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Short- and long-term outcome of constraint-induced movement therapy after stroke: a randomized controlled feasibility trial

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Objective: Constraint-induced movement therapy (CIMT) is a method to improve motor function in the upper extremity following stroke. The aim of this trial was to determine the effect and feasibility of CIMT compared with traditional rehabilitation in short and long term.
Design: A randomized controlled trial.
Setting: An inpatient rehabilitation clinic.
Subjects: Thirty patients with unilateral hand impairment after stroke.
Intervention: Six hours arm therapy for 10 consecutive weekdays, while using a restraining mitten on the unaffected hand.
Main measures: The patients were assessed at baseline, post-treatment and at six-month follow-up using the Wolf Motor Function Test as primary outcome measure and the Motor Activity Log, Functional Independence Measure and Stroke Impact Scale as secondary measurements.
Results: The CIMT group ($n = 18$) showed a statistically significant shorter performance time (4.76 seconds versus 7.61 seconds, $P = 0.030$) and greater functional ability (3.85 versus 3.47, $P = 0.037$) than the control group ($n = 12$) on the Wolf Motor Function Test at post-treatment assessment. There was a non-significant trend toward greater amount of use (2.47 versus 1.97, $P = 0.097$) and better quality of movement (2.45 versus 2.12, $P = 0.105$) in the CIMT group according to the Motor Activity Log. No such differences were seen on Functional Independence Measure at the same time. At six-month follow-up the CIMT group maintained their improvement, but as the control group improved even more, there were no significant differences between the groups on any measurements.
Conclusions: CIMT seems to be an effective and feasible method to improve motor function in the short term, but no long-term effect was found.

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Introduction

Constraint-induced movement therapy (CIMT) is a family of therapies that aims to permanently increase the quality of movement and amount of use of a paretic upper extremity following stroke.[1,2] Standard CIMT involves restraining the unaffected hand for two weeks combined with 6 hours of daily task-specific shaping training of the affected hand.[2–4]

A systematic review considering 14 trials found a trend in favour of CIMT in the short term, at post-treatment assessment. They varied according to duration, use of outcome measurements, setting, type of restraint and intensity.[5] Only two trials had evaluated the long-term effects six months or more after treatment, and showed a small, lasting effect on manual dexterity [6] and a persistent improved motor function assessed by interview.[3] More recently, Wolf *et al.*[7] published the first multisite trial of CIMT. It showed statistically significant improvements in arm motor function assessed by interview and motor performance time both in short and long term. However, the functional ability did not persist at one-year follow-up when the groups were compared.

CIMT trials have been conducted on both acute,[8–11] subacute[12,13] and chronic[3,4,6,14–17] patients following stroke.[5] Trials with acute or subacute patients have often used modified forms of CIMT, mainly concerning shorter daily therapy,[8,9,11] over a prolonged period.[10,12,13] Most of the trials show a positive effect of CIMT,[8,10–13] however it seems as if modified CIMT is less effective than standard CIMT.[15]

The effectiveness of CIMT is often assessed by using laboratory instruments, such as the Wolf Motor Function Test.[3,4,7,12,15,17] The Motor Activity Log is frequently used to assess the affected hand function in activities of daily living (ADL).[3,4,7,10–15,17] Only a few trials have considered independence in ADL[8] and self-perceived health.[7] The majority of CIMT trials are conducted in the USA and few[6,15] are published from Europe.

The primary aim of this trial was to assess the effect of CIMT compared to traditional rehabilitation, in the short and long term, considering arm motor function, independence in ADL and self-perceived health in patients after stroke. The secondary aim was to assess the feasibility of CIMT, organized as group therapy in the Norwegian health care system.

Methods

Participants

Patients with unilateral hand impairment after stroke (two weeks to eight years post-stroke) were recruited from the Stroke Unit at Trondheim University Hospital and by announcement at hospitals and rehabilitation institutions in the neighbouring counties.

Inclusion criteria were: diagnosis of a stroke according to World Health Organization definition of stroke,[18] weakness or reduced dexterity of the affected hand, time from onset of stroke more than two weeks, modified Rankin Scale[19] score 0–2 points before the stroke, more than 20 degrees active wrist extension and 10 degrees active finger extension, 20 points or more on the Mini-Mental State Examination scale,[20] age 18–80 years, able and willing to sign informed written consent.

Potential participants were excluded if they suffered from: other neurological diseases, unstable cardiovascular disease, severe depression defined as more than 12 points on Montgomery and Aasberg Depression Rating Scale,[21] marked neglect defined as line bisection more than 2 cm over the midline,[22] life expectancy less than six months, sequel from a previous stroke and clinically evaluated insufficient endurance to participate.

The participants underwent a medical examination before inclusion in the trial and were well informed of the training principles.

Study design

The study was a randomized controlled clinical trial with baseline assessment, post-treatment assessment and six-month follow-up. Eligible patients were block-randomized into a CIMT group or a control group receiving traditional rehabilitation, according to a 3 : 2 ratio. This ratio was chosen to assess the feasibility of CIMT on as many patients as possible. Sealed

opaque envelopes were used for randomization and the procedure was carried out by an external office. Two independent and blinded assessors performed the assessments.

The trial was approved by the Regional Committee for Medical Research Ethics.

Intervention

All the participants received standard stroke rehabilitation and physiotherapy during the initial hospital stay after onset of stroke. They also received further traditional rehabilitation recommended by the family physician before randomization into the trial.

Traditional rehabilitation

Traditional rehabilitation was defined as further community-based follow-up treatment given according to each patient's needs, involving both upper and lower extremity training. When long-term rehabilitation was necessary, inpatient rehabilitation was given, including both physiotherapy and occupational therapy. Patients were otherwise, or after inpatient rehabilitation, followed-up by the primary health care system including physiotherapy mainly given two sessions per week.

The control group received traditional rehabilitation during the intervention period and during the further follow-up, but were offered the CIMT intervention after completing the six-month follow-up.

Constraint-induced movement therapy

The CIMT was conducted at an inpatient rehabilitation clinic at Trondheim University Hospital and all the participants were inpatients during the intervention. The patients were intended to train 6 hours daily for 10 consecutive week days. The participants exercised in groups of four led by a physical and an occupational therapist, assisted by specially trained nurses. A mitten immobilized the non-paretic hand 90% of waking hours. It was removed for hygienic and safety reasons and its removal was registered in a log. In the afternoon the nursing staff supervised and motivated the participants to wear their mitten.

Each participant formulated five realistic aims related to ADL or leisure time activities before starting the intervention. Daily activities were the basis for an individual activity form which was updated with daily progress. Exercises were chosen from a collection of approximately 150 activities to be carried out with one hand, divided into 10 fields: personal care, kitchen and household, games, handicrafts, gardening, office work, shopping, sports, strength and mobility. The activities ranged from complex to simple tasks and were individually adjusted with regard to number of repetitions, tempo, resistance, range of motion, texture, weight, size, and shape. The participants had mini-breaks when they shifted from one field of activity to another after half an hour.

Outcome measures

All outcome measures were used at post-treatment assessment and at six-month follow-up, apart from the Stroke Impact Scale at post-treatment assessment. The same measurements were recorded at baseline.

Primary outcome measure

Wolf Motor Function Test is a standardized laboratory assessment. The test consists of two strength and 15 timed tasks which vary from gross shoulder movements to complex finger grips. Subjects who cannot perform the task within 2 minutes are given the maximum score of 120 seconds. The tasks are videotaped and the quality of movement for each task is rated on a 6-point functional ability scale.[23] In this study the mean of the 15 timed tasks was used as a test parameter. The mean of the functional ability scale for the 15 tasks are reported as well. The reliability and validity of the instrument have been ascertained in different stroke populations.[23,24]

Secondary outcome measures

The 30-item Motor Activity Log is a structured interview to evaluate the use of the paretic arm in ADL.[25] Subjects are asked to rate, on a 6-point

scale, the quality of movement and the amount of use of their affected hand in given daily activities. The reliability and validity is stated for 28 of the 30 items.[25]

The Functional Independence Measure assesses the level of independence in ADL. It consists of 13 motor items and five social and cognitive items, ranging from total need of assistance (1 point) to complete independence (7 points). The measurement scores highest in terms of reliability, validity and responsiveness compared with other tools of disability outcomes.[26]

The Stroke Impact Scale is a self-report measurement to detect consequences of stroke on the person's perceived health. It includes 64 items and assesses eight domains. Each item has a 5-point scale ranging from 1 point to 5 points. Aggregated scores, ranging from 0 (lowest level) to 100 (highest level) in each domain, are generated with an algorithm. The measurement also includes a question to assess the patient's global perception of percentage of recovery on a visual analogue scale from 0 (no recovery) to 100 (full recovery). Stroke Impact Scale is reliable, valid and sensitive to change.[27]

Statistical analysis

Analysis was on an intention-to-treat basis and was performed in the Statistical Packages for the Social Sciences version 13.0.

Changes within groups were analysed with paired *t*-test and differences between groups were analysed with analysis of covariance (ANCOVA) with the baseline score as a covariate.[28] Two-sided *P*-values <0.05 were considered significant. In a second-level analysis it was adjusted for age, gender, time from onset of stroke and dominant side affected.[29] Normal distribution assumptions were checked by visual inspection of Quantile-Quantile plots.

Wolf Motor Function Test performance time had a skewed distribution and a logarithmic transformation was performed. In the statistical tests the transformed scale was used as a test parameter. In the summary statistics, the log-transformed scale was transformed back to its original scale to aid in interpretation.

On Wolf Motor Function Test functional ability, both Motor Activity Log scales, Functional Independence Measure as well as Stroke Impact Scale, the mean score was used as a test parameter.

Results

Study sample

Figure 1 shows the flow of patients through the study. Thirty patients with subacute and chronic stroke fulfilled the inclusion criteria and were included into the trial from October 2003 to October 2005. Eighteen patients were allocated to the CIMT group and 12 patients to the control group. At the time of inclusion four patients were inpatients, two in each group. In the control group one patient walked indoors with a crutch and in the CIMT group one patient used a wheelchair and two patients walked indoors with a crutch. All participants completed the intervention and all the assessments.

At baseline the control group had a greater proportion of women (42% versus 11%) and a lesser proportion of patients whose dominant arm was affected (58% versus 78%) (Table 1). However, none of the differences in the baseline variables were statistically significant.

Primary outcome measure

Table 2 shows the results of the primary outcome measure. The CIMT group showed a statistically significant improvement on both Wolf Motor Function Test scales from baseline to post-treatment assessment ($P<0.001$). There was no such improvement in the control group. At post-treatment assessment there was a statistically significant difference between the groups on performance time score (4.76 seconds versus 7.61 seconds, $P=0.030$) and functional ability score (3.85 points versus 3.47 points, $P=0.037$) in favour of the CIMT group. From baseline to six-month follow-up both groups improved significantly according to both scales, showing no differences between the groups at this time.

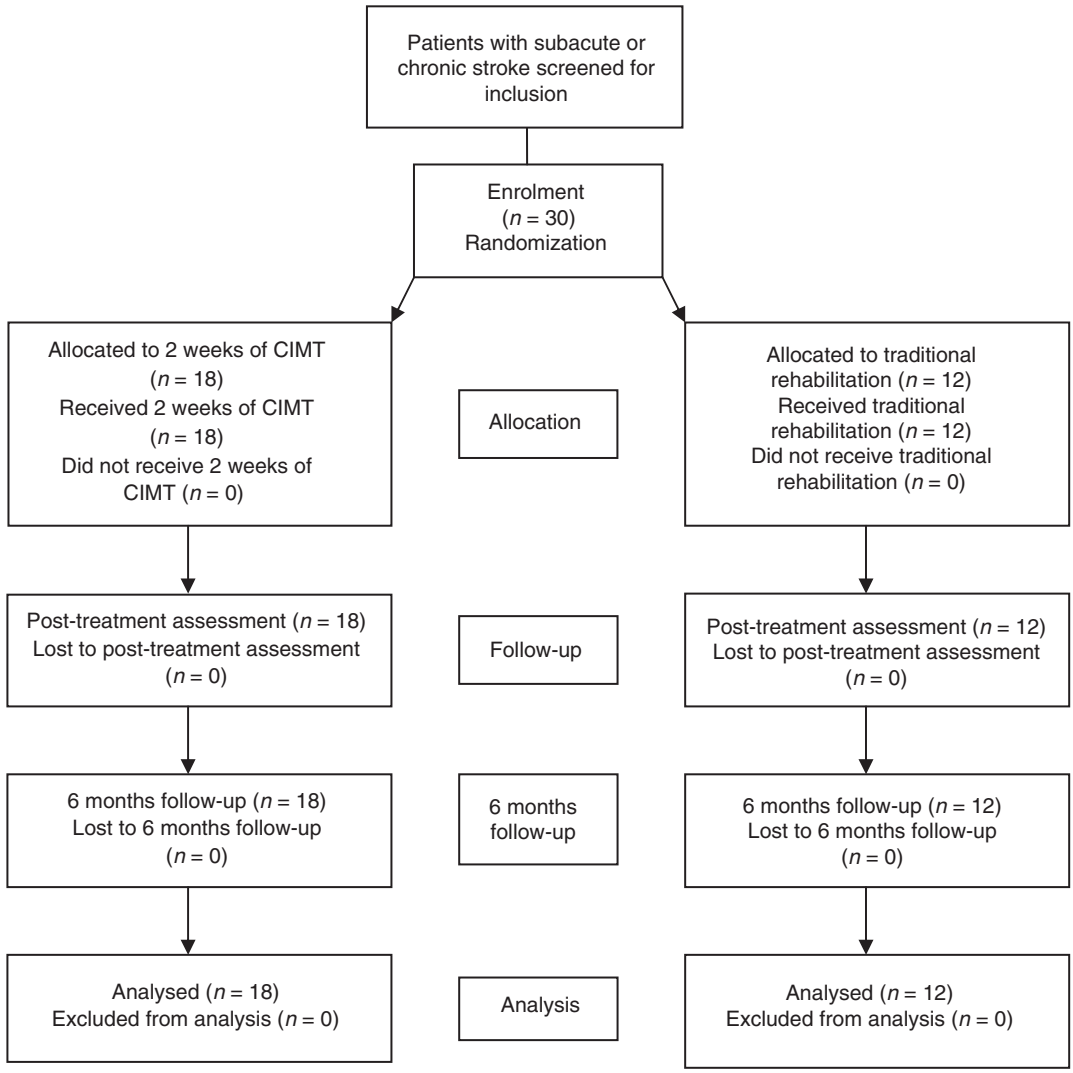

Figure 1 Flowchart of patient randomization and follow-up.

Secondary outcome measures

Table 3 shows that the CIMT group improved significantly ($P<0.001$) on Motor Activity Log quality of movement and amount of use at post-treatment assessment. No such improvement was revealed in the control group. The differences between the groups showed a non-significant trend in favour of the CIMT group, according to amount of use score (2.47 versus 1.97, $P=0.097$) and quality of movement score (2.45 versus 2.12, $P=0.105$) at post-treatment assessment. Both groups improved significantly from baseline to six-month follow-up and no statistically significant differences between the groups were present at this time.

According to the Functional Independence Measure, the CIMT group showed a statistically significant improvement from baseline to post-treatment assessment (1.17, $P=0.028$) (Table 3). The control group raised their score

0.75 points (not significant) at the same time. There were no significant difference between the groups ($P = 0.516$). Both groups improved from baseline to six-month follow-up, but there were no significant differences between the groups at this time.

The Stroke Impact Scale was only assessed at baseline and six-month follow-up, showing a statistically significant improvement in self-perceived strength (9.72 points, $P = 0.003$) for the CIMT group (Table 4). In memory, communication, emotion and overall recovery both groups raised their scores significantly, but no differences between the groups were shown on any domains.

The second-level analysis with age, gender, time from onset of stroke and dominant side affected as covariates did not influence the results and the details are not reported.

Table 1 Baseline characteristics

	CIMT group ($n = 18$)	Control group ($n = 12$)
Demographic		
Age, mean (SD)	62 (8)	60 (12)
Women, number (%)	2 (11)	5 (42)
Living alone, number (%)	5 (28)	2 (17)
Stroke related		
Dominant side affected, number (%)	14 (78)	7 (58)
Months since stroke, mean (SD)	21 (18)	26 (27)
Months since stroke, median (range)	16 (1–64)	19 (1–92)
Medical history, number (%):		
Stroke	1 (6)	2 (17)
Transient ischaemic attack	0 (0)	2 (17)
Myocardial infarction	3 (17)	2 (17)
Atrial fibrillation	2 (11)	0 (0)
Hypertension	8 (44)	5 (42)
Diabetes	4 (22)	3 (25)

Compliance

For the control group the mean (SD) time with physiotherapy was 1.7 (1.3) hours per week, including both upper and lower extremity exercises, and the mean (SD) time with occupational therapy was 0.8 (1.5) hours per week during the intervention period. In the CIMT group the mean (SD) training time was 5.7 (0.6) hours per day.

Table 2 Wolf Motor Function Test (WMFT)

	CIMT group ($n = 18$)		Control group ($n = 12$)		
	Mean ± SD (% change from baseline)	Within-group differences, mean change (95% CI)[a]	Mean ± SD (% change from baseline)	Within-group differences, mean change (95% CI)[a]	Between-group differences ANCOVA[b] *P*-value
WMFT – performance time, log transformed					
Baseline	2.17 ± 0.78		2.27 ± 0.85		
Post-treatment assessment	1.56 ± 0.57	−0.61 (−0.14 to −0.90)*	2.03 ± 0.82	−0.24 (0.11 to −0.59)	0.030
Six-month follow-up	1.82 ± 0.80	−0.35 (−0.01 to −0.68)‡	1.77 ± 0.92	−0.50 (−0.09 to −0.93)‡	0.585
WMFT – performance time, converted to seconds					
Baseline	8.76 (−00%)		9.68 (−00%)		
Post-treatment assessment	4.76 (−46%)		7.61 (−21%)		
Six-month follow-up	6.17 (−30%)		5.87 (−39%)		
WMFT – functional ability (max = 5)					
Baseline	3.51 ± 0.53		3.31 ± 0.51		
Post-treatment assessment	3.85 ± 0.50	0.34 (0.44 to 0.24)*	3.47 ± 0.60	0.16 (0.32 to −0.01)	0.037
Six-month follow-up	3.95 ± 0.61	0.44 (0.59 to 0.28)*	3.73 ± 0.58	0.42 (0.72 to 0.13)†	0.823

[a]Change from baseline to post-treatment assessment and from baseline to six-month follow-up.
[b]Covariates: baseline score of dependent variable and treatment group.
*$P < 0.001$; †$P < 0.01$; ‡$P < 0.05$.

The mean (SD) time with mitten use was 13.1 (2.6) hours per day, although one patient deviated from the protocol because of cognitive impairments.

Adverse symptoms

Four people in the CIMT group had muscle tenderness in their affected arm before starting the intervention. The symptoms either decreased or remained unchanged during the intervention. No injuries or other side-effects were reported.

Discussion

This is, to our knowledge, the first CIMT trial reporting short- and long-term results on both the Wolf Motor Function Test and Motor Activity Log conducted outside the USA. These results support findings from other trials using these measurements, showing substantial improvements immediately after CIMT.[3,4,7] However, our trial does not confirm a persisting effect of CIMT.[7]

Most CIMT trials have reported short-term improvements for both subacute[12,13] and chronic[3,4,14–16] patients, however one trial reported no significant improvement on the Wolf Motor Function Test scales.[17] Our trial included both subacute and chronic patients, but the sample size was too small to make subgroup analysis. However, our results support that CIMT is an effective therapy for improving motor skills in the upper extremity for this heterogeneous group of patients in the short range. The results showed a significant improvement in the control group at six-month follow-up and no difference between the groups at that time. Hence, from our trial it is uncertain whether CIMT is superior to standard rehabilitation in the long run. Wolf and colleagues' multisite trial showed significant differences between the groups on Wolf Motor Function Test performance time score, but not on functional ability score 12 months after the intervention.[7] Therefore, the long-term effect of CIMT is still unclear.

One possible reason for the pronounced improvement in our control group could be the

Table 3 Motor Activity Log (MAL) and Functional Independence Measure (FIM)

	CIMT group ($n=18$)		Control group ($n=12$)		
	Mean ± SD	Within-group differences, mean change (95% CI)[a]	Mean ± SD	Within-group differences, mean change (95% CI)[a]	Between-group differences ANCOVA[b] *P*-value
MAL – amount of use (max = 5)					
Baseline	1.91 ± 1.23		1.70 ± 1.19		
Post-treatment assessment	2.47 ± 1.15	−0.56 (−0.76 to −0.35)*	1.97 ± 1.16	−0.27 (−0.68 to 0.14)	0.097
Six-month follow-up	2.51 ± 1.23	−0.60 (−0.83 to −0.36)*	2.43 ± 1.34	−0.73 (−1.37 to −0.07)‡	0.715
MAL – quality of movement (max = 5)					
Baseline	1.94 ± 0.07		1.88 ± 1.00		
Post-treatment assessment	2.45 ± 0.95	−0.51 (−0.70 to −0.33)*	2.12 ± 1.00	−0.24 (−0.63 to 0.14)	0.105
Six-month follow-up	2.55 ± 1.06	−0.61 (−0.87 to −0.35)*	2.51 ± 1.11	−0.63 (−1.24 to −0.04)‡	0.955
FIM (max = 126)					
Baseline	106.17 ± 8.54		110.92 ± 5.85		
Post-treatment assessment	107.33 ± 8.80	−1.17 (−2.19 to 0.14)‡	111.67 ± 6.49	−0.75 (−1.83 to 0.33)	0.516
Six-month follow-up	109.56 ± 8.25	−3.39 (−5.53 to −1.25)†	112.92 ± 6.75	−2.00 (−3.88 to −0.12)‡	0.571

[a]Mean change from baseline to post-treatment assessment and from baseline to six-month follow-up.
[b]Covariates: baseline score of dependent variable and treatment group.
*$P<0.001$; †$P<0.01$; ‡$P<0.05$.

Table 4 Stroke Impact Scale

	CIMT group ($n=18$)		Control group ($n=12$)		
	Mean ± SD	Within-group differences, mean change (95% CI)[a]	Mean ± SD	Within-group differences, mean change (95% CI)[a]	Between-group differences ANCOVA[b] *P*-value
Strength					
Baseline	52.78 ± 16.22		53.13 ± 13.89		
Six-month follow-up	62.50 ± 16.04	−9.72 (−15.58 to −3.86)†	57.29 ± 14.31	−4.17 (−14.09 to 5.76)	0.247
Hand function					
Baseline	86.11 ± 10.89		90.63 ± 10.15		
Six-month follow-up	89.93 ± 8.34	−3.82 (−7.90 to 0.26)	90.10 ± 12.05	0.52 (−2.95 to 3.99)	0.246
Mobility					
Baseline	86.27 ± 10.46		90.28 ± 8.33		
Six-month follow-up	88.58 ± 9.90	−2.31 (−7.40 to 2.77)	86.11 ± 12.25	4.17 (−1.69 to 10.02)	0.174
ADL/IADL					
Baseline	85.52 ± 15.61		93.45 ± 8.03		
Six-month follow-up	86.71 ± 14.22	−1.19 (−4.36 to 1.98)	91.67 ± 10.59	1.79 (−0.48 to 4.06)	0.313
Memory					
Baseline	77.55 ± 9.73		78.99 ± 8.59		
Six-month follow-up	81.60 ± 9.27	−4.05 (−7.77 to −0.33)‡	87.85 ± 7.89	−8.85 (−16.53 to −1.18)‡	0.070
Communication					
Baseline	69.11 ± 11.75		71.83 ± 5.15		
Six-month follow-up	86.81 ± 13.55	−17.69 (−15.37 to −16.08)*	87.92 ± 10.27	−16.08 (−21.19 to −10.98)*	0.425
Emotion					
Baseline	47.71 ± 21.00		46.25 ± 22.27		
Six-month follow-up	63.61 ± 17.81	−15.90 (−24.25 to −7.56)*	69.17 ± 24.01	−22.92 (−37.15 to −8.68)†	0.322
Participation					
Baseline	82.41 ± 8.25		78.70 ± 11.13		
Six-month follow-up	81.79 ± 12.50	0.62 (−5.89 to 7.12)	79.40 ± 10.49	−0.69 (−7.80 to 6.41)	0.845
Overall recovery					
Baseline	55.00 ± 20.51		54.17 ± 13.11		
Six-month follow-up	64.72 ± 20.40	−9.72 (−18.89 to −0.56)‡	61.67 ± 10.94	−7.50 (−14.07 to −0.93)‡	0.628

[a]Mean change from baseline to six-month follow-up.
[b]Covariates: baseline score of dependent variable and treatment group.
*$P<0.001$; †$P<0.01$; ‡$P<0.05$.

Hawthorn effect, which might have motivated the participants in this group to use their paretic hand more. It cannot be ruled out that this, in combination with traditional rehabilitation, which most of the control patients received outside this trial, might have gradually improved hand function. A similar improvement for the control group was also found in the multisite trial.[7]

The results of Wolf Motor Function Test are supported by the results of Motor Activity Log

in our trial. Motor Activity Log is widely used in CIMT trials,[5] and several papers describe an even more convincing effect of this measurement than Wolf Motor Function Test.[3,4,7,15,17] We emphasized that the participant had to be honest in both directions when answering Motor Activity Log, which might have reduced the risk of giving socially desirable answers.[30]

There exist several versions of Motor Activity Log and there has been a question about the measurements' standardization, and its longitudinal construct validity.[5,25,30,31] The 30-item version of Motor Activity Log was chosen in this trial, which has shown good reliability and cross-sectional construct validity for 28 of the 30 items.[25] In our view, this measurement was quite demanding, depending highly on the patients' honesty, memory and insight. Some of our patients with minor cognitive impairment might have exaggerated their scores.

In our trial both groups improved their level of independence in ADL at the six-month follow-up according to Functional Independence Measure, but there were no differences been the groups at any time. Only one previous CIMT trial has used this instrument, and showed a significant change on the domain upper-extremity dressing at post-intervention.[8] A general weakness for measurements assessing ADL is that activities can be performed by compensating with the unaffected hand,[8] which may be more efficient. It cannot be ruled out that the Functional Independence Measure has an inadequate responsiveness[26] and it appears difficult to find an appropriate measurement which can assess the effects of CIMT on ADL.[8] The impression from the therapists conducting the intervention was that participants improved most in the performance of precisely that activity they exercised and particularly regarding their five aims. So far, no conclusion can be drawn concerning the effect of CIMT on ADL, and it will be of considerable interest to investigate this in the future.

According to the Stroke Impact Scale there were no significant differences between the groups. We cannot confirm the long-term improvements in hand function found in the multisite trial,[7] nor the results from a non-randomized study showing significant improvement in hand function, strength and social participation.[32] The fact that our control group was promised the intervention after completing the trial might have given new hope for recovery[33] and influenced the results of the Stroke Impact Scale. Our trial gives no indication for improved self-perceived health after CIMT in the long run.

All the participants in the CIMT group were able to fulfil the entire intervention and they gave positive feedback regarding the intensive group training. No patients experienced additional adverse symptoms or side-effects during the intervention, indicating that this therapy seems to be safe. Our CIMT programme was based on group therapy, which is more economic and exploits the therapeutic resources better than one-to-one therapy.[34] Based on our inclusion and exclusion criteria, CIMT seems to be suitable for a highly selected group of the Norwegian stroke population. In rural areas, as in many parts of Norway and Scandinavia, this therapy may be difficult to organize. However, this trial still indicated that an inpatient setting of CIMT can be feasible for the Norwegian health care system. One problem for this intervention is the very low number of patients fulfilling the criteria to participate. A challenge for the future is to find out whether modified versions of CIMT could be applied to a greater proportion of the stroke population.

This trial's main strength is the randomized controlled design with blinded evaluation and follow-up assessment on all outcome measurements. Second, we have chosen well-known measurements of different aspects of recovery following stroke. The final strength is that we had no drop-outs during this trial. This is in contrast to other studies reporting up to 25% drop-outs.[4,7]

Several limitations of this trial are noteworthy. First, we had a relatively small sample size because of difficulties of finding eligible patients. The low sample size leads to the lack of statistical power and increased risk of a type II error, and therefore our trial could be regarded as a pilot trial. The low number of patients might explain why we had no statistical differences between the groups at six-month follow-up. Second, it would have been advantageous to include an even more homogeneous group of patients according to time since stroke. Third, we lack a detailed description of the traditional rehabilitation given to the control group, as well as the CIMT group's effort after

the intervention. Further research should focus on these factors.

So far, standard CIMT trials have been performed with two weeks of intervention. Patients may benefit from periodic re-administration or longer periods of this treatment, to further improve their upper extremity motor function. It seems as though both subacute and chronic patients have the capacity for a more intensive, functional training than what is traditionally given after stroke.[35] It will also be essential to further investigate whether equivalent intensive standard rehabilitation gives the same effect as CIMT.[11] Further research should therefore focus on whether it is the intensity of training, the 'forced use' of the affected hand, the task-specific training, or a combination of these which are the most significant components of CIMT.

Clinical messages

- Constraint-induced movement therapy seems to be clinically effective in the short term, but no long-term effect was found.
- It is unclear to what extent a functional improvement after CIMT is beneficial for daily activities.
- For a selected group of patients CIMT organized as group therapy is feasible.

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Competing interests

None declared.

Contributors

AED: Specifying the questions, designing the study, identifying data needed, interpreting the data analysis, translating the protocol into practice, collecting and handling data, writing and revising drafts of the whole paper and identifying relevant references. TA: Designing the study, identifying data needed, analysing the data, interpreting the data analysis, collecting and handling data, writing paragraphs of the text, reading, editing and checking the paper and identifying relevant references. RS and EL: Designing the study, identifying data needed, translating the protocol into practice, reading, editing and checking the paper and identifying relevant references. SL: Analysing the data, reading, editing and checking the paper and identifying relevant references. BI: Specifying the questions, designing the study, identifying data needed, interpreting the data analysis, translating the protocol into practice and supervising the manuscript.

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References

1 Taub E, Uswatte G, Elbert T. New treatments in neurorehabilitation founded on basic research. *Nat Rev Neurosci* 2002; **3**: 228–36.
2 Taub E, Uswatte G, Pidikiti R. Constraint-induced movement therapy: a new family of techniques with broad application to physical rehabilitation – a clinical review. *J Rehabil Res Dev* 1999; **36**: 237–51.
3 Taub E, Miller NE, Novack TA, Cook EW III, Fleming WC, Nepomuceno CS, Connell JS, Crago JE. Technique to improve chronic motor deficit after stroke. *Arch Phys Med Rehabil* 1993; **74**: 347–54.
4 Taub E, Uswatte G, King DK, Morris D, Crago JE, Chatterjee A. A placebo-controlled trial of constraint-induced movement therapy for upper extremity after stroke. *Stroke* 2006; **37**: 1045–49.
5 Hakkennes S, Keating JL. Constraint-induced movement therapy following stroke: a systematic review of randomised controlled trials. *Aust J Physiother* 2005; **51**: 221–31.

6 van der Lee JH, Wagenaar RC, Lankhorst GJ, Vogelaar TW, Devillé WL, Bouter LM. Forced use of the upper extremity in chronic stroke patients: results from a single-blind randomized clinical trial. *Stroke* 1999; **30**: 2369–75.

7 Wolf SL, Winstein CJ, Miller JP *et al*. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. *JAMA* 2006; **296**: 2095–104.

8 Dromerick AW, Edwards DF, Hahn M. Does the application of constraint-induced movement therapy during acute rehabilitation reduce arm impairment after ischemic stroke? *Stroke* 2000; **31**: 2984–88.

9 Grotta JC, Noser EA, Ro T *et al*. Constraint-induced movement therapy. *Stroke* 2004; **35**: 2699–701.

10 Page SJ, Levine P, Leonard AC. Modified constraint-induced movement therapy in acute stoke: a randomized controlled pilot study. *Neurorehabil Neural Repair* 2005; **19**: 27–32.

11 Boake C, Noser EA, Ro T *et al*. Constraint-induced movement therapy during early stroke rehabilitation. *Neurorehabil Neural Repair* 2007; **21**: 14–24.

12 Page SJ, Sisto SA, Levine P, Johnston MV, Hughes M. Modified constraint induced therapy: a randomized feasibility and efficacy study. *J Rehabil Res Dev* 2001; **38**: 583–90.

13 Page SJ, Sisto SA, Johnston MV, Levine P. Modified constraint-induced therapy after subacute stroke: a preliminary study. *Neurorehabil Neural Repair* 2002; **16**: 290–95.

14 Page SJ, Sisto SA, Levine P, McGrath RE. Efficacy of modified constraint-induced movement therapy in chronic stroke: a single-blinded randomized controlled trial. *Arch Phys Med Rehabil* 2004; **85**: 14–18.

15 Sterr A, Elbert T, Berthold I, Kölbel S, Rockstroh B, Taub E. Longer versus shorter daily constraint-induced movement therapy of chronic hemiparesis: an exploratory study. *Arch Phys Med Rehabil* 2002; **83**: 1374–77.

16 Suputtitada A, Suwanwela NC, Tumvitee S. Effectiveness of constraint-induced movement therapy in chronic stroke patients. *J Med Assoc Thai* 2004; **87**: 1482–90.

17 Wittenberg GF, Chen R, Ishii K *et al*. Constraint-induced therapy in stroke: magnetic-stimulation motor maps and cerebral activation. *Neurorehabil Neural Repair* 2003; **17**: 48–57.

18 WHO MONICA Project. *Monica Manual (1998–1999)*. Part IV: Event Registration. Section 2: Stroke event registration data component. Available from http://www.ktl.fi/publications/monica/manual/part4/iv-2.htm

19 Sulter G, Steen C, De Keyser J. Use of the Barthel index and modified Rankin scale in acute stroke trials. *Stroke* 1999; **30**: 1538–41.

20 Folstein MF, Folstein SE, McHugh PR. "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. *J Psychiat Res* 1975; **12**: 189–98.

21 Montgomery SA, Asberg M. A new depression scale designed to be sensitive to change. *Br J Psychiatry* 1979; **134**: 382–89.

22 Plummer P, Morris ME, Dunai J. Assessment of unilateral neglect. *Phys Ther* 2003; **83**: 732–40.

23 Morris DM, Uswatte G, Crago JE, Cook EW III, Taub E. The reliability of the wolf motor function test for assessing upper extremity function after stroke. *Arch Phys Med Rehabil* 2001; **82**: 750–55.

24 Wolf SL, Thompson PA, Morris DM *et al*. The EXCITE trial: attributes of the Wolf Motor Function Test in patients with subacute stroke. *Neurorehabil Neural Repair* 2005; **19**: 194–205.

25 Uswatte G, Taub E, Morris D, Light K, Thompson PA. The Motor Activity Log-28: assessing daily use of the hemiparetic arm after stroke. *Neurology* 2006; **67**: 1189–94.

26 Cohen ME, Marino RJ. The tools of disability outcomes research functional status measures. *Arch Phys Med Rehabil* 2000; **81**(Suppl 2): S21–S29.

27 Duncan PW, Wallace D, Lai SM, Johnson D, Embretson S, Laster LJ. The stroke impact scale version 2.0. Evaluation of reliability, validity, and sensitivity to change. *Stroke* 1999; **30**: 2131–40.

28 Vickers AJ, Altman DG. Statistics notes: Analysing controlled trials with baseline and follow up measurements. *BMJ* 2001; **323**: 1123–24.

29 Pocock SJ, Assmann SE, Enos LE, Kasten LE. Subgroup analysis, covariate adjustment and baseline comparisons in clinical trial reporting: current practice and problems. *Stat Med* 2002; **21**: 2917–30.

30 van der Lee JH, Beckerman H, Knol DL, de Vet HCW, Bouter LM. Clinimetric properties of the motor activity log for the assessment of arm use in hemiparetic patients. *Stroke* 2004; **35**: 1410–14.

31 Uswatte G, Taub E, Morris D, Vignolo M, McCulloch K. Reliability and validity of the upper-extremity Motor Activity Log-14 for measuring real-world arm use. *Stroke* 2005; **36**: 2493–96.

32 Dettmers C, Teske U, Hamzei F, Uswatte G, Taub E, Weiller C. Distributed form of constraint-induced movement therapy improves functional outcome and quality of life after stroke. *Arch Phys Med Rehabil* 2005; **86**: 204–09.

33 Boylstein C, Rittman M, Gubrium J, Behrman A, Davis S. The social organization in constraint-induced movement therapy. *J Rehabil Res Dev* 2005; **42**: 263–75.
34 Brogårdh C, Sjölund BH. Constraint-induced movement therapy in patients with stroke: a pilot study on effects of small group training and of extended mitt use. *Clin Rehabil* 2006; **20**: 218–27.
35 van Peppen RP, Kwakkel G, Wood-Dauphinee S, Hendriks HJ, Van der Wees PJ, Dekker J. The impact of physical therapy on functional outcomes after stroke: what's the evidence? *Clin Rehabil* 2004; **18**: 833–62.