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Impact of constraint therapy versus hand–arm bimanual intensive training on postural control during reaching and reaching quality: Randomized trial

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ABSTRACT

Aim: To investigate the efficacy of Constraint induced movement therapy (CIMT) versus Hand–arm bimanual intensive training (HABIT) on postural control during reaching with the affected arm and reaching quality in sitting children with hemiplegia. Methods: Forty-Two children; twenty normal children and twenty –two with spastic hemiplegia were recruited for participation in the study, hemiplegic children were randomized to the CIMT or HABIT group. Two hemiplegic children were excluded. Their age ranged from four to eight years old. The primary outcome: postural control that was evaluated using Qualysis motion AB system. Secondary outcome: reaching quality that was assessed using Peabody developmental motor scales (version-2) before and after four weeks of interventions that were provided 6days/week for 3 hours/day. Results: The results of this study revealed that there was significant improvement ($p < .05$) in all measured dependent variables in the post-treatment condition compared with the pre-treatment in both study groups with preference for group (B). Conclusions: Both techniques have a positive influence on postural control and quality of reaching and it would be better to combine both of them in treatment programs.

Keywords: Spastic hemiplegia; Postural control; Intensive training; Motion analysis.

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INTRODUCTION

Spastic hemiplegia is characterized by motor impairments of one body side and it is one of the most common subtypes of cerebral palsy (CP). As many daily activities necessitate both hands, impairment of hand function is one of the most disabling symptoms (Anttila, Autti-Ramo, Suoranta, Mäkelä & Malmivaara, 2008; Sakzewski, Ziviani & Boyd, 2009). Dysfunctional postural control (PC) is a crucial problem in children with CP, that interfere with daily living activities (Brogren, Forssberg, & Hadders-Algra, 2001; van der Heide, Begeer, Fock, Otten, Stremmelaarand van Eykern, 2004).Upper extremity function requires appropriate PC. At a minimum, the trunk must provide adequate support during reaching and object manipulation (Thomas, Corcosand Hasan, 2005).Typically developing (TD) children utilize trunk motion to propel the arm forward and exhibit anticipatory postural adjustments in response to the destabilizing effects of limb movement (van der Heide, Otten, van Eckern & Hadders-Algra, 2003).Children with hemiplegia have dysfunctional timing and coordination of reaching movements, movement planning and limited capacity to modulate postural adjustments (PA) during reaching (Steenbergen & Van der Kamp, 2004).Functional impairments associated with hemiplegia lead to diminished use of the involved upper extremity (UE), compromising the performance of bimanual activities (Van Zelst, Miller, Russo, Murchland, & Crotty, 2006). Despite lack of evidence to support the efficacy of specific rehabilitation approaches (Sakzewski et al., 2009), previous studies suggest a potential benefit of intensive training of the involved UE. As both techniques comprise indirect training of anticipatory postural adjustment to compensate for limb movement, so it is believed that intensive training using Constraint induced movement therapy (CIMT) or Hand–arm bimanual intensive training (HABIT) may result in better postural control during reaching, trunk contribution and quality of reaching. Constraint induced movement therapy is a structured practice that involves using a restraint on the non-involved UE and providing structured practice that consists of both shaping and repetitive task practice (Winstein, Miller & Blanton, 2003).In a CIMT approach training activities are selected to match the child's interest and designed to target impairments considered to have direct relation to the diminished use of the affected UE (Charles & Gordon, 2005; Eliasson & Gordon, 2008).Bimanual training is another approach that focuses directly on the involved UE of children with asymmetrical impairments. Hand–arm bimanual intensive training (HABIT) is a highly structured technique that involves intensive training using graded functional activities tailored to the child's specific impairment and interests, and intervention targets bimanual hand use (Charles & Gordon, 2006).Recent studies have compared the effects of CIMT and HABIT on specific components of manual use, such as manual dexterity and the quality and amount of use of the affected UE and bimanual function (Gordon, Hung, Branda˜o, Ferre, Kuo, Friel, et al., 2011; Sakzewski, Ziviani, Abbott, Macdonell, Jackson & Boyd, 2011).However, it is worth to mention that no studies have been conducted to date to examine the effects of such interventions on postural control during reaching. Using a restraint on one upper extremity may result in profound effects on postural control and stability or postural responses could be adjusted to compensate for the restraint of the non-involved upper extremity (Charles & Gordon, 2005). So, the current study aimed to examine the effect of CIMT versus HABIT on postural control during reaching and quality of reaching movement in hemiplegic children.

MATERIALS AND METHODS

Design

The study was designed as a prospective, randomized, single blind, pre–post-test trial.

Participants and setting

Forty-Two children, from both genders were recruited for participation in these study 20 normal children (their data were used as reference in motion analysis to compare with) and, 22 children with hemiplegia met the

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inclusion criteria. After the orientation session and before randomization, two hemiplegic children were excluded (one had prior hand surgery, the parent of the other child did not agree to the evaluation process as it was too intrusive in their perspective). Hemiplegic children were randomly allocated using concealed envelopes into two equal Study groups; group A received CIMT and group B received HABIT. They were assessed and treated in labs and outpatient clinics of the Faculty of Physical Therapy, Cairo University. No subjects dropped out of the study after randomization. Patient flow is shown in the CONSORT flow diagram (Figure 1).Written informed consent was obtained from all participants' legal guardians, before the baseline evaluation. Ethical approval was obtained from the institutional review board at Faculty of physical therapy, Cairo University before study commencement. The study was conducted between January 2017 and May 2018.The inclusion criteria were: children with age range from 4-8 years old, diagnosis of congenital spastic hemiplegic cerebral palsy as diagnosed and reported by a medical specialist (i.e. neurologist, paediatrician),mild degree of spasticity according to modified Ashworth scale ranging from 1 to 1+ (Bohannon & Smith, 1987), children with active movement of the shoulder, elbow, wrist, digits and thumb of the affected upper limb; children who were able to reach forward to an elevated position in front with mid-range shoulder flexion, able to follow simple commands and to sit independently. Parents who were able to commit to an intensive therapy program and agree to cease all other upper limb therapeutic interventions for the 4 weeks period of the trial.

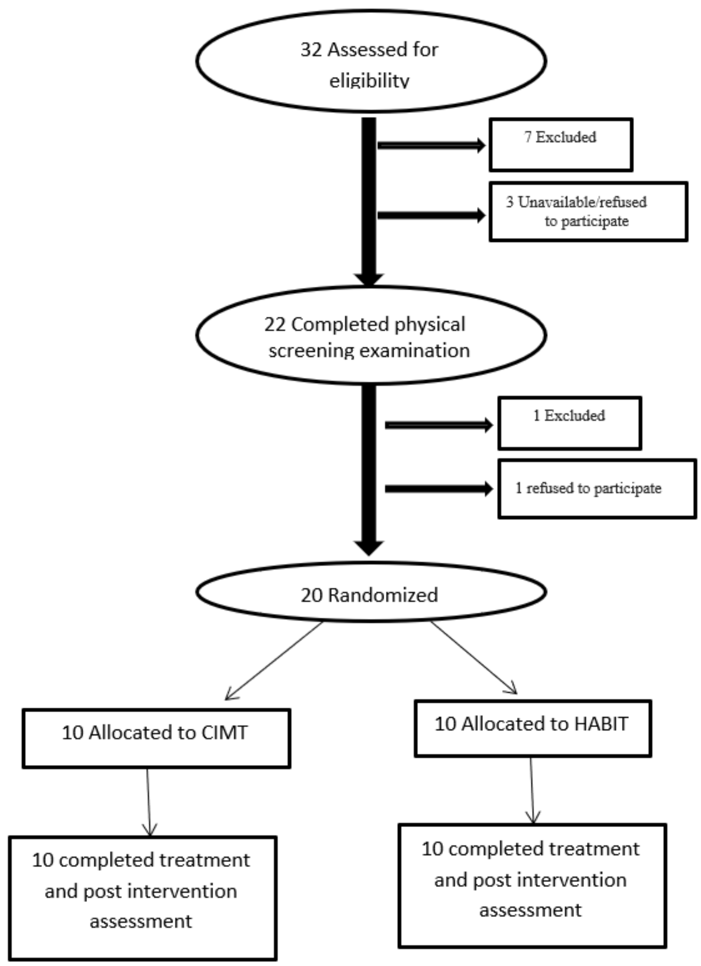

Figure 1. Patient Flow Chart (CONSORT flow diagram).

Instrumentation for evaluation

Qualysis motion AB system

Qualysis pro reflex motion analysis system was used with six cameras configuration which were connected to the computer (pro reflex) and a wand kit was used for calibration of the system. A laboratory research associate who was blinded to treatment allocation assessed each child individually before and after four weeks of treatment. Evaluation included:

1. System calibration through a period of 16 seconds.
2. Children were seated on a table without back and foot support, dressed in underwear only. An attractive object was placed on a table of adjustable height in the midline at arm's-length distance from the child.
3. The instruction was to grasp the object with the involved hand, [dominant hand for typically developing children at a natural self-paced speed. For each child 3 to 5 trials were performed.
4. Motion capture started briefly before movement onset and lasted 6 seconds.
5. Reflective markers were placed on the following landmarks:

Condyle of mandible, (2) spinous process C 7, (3) spinous process T 10, (4) spinous process L 5 ,[(5) Anterior superior iliac spine (ASIS), (6) Greater trochanter , (7) Acromion, bilaterally].(8) radial epicondyle , (9) radial styloid process , the last two markers were placed only on the affected arm (dominant arm in TD children) Figure 2.

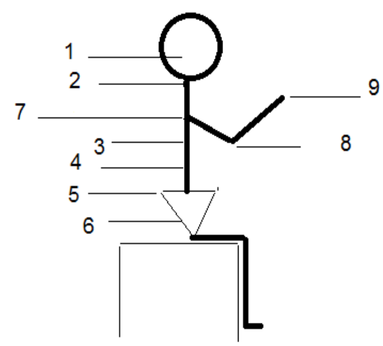

Figure 2. Reflective markers were placed on the following landmarks: (1) condyle of mandible, (2) spinous process C 7, (3) spinous process T 10, (4) spinous process L 5, (5) Anterior superior iliac spine (ASIS), (6) Greater trochanter, (7) Acromion (8) radial epicondyle, (9) radial styloid process, the last two markers were placed only on the affected arm (dominant arm in TD children).

Data processing: (performed by researcher blinded to treatment allocation)

First: Using Q Tools software the kinematic analysis consisted of the calculation of the spatial angles for the: 1- head (by a vector between markers 1 and 2); 2- the pelvis (by a vector between markers 5 and 6), and 3- Trunk flexion (by a vector between markers 2 and 4) in relation to the horizontal plane (X).

4- Trunk side flexion angle was calculated by a vector between markers 2 - 4 and trunk rotation was calculated by a vector between markers 7 on both sides in relation to the vertical plane (Y). 5- Back straightening was defined by calculating the angle of the two intersecting vectors between markers 2, 3 and 3, 4, and 6- The elbow angle was defined as the angle between the two vectors between markers 7 and 8, 8 and 9.

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In the kinematic analysis only trials with clearly demarcated start and stop were included. Analysis focused on:

1. Initial body configuration.
2. Angular displacements throughout the entire duration of the reaching movement.

Peabody developmental motor scales (version-2)

The PDMS-2 is composed of six subtests to assess the motor skills in children from birth through five years of age. This standardized norm-referenced test measures hand use, eye–hand coordination, and manual dexterity via typical preschool activities such as cutting, building blocks and lacing. Items are rated through a 3-point scale. PDMS–2 was administered to measure fine motor performance mainly reaching abilities. After administration of all tests in visual motor integration, raw and standard scores were calculated. Evaluation was carried out for each child in both study groups individually before and after four weeks of treatment (Folio & Fewell, 2000).

Treatment

Therapeutic procedures for group A

- Children in group A received CIMT as each child wore the sling on the non-involved extremity for 6 hours per day for four consecutive weeks. The child was allowed to take off the sling for short periods on request at the beginning of training to avoid excessive child frustration and rejecting the whole program. Concentrated, repetitive training of was given for 3 hours for:
- Postural control during reaching activities with the affected limb as follows:
- Treatment sessions: (using shaping techniques and repetitive task practice): Children attended treatment sessions 3 days per week.
- Home routine: Mothers were instructed to ensure that the child wore the sling for six hours per day and repeat the treatment program every other day vice versa with the treatment sessions.
- Training of fine motor activities (e.g., small blocks and puzzles), self-care activities (e.g., eating, dressing), and gross motor activities (e.g. balance reactions and anticipatory postural adjustments), activities were selected according to the child’s interests and motivation.

Interventions were provided 6days/week for 3 hours/day.

While Children in group B received HABIT as they had the same frequency and duration of treatment sessions and home routine as group A, however children were engaged in bimanual training of age appropriate fine motor, self-care and gross motor activities, in addition to concentrated, repetitive training of postural control during reaching activities with the affected limb.

Sample size estimation

Sample size estimation was performed preceding the investigation utilizing G*POWER statistical programming (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) [power (1−α error P) = .85, α = .05, effect size = 1.5, with a two-tailed for a comparison of 2 independent groups] determined a sample size of 9 for each group in this study (Figure 3). This effect size was calculated according after a pilot study on 6 participants (3 in each group) considering Standard score(PDMS) as a primary outcome.

Statistical analyses

All statistical measures were performed using the Statistical Package for Social science (SPSS) program version 20 for windows. Descriptive analyses showed that the data were normally distributed and not violates the parametric assumption for all measured dependent variables. Additionally, testing for the homogeneity of covariance using Box's test revealed that there was no significant difference with p values of > .05. The box and whiskers plots of the tested variables were done to detect the outliers. Normality test of data using Shapiro-Wilk test was used, that reflect the data was normally distributed for all dependent variables that allowed the researchers to conduct parametric analysis. So, 2 × 2 mixed design MANOVA was used to compare the tested variables of interest at different tested groups and measuring periods. As well as one sample t test was used to compare all dependent variables with normal value. The alpha level was set at .05.

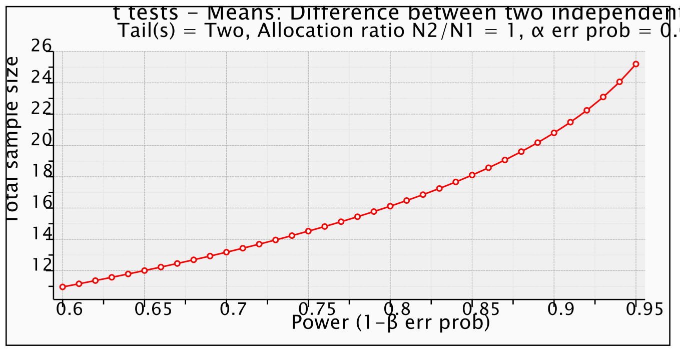

Figure 3. Plot of sample size calculation.

RESULTS

The children participating in this study were classified into three groups. Twenty normal children (8 boys and 12 girls) with age ranged from 4-8 years, Group (A): included ten hemiplegic children (6 boys and 4 girls) with age ranged from 4-8 years and Group (B): included ten hemiplegic children (4 boys and 6 girls) with age ranged from 4-8 years. Statistical analysis revealed non-significant differences (p > .05) between the three groups regarding to demographic characteristics as shown in Table 1.

Table 1. Demographic data and sex distribution within the three groups.

Groups	Age (Years) X ± SD	F-value	p-value	Boys	Girls	Right Side	Left Side
Normal	5.875 ± 1.022			8 (40%)	12 (60%)	-------	------------
Group A	5.48 ± 1.29	1.873	.3919	6 (60%)	4 (40%)	6 (60%)	4 (40%)
Group B	5.88 ± 1.28			4 (40%)	6 (60%)	6 (60%)	4 (40%)

As indicated from the results of descriptive data of all groups (Normal, A and B), children in all groups were homogenous concerning age and frequency distribution of sex. Statistical analysis using one sample t test (Pre and post) for all dependent variables compared to normal value revealed significant difference in all measured dependent variables before intervention (p < .05). However, there were no significant difference between both study groups (p > .05) (Table 2).

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Table 2. Descriptive statistics and One sample t test (Pre and post) for all dependent variables compared to normal value.

Angle (degree)	Variables		Mean ± SD	Typically developing children	t-value	p-value
Head angle Initial configuration	HABIT	Pre	30.09 ± 6.8	37.39	-3.394	.008
		Post	38.72 ± 5.73		0.734	.482
	CIMT	Pre	29.18 ± 8.38		-3.095	.013
		Post	33.01 ± 5.50		-2.515	.033
Head angle Angular Displacement	HABIT	Pre	8.72 ± 2.71	6.715	2.338	.044
		Post	5.23 ± 2.05		-2.290	.05
	CIMT	Pre	9.17 ± 3.98		1.949	.083
		Post	5.74 ± 3.93		-0.784	.453
Trunk side flexion Initial configuration	CIMT	Pre	3.66 ± 1.08	2.07	4.641	.001
		Post	2.07 ± 0.83		0.000	1.000
	HABIT	Pre	3.01 ± 1.15		2.578	.030
		Post	1.5 ± 1.18		-1.519	.163
Trunk side flexion Angular Displacement	CIMT	Pre	5.58 ± 1.84	2.71	4.932	.001
		Post	3.32 ± 1.16		1.658	.132
	HABIT	Pre	6.9 ± 2.57		5.145	.001
		Post	2.27 ± 0.81		-1.707	.122
Trunk Rotation Angular Displacement	CIMT	Pre	13.72 ± 3.54	10.51	2.866	.019
		Post	9.26 ± 2.96		-1.335	.215
	HABIT	Pre	11.72 ± 4.19		0.911	.386
		Post	8.16 ± 3.20		-2.316	.05
Trunk Flexion Initial configuration	CIMT	Pre	78.57 ± 6.02	83.91	-2.801	.021
		Post	81.34 ± 3.99		-2.032	.073
	HABIT	Pre	79.01 ± 4.32		-3.583	.006
		Post	85.43 ± 2.12		2.261	.050
Trunk Flexion Angular Displacement	CIMT	Pre	10.01 ± 3.95	5.84	3.332	.009
		Post	6.47 ± 3.51		0.566	.585
	HABIT	Pre	11.04 ± 4.75		3.460	.007
		Post	5.49 ± 2.61		-0.424	.682
Pelvic Angle Initial configuration	CIMT	Pre	35.37 ± 15.20	51.265	-3.306	.009
		Post	41.11 ± 15.63		-2.053	.070
	HABIT	Pre	35.97 ± 13.71		-3.527	.006
		Post	47.32 ± 11.96		-1.043	.324
Pelvic Angle Angular Displacement	CIMT	Pre	13.78 ± 7.24	9.536	1.854	.097
		Post	6.63 ± 4.18		-2.195	.056
	HABIT	Pre	19.77 ± 16.6		1.850	.001
		Post	8.42 ± 5.75		-0.580	.578
Back straightening Initial configuration	CIMT	Pre	151.37 ± 8.04	165.345	-5.495	.000
		Post	165.04 ± 8.35		-0.115	.911
	HABIT	Pre	154.92 ± 8.61		-3.826	.004
		Post	169.5 ± 5.84		2.247	.051
Back straightening Angular Displacement	CIMT	Pre	12.88 ± 6.34	5.605	3.629	.005
		Post	6.05 ± 3.31		0.425	.681
	HABIT	Pre	11.75 ± 5.69		3.412	.008

		Post	6.33 ± 2.88		0.796	.447
Elbow Angle Angular Displacement	CIMT	Pre	139.31 ± 12	154.465	-3.991	.003
		Post	149.67 ± 8.76		-1.730	.118
	HABIT	Pre	126.63±14.37		-6.123	.000
		Post	144.16 ± 7.44		-4.376	.002

Table 3. One sample T test (pre and post) for Peabody developmental motor scale(standard score).

Standard score(PDMS)	Pre test	Post test
	Mean ± SD	Mean ± SD
Group (CIMT)	2.5 ± 0.84	6.1 ± 1.44
Group(HABIT)	2.33 ± 0.86	6.22 ± 1.56

Note. SD: Standard Deviation.

Statistical analysis using mixed design MANOVA revealed that there were significant within subject effect (F = 150.505, p = .0001) and treatment*time effect (F = 68.56, p = .0001*). As well as there was no significant between subject effect (F = 2.9, p = .78). (Table 4) present descriptive statistic, Within and between groups differences at 95 % CI for the effects of interventions for all dependent variables.

Within groups

In the same context, regarding within subject effect, the multiple pairwise comparison tests revealed that there was significant improvement (p < .05) in all measured dependent variables in the post-treatment condition compared with the pre-treatment in both groups except for: [head angle initial configuration and pelvic angle angular displacement in group (a)] showed no significant difference(p > .05) (Table 4).

Table 4. Multiple pairwise comparison tests (Post hoc tests) for all dependent variables (between group Comparison).

Angle (degree)	Time	(A) Group	(B) Group	p-value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Head angle	Pre	CIMT	HABIT	.728	-6.307	8.843
Initial configuration	Post	CIMT	HABIT	.034	.514	11.615
Head angle	Pre	CIMT	HABIT	.890	-3.586	3.137
Angular Displacement	Post	CIMT	HABIT	.970	-2.812	2.917
Trunk side flexion	Pre	CIMT	HABIT	.182	-.376	1.830
Initial configuration	Post	CIMT	HABIT	.229	-.416	1.623
Trunk side flexion	Pre	CIMT	HABIT	.292	-3.324	1.061
Angular Displacement	Post	CIMT	HABIT	.040	.052	2.055
Trunk Rotation	Pre	CIMT	HABIT	.364	-2.124	5.498
Angular Displacement	Post	CIMT	HABIT	.468	-1.997	4.161
Trunk Flexion	Pre	CIMT	HABIT	.706	-6.048	4.188
Initial configuration	Post	CIMT	HABIT	.009	-7.510	-1.255-
Trunk Flexion	Pre	CIMT	HABIT	.649	-5.316	3.402
Angular Displacement	Post	CIMT	HABIT	.392	-1.768	4.286
Pelvic Angle	Pre	CIMT	HABIT	.790	-16.003	12.365
Initial configuration	Post	CIMT	HABIT	.351	-20.198	7.573
Pelvic Angle	Pre	CIMT	HABIT	.313	-18.167	6.171
Angular Displacement	Post	CIMT	HABIT	.445	-6.627	3.043

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Back straightening	Pre	CIMT	HABIT	.434	-11.405	5.122
Initial configuration	Post	CIMT	HABIT	.264	-10.943	3.200
Back straightening	Pre	CIMT	HABIT	.809	-5.240	6.622
Angular Displacement	Post	CIMT	HABIT	.890	-2.716	3.105
Elbow Angle	Pre	CIMT	HABIT	.05	-1.083	25.192
Angular Displacement	Post	CIMT	HABIT	.191	-2.861	13.312
Standard Score	Pre	CIMT	HABIT	.678	-.665	.998
(PDMS)	Post	CIMT	HABIT	.862	-1.580	1.336

Between groups

Between groups comparison showed significant difference (p < .05) in head angle and trunk flexion initial configuration plus trunk side flexion angular displacement in favour of group (B) (Table 5).

Table 5. Within groups comparison of measured variables.

Angle (degree)	Group	(I) Time	(J) Time	p-value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Head angle	CIMT	Pre	Post	.162	-9.372-	1.705
Initial configuration	HABIT	Pre	Post	.003	-13.885-	-3.375-
Head angle	CIMT	Pre	Post	.012	0.885	6.095
Angular Displacement	HABIT	Pre	Post	.010	1.021	6.513
Trunk side flexion	CIMT	Pre	Post	.002	0.653	2.527
Initial configuration	HABIT	Pre	Post	.006	0.479	2.454
Trunk side flexion	CIMT	Pre	Post	.009	0.638	3.882
Angular Displacement	HABIT	Pre	Post	.000	2.735	6.154
Trunk Rotation	CIMT	Pre	Post	.000	2.346	6.574
Angular Displacement	HABIT	Pre	Post	.002	1.627	6.084
Trunk Flexion	CIMT	Pre	Post	.029	-5.22	-0.317
Initial configuration	HABIT	Pre	Post	.000	-8.808-	-3.637-
Trunk Flexion	CIMT	Pre	Post	.003	1.419	5.661
Angular Displacement	HABIT	Pre	Post	.000	3.520	7.991
Pelvic Angle	CIMT	Pre	Post	.090	-12.473-	0.993
Initial configuration	HABIT	Pre	Post	.007	-17.331-	-3.136-
Pelvic Angle	CIMT	Pre	Post	.054	-0.132-	14.432
Angular Displacement	HABIT	Pre	Post	.006	3.680	19.031
Back straightening	CIMT	Pre	Post	.000	-19.541-	-7.799-
Initial configuration	HABIT	Pre	Post	.000	-20.589-	-8.211-
Back straightening	CIMT	Pre	Post	.000	3.651	10.009
Angular Displacement	HABIT	Pre	Post	.001	2.982	9.684
Elbow Angle	CIMT	Pre	Post	.012	-18.092-	-2.628-
Angular Displacement	HABIT	Pre	Post	.000	-25.339-	-9.038-
Standard Score	CIMT	Pre	Post	.000	-4.233-	-2.967-
(PDMS)	HABIT	Pre	Post	.000	-4.556-	-3.222-

DISCUSSION

The purpose of this study was to investigate the efficacy of CIMT versus HABIT on postural control during reaching with the affected arm and reaching quality in sitting children with hemiplegia. Postural control development in early life is a complicated and long term process (Heyrman, Desloovere, Molenaers, Verheyden, Klingel, Monbaliu et al., 2013). During this process postural control mechanism provides a vertical posture by stabilizing head and trunk against gravity which in turn allow proper base for performing adequate activities like sitting, reaching, standing and walking (Saether, Helbostad, Adde, Jorgensen & Vik, 2013), the head becomes the dominant frame of reference from the age of 4 years in typically developing children during reaching from sitting, as a descending recruitment pattern for posterior postural muscles (cervical, thoracic, lumbar) starts to predominate at this age (van der Heide et al., 2003). Moreover, from 4 years onwards children stabilize the head in space instead of stabilizing the head-on trunk (Sveistrup, Schneiberg, McKinley, McFadyen & Levin, 2008), this would justify the choice of age range from 4-8 years. In addition, sitting is the position in which children with hemiplegia carry out most functional activities.

The findings of the current study indicate that children with hemiplegia differ from typically developing children in both postural control and trunk contribution during reaching from sitting position as follows: Children with hemiplegia showed more head flexion, more reclined pelvis and more collapsed trunk. This results were in line with the findings of Van Der Heide, Fock, Otten, Stremmelaar and Hadders-Algra (2005) who assessed the relationships between kinematic characteristics of sitting posture during reaching movements of the dominant arm and 1) the kinematics of the reaching movement itself and 2) functional performance during daily life activities using paediatric evaluation of disability inventory (PEDI) in 51 sitting preterm children with CP. The data were compared with those of 26 typically developing (TD), he found that the children with CP sat with a more flexed trunk and had their pelvis, especially children with spastic hemiplegia, in a more reclined posture than the TD children. It could be justified as the child's strategy to counterbalance for postural instability. For, in the crouched sitting position with pelvic retro-flexion, children with CP can adapt postural muscle activity to environmental conditions more efficiently than in a sitting position with less pelvic retro-flexion (Brogren & Hadders-Algra, 2005), this was confirmed by the results of (van der Heide et al., 2003) who found that this different sitting posture didn't result in worse functional performance during daily life activities, in contrast the retroflexed pelvic position results in a better quality of reaching movements(van der Heide et al., 2003).

In addition, children with hemiplegia showed more angular displacement for head angle than normal children. This finding was in line with the studies of head control in children with CP, as they showed increased head movement during transitions between postures (Dan, Bouillot, Bengoetxea, Noel, Kahn & Cheron, 2000) during reaching, when making visual saccades (Saavedra, Joshi, Woollacott & van Donkelaar, 2009) and even during quite sitting (Saavedra, Woollacott & Van Donkelaar, 2010). These findings indicate that these children can't adequately stabilize their head in space during dynamic tasks which could be related to immature or abnormal patterns of trunk muscle activation. This was in line with the results of Saavedra et al., (2010) who evaluated postural control by measuring head stability during quiet sitting, meanwhile the researcher systematically manipulated the level of trunk support and vision in 15 children with CP (6–16 years), 26 typically developing children (4–14 years), and 11 adults. He found that all measures of head sway (displacement, rate and frequency) were reduced in the Torso Support condition as compared to No Support or Pelvic Support in all groups and both planes. He assumed that biomechanical factors (decreased degrees of freedom, shorter lever arm and increased passive stiffness) as well as augmented somatosensory information through tactile input from the support device were the cause for better postural control in the test subjects (Jeka and Lackner, 1994).

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Children with hemiplegia also, showed more angular displacement for both back straightening and pelvic angle, these results were not in line with Van der Heide et al., 2005 who found that angular displacement during the reaching movement in general did not differ between the three groups. This could be attributed to the difference between that study and the current one in that in the latter mentioned study the children reached for the target with the dominant arm (less affected) where in the current study the children reached with the affected arm which was more challenging for balance thus requires more angular displacement. This was confirmed by the results of Van der Heide et al., 2003 who found that during the development of postural adjustments in a reaching task the end bloc strategy (which consists of an in concert activation of direction-specific head and trunk muscles) is the dominant strategy for a less time than it is during the development of postural adjustments for external perturbations in a sitting position i.e. it's timing depends on the nature of the postural task. In other words, the duration of the end bloc phase appears to be positively related to the magnitude of balance control challenge imposed by the task. In the sitting position, an external perturbation challenges balance more than a self-generated reaching movement (Hadders-Algra, Brogren & Forssberg, 1998).

Moreover, children with hemiplegia showed more trunk side flexion before the onset and during reaching, which was in line with (Liao, Yang, Hsu, Chan & Wei, 2003) who stated that studies of sitting postural control have reported increased sway in the frontal plane in children with spastic CP compared to TD peers in both static and dynamic conditions. This could be attributed to the well-known clinical problem in children with hemiplegia which is the utilization of shoulder elevation and lateral trunk flexion to increase the height of the arm for reach thus they have difficulty maintaining upright body posture when reaching forward or across midline.

Finally, the findings of our study revealed that hemiplegic children show more trunk contribution than normal children during reaching movement which was reflected by increased angular displacement of trunk angles, as mentioned previously they showed more trunk side flexion and increased trunk flexion, this could be attributed to their inability to dissociate arm motion from trunk motion. Moreover, with limited arm contribution to the movement the child needs to side flex the trunk to increase the height of the arm and flex the trunk to reach his target as a consequence to limited elbow extension. These results were in line with (Ricken, Bennett and Savelsbergh, 2005) were they found that children with hemiplegic cerebral palsy tended to show more trunk motion and justified that this could be the children's strategy to cope with the diminished shoulder and elbow excursions.

The results of the current study showed that both techniques resulted in improvement of postural control and quality of reaching, these comes in line with (Robert, Guberek, Sveistrup & Levin, 2013)who investigated the effect of task-oriented training during a reach-to-grasp task on improving upper limb kinematics in children with CP and concluded that the improvements following upper limb training program in these children were retained for at least 3 months in some children and could be generalized to a similar task. In addition, Graaf-Peters, Blauw-Hospers, Dirks, Bakker, Bos and Hadders-Algra, (2007) suggested that training involving active trial and error experience could accelerate postural development in TD infants and may enhance postural control in children with or at high risk for a developmental motor disorder.

In contrast, Ballaz, Huffenus, Lamarre, Koclas and Lemay, (2012) concluded that wearing a sling or forced use therapy (FUT) did not resulting significant improvement of balance. This suggests that wearing the sling or FUT neither comprise risk to patient, nor result in a positive impact on balance. This could be attributed to two factors: first, the aforementioned study used FUT rather than CIMT i.e. did not include structured repetitive practice. Second, the short duration of intervention (12 days) might have been insufficient to induce significant change.

The results of the current study showed that HABIT resulted in more improvement of postural control during reaching, as children who received CIMT showed more flexed head and collapsed trunk at the beginning of the movement, in addition to increased trunk side flexion during the movement and decreased elbow extension at the end of the movement. This could be attributed to the fact that CIMT involves exclusive provision of unimanual training; everyday functional activities that necessitate bimanual UE use are not practiced during its implementation (Charles & Gordon, 2006; Gordon & Friel, 2006). So, it is believed that bimanual activities would result in more displacement of centre of mass thus leading to more practice of anticipatory postural adjustments.

Moreover Saavedra et al., (2010) deduced that children with CP showed greater amplitude and velocity of head movement than adults in the sagittal but not in the frontal plane. This implies that these children lack the basic postural mechanisms required for head stability in the sagittal plane and that these deficits are in central control mechanisms, not just related to biomechanical challenges or to trunk motor control. Children with CP may have deficits in the fundamental sensory systems that contribute to postural control i.e. the visual system, the vestibular system and the somatosensory system(Bodensteiner, Smith & Schaefer, 2003).

However, Boyd, Morris and Graham, (2001) stated that reviewed brain research revealed that the structure and function of the CNS could be modulated throughout the life span via participating in highly structured, repetitive, rewarded behaviours. Also, children have demonstrated that practice or experience influence the development of automatic postural responses; in addition, recent evidence suggests that children with hemiplegic CP can improve their motor performance if engaged in sufficient practice (Shumway-Cook, Hutchinson, Kartin, Price & Woollacott, 2003).

So as the two techniques involve intensive practice it would be more beneficial to combine both techniques to benefit from intensive concentrated practice for the affected arm (i.e. CIMT) plus generalization of such skills in daily living as a result of (HABIT).This was confirmed by the review of Gordon, (2011) who concluded that 1) Bimanual training may allow direct practice of functional goals, which could be transferred to unpractised goals and enhance bimanual coordination, (2) higher doses might be necessary with bimanual training.

Clinical messages

Both techniques have a positive influence on postural control and quality of reaching.

It would be better to combine both of them in treatment programs.

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