The effectiveness of task-oriented intervention and trunk restraint on upper limb movement quality in children with cerebral palsy

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AIM The goal of this study was to contribute evidence towards the effectiveness of task-oriented training with and without restriction of trunk movement (trunk restraint) on the quality of upper limb movement in children with cerebral palsy (CP).

METHOD We used a prospective, single-subject research design in 12 children (three males, nine females; aged 6–11y; median 9y) with di-, hemi-, or quadriplegia. Movements of the most affected arm were assessed five times: three times before training, immediately after training, and 3 months after training. The main outcome measures were the Melbourne Assessment of Unilateral Upper Limb Function (Melbourne) and upper limb movement kinematics during a functional reaching task. Children were randomly allocated to one of two groups: task-oriented training with or without trunk restraint. Treatment consisted of three 1-hour sessions per week for 5 weeks (total training duration 15h). Treatment effects were determined using single-subject research design analysis – regression through baseline data and standard mean differences.

RESULTS Although the Melbourne scores were largely unchanged after training, some children in each group improved arm trajectory smoothness (effect size 0.55–1.87), and most children improved elbow extension range (effect size 0.55–4.79). However, more children in the trunk restraint group than in the no restraint group demonstrated reduced trunk displacement (effect size 0.94–2.25) and longer-term improvements in elbow extension and trunk use. Among the group who underwent training without trunk restraint, trunk displacement was unchanged or increased, and fewer carry-over effects were apparent at follow-up.

INTERPRETATION This proof-of-principle study showed that greater improvement in the quality of upper limb movement in children with CP, including less compensatory trunk use and better carry-over effects, was achieved by training with trunk restraint.

Upper limb motor deficits in children with cerebral palsy (CP) include reaching, grasping, and prehension impairments affecting activities of self-care, education, and social interaction.[1] Early brain lesions affecting motor development may result in reorganization in the immature brain.[2,3] This, together with atypical limb use during critical periods of corticospinal tract development, may result in abnormal upper limb movement synergies including recruitment of excessive trunk movement (motor compensations).[4,5]

Upper limb function is affected by trunk positioning and postural control deficits in children with CP.[6,7] Van der Heide et al.[8] showed that altered sitting posture during reaching was unrelated to upper limb functional performance. Rather, better functional performance and upper limb kinematics were associated with head and pelvic stability and trunk curvature mobility. Altered arm kinematics during reaching was also related to atypical trunk movements,[8] including excessive anterior trunk displacement.[5] Increased trunk use during upper limb tasks may be a problem-solving strategy of the injured central nervous system.[5,9]

Because children with CP usually display non-typical trunk and upper limb movement patterns, interventions can focus on improving movement quality to avoid ‘learned bad use’.[3] Restriction of excessive trunk movement during upper limb task practice may promote improved arm movement patterns by providing more intensive and relevant task-appropriate upper limb somatosensory information.[10] In adults with hemiparesis manifesting similar movement deficits despite different aetiologies,[11] physical trunk restraint during task-oriented training led to arm movement pattern recovery. This recovery was partly attributed to the biomechanical advantage afforded by limiting forward trunk displacement and ‘forcing’ muscle

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use in previously unavailable ranges. Use of trunk restraint during upper limb activities may be more desirable than practice alone, which may increase undesirable trunk movement.[11,12]

Our aim was to contribute evidence towards the effectiveness of a trunk restraint strategy combined with a typical upper limb treatment intervention (impairment and task-oriented treatment) to improve upper limb movement quality in children with CP. We assumed that excessive trunk use is maladaptive and that restriction of trunk displacement will facilitate the adoption of more desirable upper limb movement patterns. Indeed, increased trunk use is not a primary manifestation of CP but children flexibly tune trunk movement to task demands (e.g. for high accuracy tasks like eating with a spoon) even when trunk use is not observed for similar tasks in typically-developing children.[5]

We used reliable upper limb kinematic measures and clinical outcome scales to quantitatively and qualitatively analyse postintervention changes in movement quality.[13] We assumed that task-oriented training with trunk restraint would decrease excessive trunk displacement and improve upper limb movement quality in children with CP more than task-oriented training alone and that improvements would be maintained for up to 3 months post intervention. Preliminary results have appeared in abstract form.[14]

What this paper adds

- Proof-of-principle support for the use of a trunk restraint strategy during task-oriented treatment in children with CP.
- New information about the possible benefits of task-oriented training in children with CP.
- Preliminary evidence that the use of trunk restraint during upper limb training may result in decreased trunk displacement during reaching in children with CP.

METHOD

Participants

Twelve children with CP were recruited from five Quebec paediatric centres. Children were included if they had a diagnosis of spastic CP, were aged 5 to 12 years, had sensorimotor deficits in at least one arm (di-, hemi-, or quadriplegia), could sit unsupported, and could understand instructions. Those with CP of traumatic origin were excluded, as were those with moderate to severe cognitive deficits, athetosis, ataxia, choreoathetosis, arm, neck, or trunk pain/orthopaedic problems, and elbow and/or shoulder contractures more than 10°. Parents signed consent forms and children aged over 11 years signed child assent forms approved by the local ethics committee of the Centre for Interdisciplinary Research in Rehabilitation (CRIR).

Study design

Because of the small sample size and heterogeneity of participants, training effects for a 5-week intervention were investigated with a single-subject research design, as this alone, or combined with case reports and group analysis, was used previously to evaluate treatment outcomes in CP.[15] Five assessment periods were three baseline assessments at weeks 1, 3, and 5; one immediate postintervention assessment at week 11; and one 3-month follow-up assessment at week 23. Upper limb impairment and function were tested with one primary and five secondary clinical evaluations as well as kinematic analysis of reach-to-grasp tasks, which assessed movement quality using measures sensitive to changes in movement pattern.[16] Children were screened for inclusion/exclusion criteria and randomly allocated to one of two treatment groups consisting of impairment and task-oriented upper limb training with or without trunk restraint. The affected arm was used for all assessments.

Randomization and blinding

Children were paired by age and randomly allocated, by means of confidential e-mails to their therapists and to one of the groups by an individual uninvolved in recruitment, evaluation, or treatment. Therapists were unaware of evaluation outcomes. Evaluators and children were blinded to group allocation. Kinematic and videotaped clinical evaluations were coded and randomized, and evaluators had no contact with children or therapists. Children were blind to treatment allocation as trunk restraint straps were used in both interventions. However, straps were unfastened and did not limit trunk use in the no restraint group.

Measures

The main clinical outcome was the valid and reliable (ICC>0.87) Melbourne test,[17,18] which assesses 16 arm and hand movements for range of motion, accuracy, fluency, quality, accomplishment, and/or speed on four- or five-point scales. The maximum raw score is 122. Evaluations were videotaped for later analysis. A laboratory test assessed the ability to reach and grasp a $2cm^3$ block (target) in a simulated self-feeding task. For standardization, all children sat at a table adjusted to elbow height. Targets were aligned with the body midline and placed at distances proportional to the child's arm length (T1, two-thirds arm length; T2, arm length), with arm length defined as the distance from the medial axillary border to the distal wrist crease with elbow extended. In the initial position, the hand was 5cm from the sternum with fingers straight, thumb abducted, wrist and shoulder in neutral, elbow flexed ~90°, and forearm pronated. The same protocol was previously used to characterize reaching in typically developing children.[19] Blocks of 10 to 15 trials were counterbalanced by target. Self-paced movements were made with the most affected arm. Kinematic variables with high test–retest reliability (intraclass correlation >0.9)[13] were used to assess hand trajectory smoothness, final elbow angle, and trunk displacement.

Baseline clinical characteristics were assessed by five measures. Upper limb passive range of motion and pain were measured on a scale where a maximum score of 24 represented full, painless passive range of motion. Light touch and position sense were measured on scales with maximum scores of 20 and 8, indicating no impairments. Tactile perception was assessed using a two-point discrimination test and a Semmes–Weinstein Monofilament test (Lafayette Instrument Company, Lafayette, IN, USA), on which typically developing children aged 5 to 9 years scored 2 to 3mm[20] and 2.83 to 3.61mm respectively.[21] Spasticity was quantified with the valid Composite Spasticity Index,[22] which measures phasic reflex excitability (four-point scale), resistance to muscle stretch (elbow, eight-point scale), and wrist clonus (four-point scale), where a maximal score of 16 represents severe spasticity.

Treatment intervention

The intervention consisted of three 1-hour sessions per week for 5 weeks (15h). Children sat on height-appropriate chairs with foot support in front of a table that was adjusted to elbow height. Interventions were delivered by specially trained paediatric physical or occupational therapists in each paediatric centre. A standardized intervention, developed with expert clinicians, included impairment-based, task-oriented, and client-centred approaches to closely approximate usual care. Standardization was important as the intervention was delivered by different therapists and in different settings. It was necessarily a compromise between usual clinical interventions and what could be compared in a multicentre study. Sessions were divided into five blocks. Block 1 consisted of 3 minutes of preparatory activity (i.e. upper limb stretching and/or mobilizing). In block 2, children performed 20 minutes of task-oriented uni- and bimanual activities in a standardized environment (custom-built tabletop with defined workspace zones; Fig. 1a,b). Using the tabletop workspace (Fig. 1c), upper limb movements could be performed in the horizontal (e.g. ipsilateral, contralateral, close, and far zones) and vertical planes (e.g. high and low zones divided at shoulder height). Various types of grasping activities were incorporated into the training, including grasping toys of different shapes, sizes, and weights in all workspaces and manipulating magnets on the posterior wall. Task-oriented activities were progressed according to child/therapist preference and clinical goals using a standardized approach across centres. Block 3 was a 7-minute rest period. In block 4, children engaged in 20 minutes of task-specific activities within a video-capture-based virtual reality environment (IREX; GestureTek, Toronto, ON, Canada). Upper limb activities were targeted in virtual reality as the child's hand and forearm were projected onto and interacted with objects on a screen (Fig. 1d). Therapists emphasized arm movement in ranges challenging the child's motor ability. During virtual reality activities, children received feedback as sounds and game scores. Sessions ended with 10 minutes of functional training that involved practising a challenging activity chosen by the child or his or her family (block 5). All five paediatric centres were provided with the same equipment (tabletop, toys, virtual reality computer system) and therapists kept work-logs of activities/tasks used.

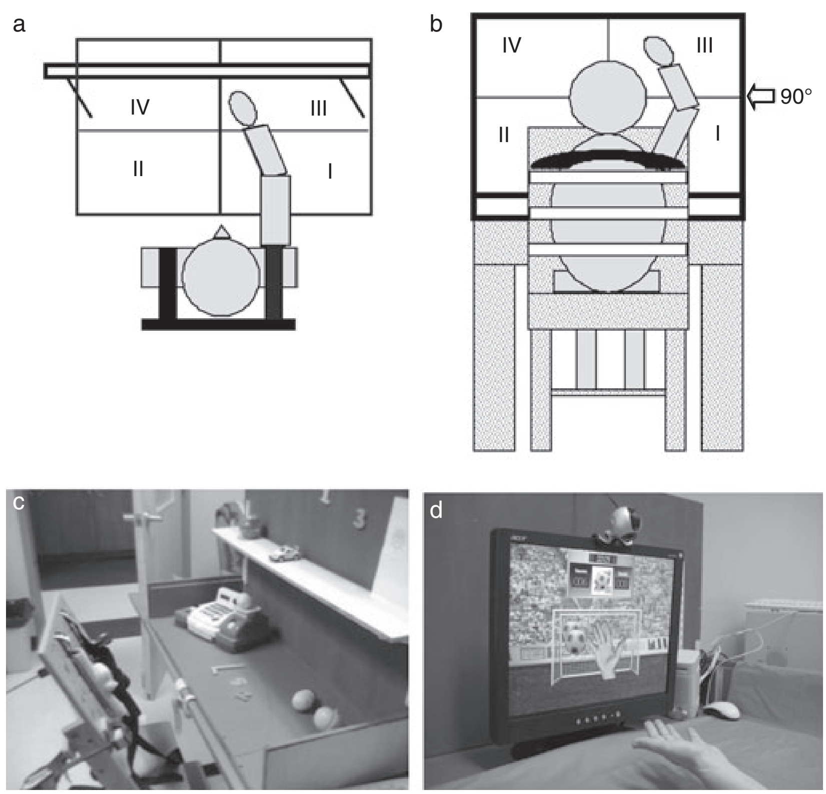

Figure 1: Illustration of calibrated workspace (wooden tabletop box) used for the task-oriented training. (a) Horizontal plane showing zones to perform reaches to the close ipsilateral (I) and contralateral (II) side, and to the far ipsilateral (III) and contralateral (IV) side of the most affected arm. (b) Vertical plane; the arrow marks the shelf position at which reaches were done above 90° of shoulder flexion. (c) Trunk restraint system. Shoulder straps passed through a hole in the back of the chair, which was adjusted to the height of the spine of the child's scapula. The box used for the task-oriented intervention and some toys are seen. (d) Example of video-capture virtual reality game in which the child's hand interacts with objects on the computer screen.

Trunk restraint

During blocks 2 and 4, two 3-inch-wide straps were placed diagonally across the child's chest. For children in the trunk restraint group, straps were attached to the chair (Fig. 1c) to limit forward trunk displacement and rotation. Straps were adjusted to permit age-appropriate amounts of trunk movement during upper limb tasks based on previous studies in typically-developing children (5y, 5cm; 6–7y, 4cm; 8–9y, 3cm; 10–12y, 2cm).[19] Scapular movements were unconstrained. Trunk restraint was not applied during block 5 so as not to limit the choice of child-centred activities. In the no trunk restraint group, straps were only loosely draped over the shoulders, without limiting trunk movement, so that both treatment approaches seemed equivalent to families. No instructions regarding trunk use during upper limb activities were provided, but therapists could guide arm movement or motivate the child as usually done in routine practice.

Kinematic data analysis

Ten infrared-emitting diodes were placed on strategic arm and trunk anatomical landmarks: fingertip, thumb, first metacarpal head, radial styloid, mid-forearm, lateral epicondyle, ipsilateral and contralateral acromions, sternum, and lateral iliac spine. Positional data (x, y, z) were recorded with Optotrak 3020 (100Hz; Northern Digital, Waterloo, ON, Canada) for 5 to 8 seconds. Data were low-pass filtered (cut-off 10Hz) and used to plot three-dimensional arm and trunk trajectories. Movement start and end times were defined as the times that the hand tangential velocity trace increased or decreased and remained above or below respectively, 5% of the peak velocity for at least 50 milliseconds. Trajectory smoothness was computed as the number of movement units in the hand tangential velocity profile. A movement unit was defined as a local maximum velocity preceded and followed by increasing or decreasing values respectively, for at least 20 milliseconds.[23] Elbow angle at the time of grasping was calculated by analysis of vectors formed between infrared-emitting diodes placed on the radius and epicondyle, and epicondyle and ipsilateral acromion, where 180° corresponded to full elbow extension. Trunk displacement was computed as the sagittal distance moved by the sternal marker between the movement start and end. Each assessment comprised 7 to 13 trials. Trials were discounted if the child had trouble grasping or dropped the object or if missing marker data could not be replaced (<4% of trials).

Statistical analysis

To estimate the intervention effect on kinematic outcomes in each child, two single-subject research design statistical approaches were used[24]: regression with visual trend analysis and effect size obtained through the standard mean difference. For visual trend analysis, autocorrelation (Bartlett test[25]) revealed no dependency in pre-baseline observations; therefore, all observations made in the pre-baseline phase were combined and a linear regression line was fitted through the data. A second straight line was fitted from the end of this regression line horizontally through the postintervention and follow-up phases. The number of observations above or below the second line was counted for each phase. To determine the effect size, between-mean differences of postintervention and pre-baseline assessments were divided by pre-baseline standard deviation. The same was done to calculate the effect size of the follow-up for each child, but postintervention assessment was replaced with follow-up assessment. Effect sizes of 0.20, 0.50, and 0.80 were considered to be small, moderate, and large respectively.[26]

Intervention effects were estimated using the 2SD band method, in which a horizontal band representing 2SD of the mean pre-baseline Melbourne data was extended into postintervention and follow-up.[15] Data falling outside the band were considered significantly different from baseline. The chance of a data point occurring outside the band without any real change taking place was less than 5% (p<0.05).

RESULTS

All children completed all study phases and fully complied with the intervention. Several children had sensory deficits and/or spasticity (Table I).

Clinical outcome measure

Only one child (child 5) from the restraint group showed improved Melbourne scores both immediately postintervention and at follow-up. Melbourne scores were unchanged in all remaining children. One child (child 11) in the no restraint group slightly improved at follow-up, whereas four had mild deterioration: three at the postintervention assessment (children 8, 9, and 10) and one at follow-up (child 12). All but three children (children 3, 4, and 8) had a deficit in at least one sensory modality (Table I).

Kinematic outcomes

Overall trend analysis and effect size for each measure, child, and time period indicated smoother arm trajectories and greater elbow extension at the postintervention assessment in most children (T1, T2), but deterioration in elbow extension for reaches to T2 at follow-up among children in the no restraint group (Tables II–IV). Trunk displacement was reduced at the postintervention (T1) and follow-up (T1, T2) assessments in the restraint group but was unchanged or increased in the no restraint group. Figure 2 shows examples of trend line analyses for the three kinematic outcomes for one child per group (restraint group: child 1; no restraint group: child 7).

Hand trajectories

Hand trajectory smoothness data were summarized for each child, time period, and target. Improvements are indicated by data points below the baseline trend line in Figure 2 (left) and by negative effect sizes in Table II. Mixed results were observed in the trunk restraint group, in that trajectories for both targets were smoother at the postintervention or follow-up assessments in four out of six children (children 1, 3, 4, and 6). Similarly, in the no restraint group, trajectories to T1 were smoother at the postintervention or follow-up assessment in three children (8, 11, and 12) and to T2 in four children (7, 8, 9, and 12). Move-

Table I: Demographic and clinical characteristics of children with cerebral palsy grouped by type of practice

Child no.	Sex	Age (y)	Type/ side[a]	Melbourne[b]			Semmes–Weinstein		Two-point discrimination (mm)[c]		Stereognosis (max=5 objects)		Light touch (max=20)[d]	Proprioception (max=8)	CSI (max=16)	PROM (max=24)
				Pre	Post	Follow-up	R	L	R	L	R	L				
With trunk restraint																
1	M	11	H/R	58	60	62	4.74	2.44	>9	4	1	5	20	6	9	24
2	M	10	H/L	96	97	97	2.83	2.44	3	3	5	4	19	4	7	24
3	F	9	H/R	89	93	87	2.83	2.83	2	2	4	5	18	8	6	23
4	F	9	H/R	86	78	83	3.22	3.22	2	2	5	5	20	8	6	24
5	F	8	H/R	84	92	90	3.22	2.83	9	2	3	5	14	6	10	20
6	F	7	Q/L	75	79	75	2.83	2.83	3	4	5	4	15	4	7	22
No trunk restraint																
7	M	11	H/L	91	97	93	2.83	2.36	3	3	5	4	14	8	7	24
8	F	10	H/L	97	92	95	2.83	2.44	2	2	5	5	20	8	4	23
9	F	9	H/L	69	64	72	2.83	3.61	3	3	5	5	17	8	9	22
10	F	9	H/R	77	64	83	1.65	2.83	2	2	5	5	20	5	6	22
11	F	8	Q/L	57	62	67	2.83	4.08	NA	NA	4	0	19	0	9	17
12	F	7	D/L	95	98	89	3.22	3.22	2	4	5	4	20	6	9	24

[a]Type of hemiparesis/most affected side. [b]Melbourne Assessment of Unilateral Upper Limb Function. [c]One child refused to be tested. [d]Score out of 20 locations tested. NA, not available; CSI, Composite Spasticity Index; PROM, passive range of motion; R, right; L, left; M, male; F, female; H, hemiplegia; Q, quadriplegia; D, diplegia.

ments to T1 were less smooth at the postintervention or follow-up assessment for two children in each group.

Elbow angle

Improvement in elbow extension (points above baseline; Fig. 2, middle) occurred in most children but was more marked and longer lasting in the restraint group. All children in this group increased elbow extension for T1 at the postintervention assessment, with moderate to large effect sizes (0.60–3.34; Table III), and this improvement was maintained at follow-up in four children (1, 3, 5, and 6). Extension returned to baseline in child 2 and worsened in child 4. Among the no restraint group, four children (7, 8, 10, and 11) used elbow extension for both targets at the postintervention assessment, with large effect sizes (1.06–3.54). However, at follow-up, improvements were maintained in child 7 for reaches to T1 and in child 11 for reaches to T2, whereas elbow extension for T2 decreased in three children (children 8, 9, and 10) at follow-up. Another child (child 12) showed improved scores only at the follow-up assessment. Extension decreased in one child (child 9) for both targets at both assessments (Table III). Thus, postintervention improvements were observed in more children in the trunk restraint group than in the no restraint group and were more likely to be maintained at follow-up in the trunk restraint group.

Trunk displacement

Five of six children in the trunk restraint group had reduced trunk displacement (data points below baseline; Fig. 2, right) for T1, and all but one child (child 3) continued to use reduced trunk displacement at follow-up (Table IV). In the case of T2, one child (child 1) improved at the postintervention assessment and four (children 1, 2, 4, and 5) improved at follow-up.

In contrast, only one child (child 12) in the no restraint group had reduced trunk displacement for both targets at the postintervention assessment, and this child continued to improve at follow-up for T1 (Table IV). In the other children, trunk displacement did not change or increase at postintervention (T1, in child 7; T2, children 7, 10, and 11) and follow-up (increased: T1, children 7 and 11; T2, children 7, 10, and 11). Thus, in the case of T1, more children in the restraint group improved trunk displacement than in the no restraint group. In the case of T2, children in the trunk restraint group showed delayed improvement at follow-up whereas those in the no restraint group deteriorated after intervention. Overall, more children in the restraint group than in the no restraint group showed improvement (Table V).

DISCUSSION

This study provides evidence to support the effectiveness of using trunk restraint combined with task-oriented training to improve upper limb movement patterns in children with CP.

Effect of intervention on movement quality

Improvements in movement quality depended on reaching distance and intervention type. Hand trajectory smoothness

Table II: Number of points below the baseline trend line, indicating improvement, mean differences, and effect sizes for smoothness of hand trajectories

	T1						T2					
	Postintervention			Follow-up			Postintervention			Follow-up		
Child no.	Points below baseline trend line	Postintervention–baseline difference	Effect size	Points below baseline trend line	Follow-up–baseline difference	Effect size	Points below baseline trend line	Postintervention–baseline difference	Effect size	Points below baseline trend line	Follow-up – baseline difference	Effect size
With trunk restraint												
1	4/10	0.29	0.15	9/10	−1.70	**−0.88**	0/9	−0.25	−0.15	5/11	−1.14	**−0.68**
2	3/10	0.47	0.78	1/11	1.66	2.75	5/11	−0.45	−0.45	4/10	−0.20	−0.20
3	9/10	−0.90	**−1.13**	8/11	−0.52	**−0.65**	10/11	−0.65	**−0.59**	9/12	−0.73	**−0.67**
4	5/9	−0.98	**−0.55**	6/12	0.38	0.21	7/9	−1.68	**−0.98**	5/9	0.65	0.38
5	8/12	−0.23	−0.23	7/12	−0.06	−0.06	10/11	−0.28	−0.34	8/10	−0.09	−0.11
6	0/5	0.96	0.83	5/6	−1.64	**−1.43**	5/5	−1.44	**−0.82**	6/6	−1.80	**−1.03**
No trunk restraint												
7	7/10	−0.23	−0.19	7/11	−0.59	−0.48	8/11	−0.83	**−0.67**	7/11	0.76	0.47
8	9/9	−1.75	**−1.50**	11/11	−1.10	**−0.95**	9/9	−1.14	**−1.06**	8/11	−0.79	**−0.73**
9	0/8	1.88	1.23	0/9	0.38	0.25	5/9	−0.14	−0.06	8/8	−2.38	**−0.98**
10	7/13	0.12	0.09	8/10	1.36	1.04	0/10	0.76	0.47	0/9	0.60	0.37
11	7/10	−0.77	**−0.81**	6/11	−0.59	**−0.62**	2/11	−0.48	−0.34	3/10	−0.57	−0.40
12	3/11	0.11	0.13	9/10	−1.01	**−1.87**	7/10	−0.20	−0.17	9/10	−0.63	**−0.71**

Children are grouped by the type of practice and data are indicated for reaches to close (T1) and far (T2) targets. The values indicated are mean differences between postintervention assessment and baseline, and between follow-up and baseline assessments. Effect sizes are shown for each child by target and intervention phase. Moderate to large effect sizes indicating improvement are in bold and those indicating deterioration are shaded in grey.

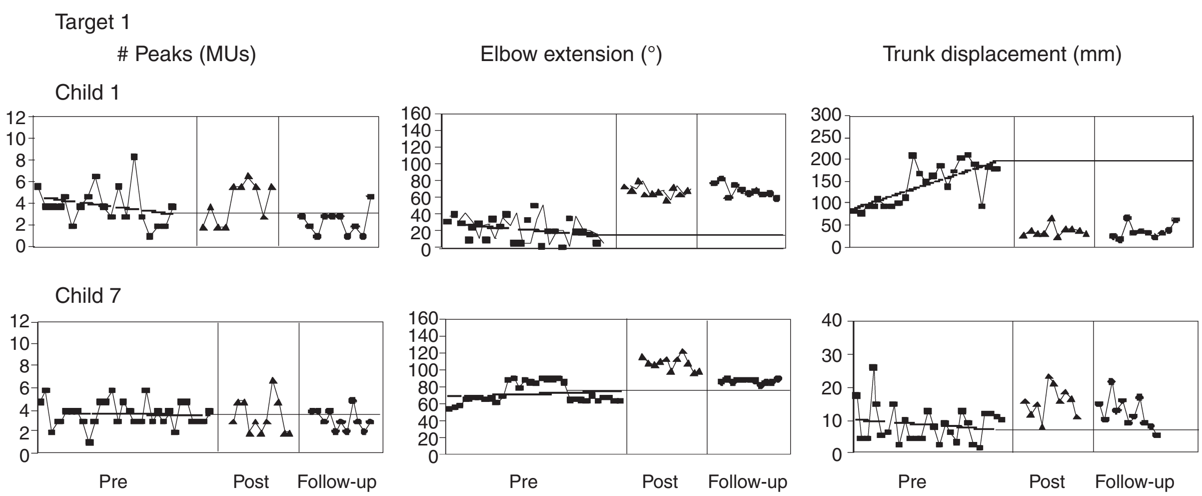

Figure 2: Example of trend line analysis. All data points observed in two children (child 1, trunk restraint group; child 7, no trunk restraint group) for reaches to target 1 in each phase: baseline (Pre), postintervention (Post), and follow-up. A regression line was drawn through all baseline points and a straight line was extended through postintervention and follow-up phases. Data are shown for trajectory smoothness (left), elbow extension (middle), and trunk displacement (right).

improved in half the children in each group. However, only children in the trunk restraint group increased movement smoothness to both targets; children in the no restraint group improved smoothness for only one of the two targets. Smoother reaches could result from a better ability to generate hand trajectories in a feed-forward manner[27] and may reflect the ability to solve dynamical and biomechanical problems resulting from redundancy by finding more efficient ways to coordinate multijoint movement.[28] This ability may have been enhanced by training with restraint, which ‘forced’ the system to find motor solutions using only upper limb joint rotations.

Elbow extension range to both targets improved following intervention in both groups (except child 9, in the no restraint group). The large postintervention effect sizes, corresponding to increases of 10 to 47°, were the result of low baseline variability combined with large postintervention changes. The question arises as to why the two groups of children benefited equally from the reaching training whereas previously it was

Table III: Number of points above the baseline trend line, indicating improvement (increase), mean differences, and effect sizes for elbow extension angle

Child no.	T1 Postintervention: Points above baseline trend line	T1 Postintervention: Postintervention–baseline difference	T1 Postintervention: Effect size	T1 Follow-up: Points above baseline trend line	T1 Follow-up: Follow-up–baseline difference	T1 Follow-up: Effect size	T2 Postintervention: Points above baseline trend line	T2 Postintervention: Postintervention–baseline difference	T2 Postintervention: Effect size	T2 Follow-up: Points above baseline trend line	T2 Follow-up: Follow-up–baseline difference	T2 Follow-up: Effect size
With trunk restraint												
1	10/10	47	**3.34**	10/10	47	**3.34**	11/11	43	**2.74**	12/12	56	**3.51**
2	9/10	26	**1.91**	0/9	−1	0.00	11/11	26	**2.11**	0/10	3	0.25
3	9/10	10	**0.60**	11/11	9	**0.55**	11/11	11	**0.73**	13/13	14	**0.94**
4	7/9	17	**1.89**	0/11	−33	−3.57	5/9	1	0.07	0/9	−21	−1.77
5	1/5	12	**0.80**	1/8	13	**0.88**	10/11	20	**3.75**	10/10	25	**4.79**
6	3/3	28	**2.31**	6/6	33	**2.71**	3/3	25	**2.09**	6/6	26	**2.20**
No trunk restraint												
7	11/11	38	**3.17**	11/11	15	**1.21**	11/11	10	**0.97**	11/11	1	0.13
8	7/9	7	**1.06**	4/11	2	0.33	4/9	6	**0.96**	0/11	−12	−1.95
9	0/7	−47	−3.11	0/11	−35	−2.32	0/8	−55	−6.95	0/8	−43	−5.40
10	13/13	21	**2.50**	4/10	−0.2	−0.03	10/10	13	**1.47**	0/9	−17	−1.92
11	10/10	15	**3.54**	0/11	0	0.01	11/11	5	**0.81**	10/10	10	**1.62**
12	9/11	−6	−0.48	10/10	13	**1.12**	10/10	2	0.11	10/10	10	**0.68**

Children are grouped by the type of practice and data are indicated for reaches to close (T1) and far (T2) targets. The values indicated are mean differences between postintervention and baseline assessments, and between follow-up and baseline assessments. Effect sizes are shown for each child by target and intervention phase. Moderate to large effect sizes indicating improvement are in bold, and those indicating deterioration are shaded in grey.

found that only a trunk-restraint paradigm led to better elbow extension and reduced trunk displacement in adults with post-stroke hemiparesis.[11] The difference may be due to different underlying mechanisms of upper limb impairments in children and adults.[29] In adult-onset stroke, neuronal damage results in the loss of previously acquired coordinated movement.[30] Thus, use of trunk restraint may have permitted the system to re-experience previously learned movement. However, considering the early brain lesion and concomitant neuroplasticity in CP, it is likely that children may never have experienced optimal movement patterns. The training effect on elbow extension may have been similar in all children as they were still learning optimal upper limb coordination patterns for reaching tasks. Thus, directed practice in reaching with or without trunk restraint may have led to the more effective use of elbow extension.

Table IV: Number of points below the baseline trend line, indicating improvement (decrease), mean differences, and effect sizes for trunk displacement

Child no.	T1 Postintervention: Points below baseline trend line	T1 Postintervention: Postintervention–baseline difference	T1 Postintervention: Effect size	T1 Follow-up: Points below baseline trend line	T1 Follow-up: Follow-up–baseline difference	T1 Follow-up: Effect size	T2 Postintervention: Points below baseline trend line	T2 Postintervention: Postintervention–baseline difference	T2 Postintervention: Effect size	T2 Follow-up: Points below baseline trend line	T2 Follow-up: Follow-up–baseline difference	T2 Follow-up: Effect size
With trunk restraint												
1	10/10	−107	**−2.25**	10/10	−108	**−2.28**	11/11	−56	**−2.00**	12/12	−117	**−4.20**
2	8/8	−6	**−0.94**	9/9	−7	**−1.13**	4/11	4	0.24	9/9	−27	**−1.54**
3	8/8	−23	**−1.63**	7/9	1	0.04	1/5	−16	−0.47	0/7	65	1.95
4	5/5	−50	**−1.63**	7/7	−54	**−1.73**	3/7	−3	−0.06	4/4	−83	**−1.77**
5	11/11	−19	**−1.22**	10/10	−20	**−1.33**	5/10	20	0.70	10/10	−32	**−1.13**
6	2/3	−5	−0.29	4/4	−15	**−0.93**	0/3	30	1.51	0/5	8	0.42
No trunk restraint												
7	0/10	8	1.26	1/11	4	0.63	0/9	27	3.75	11/11	50	6.89
8	6/9	3	0.47	11/11	−2	−0.31	6/9	1	0.04	8/11	−5	−0.36
9	8/8	−6	−0.19	10/10	−13	−0.40	10/10	−9	−0.29	6/9	6	0.19
10	9/12	2	0.12	3/10	6	0.42	1/10	50	2.58	0/8	97	5.05
11	8/10	2.5	0.33	10/11	5	0.60	0/11	45	3.02	0/10	13	0.73
12	11/11	−5	**−0.94**	8/10	−34	**−1.34**	10/10	−34	**−1.34**	5/9	9	0.34

Children are grouped by the type of practice and data are indicated for reaches to close (T1) and far (T2) targets. The values indicated are mean differences between postintervention and baseline assessments, and between follow-up and baseline assessments. Effect sizes are shown for each child by target and intervention phase. Moderate to large effect sizes indicating improvements are in bold, and those indicating deterioration are shaded in grey.

Table V: Numbers of children who improved kinematic variables and clinical scores following task-oriented training in the group with trunk restraint and in the no trunk restraint group and totals of both groups

	Trajectory smoothness				Elbow angle				Trunk displacement				Melbourne	
	Post-intervention		Follow-up		Post-intervention		Follow-up		Post-intervention		Follow-up		Post-intervention	Follow-up
Type of task-oriented training	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2		
With trunk restraint (*n*=6)	2	3	3	3	6	5	4	4	5	1	5	4	1	1
No trunk restraint (*n*=6)	2	2	3	3	4	4	2	2	1	1	1	0	0	1
Total (*n*=12)	4	5	6	6	10	9	6	6	6	2	6	4		

T1, close target; T2, far target.

Effect of intervention on compensatory trunk movement

The largest intervention effect occurred for trunk displacement in the restraint group, with only the children in this group decreasing trunk movement for reaches to both targets. In previous studies in children and adults,[11,12] task-oriented training without trunk restraint resulted in trunk movement increases ranging from 5 to 97mm (effect size=1.26–6.89). This suggests that interventions that do not restrict motor compensations should be carefully monitored if the goal is to improve movement quality.

Longer-term effect

Changes in elbow extension and trunk displacement were maintained or increased at 3 months' follow-up only in the trunk restraint group: improvement in elbow extension was maintained at follow-up in four out of six children, and excessive compensatory trunk movement continued to be effectively reduced in five (T1) and four out of six (T2) children. Thus, the effect of task-oriented training with trunk restraint resulted not only in better trunk use, but also in better longer-term elbow use. In some children, active elbow extension increased in the absence of decreasing trunk displacement. These children may have used compensatory movements other than forward trunk displacement for reaching, such as changes in hand or wrist orientation, trunk lateral inclination or rotation, and/or scapular movement.

Clinical outcome measure

Changes in kinematics were not reflected in the clinical measure. Melbourne scores were stable in all children except one (child 5). Indeed, Van der Heide et al.[8] also noted that head, trunk, and pelvis positioning had little effect on functional performance in this population, as assessed by the Pediatric Evaluation of Disability Inventory. We used the Melbourne test because it is reliable and valid, quantifies upper limb movements at both impairment and functional levels, and identifies compensations. Our finding suggests that functional scales such as the Melbourne may not be as sensitive as kinematic analysis in capturing movement quality changes, as suggested by previous studies of scale responsiveness to change after botulinum toxin treatment in CP.[31]

CONCLUSION

In this preliminary study, the hypothesis that the effect of task-oriented training on upper limb movement quality is increased by combining it with limitation of trunk movement was supported. However, our study design allows us to conclude only that trunk displacement during reaching was effectively reduced in the trunk restraint group. It is also important to note, that when task-oriented training was used alone (without trunk restraint), the apparent improvements in movement quality could be accompanied by an increase in compensatory trunk displacement.

Some children who decreased trunk displacement did not improve hand trajectory smoothness. This is consistent with findings that trajectory formation may be the most difficult, or latest, aspect of movement quality to mature.[19] It is likely that more intensive or prolonged training may result in smoother hand trajectories once patterns of trunk use and arm interjoint coordination are improved.

This study provides preliminary evidence of the effectiveness of an upper limb intervention that includes restriction of excessive trunk movement for improving movement quality. The feasibility of this approach can be tested in future trials. In addition, more research is needed to determine whether improvements in movement quality lead to better upper limb function and activity levels.

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