European Review for Medical and Pharmacological Sciences 2021; 25: 5412-5423

Efficacy of different approaches on quality of upper extremity function, dexterity and grip strength in hemiplegic children: a randomized controlled study

R.A. MOHAMED[1], A.M. YOUSEF[2], N.L. RADWAN[3,4], M.M. IBRAHIM[1,3]

[1]Department of Physical Therapy for Growth and Developmental Disorders in Children and Its Surgery, Faculty of Physical Therapy, Cairo University, Egypt
[2]Department of Basic Sciences, Faculty of Physical Therapy, Cairo University, Egypt
[3]Department of Physical Therapy and Health Rehabilitation, Faculty of Applied Medical sciences, Prince Sattam Bin Abdul-Aziz University, Kingdom of Saudi Arabia
[4]Department of Biomechanics, Faculty of Physical Therapy, Cairo University, Egypt

Abstract. – OBJECTIVE: To investigate the effect of mirror therapy (MT) together with taping compared to modified constraint-induced movement therapy (mCIMT) and MT alone on the quality of upper extremity (UE) function, dexterity, and grip strength in children with hemiplegic cerebral palsy (CP).

PATIENTS AND METHODS: Sixty children with hemiplegic CP ranging in age from 6 to 8 years were enrolled. The participants were randomly distributed into three groups. The three groups underwent the same suggested upper limb (UL) exercise programme for 1h/5 days/week for 12 successive weeks. Group A performed the programme with MT and taping. Group B performed the same programme using mCIMT alone, while group C performed this programme with MT alone. In addition, the three groups underwent a routine physical therapy programme for 1 h. The quality of UE function, dexterity, and grip strength was measured using the Quality of Upper Extremity Skills Test (QUEST), Box and Block Test (BBT), and hand-held dynamometer before and after 12 successive weeks of treatment.

RESULTS: After treatment, the measurement of all variables in the three groups showed significant improvements with superior effects seen in group A.

CONCLUSIONS: Based on the results obtained in this study, MT with taping, mCIMT alone, and MT alone are good supplements to traditional physical therapy programmes in improving the quality of UE function, dexterity, and grip strength in children with hemiplegic CP with more superior effects seen after using MT together with taping.

Key Words:
Dexterity, Grip, Hemiplegia, Mirror therapy, mCIMT.

Abbreviations

ADL_S: Activities of daily living; BBT: Box and Block Test; CIMT: Constraint-induced movement therapy; CP: Cerebral palsy; GMFCS: Gross Motor Function Classification Scale; KT: Kinesio tape; mCIMT: Modified constraint-induced movement therapy; MT: Mirror therapy; QUEST: Quality of Upper Extremity Skills Test; UE: Upper extremity; UL: Upper limb.

Introduction

Cerebral palsy involves a group of motor and sensory impairments, as well as postural dysfunctions caused by a non-progressive lesion in the immature brain[1]. It can be classified according to the topographical presentation as monoplegia, hemiplegia, diplegia, and quadriplegia[2]. The prevalence of neonatal hemiplegic CP has been reported as between 0.6 and 0.9 per thousand live births[3]. UL dysfunctions affect half of the children with CP[4]. The hand is often more affected than the foot, and trouble using the hand is evident as early as the first year of life[5]. UL impairments in hemiplegic children, especially reaching and grasping, are caused by increased muscle tone, muscle weakness, and a lack of selective motor control, all of which impair functions and motor independence in activities of daily living (ADL_S)[6]. On a biomechanical basis, proper handgrip strength is essential for conveying exact hand capacities[7]. Under typical biokinetic conditions, handgrip strength is characterised by the maximum intensity of powerful intentional

Corresponding Author: Rasha A. Mohamed, MD; e-mail: dr.rashapt@gmail.com

flexion of all fingers. The hand grip strength is possibly the best indicator of the UL's overall consistency[8]. Various rehabilitation approaches, such as neurodevelopmental treatment, MT, constraint-induced movement therapy (CIMT), and taping have been shown to enhance UL function in children with CP.

Mirror therapy is a simple, low-cost, and non-invasive adjunct to rehabilitation of children with hemiplegic CP. It provides visual feedback that can compensate for a lack of age-appropriate sensorimotor stimulation, resulting in changes in the deficient cerebral cortex and the facilitation of UL skills. The daily use of a mirror box is an easy and feasible treatment strategy. The children look into a mirror mounted along their midline and the affected limb is concealed behind the mirror. This encourages the child to engage in activities with the unaffected UL[9]. The non-affected UL's reflection in the mirror gives the impression that the affected UL is working normally. This visual illusion fools the brain into believing that the affected UL is moving, resulting in improved motor function in the affected UL[10]. In many previous studies, MT has been shown to improve the function of the affected limb in children with hemiplegic CP[9-12].

One of the interventions' main goals is to resolve learned non-use, which is described as a reduction in the use of the affected extremity. Learned non-use occurs as a result of many children with CP compensating for the affected UL rather than attempting to use it, which hinders the progress of its functioning[13]. Evidence suggests that many neurologically impaired children could boost their UL motor performance if given sufficient practice[14,15]. CIMT is a treatment method that offers opportunities for practice[16]. It is mostly used to treat people with decreased UL function[17]. CIMT ensures massed training of the affected UL while restraining the use of the less affected UL[18]. CIMT improves not only motor skills, but also the practical use of the extremity in real-world situations[19]. Many studies have noted that the original CIMT schedule is exhausting and may result in non-compliance because it requires six or more hours of therapy and constraining of the unaffected UL for 90 percent of waking hours a day for two weeks. Therefore, the mCIMT is a shorter version of CIMT which was designed to overcome such limitations[20]. The mCIMT period ranges from 30 minutes to three hours daily for 2–10 weeks[21]. Several previous studies[22-24] on the effectiveness of mCIMT in hemiplegic children have shown its effect in enhancing the function of the UL.

Kinesio tape (KT) is popular as an adjunctive therapy because it is simple to use and inexpensive, and it may be removed or adjusted according to the treatment goals[25]. KT is used to strengthen and relax muscles and improve joint stability[26]. It provides immediate sensorimotor feedback through a pulling force on the skin, fascia, and soft tissues, resulting in improved communication with mechanoreceptors, increasing the recruitment of motor units[27], stimulating the supraspinal centres, and thus improving the kinesthetic senses and motor control[28]. Previous studies have discussed the effectiveness of taping in children with CP, especially spastic hemiplegia[29-31]. Most of these studies showed statistically significant improvements following taping application.

Several studies have been published on the effects of MT, mCIMT, and taping in children with hemiplegic CP. This study aimed to investigate the effect of MT together with taping and compare its effect with that of the mCIMT and MT alone on the quality of UE function, dexterity, and grip strength in children with hemiplegic CP.

Patients and Methods

Study Design, Ethics, and Consent

This is an interventional, randomised, parallel-group, controlled trial with a planned duration of 12 weeks. The study was conducted at the Outpatient Clinic, College of Applied Medical Sciences, Prince Sattam Bin Abdul-Aziz University, Al Kharj City, Saudi Arabia, from February to July 2020. Furthermore, the study was registered with the UMIN-CTR Clinical Trials platform (UMIN000042377).

This study was approved by the Ethics Committee of the Prince Sattam Bin Abdul-Aziz University and by the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Each participating patient received written and verbal explanations of the study and evaluation procedures. Before the patients were allowed to participate, their parents signed a consent form.

The study adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines and the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT)[32-34].

Sample Size

Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2; Franz Faul, University Kiel, Germany). Calculations were made using α=0.05, β=0.2, Pillai V= 0.12, and effect size = 0.37, and revealed that the appropriate sample size for this study was N= 60.

Participants

Sixty children with hemiplegic CP, ranging in age from 6 to 8 years, were enrolled in this study. Eligibility was based on the following criteria: no cognitive impairments and the ability to understand the commands given to them. Participants had to be able to focus attention on the mirror and demonstrate level II on the Gross Motor Function Classification Scale (GMFCS) and level II or III on the Manual Ability Classification System (MACS). The degree of spasticity was grades 1^{+} and 2, based on the Modified Ashworth Scale. Participants had to have sufficient trunk control to enable sitting unsupervised in a chair.

The exclusion criteria were skin diseases or sensitivity for KT, previous surgery of the UL, Botox injection of the UL within the preceding 6 months, fixed deformities of the UL, visual or auditory problems, unilateral neglect disorder, orthopaedic problems, and severe sensory loss in the area to be taped.

Randomisation, Allocation, and Blinding

All patients were scheduled for regular outpatient physical therapy sessions in the Outpatient Clinic, College of Applied Medical Sciences, Prince Sattam Bin Abdul-Aziz University, Al Kharj City, Saudi Arabia. Seventy-two children were examined for eligibility by a research coordinator. Twelve children did not meet eligibility requirements. The final number of participants was 60. Following the study inclusion, the 60 eligible children were randomly assigned to one of three groups (A, B, or C) with a 1:1:1 allocation ratio of equal numbers n= 20, according to a computer-generated randomisation schema stratified by centre and employing permuted blocks of randomly varied sizes.

The block sizes were not disclosed to ensure concealment. Once randomisation was performed (concealed allocation), the group allocation was revealed exclusively via computer software (CleanWeb) to the non-blinded physiotherapist. The physiotherapist verbally informed the patients. The randomisation list was constructed before the beginning of the study by an off-site independent statistician who was not involved in the study.

After allocation, no children dropped out of the study. Figure 1 depicts the experimental flow diagram of the study according to the CONSORT guidelines[32,33].

Outcome Measurements

The same author who was blinded to the separation groups performed all measurements under similar conditions for all children in the three groups, just before and after 12 successive weeks of treatment. The measurement of quality of UE function and dexterity were considered as primary outcomes, while the secondary outcome measure included grip strength.

Quality of Upper Extremity Function

Quality of UE function was assessed using the QUEST. This tool was created to assess children with neuromotor dysfunction. QUEST is strongly reliable for ages ranging from 2 to 12 years[35]. It includes four subscales: dissociative movements, grasp, weight-bearing, and protective extension. Each subscale has different items to be tested. Each child was asked to complete the assessment. The child actively engaged in each item without assistance, and the consistency of his or her movement was observed and recorded. In this study, all the items in each subscale were tested. The score was entered in every scoring box (i.e., yes, no, and not tested). The score for each item was yes = 2 points and no = 1 point. The scores of each subscale and the average of the total scores of all subscales were collected.

Dexterity

The BBT was used to evaluate dexterity. This test is a validated and reliable test[36]. It includes a rectangular wooden box divided into two compartments using a partition and 150 wooden blocks. The child was seated at a table facing the box and asked to move blocks one by one from one compartment of the box to another. The number of blocks moved was recorded for one minute. The children were allowed a 15 s trial period before testing.

Grip Strength

The grip strength of the affected hand was measured using a Jamar dynamometer (Therapeutic Equipment Corporation, USA). In children with CP, the intraclass correlation coeffi-

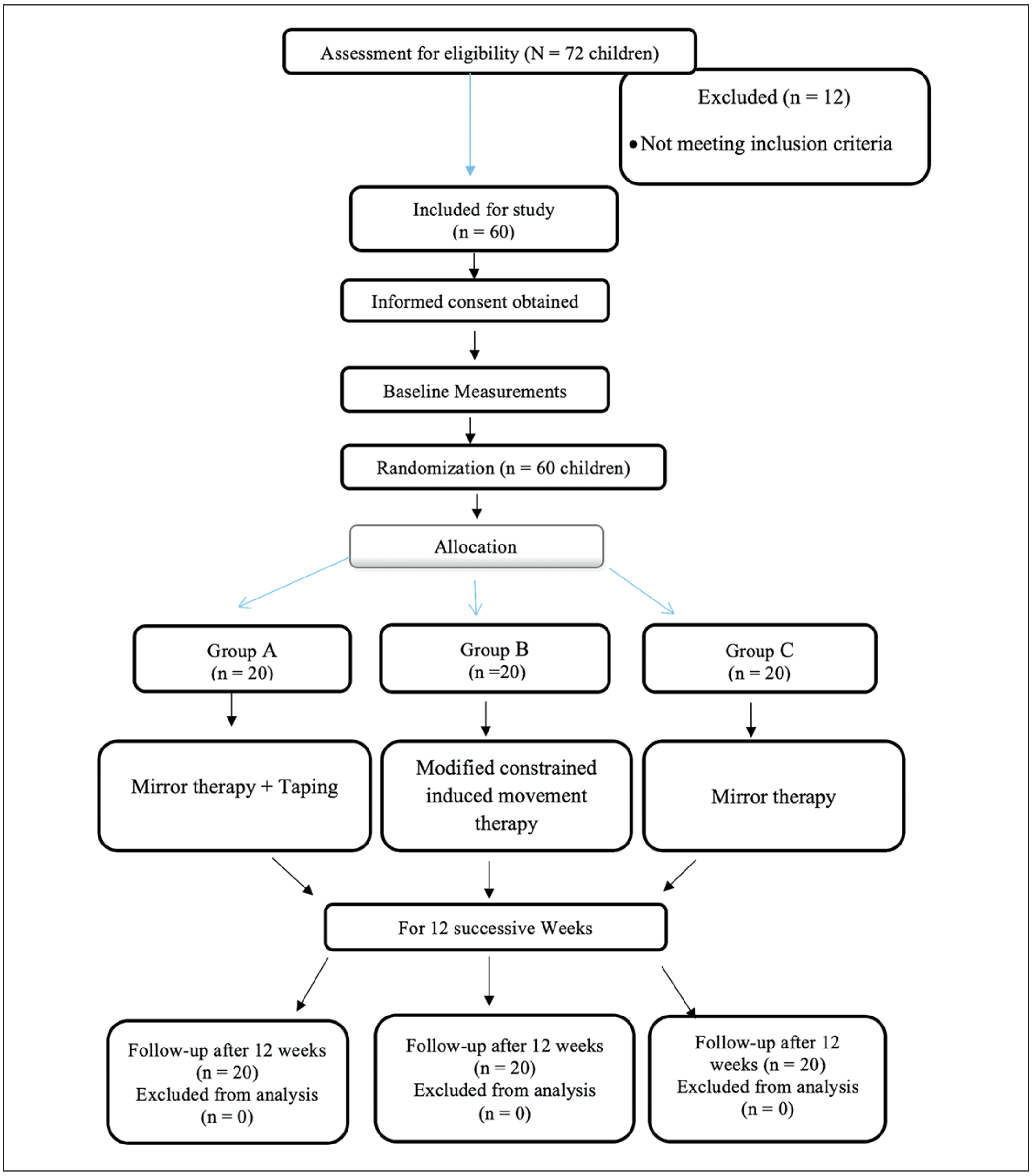

Figure 1. Experimental flow diagram of the study.

cients for test-retest and inter-rater reliability of isometric grip strength using the Jamar dynamometer were 0.96 and 0.95, respectively[37]. Each child sat with the wrist of the affected arm between 0° and 30° extension and between 0° and 15° ulnar deviation, forearm in a neutral position, elbow flexed at 90°, and shoulder adducted and neutrally rotated[38]. The child was then asked to squeeze the dynamometer with maximum force for approximately 5 s without moving any other body parts. Three trials were performed with a delay of 10-20 s between each trial[39] to prevent muscle exhaustion. The combination of these three trials was used to calculate average grip strength.

Intervention

The children in the three groups underwent the same suggested UL exercise programme for 1 h/5 days/week for 12 successive weeks. The children in group A underwent a programme of using MT with both ULs and taping of the affected UL. Group B underwent the same programme on the affected side with mCIMT alone, while group

C underwent the same programme with MT alone. Each intervention was performed by the same researcher for all children throughout the treatment period. In addition, the children in the three groups underwent routine physical therapy programmes according to each child's needs (including stretching and strengthening exercises, neurodevelopmental treatment, and balance exercises) for 1 h which was conducted by a therapist who was not involved in the study.

Kinesio Taping

All the children's wrist joint alignments in Group A were corrected for extension. The KT (1.5 or 2 inches "I" tape) was applied from the metacarpophalangeal joints on the dorsum of the hand to the wrist and forearm to cover the wrist extensor muscles. It was worn continuously for 5 days and then removed for 2 days unless the child experienced any skin irritation[40]. The parents were given instructions on how to remove and apply KT when needed.

Mirror Therapy

A mirror of 30 × 20 inches was used for the MT, which was large enough to cover the entire affected limb while still allowing the reflection of the non-affected limb to be seen. The child was seated in a chair with the forearms resting on the table. In the mid-sagittal plane, the mirror box was positioned at an angle of 70° to 80° to the trunk. The affected limb was placed behind the mirror. The child was asked to perform the exercises bilaterally and symmetrically as much as possible. Even if the affected side did not move easily or fully, the child was advised to execute the motions with both hands and arms synchronously. The child was constantly reminded by the researcher to concentrate on the movement of the non-affected limb in front of the mirror, which helped to increase the mirror illusion.

Modified Constraint-Induced Movement Therapy

The mCIMT required the non-affected UL to be restrained from moving and the affected UL to perform the exercises repeatedly. An UL sling was used as the means of restraint. To prevent the non-affected hand from being used as an aid, it was strapped to the child's trunk. The sling was worn only during treatment. When conducting the exercises, the child was advised to look directly at the affected limb.

The Suggested UL Exercises Programme

Before starting the exercise, familiarisation sessions were held to show the children the exercises to ensure that they were done correctly. The exercise was stopped for 2 to 3 min when the child complained of pain or exhaustion. A break was issued which was excluded from the exercise time. The Template for Intervention Description and Replication (TIDieR) checklist was used to ensure that the interventions were completed[41]. Attendance was calculated as the number of prescribed visits attended and the percentage of the prescribed exercises completed to the researcher's satisfaction. The patient was considered a dropout from the study when more than two sessions were missed, and the patient did not complete >90% of the exercises.

The suggested UL exercises programme included three stages:

Stage 1: Warm-up exercises for 5 minutes included pendulum exercises from a prone position on the bed and wall push-ups (10 times for two sets).

Stage 2: The children performed the exercises for 50 minutes. Each exercise was performed 10 times for two sets.

Stage 3: Cooling down exercises in the form of pendulum exercises were performed for 5 minutes.

1. Exercises of the shoulder, elbow, forearm, and wrist joints

- Shoulder flexion, extension, abduction, and adduction
- Elbow flexion and extension
- Forearm pronation and supination
- Wrist flexion and extension, ulnar and radial deviations

2. Exercises of the hand

The exercises were performed using hand therapy balls, putty, coins, water bottles, and a pen. The hand therapy balls are available at three different resistance levels (soft, medium, and firm) and are perfect for progressive exercises. The exercises were started with soft and then progressed to medium and firm as the hands and fingers strengthened.

Ball Grip: The child was instructed to hold the ball tightly in the palm of their hand and squeeze it, hold for 1 s, and relax for 1 s.

Side Squeeze: The child was instructed to place the ball between any two fingers and squeeze the two fingers together, hold for 1 s, and relax for 1 s.

Extend Out: The child was instructed to place the ball on a table with the tips of the fingers on the ball and roll the ball outward on the table.

Roll Movement: The child was instructed to place the affected arm on the table in a relaxed position and hold a water bottle in the hand, curl the fingers in, grasp the water bottle, and then release it.

Wrist Curl: The child was instructed to grasp the water bottle in the affected hand and use the non-affected hand for support. The child then stretched the wrist down and curled it up.

Scissor Spread: The child was instructed to wrap the putty around every two fingers and try to spread the fingers apart.

Thumb Press: The child was instructed to place the putty in the palm and push into it with the thumb toward the base of the small finger.

Thumb Extension: The child was instructed to bend the thumb, loop the putty around it, and extend the thumb.

Thumb Adduction: The child was instructed to keep the fingers and thumb extended while pressing the putty between the index finger and thumb.

Thumb pinch strengthening: The child was instructed to squeeze the putty between the thumb and the side of the index finger.

Three Jaw Chuck Pinch: The child was instructed to use the thumb, index, and middle fingers and pull the putty upwards.

Finger Hook: The child was instructed to place the putty in the palm and press fingers into a hook shape, attempting to bend only the last two joints of the fingers.

Full Grip: The child was instructed to place the putty in the palm and make a fist while squeezing the fingers into the clay.

Finger Pinch: The child was instructed to pinch the putty between each finger and thumb. This was performed for each finger 10 times for two sets.

Finger Extension: The child was instructed to bend the finger and loop the putty around it and extend the finger. This was performed for each finger 10 times for two sets.

Finger Scissor: The child was instructed to place a 1” diameter ball of putty between the fingers and to squeeze and release. Each finger completed this exercise 10 times for two sets.

Pinch and Release: The child was instructed to place a pen on the side of the table and then gently grip it with the affected fingers. The pen was then to be slid across the table and released.

Spin the pen: The child was instructed to spin a pen quickly for 15 s using the thumb and fingers without moving the shoulder joint.

Drop of the coins: The child was instructed to hold eight coins in a row in the palm of the affected hand, then by the thumb, sliding one coin down into the index finger and thumb to place the coin down onto the table while keeping the other coins in the hand using the other fingers. This was repeated with all eight coins.

Statistical Analysis

An analysis of variance (ANOVA) test was conducted to compare age between the groups. A chi-squared test was used to compare sex and hand dominance distribution between the groups. The normal distribution of the data was checked using the Shapiro-Wilk test. Levene’s test for homogeneity of variances was conducted to ensure homogeneity between the groups. Mixed design multivariate ANOVA was performed to compare the effects of QUEST, dexterity, and grip strength within and between groups. Post-hoc tests using Bonferroni correction were performed for subsequent multiple comparisons. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analyses were conducted using the Statistical Package for Social Studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Results

Participants' Characteristics

Table I shows the participants' characteristics in groups A, B, and C. There was no significant difference between groups in age, sex distribution, hand dominance, degree of spasticity, and MACS level ($p > 0.05$).

Effect of treatment on QUEST, handgrip strength, and dexterity

There was a significant interaction between treatment and time (F = 10.66, $p = 0.001$). There was a significant main effect of time (F = 152.82, $p = 0.001$) and of treatment (F = 4.18, $p = 0.001$).

Within-Group Comparison

There was a significant increase in all items of the QUEST, dexterity, and grip strength in groups A, B, and C post-treatment compared with pre-treatment ($p < 0.01$) (Table II).

Between Groups Comparison

There was no significant difference between the pre-treatment groups ($p > 0.05$). Post-treatment comparison revealed a significant increase in QUEST, dexterity, and grip strength in group A compared with that in group B ($p < 0.05$) and group C ($p < 0.001$). There was a significant increase in all variables in group B compared to group C ($p < 0.05$) (Table III).

Discussion

One of the most common motor disorders in children is hemiplegic CP[3]. The most important complication among these patients is the movement and function of the affected limb, especially the hand. Therefore, this study aimed to investigate the effect of MT together with taping and compare its effect with that of the mCIMT and MT on the quality of UE function, dexterity, and grip strength in children with hemiplegic CP.

Our results showed improvements in the quality of UE function, dexterity, and grip strength in the three groups (the group that underwent MT together with KT, the group that underwent mCIMT alone and the group that underwent MT alone) with the most significant improvement seen when using MT together with KT. In addition, the group that underwent mCIMT alone had a higher significant effect in comparison to the group that underwent MT alone.

The superior effect observed in the group that underwent both MT and KT is thought to be due to the combination the two therapies. The effects of KT have been demonstrated in previous studies. After 45 min of KT of the wrist extensor muscles in children with CP, there were statistically significant differences in wrist extension, radial, and ulnar deviations[42]. The use of KT has led to improved grip strength and active range of motion of the wrist and thumb[30]. Significant

Table I. Basic characteristics of the participants.

	Group A Mean ± SD	Group B Mean ± SD	Group C Mean ± SD	*p*-value
Age (years)	7.6 ± 0.88	7.7 ± 0.86	7.75 ± 0.91	0.86
Sex (%)				
Male	9 (45%)	10 (50%)	12 (60%)	0.62
Female	11 (55%)	10 (50%)	8 (40%)	
Hand dominance (%)				
Right	17 (85%)	19 (95%)	18 (90%)	0.57
Left	3 (15%)	1 (5%)	2 (10%)	
Degree of spasticity (%)				
Grade 1+	15 (75%)	14 (70%)	15 (75%)	0.91
Grade 2	5 (25%)	6 (30%)	5 (25%)	
MACS (%)				
Level II	15 (75%)	14 (70%)	15 (75%)	0.91
Level III	5 (25%)	6 (30%)	5 (25%)	

SD, Standard deviation; *p* value, Level of significance, Significant at $p < 0.05$.

Table II. Pre and post-treatment mean values of the QUEST, dexterity, and grip strength of the groups A, B and C.

	Group A					Group B					Group C				
	Pre Mean ± SD	Post Mean ± SD	MD	% of change	*p* value	Pre Mean ± SD	Post Mean ± SD	MD	% of change	*p* value	Pre Mean ± SD	Post Mean ± SD	MD	% of change	*p* value
Total movement quality	72.75 ± 6.6	84.15 ± 3.15	-11.4	15.67	0.001*	73.15 ± 6.22	80.25 ± 4.05	-7.1	9.71	0.001*	73.7 ± 6.56	77 ± 4.06	-3.3	4.48	0.01*
Dissociative movements	73.8 ± 7.25	86.55 ± 4.93	-12.75	17.28	0.001*	75.35 ± 5.27	81.8 ± 5.18	-6.45	8.56	0.001*	73.4 ± 7.63	77.75 ± 2.86	-4.35	5.93	0.004*
Grasps	75.75 ± 5.01	89.25 ± 4.03	-13.5	17.82	0.001*	75.1 ± 3.59	84.3 ± 5.84	-9.2	12.25	0.001*	75.25 ± 5.27	78.45 ± 4.96	-3.2	4.25	0.01*
Weight bearing	56.75 ± 6.14	71.1 ± 4.47	-14.35	25.29	0.001*	55.2 ± 4.91	66.2 ± 4.34	-11	19.93	0.001*	56.75 ± 5.43	61.75 ± 4.74	-5	8.81	0.001*
Protective extension	84.05 ± 2.58	92.45 ± 3.47	-8.4	9.99	0.001*	83.05 ± 3.61	89.2 ± 3.72	-6.15	7.41	0.001*	83.75 ± 2.86	85.85 ± 4.03	-2.1	2.51	0.001*
Dexterity	28.75 ± 5.6	36.9 ± 5.26	-8.15	28.35	0.001*	26.95 ± 6.41	33.45 ± 3.72	-6.5	24.12	0.001*	26.4 ± 3.93	29.9 ± 3.56	-3.5	13.26	0.002*
Grip strength	6.2 ± 1.32	8.15 ± 0.98	-1.95	31.45	0.001*	6.2 ± 1.23	7.25 ± 1.07	-1.05	16.94	0.001*	5.95 ± 1.19	6.4 ± 1.05	-0.45	7.56	0.003*

SD, standard deviation; MD, Mean difference; *p*-value: level of significance; *Significant at $p < 0.05$.

Table III. Comparison of post treatment mean values of the QUEST, dexterity, and grip strength among the three groups.

	A *vs* B **MD (*p*-value)**	**A *vs* C** **MD (*p*-value)**	**B *vs* C** **MD (*p*-value)**
Total movement quality	3.9 (0.006*)	7.15 (0.001*)	3.25 (0.02*)
Dissociative movements	4.75 (0.004*)	8.8 (0.001*)	4.05 (0.01*)
Grasps	4.95 (0.008*)	10.8 (0.001*)	5.85 (0.001*)
Weight bearing	4.9 (0.003*)	9.35 (0.001*)	4.45 (0.009*)
Protective extension	3.25 (0.02*)	6.6 (0.001*)	3.35 (0.01*)
Dexterity	3.45 (0.03*)	7 (0.001*)	3.55 (0.03*)
Grip strength	0.9 (0.02*)	1.75 (0.001*)	0.85 (0.03*)

MD, mean difference; *p*-value: level of significance; *Significant at $p < 0.05$.

improvements in UE function were seen both immediately and after 3 days of KT in children in an acute rehabilitation setting[26]. The firing of cutaneous afferents on the underlying skin when using KT on the dorsum of the wrist and forearm could lead to enhancement of proprioceptive feedback[43]. Integration of signals from different proprioceptive afferents may occur at the spinal cord level[44], which might affect the muscle spindle sensitivity through modulation of gamma motor neuron firing, and perhaps change the balance of muscle activity to strengthen wrist extensors over time[45].

The effect of MT seen in our study agrees with the findings of Yavuzer et al[46] and Gygax et al[9], who found that grasp and dexterity were significantly increased during a regular and continuous training programme. Moreover, other studies have shown improvements in range of motion and scores on the QUEST and BBT[12,47]. Several researchers have proposed various hypotheses to address the effectiveness of MT. The mirror illusion of normal movement of the affected UL may compensate for a lack of proprioceptive information from the affected UL, allowing the recruitment of the premotor cortex[48]. The ventral premotor cortex, inferior parietal lobe, and caudal portion of the inferior frontal gyrus are activated by visual feedback of the movement provided by the mirror. These neural associations convert sensory representations of perceived motor movements into motor representations[49]. Visual stimuli pass from the occipital lobes to motor cortical regions through multisynaptic connections and elicit potentials in specific areas of the cerebellum[50]. The cerebellum is important for the learning and execution of motor actions[51]. The cerebellum serves as a comparator and an error-correcting tool. It compares the movement commands sent by the motor cortex to the actual output of the body part from peripheral feedback systems[52]. By reversing the non-use learning process, MT may also aid the patient in using the affected UL in ADL_S[53]. MT stimulates neurons in the undamaged motor cortex, which transfers ipsilateral motor pathways to the hemiplegic side, according to focal magnetic stimulation. Small uncrossed fibres in the corticospinal tracts transmit impulses from the cortex, resulting in motor stimulation of the muscles in the affected muscles[54]. This can result in a change in primary motor cortex activation toward the lesioned hemisphere, implying neural reorganization[55]. The findings of a previous study did not validate the efficacy of MT on the bimanual performance of children with CP, resulting in inconsistent results[56]. However, MT could improve affected UL motor function by increasing motor neuron activity and reducing movement disorder to a minimum, which is consistent with the findings of the current study[57,58].

In addition, the results of this study indicated a positive effect of the combination of mCIMT with traditional rehabilitation techniques. These findings are consistent with those of El-Kafy et al[22], Zafer et al[24], and Stearns et al[59], who found that mCIMT improved QUEST, dexterity, and grip strength in children with hemiplegic CP. Various studies have suggested different explanations for the effects of mCIMT. Following a brain injury, the representation of the affected cortical region decreases, resulting in motor performance errors and an increase in learned nonuse[60]. The mCIMT includes repeated practice of activities with motivation[61]. The forced use of the affected limb for ADL_S has a direct impact on motor learning[62]. Therefore, it was hypothesised that the mCIMT works by stimulating use-dependent cortical reorganisation and increasing the representation of impaired cortical areas, which alters the resulting adverse effects on brain functions after nervous system damage, and therefore improves recovery. Better motor function and learning outcomes are associated with plastic changes in the brain[63]. Plasticity encourages reorganisation not only in the injured cortex but also in the contralateral cortex, restoring motility and functionality[64].

This study had some limitations, including a lack of follow-up several months after training. Furthermore, the study only included children with hemiplegic CP. Although the sample size is consistent with a previous statistical estimate, increasing the sample size can improve the power of the results. The children's attention to the unaffected UL image in the mirror was also a limitation of this study. Although no cognitive impairment was present, some children exhibited a high level of attention, while others were unable to focus their maximal attention, which could have influenced the results of the study. Therefore, larger randomised trials including children with different types of CP are needed to confirm these results. The evaluation of the data among the members of the research group and frequent discussion of the results during the entire analysis process were performed to minimise interpretation bias in our study.

Conclusions

Based on the results obtained in this study, MT with taping, mCIMT alone, and MT alone are good supplements to the traditional physical therapy programme in improving the quality of UE function, dexterity, and grip strength in children with hemiplegic CP. Using MT with KT resulted in the most significant improvements.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Acknowledgements

The authors appreciate all the parents' and children's cooperation and trust.

Statement/Declarations of Interest

No potential conflict of interest was reported. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contribution

Rasha A. Mohamed: Conceptualization, methodology, writing, reviewing and editing. Abeer M. Yousef: Conceptualization and writing –review. Marwa M. Ibrahim: Methodology and writing-original draft. Nadia L. Radwan: Methodology and writing –review.

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