Is modified constraint-induced movement therapy effective in improving motor performance in patients with hemiplegia?

Modifiye zorunlu kullanım terapisi hemipleji hastalarında motor performansı iyileştirmede etkili midir?

Abstract

Aim: To investigate the effect of modified constraint-induced movement therapy (mCIMT) on upper extremity motor recovery, performance, and functional independence in addition to conventional rehabilitation in stroke patients.

Methods: The study included 40 participants, including 20 chronic stroke cases in the intervention group (IG) (64.45±9.18 years) and 20 chronic stroke cases in the control group (CG) (64.45±9.18 years) who met the selection criteria. IG received mCIMT with regular physiotherapy, while CG received only regular physiotherapy. The patients were evaluated with the Motor Activity Log-28 (MAL-28), the Functional Independence Measure (FIM), and the Fugl-Meyer Upper Extremity Scale (FMUES) before treatment, immediately after treatment (post-treatment), and at three months after treatment (follow-up).

Results: The MAL-28 and FIM scores significantly increased in both groups compared with the baseline values after treatment and at the third-month follow-up ($p<0.05$). After treatment and at the third-month follow-up, the FMUES scores significantly increased in both groups compared with the baseline values ($p<0.001$).

Conclusion: This study showed that mCIMT added to conventional therapy improved upper extremity motor function, performance, and functional independence in chronic stroke patients; however, mCIMT had no additional benefit to conventional therapy.

Keywords: Hemiplegia; physical functional performance, stroke rehabilitation

Öz

Amaç: Bu çalışmanın amacı, inmeye bağlı hemipleji gelişmiş hastalarda konvansiyonel rehabilitasyona ek olarak modifiye zorunlu kullanım terapisinin (mZKT) üst ekstremite motor iyileşme, performans ve fonksiyonel bağımsızlık üzerindeki etkisini araştırmaktı.

Yöntemler: Çalışmaya; çalışma grubu (64,45±9,18 yıl) 20 olgu, kontrol grubu (64,45±9,18 yıl) 20 olgu olacak şekilde toplam 40 kronik inme olgusu dâhil edilmiştir. Çalışma grubu düzenli fizyoterapi ile mZKT alırken, kontrol grubu sadece düzenli fizyoterapi aldı. Hastalar tedavi öncesi, tedavi sonrası ve tedavi sonrası 3. ayda Motor Aktivite Günlüğü-28 (MAG-28), Fonksiyonel Bağımsızlık Ölçümü (FBÖ) ve Fugl-Meyer Üst Ekstremite Skalası (FMÜES) ile değerlendirildi.

Bulgular: MAG-28 ve FBÖ skorları tedavi sonrası ve üçüncü ay takibinde başlangıç değerlerine kıyasla her iki grupta da istatistiksel açıdan anlamlı olarak arttı ($p<0.05$). Tedavi sonrası ve üçüncü ay takibinde, FMUES skorları başlangıç değerlerine göre her iki grupta da anlamlı olarak arttı ($p<0.001$).

Sonuç: Bu çalışma, konvansiyonel tedaviye eklenen mZKT'nin kronik inmeli hastalarda üst ekstremite motor fonksiyonunu, performansını ve fonksiyonel bağımsızlığını iyileştirdiğini göstermiştir; ancak, mZKTnin geleneksel tedaviye kıyasla ek bir faydası olmamıştır.

Anahtar Sözcükler: Hemipleji, fiziksel fonksiyonel performans, inme rehabilitasyonu

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INTRODUCTION

Stroke is a cause of a high degree of disability (1) and negatively affects different areas of physical and social function (2), therefore patients need neurorehabilitation following stroke. Stroke causes adult disability worldwide (3) and 80% of patients with stroke have a motor impairment (4). Recovery from upper limb impairment is crucial since it ensures independence during daily activities (5). Spontaneous recovery processes over several days or weeks after the onset of stroke promote neural reorganization and recovery (6).

Although motor recovery is observed in the early period of stroke; motor deficit may persist in the upper extremity in the chronic phase. However, it has been found that 80% of patients with mild paresis in the upper extremity and only 20% of those with severe paresis can regain full upper extremity function after stroke (7). In the motor development process after stroke, lower extremity functions generally improve in the short term whereas upper extremity and hand functions improve in the long term. In the process of chronic stroke; it is very important to develop motor learning strategies to reduce motor impairment (8,9).

In recent years, numerous stroke rehabilitation programs have been proposed to improve limb function following a stroke. Conventional therapies, such as the Bobath concept, proprioceptive neuromuscular facilitation exercise therapy, occupational therapy, and the use of a brace or other device are common treatment approaches (8,9). A meta-analysis study showed that such programs were effective in enhancing motor function (10). However, this conventional therapy is often time-consuming with a low compliance rate, and outcomes often depend on the experience and ability of medical personnel. Besides, It is also questionable whether these methods are sufficient to induce the neural-plasticity-based motor improvement of the disabled limb (11). Therefore, novel adjuvant therapies added to conventional methods could be more efficient in regaining the functional recovery of the impaired limb in stroke patients.

Constraint-induced movement therapy (CIMT) is a novel adjuvant treatment option based on the prevention of intact upper extremity use in hemiplegic patients and the compulsory use of the affected extremity. Many studies have shown that CIMT improves hemiplegic upper extremity functions in the acute and chronic phases of stroke (12,13). CIMT is considered to accelerate healing through brain remodeling (axonal and dendritic sprouting), called neuroplasticity (14). Additionally, in correlation with the motor improvement via the application of CIMT, it has been proven to increase the volume of grey matter in the sensorimotor cortex, mostly in the anterior motor areas, and the hippocampus on both sides of the brain, (15) as well as resulting in other neuroplastic brain changes (16-19).

The classic CIMT protocol involves the restriction of the patient's use of the intact upper extremity for 80-90% of the time while awake and applying an intense motor exercise program to the affected extremity for at least six hours a day (20). However, this protocol causes application difficulties in daily life, and therefore the modified CIMT (mCIMT) protocol with different intensities and durations of exercise has been developed (21-23).

There are limited studies in the literature on the efficacy of mCIMT as an adjuvant therapy In addition, available studies have reported conflicting results in the chronic period. Therefore, in the current study, we aimed to investigate the efficacy of mCIMT in upper extremity motor recovery, performance, and functional independence when added to conventional physiotherapy in chronic stroke patients.

MATERIALS AND METHODS

This was a prospective, single-blinded, randomized, controlled study. All participants were informed about the procedures and assessments to be performed in the study, and those who agreed to participate signed consent forms. The study was conducted between March 2019 and February 2020 and Clinical Research Ethics Committee of the Kutahya Health Science University (date: 09.01.2019; decision no: 2019/01-3). The methods used in this study were reported using the CONSORT statement.

Participants

Recruitment and setting

Patients who were followed up with a diagnosis of hemiplegia during the study period were screened for eligibility by an independent physician and sub-

sequently invited to participate in the study. All the participants were informed in advance about the procedures and assessments to be performed in the study.

Inclusion criteria

- Age between 18 and 75 years
- Diagnosed with hemiplegia at least six months ago
- Having at least 10 degrees of extension in the wrist, metacarpal, and interphalangeal joints

Exclusion criteria

- Poor cooperation
- Presence of an additional chronic systemic disease
- Uncontrolled hypertension
- Having a history of botulinum toxin therapy for upper extremity
- Presence of heart failure
- Presence of contracture in the upper extremity
- Presence of shoulder-hand syndrome
- Having hearing or vision problems

Study procedures

After patients were randomly divided into two groups [intervention group (IG) and control group (CG)], evaluation by a blinded investigator followed by four weeks of treatment by a different investigator. At the end of the treatment and 12 weeks after the treatment the participants were reevaluated by the same blinded investigator. Patients in IG received conventional physiotherapy and mCIMT, while patients in CG received conventional physiotherapy.

Interventions

Control group received 28 sessions of standard conventional physiotherapy for 4 weeks, approximately 120 minutes per day, and each day of the week.

The conventional physiotherapy program included neural facilitation techniques tailored to each patient, range of motion exercises, strengthening exercises, motor skills training, occupational therapy, and speech therapy if necessary.

The patients in IG received mCIMT in addition to the conventional physiotherapy explained above. mCIMT involved the restraint of the non-involved extremity using a sling. The participants in IG were taught how to apply the sling and encouraged to wear it on their less-impaired upper extremities for six hours a day over four weeks, including four weekends (28 days in total). On each weekday, the participants received motor task training with the involved extremity for two hours a day for four weeks (40 hours in total) (24).

Outcomes

Data on age, gender, height, body weight, body mass index, duration of the stroke, affected side, chronicity, and education level of the participants were recorded. The upper extremity functions of the participants were evaluated by the same physician (E.S.) before, upon completion, and 12 weeks after the treatment. The Motor Activity Log-28 (MAL-28) score was the primary outcome measure, and the Functional Independence Measure (FIM) and the Fugl-Meyer Upper Extremity Scale (FMUES) scores were the secondary outcome measurements.

The Motor Activity Log-28 (MAL-28)

MAL-28 consists of two sub-scales: MAL-28 Amount of Use (AOU), which measures how often the patient uses the affected side upper extremity for each activity, and Quality of Movement (QOM), which questions how well the patient can perform the activity when using this extremity. In both subscales, the patient is evaluated with full and half points ranging from 0 to 5 (0,0.5,1,1.5,…,4.5, and 5). High scores indicate a higher use and movement quality (25). The Turkish version of the MAL-28 AOU and QOM scales were previously determined to be reliable (Intraclass Correlation Coefficient**:** 0.97 and 0.96, respectively) and internally consistent (Cronbach's α: 0.96 for both) (26).

The Functional Independence Measure (FIM)

The level of disability was measured with the Functional Independence Measure (FIM). Developed as a measure of disability in different disease groups, the FIM includes measuring patients' self-care independence, including sphincter muscle control, mobility, communication, and social cognition. The scale is ordinal and has18 seven-level items (1: total assistance, 7: full independence) (27). In the FIM, 13 items evaluate motor functions, and five items evaluate cognitive functions. Küçükdeveci et al. (28) showed that the Turkish version of the scale is valid and reliable.

The Fugl-Meyyer Upper (FMUES)

FMUES is a widely used stroke-specific, performance-based measure of impairment. It is designed to assess reflex activity, movement control, and muscle strength in the upper extremity of people with post-stroke hemiplegia. The scale includes four subsections (A: Shoulder region, B: Wrist region, C: Hand region, and D: Coordination and speed). The patient's inability to perform the activity at any level is evaluated as 0 points, the partial performance of the activity is evaluated as 1 point, and the complete performance of the activity is evaluated as 2 points. The total score ranges from 0 to 66 points (29).

Blinding

During the assessment, researchers were blind to group distribution. The principal investigator was not involved in the treatment and evaluation processes of the individuals and the data analysis processes. In addition, the participants were asked not to tell the researcher who evaluated the treatment methods they received.

Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, IBM, Armonk, NY, USA), version 21.0. Continuous variables were given as mean ± standard deviation values, and categorical variables were given as numbers (percentage). The Chi-square test was used to compare categorical variables between groups. The distribution of the data was analyzed with the Shapiro-Wilk test. Since the data represents normal distribution and parametric assumptions were met, the independent samples t-test was used to compare independent groups. In the comparison of dependent groups, a non-parametric Friedman test of differences among repeated measures was conducted. The significance level was $p<0.05$.

RESULTS

This study was completed with 40 participants, including 20 chronic stroke patients in IG (mean age, 64.45 ± 9.18 years) and 20 chronic stroke patients in CG (mean age, 64.45 ± 9.18 years). There were 11 men (55%) and 9 women (45%) in each group. Table 1 presents the age, gender, height, body weight, body mass index (BMI), stroke duration, and education levels of the individuals participating in the study. In the comparison of the demographic data of the patients included in the study, no statistically significant difference was found in terms of height, body weight, BMI, duration of disease, affected side, type of stroke, and education level (Table 1).

Primary outcomes

There were no significant differences between the two groups in terms of the MAL-28 AOU and MAL-28 QOM scores before treatment (130.30 ± 11.57 and 87.08 ± 12.60, respectively, p=0.394 for IG and CG 123.78 ± 21.50 and 90.68 ±17.47, respectively, p=0.291 for CG). Both after treatment and at the third-month follow-up, the MAL-28 AOU and QOM scores significantly increased in both groups compared with the baseline values (p=0.011 in IG and p<0.001 in CG for MAL-28 AOU, and p<0.001 in IG and p<0.001 in CG for MAL-28 QOM). However, there was no significant difference in the mean MAL-28 AOU and QOM of the two groups (p = 0.377 and p= 0.466, respectively) (Table 2).

Secondary outcomes

There were no significant differences between IG and CG in the FIM scores before treatment (93.75 ± 14.64 and 93.95 ± 17.77, respectively, p=0.745). After treatment and at the third-month follow-up, the FIM scores significantly increased in both groups compared with the baseline values (p=0.015 for IG and p=0.018 for CG). However, there was no significant difference in the mean FIM scores between the two groups (p = 0.976).

IG and CG did not significantly differ in terms of the FMUES A, B, C, and D scores before treatment (p=0.838, p=0.501, p=0.589, and p=0.280, respectively). Both after treatment and at the third-month follow-up, the FMUES A, B, C, and total scores significantly increased in both groups compared with the baseline values (p<0.001, p=0.018, p=0.005, and p<0.001, respectively for IG and p<0.001, p=0.001, p=0.001, and p<0.001, respectively for CG). In addition, no significant difference was observed in the mean FMUES A, B, C, D, and total scores between the two groups (p = 0.780; p=0.442; p=0.966, p=0.338, and p=0.923, respectively) (Table 3).

Table 1. Demographic characteristics of the groups

	Intervention Group (n = 20) (Mean ± SD)	Control Group (n = 20) (Mean ± SD)	*p value*
Age (years)	64.45 ± 9.18	64.45 ± 9.18	0.957
Height (cm)	164.55 ± 9.51	164.65 ± 10.17	0.975
Weight (kg)	74.56 ± 10.87	75.60 ± 11.78	0.777
BMI (kg/m^2)	27.46 ± 4.16	27.82 ± 4.26	0.789
Duration of disease (months)	36.55 ± 27.86	30.20 ± 29.32	0.242
Affected side	**n (%)**	**n (%)**	
Left	9 (55)	4 (20)	
Right	11 (55)	16 (80)	0.096
Type of stroke	**n (%)**	**n (%)**	
Hemorrhagic	4 (20)	3 (15)	0.681
Ischemic	16 (80)	17 (85)	
Education level	**n (%)**	**n (%)**	
Illiterate	3 (15)	4 (20)	
Primary school	12 (60)	9 (45)	
Middle school	1 (1)	2 (2)	0.837
High school	2 (10)	3 (15)	
University	2 (10)	2 (10)	

Cm: Centimeter, kg: Kilogram, BMI: Body mass index, kg/m^2: Kilogram/meter square, n: Number of participants, SD: Standard deviation, p: Level of significance

Table 2. Changes in primary outcomes from the baseline to the post-treatment and third-month follow-up evaluations

	Intervention Group			Control Group			Inter-group Comparison	
Variables	**Baseline (Mean ± SD)**	**After treatment (change from baseline) (Mean ± SD)**	**Third-month (change from baseline) (Mean ± SD)**	**Baseline (Mean ± SD)**	**After treatment (change from baseline) (Mean ± SD)**	**Third-month (change from baseline) (Mean ± SD)**	**Mean differences in changes between groups at third month [95% CI]**	**p value**
MAL-28 (AOU)	130.0 ± 11.57	0.80 ± 0.66*	0.93 ± 0.71*	123.78 ± 21.50	3.17 ± 1.22*	3.62 ± 1.40*	-4.83 [-6.11 ; 15.78]	0.377
MAL-28 (QOM)	87.08 ± 12.60	7.17 ± 4.79*	6.84 ± 4.78*	90.68 ± 17.47	6.10 ± 4.37*	6.00 ± 4.52*	2.96 [-13,12 ; 7,20]	0.466

MAL-28: Motor Activity Log-28 , AOU: Amount of Use, QOM: Quality of Movement, Standard deviation, CI: Confidence level, p: Level of significance, *: p<0.05

DISCUSSION AND CONCLUSION

In this study, we investigated the efficacy of mCIMT in chronic stroke patients and determined that both IG and CG showed improvement in upper extremity function after the treatment and third-month follow-up. However, mCIMT was not found to be superior to conventional treatment.

One of the primary goals of neurorehabilitation is the functional improvement of the upper limb after a stroke (30). It has been reported that only 20% of patients can regain full upper extremity function (31). This may be due to the more complex structure of the upper extremity and most daily life activities being performed with the unaffected extremity. One of

Table 3. Changes in secondary outcomes from the baseline to the post-treatment and third-month follow evaluations

Variables	Intervention Group			Control Group			Between Group Comparison	
	Baseline (Mean ± SD)	After treatment (change from baseline) (Mean ± SD)	Third-month (change from baseline) (Mean ± SD)	Baseline (Mean ± SD)	After treatment (change from baseline) (Mean ± SD)	Third-month(change from baseline) (Mean ± SD)	Mean differences in changes between groups at third month [95% CI]	p value
FIM score	93.75 ± 14.64	1.05 ± 0.83*	1.85 ± 1.46*	93.95 ± 17.77	1.45 ± 1.10*	1.45 ± 1.10*	-0.20 [-9,97 ; 9,57]	0.976
FMUESA score	23.60 ± 3.50	2.00 ± 0.41*	1.95 ± 1.41*	22.90 ± 5.23	2.35 ± 2.42*	2.45 ± 2.42*	0.10 [-2,92 ; 3,12]	0.780
FMUESB score	5.60 ± 2.11	0.40 ± 0.51*	0.40 ± 0.51*	6.00 ± 2.87	0.75 ± 0.51*	0.75 ± 0.51*	-0.63 [-2,21 ; 0,94]	0.442
FMUESC score	11.75 ± 2.77	0.20 ± 0.06*	0.20 ± 0.06*	11.15 ± 2.96	1.15 ± 0.18*	1.15 ± 0.18*	-0.33 [-1,62 ; 1.55]	0.966
FMUESD score	2.95 ± 1.10	0.25 ± 0.03	0.25 ± 0.03	2.65 ± 1.35	0.25 ± 0.02	0.25 ± 0.02	0.30 [-0,32 ; 0,92]	0.338
FMUEStotal score	49.90 ± 7.13	2.85 ± 2.71*	2.80 ± 2.70*	48.85 ± 10.11	5.00 ± 4.82*	4.60 ± 4.82*	-0.27 [-5,80 ; 5,27]	0.923

FIM: Functional Independence Measure, FMUES: Fugl-Meyer Upper Extremity Scale, SD: Standard deviation, CI: Confidence level, p: Level of significance, *: p<0.05

the various rehabilitation interventions that have been investigated for upper extremity recovery is mCIMT, which is based on neural plasticity mechanisms (32). According to the literature, deficits in the upper extremity may affect the life quality negatively, and there is a correlation between hand skills and independence when performing daily life activities (33). In our study, we found that conventional treatment could improve upper extremity functions, but mCIMT had no additional contribution to conventional treatment in improving upper extremity functions.

In the current study, improvement in FIM scores was observed as a result of treatment in both the study and control groups. Even if they were patients in the chronic period, the improvement in the FIM score was also detected at the third-month follow-up. This showed that the rehabilitation received by the patients, even in the chronic phase, was effective in improving the upper extremity function while performing the activities of daily living.

In our study, the analysis of motor activity scores (MAL-QOM and MAL-AOU) showed that the motor functions of both groups were better than the baseline at the third-month follow-up, but there was no significant difference between the groups. There was no significant difference between the post-treatment and third-month follow-up MAL-28 scores in the study group and control group. Studies are showing that early rehabilitation in neural recovery and neuroplasticity has very successful results in treatment (32,33). The lack of significant changes in functional independence and upper motor function can be explained by the chronic stage of the disease.

Similar results were found in a study by Barzel et al., although the participants received a home CIMT program rather than a supervised program applied in our study. Barzel et al. included 71 stroke patients and compared conventional treatment with home CIMT. The home CIMT group applied this program for 5 days/week for four weeks with 2h/day of restriction. The primary outcomes were the MAL-QOM and Wolf Motor Function Test scores. The patients in both groups improved but the results showed that CIMT was not superior to the conventional rehabilitation intervention (34). In contrast with these studies, Wu et al. investigated the functional and psychological effects of mCIMT in elderly stroke patients and reported significant improvement in the Stroke Impact Scale,

FIM, MAL-28, and Beck Depression scores compared to the mCIMT group receiving only conventional therapy (35).

The optimal dosage of mCIMT remains unclear but should be within the specified CIMT protocol range. In our study, the mCIMT groups received four hours of conventional therapy every day for four weeks with 6h/day of restriction. In a previous study by Dromerick et al., early CIMT therapy was given 90 days later after stroke and standard CIMT and high-intensity CIMT were compared. The standard CIMT group received occupational therapy 2 h/day and wore restraint gloves 6 h/day, and the high-intensity CIMT group received occupational therapy 3h/day with restriction 90% of the waking hours. The authors found that the high-intensity CIMT group had significantly less upper extremity motor improvement at 90 days. They concluded that the high-intensity CIMT therapy negatively affected spontaneous motor learning (36). In our study, similar results were obtained, confirming that the total application time of the daily restriction period should be regulated. Long-term treatment (over four weeks without interruption) may be the reason for the lack of difference in improvement between our two groups.

We determined the number of patients based on similar studies and did not perform a power analysis, which can be considered one of the limitations of the study. As with other limitations, the treatment plan was not made by questioning the dominant extremity of the patients. Patients were not evaluated according to the presence of neglect syndrome. We were also unable to investigate possible effect modifiers, such as cognitive disorders, dyspraxia, and type of stroke.

This study showed that both mCIMT and conventional therapy improved upper extremity motor function, performance, and functional independence in chronic stroke patients; however, MCIMT had no additional benefit to conventional therapy. Future studies can investigate the efficacy of mCIMT with different intensities and duration in larger chronic stroke populations.

Conflict-of-interest and financial disclosure

The authors declares that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study

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