment was not realistic within a rather small team of therapists. In

each centre, two experienced clinical team members rated the assessments together. Furthermore, patients in group A were asked to report their subjective impression on the robot-assisted group therapy, particularly whether it was a meaningful supplement to individual arm therapy or whether it could even substitute individual arm therapy.

The efficiency calculation (i.e. the actual costs per treatment) was based on the list prices of the devices, the employer's costs of the staff and the mean number of patients treated in the arm studio or by a single therapist in one year. The clinic was reimbursed per number of days the patient stayed in the rehabilitation unit. The benefactor required a minimum of five treatment sessions per day and individual or group therapy to promote the upper limb function was counted equally.

An intention-to-treat analysis was carried out, i.e. in case of a drop out, assessment went on or the last available value was continued. All data were interpreted quantitatively using 95% CI, Median, IQR, Means and standard deviation. To compare the change in scores over time we applied the Wilcoxon test for paired-samples, to compare the scores at baseline assessment, four-week assessment, and three-month assessment.

In the next step, the relative effectiveness of the interventions was compared by assessing the change in the primary outcome in each group between the start and end of treatment (four-week assessment – baseline assessment), and the start of treatment and at follow-up assessment (three month assessment – baseline assessment), using a Mann-Whitney test. A Bonferroni–adjustment for the two time points were made and the alpha value was set to p=0.025 accordingly. The secondary outcomes (Action Research Arm Test, Box & Block Test, Modified Ashworth Scale score, Medical Research Council and Barthel Index) were handled in the same way. Additionally we calculated the incremental cost effectiveness of the arm studio in comparison to individual arm therapy.

Results

Fifty patients were recruited into the trial, Figure 1 shows the process of recruitment and what happened to them.

Both groups were homogenous before study onset (Table 2). Table 3 provides the raw data in means (SD) for all parameters at any of the measurement points.

The blinded Fugl-Meyer Score improvements during the intervention and follow-up period did not differ between groups (Table 4). The blinded Fugl-Meyer Score improvements over time were significant in both groups (Table 5). The mean scores (SD) were 14.6 (9.4) at baseline, and 25.7 (16.5) at four-week assessment, and 31.3 (21.2) and three-month assessment for group A, the corresponding values for group B were 16.5 (9.8) at baseline, 31.1 (19.1) at four-week assessment, and 36.7 (21.8) at three-month assessment (Table 4).

Among the secondary outcomes, the Action Research Arm Test, Box & Block Test, Medical Research Council scores and the Barthel Index improved in both groups over time (Table 5), but there were no group differences between four-week and three-month assessment (Table 4). For the Action Research Arm Test there was a trend (p=0.044) in favour of the control group at three-month assessment (Table 4). With respect to the Box & Block Test, 11/25 patients in group A reached the minimum criterion (transfer of three wooden blocks) after the intervention period, compared to 15/25 patients in group B. This was a mean gain + 9 in group A, and + 8 in group B (two patients in group A and seven patients in group B were able to achieve this at baseline). Muscle tone remained unchanged in both groups (Table 4).

Major side effects did not occur, two patients in group A developed blisters in the finger tips following the treatment with the Reha-Digit, so the treatment was interrupted for one week, and the patients practiced with the BMT instead. Shoulder pain requiring prescription of a non-steroidal pain killer, and/or a shoulder orthosis and/or physical therapy occurred in four patients of group A and three of group B.

Seventeen of the 24 patients receiving the robot-assisted group therapy were positive about it, they found the group setting challenging and communicative, and would recommend it as a meaningful supplement but not as a substitute for individual upper limb training. Seven group A patients

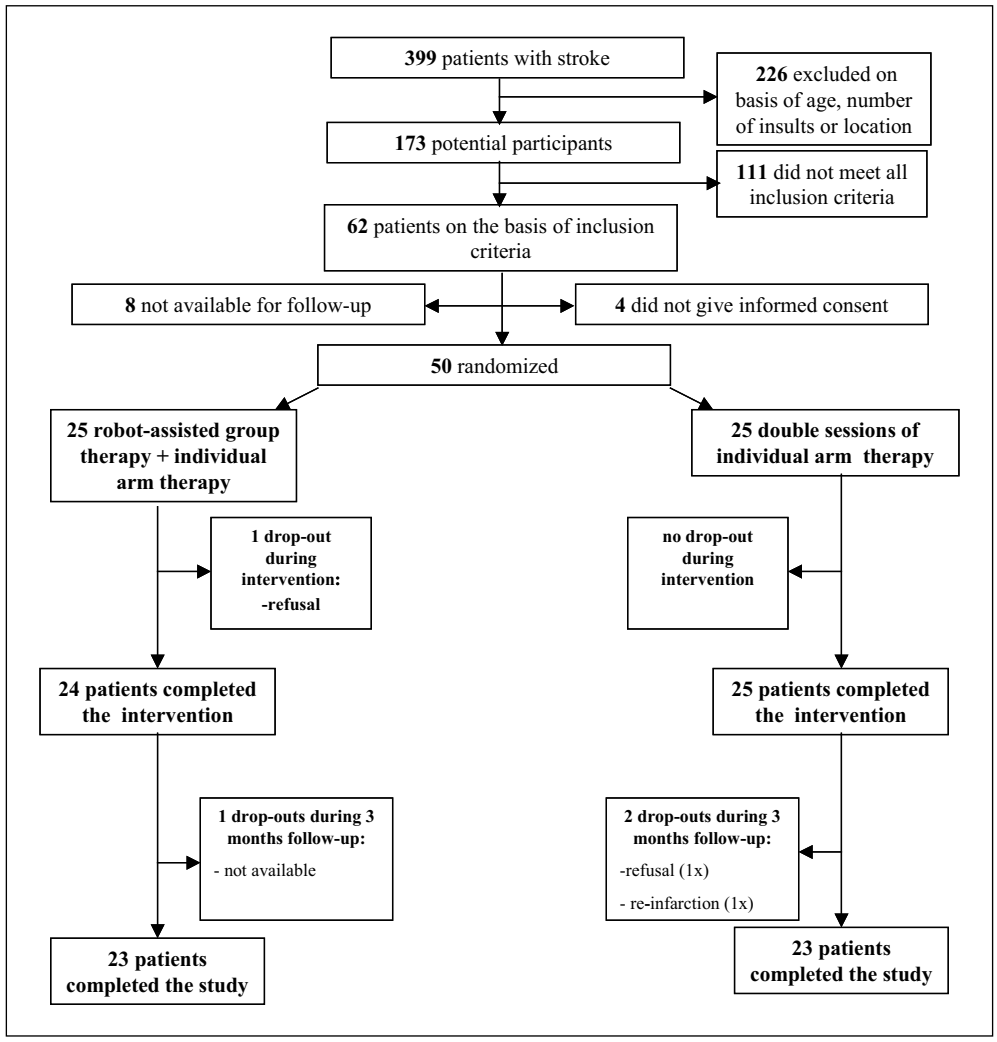

Figure 1. Flow diagram.

reported discomfort with robot-assisted group therapy, that it was rather demanding, and had little relevance to their rehabilitation goals.

An assistant staff (or a deputy), semiskilled within an eight-week training course, was responsible for the group therapy in the arm studio, which a median of 35 patients frequented per day. Well qualified therapists with a work experience of several years conducted the individual arm training, they treated a median of 15 patients per day. Excluding weekends and bank holidays the clinic fully operated 255 days in the year, on Saturday a limited service was offered.

The net investment costs for the devices (EU list prices) plus a 25% overhead (for maintenance, energy, consumables) were 48.000 €, to be deducted within four years resulting in annual cost of 12.000 €. The annual gross salary of the assistant therapist was 25.000 €, and 35.000 € for the experienced therapist. The assistant therapist treated 8,925 patients per year, thus the total costs (device, overhead, salary) of the robot-assisted group therapy

Table 2. Clinical data and initial assessment scores in means and SD for both groups.

	Robot-assisted group therapy + individual arm therapy (group A)	Double session of individual arm therapy (group B)	*p*-value
n	25	25	1.000
Diagnosis	22 = ischemic. 3 = hemorrhagic	19 = ischemic. 6 = hemorrhagic	.712
Hemiparesis	14=left. 11=right	13=left. 12=right	.899
Stroke interval (weeks)	4.5 (1.7)	4.5 (1.4)	.909
Age (years)	71.4 (15.5) (range: 43-85)	69.7 (16.6) (range: 34-85)	.813
Sex	12 = female, 13 = male	10 = female, 15 = male	.856
Neglect	7	5	.662
Fugl-Meyer Score (FM, 0-66)	14.6 (9.4)	16.5 (9.8)	.402
Action Research Arm Test (ARAT, 0-56)	4.9 (6.9)	7.3 (6.8)	.301
Box & Block Test (BBT,*n*)	0.2 (0.7)	0.9 (1.6)	.068
Medical Research Council Sum Score (MRC, 0-45)	6.4 (6.7)	8.9 (7.8)	.223
Modified Ashworth Sum Score (ASG, 0-45)	2.6 (3.2)	2.3 (3.5)	.642
Barthel Index (BI, 0-100)	26.0 (10.8)	27.3 (15.7)	.462

Table 3. Showing the mean and SD for the primary and all secondary parameters for both groups at baseline assessment, four-week assessment and three-month assessment.

Parameter	Group*	Baseline assessment	Four-week assessment	Three-month assessment
Fugl-Meyer Score (FM, 0-66)	A	14.6 (9.4)	25.7 (16.5)	31.3 (21.2)
	B	16.5 (9.8)	31.1 (19.1)	36.7 (21.8)
Action Research Arm Test (ARAT, 0-56)	A	4.9 (6.9)	14.1 (15.5)	18.3 (20.2)
	B	7.3 (6.8)	20.3 (15.4)	28.2 (20.5)
Box & Block Test (BBT,*n*)	A	0.2 (0.7)	10.7 (14.8)	14.4 (19.3)
	B	0.9 (1.6)	14.7(18.1)	19.2 (24.1)
Medical Research Council Sum Score (MRC, 0-45)	A	6.4 (6.7)	15.8 (11.1)	17.6 (13.4)
	B	8.9 (7.8)	17.0 (12.0)	19.6 (13.8)
Modified Ashworth Sum Score (ASG, 0-45)	A	2.6 (3.2)	2.2 (2.8)	2.4 (3.1)
	B	2.3 (3.4)	2.4 (3.5)	2.8 (4.9)
Barthel Index (BI, 0-100)	A	42.0 (14.5)	68.0 (17.7)	80.8 (18.3)
	B	46.8 (19.0)	62.8 (20.8)	76.0 (22.7)

*Group A: robot assisted group therapy plus individual arm therapy; group B: individual arm therapy of double intensity, every workday, four weeks.

were 37.000 €, i.e. one treatment cost 4.15 €. The experienced therapist treated 3.825 patients per year, the total costs (salary, 10% overhead) of the individual arm therapy were 38.500 €, i.e. one treatment cost 10.00 €. The difference in actual costs for the employer is thus 5.85 € per session.

Discussion

The upper limb function of subacute patients with stroke and a moderately to severely affected upper limb improved in both groups over time, but we found no between group differences. Both

Table 4. Initial means (SD) and mean (SD) between group differences during the time periods baseline to four-week assessment and baseline to three-month assessment of the primary and all secondary variables, as well as the *p*-values calculated for the between group differences.

Dependent variable	Group*	Initial value	Mean (SD) for differences from four-week assessment-baseline	Between group differences (*p*-value)	Mean (SD) for differences from period three-month assessment-baseline	Between group differences (*p*-value)
Fugl-Meyer Score (0-66)	A	14.6 (9.4)	11.1 (10.6)	.240	16.8 (16.0)	3.02
	B	16.5 (9.8)	14.6 (11.2)		20.2 (14.6)	
ARAT (0-56)	A	4.9 (±6.9)	9.2 (±12.0)	0.78	13.4 (±17.0)	0.044
	B	7.3 (±6.8)	13.0 (±10.2)		20.9 (±16.1)	
Box & Block test (*n*)	A	0.2 (±0.7)	11.5 (±19.6)	0.130	16.2 (±19.2)	0.235
	B	0.9 (±1.6)	13.8 (±17.2)		18.3 (±23.4)	
Sum score of the MRC (0-45)	A	6.4 (±6.7)	7.5 (±7.1)	0.497	11.3 (±10.1)	0.403
	B	8.9 (±7.8)	8.1 (±6.4)		12.6 (±12.0)	
Sum score of Modified Ashworth Scale (0-45)	A	2.6 (±3.2)	0.1 (±3.6)	0.743	0.6 (±4.9)	0.695
	B	2.3 (±3.5)	0.2 (±4.1)		0.6 (±5.4)	
Barthel Index (0-100)	A	42.0 (±14.5)	26.0 (±10.8)	0.085	35.6 (±18.3)	0.135

*Group A: robot assisted group therapy plus individual arm therapy; group B: individual arm therapy of double intensity, every workday, four weeks.

treatments, robot-assisted group therapy + individualized arm therapy vs. individual arm therapy of double intensity, were equally effective.

In the current trial, the mean Fugl-Meyer Score improvements of the moderately to severely affected subacute patients with stroke were +11.1 (10.6) in the experimental and +14.5 (11.2) in the control group after four weeks of intervention, i.e. they were clinically meaningful.[17] The initial mean Fugl-Meyer Score was 14.6 (9.4) and 16.5 (9.8), respectively.

The blinded Fugl-Meyer Score and the Action Research Arm Test improvements during the study period and follow-up tended to be greater in the control group, but did not reach the chosen level of significance. Particulary the lack of significance of the Action Research Arm Test outcome in favour of the control group at follow up (p=.044) suffered of two limits: the non-blindness of the evaluation and the chosen Bonferroni correction. Moreover, one had to take into consideration that the individual arm therapy followed the concept of the positively evaluated task-oriented Motor Relearning Programme. Langhammer and Stanghelle reported that the Motor Relearning Programme had proven more effective than the commonly applied Bobath approach in restoring arm function and quality of movement in subacute in-patient stroke rehabilitation patients.[14,25–27] For outpatients after stroke, Chan et al. had also reported that the programme, as compared to a conventional training, was more effective.[24] On the other hand, the control patients (group B) tended to be less impaired at study onset. With respect to the disability-based Box & Block test, for instance, five B- but only one A-patient managed to transfer three wooden blocks within one minute with the paretic hand at study onset.

The major advantages of the robot-assisted group therapy were a higher training intensity and lower costs. A participant trained approximately 600-800 movements during one single robot-assisted group therapy session, presumably more than a B-patient during his extra individual arm therapy. The higher training intensity, known to positively influence motor rehabilitation after

Table 5. Paired differences of the dependant variables for both groups between baseline and four-week assessment and between baseline and three-month assessment.

Parameter	Group*	Mean	SD	95% confidence interval of the difference		*p*-value
				Lower	Upper	
Fugl-Meyer Score (FM, 0-66)	A	11.1	10.6	5.7	15.4	<.0001
FM four-week – FM baseline	B	14.6	11.2	9.3	19.8	<.0001
FM three-month – FM baseline	A	16.8	16.0	8.7	23.3	<.0001
	B	20.2	14.6	13.4	27.0	<.0001
Action Research Arm Test (ARAT, 0-56)	A	8.7	11.8	3.3	14.1	.003
ARAT four-week – ARAT baseline	B	12.8	11.7	7.3	18.2	<.0001
ARAT three-month – ARAT baseline	A	12,7	,6,8	5,1	20,4	.002
	B	22.2	16.9	14.2	30.1	<.0001
Box & Block Test (BBT,*n*)	A	8.1	11.5	2.9	13.3	.004
BBT four-week – BBT baseline	B	13.8	17.2	5.8	21.8	.002
BBT three-month – BBT baseline	A	13.5	19.0	4.9	22.2	.004
	B	18.3	23.4	7.4	29.2	.002
Medical Research Council Sum Score (MRC, 0-45)	A	7.1	7.1	3.9	10.3	<.0001
	B	7.8	6.9	4.6	11.0	<.0001
MRC four-week – MRC baseline						
MRC three-month – MRC baseline	A	10.7	10.1	6.1	15.3	<.0001
	B	8.4	12.1	2.7	14.0	.006
Modified Ashworth Sum Score (ASG, 0-45)	A	–.86	2.51	–2.00	.29	.134
	B	0.15	4.15	–1.79	2.09	.873
MAS four-week – MAS baseline						
MAS three-month – MAS baseline	A	–.57	2.87	–1.88	.74	.373
	B	0.20	6.05	–2.63	3.03	.884
Barthel Index (BI, 0-100)	A	25.2	11.1	20.2	30.3	<.0001
BI four-week – BI baseline	B	16.0	15.7	8.7	23.3	<.0001
BI three-month – BI baseline	A	37.1	16.9	29.5	44.8	<.0001
	B	29.3	21.4	19.3	39.2	<.0001

*Group A: robot assisted group therapy plus individual arm therapy; group B: individual arm therapy of double intensity, every workday, four weeks.

stroke, seemed to have outweighed the disadvantages. Namely a less task-oriented approach in the robot-assisted group therapy as compared to the individual arm therapy, and the discomfort with the group setting reported by nine of the 25 A-participants.

The actual costs of one session for a single patient in the robot arm studio were 4.15 €, and 10.00 € for one individual therapy session per patient, i.e. the robot-assisted group therapy cost less but both approaches were equally effective. English et al. also found for improving walking ability and functional balance in subacute stroke participants that circuit class therapy (analogous to the chosen setting of the robot group therapy session) appeared as effective as individual physiotherapy sessions. [28]

The Fugl-Meyer improvements in the current trial corresponded to those of other robot trials after stroke. In the Bi-Manu-Track [8] and Reha-Slide[20] trials, subacute patients with stroke and an initial mean Fugl-Meyer Score of 8.6 (4.2) and 8.8 (4.7) had improved their Fugl-Meyer Score for a

mean of 11.8 and 10.4 points, the treatment period in those two studies had been six weeks of daily training. For the MIT-Manus, Volpe et al. reported a mean Fugl-Meyer Score improvement of 12.0 (3.0) in the robot group of subacute patients with stroke after five weeks of training, their initial mean Fugl-Meyer Score was 6.0 (2.5) . [7] For the NeReBot, Masiero et al. reported a mean Fugl-Meyer Score improvement of 15.8 in the robot group in subacute patients with stroke after five weeks of training. Their initial mean Fugl-Meyer Score was 8.0, they had included the patients already within the first week after stroke onset. [9]

In conclusion, treatment of the upper limb using robot-assisted group therapy and individual arm therapy is clinically equally effective to individual arm therapy of double intensity in restoring arm function in moderately to severely affected subacute patients with stroke. The treatment in a robot-assisted group therapy, consisting of six work stations, supervised by an assistant therapist, cost less. Further research is needed, both to confirm the clinical equivalence but also to confirm the cost advantage of the robot-assisted group therapy.

Clinical messages

- Robot-assisted group therapy + individual arm therapy is as effective as a double session of individual arm therapy in subacute patients with stroke.
- Robot-assisted group therapy is probably more cost-efficient than individual arm therapy.

Conflict of interest

Reha-Stim, Berlin, produces the arm studio devices. The company is owned by Dr. Brandl-Hesse, the spouse of the first author SH. The company neither influenced the design of the study, the analysis or the decision to submit the manuscript.

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