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Effectiveness of motor learning coaching in children with cerebral palsy: a randomized controlled trial

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Objective: To evaluate effectiveness of motor learning coaching on retention and transfer of gross motor function in children with cerebral palsy.
Design: Block randomized trial, matched for age and gross motor function.
Setting: Coordinated, multinational study (Israel, Jordan and Palestinian Authority) in schools and rehabilitation centers.
Subjects: 78 children with spastic cerebral palsy, gross motor functional levels II and III, aged 66 to 146 months.
Interventions: 1 hr/day, 3 days/week for 3 months treatment with motor learning coaching or neurodevelopmental treatment: two groups.
Main measures: Gross motor function Measure (GMFM-66), stair-climbing mechanical efficiency (ME) and parent questionnaire rating their child's mobility. Immediate treatment effects were assessed after 3 months and retention determined from follow-up measurements 6 months after treatment.
Results: GMFM-66, ME and parent questionnaires were obtained from 65, 31 and 64 subjects, respectively. Although both groups increased GMFM-66 score over 3 months, measurements 6 months later indicated retention was significantly superior by 2.7 in the motor learning coaching children of level-II. Similar retention trend was evident for ME, increasing 6 months after motor learning coaching by 1.1% and declining 0.3% after neurodevelopmental treatment. Mobility performance in the outdoors and community environment increased 13% from 3 to 9 months after motor learning coaching and decreased 12% after neurodevelopmental treatment. Minor group differences occurred in children of level-III.
Conclusions: In higher functioning children with cerebral palsy, the motor learning coaching treatment resulted in significantly greater retention of gross motor function and transfer of mobility performance to unstructured environments than neurodevelopmental treatment.

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Introduction

The definition of cerebral palsy (CP) includes activity limitations.[1] Current treatment interventions and rehabilitation for children with CP emphasize the ultimate goal of improving motor functions and learning new motor tasks to improve function and interaction with the everyday environment.[2] Rehabilitation is predicated on the assumption that practice or training leads to improved motor function. Although many variables influence motor function improvement, it has been demonstrated that intensive physiotherapy has a positive effect when incorporated into a variety of training approaches. However, the retention of this improvement upon follow-up is variable and often poor.[3–7] Other factors may also be effective in improving retention and transfer of newly learned motor functions, such as walking, but the benefits of their inclusion in structured training programs have not been investigated.

Few high quality randomized control trials have been undertaken to study the effectiveness of physical therapy interventions on motor function in children with CP. A recent review of these concluded that limited evidence of effectiveness of interventions was available because of shortcomings in methodological quality and variations in populations, interventions and outcomes.[8] Moderate evidence was found for some effectiveness of upper extremity training and it was suggested that more well-designed studies were needed.

The term *motor learning* can be described as 'the acquisition of new skills with practice'.[9] The process involves acquisition, assisted by the therapist, and subsequent retention and transfer. The concept of a motor learning 'coaching' approach is based on structured practice of goal-oriented motor function tasks, with specific feedback matched to the learner's abilities, for successful retention and transfer to other motor activities or environments.[10]

The purpose of this randomized controlled study was to evaluate the effectiveness of an intensive 3-month motor learning coaching treatment course on immediate change and 6-month retention of gross motor function in 6–12 year old children with CP. Secondly, we wished to determine whether motor learning coaching would advance performance up to capabilities in the outdoor and community environments. We hypothesized that practicing motor functions in a clinical setting according to conventional neurodevelopment treatment would result in improved performance in the clinic, but that the retention and transfer would be greater with motor learning coaching in diverse environments because it includes 'strategies' of optimal motor learning.

Methods

Design

This study was conducted between March 2006 and October 2007. Participants were matched by age and gross motor function classification system (GMFCS), levels II and III[11] within each of the three test sites. The matching ensured that an equivalent sample from each site was included in the final total for each group.

The subjects of each pair were randomly assigned to neurodevelopment treatment or motor learning coaching experimental groups, as follows: Each pair (pre-assigned as ***a*** and ***b*** subjects) was given a random three-digit number by a Microsoft-Excel software random numbers generator. The digits were summed. In pairs with odd sums the ***a*** subject was assigned to the neurodevelopment treatment group and the ***b*** subject was assigned to the motor learning coaching group. The pairs with even sums were assigned oppositely, i.e., the ***b*** subject was assigned to neurodevelopment treatment and the ***a*** subject was assigned to motor learning coaching.

Clinicians that conducted the tests and collected test data were blinded to the children's allocation to the two interventions.

Participants

A total of 78 children participated in the study: 24 in Israel, 26 in Jordan and 28 in the Palestinian Authority. The desired sample size was calculated, with some assumptions, based on the gross motor function measure (GMFM-66) values[12] from a previous study, measured in two groups of 10 children each, comparing neurodevelopment treatment therapy vs. pseudo- motor learning coaching therapy.[13] Subjects were identified and recruited by pediatric physiotherapists, based on clinical examinations at the participating centers: (a) Amman and Zarka in Jordan, (b) East Jerusalem, Hebron, Nablus, Bethlehem and the surrounding villages in the Palestinian Authority and (c) five special education schools in Tel-Aviv and Jerusalem, Israel.

The study was approved by national and local Research Ethics Committees for each of the three participating centers and by the Israeli Ministry of Education. The study was explained to the parent(s) or guardian(s) and all provided signed informed consent.

Participants were diagnosed as spastic or mixed type CP with distribution of diplegia or quadriplegia and aged 6 to 12 years, because at this age they were expected to have attained at least 90% of their motor function.[14] They were at GMFCS levels II and III.[11,14] During preliminary screening the children were asked to carry out related motor and cognitive tasks (e.g., arranging a puzzle) in response to instructions. All were students in schools at the normal cognitive level; there was no apparent difference in cognitive level between the two groups.

The raters were experienced pediatric physiotherapists who had attended a joint 3-day course on gross motor function practice, theory and testing. Videotaping all gross motor function tests optimized scoring standardization. Four tests were selected randomly for each rater and scored by the instructor and found to be consistent with those of the rater.

Participants were excluded if they had received tone reduction treatment (e.g., botulin toxin, baclofen pump therapy) or orthopedic surgery 6 months before study onset.

Interventions

In the neurodevelopment treatment approach the focus of intervention is on remediation of the child's abilities through changing the components of body function and structure. The treatment protocol is not strict, but oriented towards improving muscular tone and movement patterns. It is assumed that 'typical' patterns of movement lead to functional improvements and reduced activity restrictions.

After a precise determination of the individual's motor tasks (e.g., improved sitting stability) and goals (e.g., walking or riding tricycles) by the therapist, a structured program was set for each child. This program included passive stretching of the legs at the beginning of each session, followed by techniques to reduce spasticity and facilitate more normal movement patterns. Functional motor activities included walking, standing up from sitting and sitting. These were practiced at the end of each session.

The motor learning coaching approach followed the principles of motor learning and their application within activity-focused sessions. The approach emphasizes practicing motor functions in a random order in several environments, using augmented feedback that matches the stages of the learner.[15,16] An outline of these therapy/treatment sessions follows: 1) Ask learner to set the gross motor goal, e.g., sit-to-stand, stair climbing, cycling, etc. 2) 15 min of muscle stretching, applied randomly either before or after the session. 3) Identify the learner's stage of ability to learn. 4) Provide verbal or non-verbal instructions for guidance of task performance, e.g., 'walk to door and open it.' 5) Change environment of task at least once/week, e.g., for stair climbing: 1st week, climb stairs in laboratory; 2nd week, in schoolyard; 3rd week, in a mall. 6) Follow Gentile's taxonomy[15] by manipulating biomechanical task features and environment. 7) Practice chosen motor task (goal) for 30 min, e.g., climbing stairs. 8) Perform and practice two cognitive tasks between the motor task practices at random times, e.g. arithmetic problem or jigsaw puzzle. 9) Provide realistic distractions while performing motor tasks, e.g., noise and people nearby. 10) Provide feedback at end of task practice to provide knowledge of results, e.g., 'you walked to the class in 10 min, one min faster than last time' or knowledge of performance feedback regarding kinematics during the performance, e.g., 'your right foot was too low.' 11) Use tests to evaluate task performance at end of each session, e.g., by having child perform main task at end of each session and recording change in time, coordination, number of steps and symmetry.

Children in the neurodevelopment treatment group were treated by pediatric physical therapists that had taken the neurodevelopment treatment basic course, with at least two years of experience of treating children with cerebral palsy. Pediatric physiotherapists from all sites treating the motor learning coaching group were instructed jointly during a 4-day instructional course. The motor learning coaching course took place after the neurodevelopment treatment group finished the 3-month treatment. This course accentuated the stages of task learning, including variability of practice and type of augmented feedback, according to Fitts and Posner.[16] Children in both groups were treated for one hour, three times per week over three months (36 treatment sessions). Physiotherapists recorded activities in each session for continuity. Sessions missed were rescheduled on the earliest possible date. During the 6-month interval before follow-up testing (between 3 and 9 months) the children returned to their usual treatment schedule.

Outcome measures

Learning and retention were measured by: (a) the gross motor function measure, GMFM-66,[12] (b) mechanical efficiency (ME) during stair-climbing as a quantitative physiological measure of coordination,[17] and (c) a parent questionnaire on mobility methods to measure mobility performance in different environments.[18] The latter measured 'performance' in relation to 'capability,' to estimate mobility performance. The performance of usual mobility methods in natural environments was obtained from the questionnaire originally designed for children with cerebral palsy.[18] The four environmental categories were home and school (structured environment) and community buildings and outdoors (unstructured environment). The questionnaire asked parents to state the one mobility method that best described the child in the four environments. The mobility methods are: (a) carried by adult, (b) pushed in wheelchair (c) moves on floor (d) walks with support, (e) walks alone without assistance, (f) propels self in regular wheelchair and (g) operates battery-powered motorized wheelchair. Capability was based on the score on three items (no. 44, 68 and 70) of the GMFM-88 that corresponded best to the mobility methods listed in the parent questionnaire. These items also represent self-initiated movements used in everyday settings.[18–21] Those who performed on par with capability received a score of 1 and those who did not were given a zero. The performance/capability for each group and time was calculated as 100× the number of subjects scoring 1, divided by the total number in the group. Performance was compared to capability as an average of the two combined pairs of environmental settings (Home + School and Outdoors + Community) for each child.

To evaluate and compare the efficacy, retention and transfer of the two interventions, the three measures were taken in the week before the treatments started (baseline – T1), three months later within the first week after treatment ended (T2) and within the seventh month after treatment stopped (9 months after baseline – T3). All tests were performed in the same room by certified and experienced physiotherapists at each site.

Statistical analyses

The effectiveness of motor learning coaching compared with the neurodevelopment treatment was assessed by two primary outcomes, GMFM-66 and ME, both continuous measurements. Changes from baseline to 3 months in GMFM-66 and ME within each group were considered as the immediate treatment effect and the changes from 3 to 9 months quantified retention. Changes within each group, from baseline (T1) to T2 and T2 to T3, were evaluated by two-tailed t-tests, where t = mean change/SE of mean change. Significance was set at $P < 0.05$, with trends suggested by P-values between 0.05 and 0.10. Analysis of covariance was used to compare the changes between neurodevelopment treatment and motor learning coaching treatment groups for each trial. The control variables for the immediate effect and retention were T1 and T2, respectively, because the pre- and post-test measures for each trial were highly correlated (mean r-values $= 0.92$). Retrospectively, similar analyses evaluated subjects at GMFCS-II and III. Least-squares linear regressions served to correlate GMFM-66 and ME values. Significance of performance/capability changes within groups and differences of changes between groups was obtained by proportion comparisons according to Altman.[22] Changes in performance/capability from baseline to 9 months were similarly tested to evaluate changes in mobility transfer over the total time of the study.

Due to the longitudinal nature of this data, repeated measures ANOVA and fitted linear mixed models were also used to assess time and motor learning coaching and neurodevelopment treatment effects on GMFM-66 and ME.

Results

As shown in the flow diagram (Figure 1), 65 of the 78 children enrolled completed treatments and follow-up GMFM-66 measures and 64 parent questionnaires were obtained to evaluate mobility performance/capability and its transfer. While the patients in each treatment arm were matched on age and functional level, other baseline characteristics were assessed to assure proper randomization. Table 1 shows these comparisons and displays no significant differences between treatment arms across all three sites. The average age was 106 months, ranging from 66 to 146 months. There were no baseline differences between groups in the three outcome measures, although the mobility performance/capability was higher in Home + School than in Outdoors + Community ($P = 0.02$).

GMFM-66

These mean values increased similarly and significantly by ~2.4 in both groups (Table 2) over the period of treatment, with the adjusted 3-month values being similar. This was true for subjects at levels II and III of GMFCS, as shown. Retention, measured 6 months after treatment stopped, differed between groups; the subjects treated by neurodevelopment treatment showed a significant decline of 1.2 in GMFM-66, this change differing significantly from the unchanged score at 9 months for subjects treated by motor learning coaching. The decreased GMFM-66 after neurodevelopment treatment for all subjects occurred primarily in subjects at level II of GMFCS.

Mechanical Efficiency (ME)

This was measured in fewer subjects due to dropouts and technical difficulties. The immediate effects of neurodevelopment treatment or motor learning coaching treatment on ME after 3 months of treatment were negligible (Table 2). In GMFCS-II subjects there was a small decline in ME for motor learning coaching compared to a small rise for neurodevelopment treatment, but not in level III subjects. ME showed retention trends similar to GMFM-66, where ME increased in the motor learning coaching group ($P = 0.06$) and declined in the neurodevelopment treatment group, resulting in a significant difference in the adjusted mean value at 9 months. The 0.6% increase in ME in the motor learning coaching group resulted primarily from a 23% increase in external work, compared with a 7% increase in the neurodevelopment group. This increase in ME from 3 to 9 months predominated in children at level GMFCS-II; the 1.1% increase in ME by the 8 motor learning coaching subjects resulted from a 24% increase in external work, compared with 5% for neurodevelopment treatment.

During baseline testing the GMFM-66 scores and ME were different by 16.0 and 5.0%, respectively ($P < 0.001$) between subjects at GMFCS levels II and III, with a direct relationship between GMFM-66 scores and ME during baseline, 3-months and 9-months test sessions as indicated by r-values of 0.82, 0.84 and 0.80, respectively.

Mobility performance measured by parent questionnaire as performance/capability

Mobility performance/capability increased over treatment time for all the neurodevelopment subjects in Home + School (Figure 2A) and in the Outdoors + Community in both groups (Figure 2B), but the differences between groups were not significant. These changes predominated in subjects at the GMFCS-II level (Figure 2C and Figure 2D), but changes at level III were minor

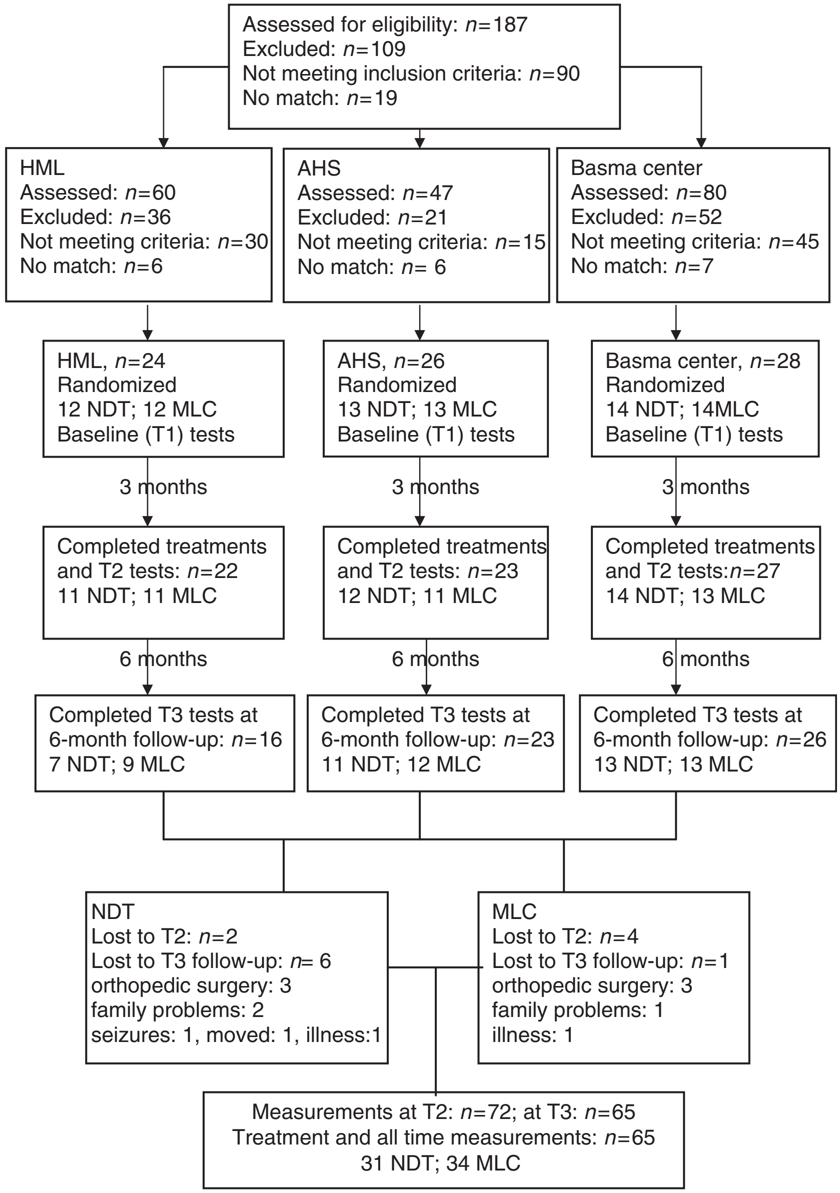

Figure 1 Flow diagram of subjects during study at the 3 sites. HML, Human Motion Laboratory – Israel; AHS, Al Hussein Society – Jordan, Basma Center: East Jerusalem; NDT, neurodevelopmental treatment; MLC, motor learning coaching; T1, baseline tests; T2, tests immediately after treatment; T3, tests 6 months after T2.

(Figure 2E and Figure 2F). The retention of mobility performance, measured 6 months after treatment stopped, showed minor changes or differences between groups in Home + School (Figure 2A). However, for level-II subjects after neurodevelopment treatment the mobility performance in the Outdoors + Community declined non-significantly by 11.5%, compared to a

Table 1 Characteristics and baseline values of children in two treatment groups

Variable		*n*	NDT % of total	*n*	MLC % of total	*P*
		39	50	39	50	
Gender	Male	19	24	25	32	0.18
	Female	20	26	14	18	
Type	Spastic	34	44	31	40	0.55
	Mixed	5	6	8	10	
Distribution	Diplegia	29	37	31	40	0.45
	Quadriplegia	10	13	7	9	
GMFCS	II	17	22	14	18	0.55
	III	22	28	25	32	
Baseline Measurements			value (SD)		value (SD)	
Age (months)	–	39	105.5 (20.6)	39	107.2 (20.6)	0.72
Height (cm)	–	39	121.0 (9.4)	39	122.7 (10.6)	0.45
Weight (kg)	–	39	23.7 (6.9)	39	25.5 (6.9)	0.27
GMFM-66	–	39	59.7 (9.4)	39	59.9 (10.0)	0.92
ME (%)	–	31	4.03 (2.95)	34	3.91 (2.80)	0.86
P/C-Home + School (%)	–	39	75.7	38	75.0	0.97
P/C-Outdoor + Community (%)	–	39	65.4	38	59.2	0.75

P, probability of significant difference between groups; GMFM-66, gross motor function measure; ME, mechanical efficiency of stair-climbing; P/C, mobility performance/capability; NDT, neurodevelopmental treatment; MLC, motor learning coaching.

Table 2 Mean (SD) values for GMFM-66 and mechanical efficiency (ME) for subjects in 2 treatment groups

			Immediate Treatment Effect						Retention				
GMFM-66		*n*	base	3 mon	adj. mean	*P*	change	*n*	3 mon	9 mon	adj. mean	*P*	change
All	NDT	38	59.5 (9.6)	62.0 (10.7)*	62.5	0.61	2.5 (2.8)	31	62.6 (10.8)	61.4 (9.8)*	61.5	0.042	−1.2 (3.4)
	MLC	38	60.4 (9.3)	62.7 (9.8)*	62.2		2.3 (2.0)	34	62.9 (9.5)	63.0 (9.9)	63.0		0.1 (1.9)
GMFCS-II	NDT	16	69.0 (4.7)	72.9 (4.8)*	73.5	0.22	3.9 (2.9)	13	73.3 (5.0)	70.7 (4.8)*	70.4	0.035	−2.6 (4.0)
	MLC	14	70.4 (5.5)	73.1 (5.6)*	72.5		2.7 (1.1)	13	72.7 (5.6)	72.8 (6.2)	73.1		0.1 (1.7)
GMFCS-III	NDT	22	52.6 (5.3)	54.2 (5.7)*	55.2	0.47	1.6 (2.4)	18	54.8 (6.1)	54.6 (6.0)	55.6	0.37	−0.2 (2.6)
	MLC	24	54.6 (5.1)	56.6 (5.6)*	55.7		2.0 (2.4)	21	56.8 (5.5)	56.9 (6.1)	56.0		0.1 (2.1)
ME (%)													
All	NDT	20	4.2 (3.5)	4.4 (3.3)	4.4	0.49	0.2 (2.0)	19	4.5 (3.3)	4.2 (3.3)	3.9	0.042	−0.3 (1.3)
	MLC	21	4.2 (2.7)	4.1 (2.6)	4.1		−0.1 (1.1)	19	4.0 (2.8)	4.6 (3.4)#	4.8		0.6 (1.2)
GMFCS-II	NDT	9	7.3 (2.7)	7.6 (1.8)	7.6	0.30	0.3 (3.1)	8	8.0 (1.6)	7.3 (2.7)	6.5	0.12	−0.7 (2.0)
	MLC	8	6.9 (1.8)	6.5 (2.2)	6.6		−0.4 (1.3)	8	6.2 (2.5)	7.3 (2.8)#	8.1		1.1 (1.5)
GMFCS-III	NDT	11	1.6 (0.9)	1.8 (0.9)	2.2	0.77	0.2 (0.3)	11	2.0 (1.4)	1.9 (1.0)	2.1	0.37	−0.1 (0.6)
	MLC	13	2.5 (1.5)	2.6 (1.5)	2.3		0.1 (1.1)	11	2.4 (1.6)	2.7 (2.3)	2.4		0.3 (0.9)

ME, mechanical efficiency of stair-climbing; NDT, neurodevelopmental treatment; MLC, motor learning coaching; GMFM-66, gross motor function measure; GMFCS, gross motor function classification system; adj. mean, post-test mean adjusted for pre-test differences by analysis of covariance; *P*, probability of group difference in adj. mean; change, mean post-test minus pre-test difference; *, significant change ($P<0.05$) within group from pre-test to post-test; #, change ($P<0.10$) within group from pre-test to post-test.

12.5% increase after motor learning coaching (Figure 2D), this difference being almost significant ($P=0.06$). There was a small decrease in mobility performance in the Outdoors + Community after motor learning coaching treatment in level III subjects.

Overall changes

The GMFM-66 based on these 65 patients was indicative of a time-treatment interaction, where both treatments showed immediate effectiveness but then differed in retention, with neurodevelopment treatment displaying some drop-off at 9

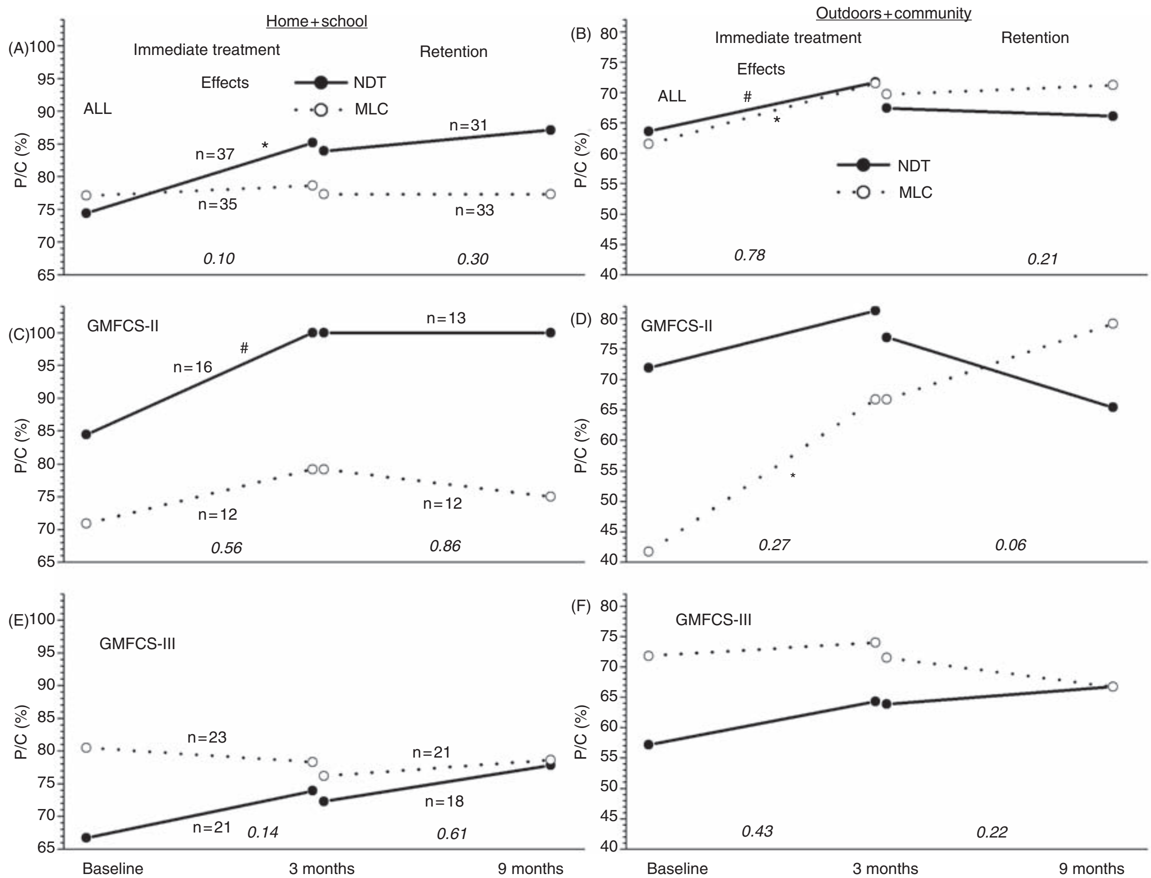

Figure 2 Average mobility performance (P) in relation to motor capability (C) as a percentage (P/C) averaged for Home + School and Outdoors + Community environments. Parent questionnaire was completed at baseline and after 3 months of NDT and MLC treatment and at 6-month follow-up (9 months) in two treatment groups for all subjects (A and B) and those at level II (C and D) and level III (E and F) of GMFCS. Number of subjects (*n*) for Outdoors + Community is the same as shown for Home + School. *P*-value for group change difference is in italics. *, within group change significant at $P<0.05$; #, at 0.10; *n*, number of subjects completing each pair of measurements. For MLC-level II the P/C for Outdoors + Community (D): *P*-value<0.03 for group difference for change from baseline to 9 months. NDT, neurodevelopmental treatment; MLC, motor learning coaching; GMFCS, gross motor function classification system.

months while the effects of motor learning coaching remained. An ANOVA test for this interaction indicated no overall treatment effect ($P=0.37$), but a highly significant time effect ($P<0.001$). The overall visit by treatment interaction was non-significant ($P=0.14$). A linear mixed effects model was used to ascertain whether a non-significant interaction from baseline to 3 months overshadowed a significant one during the retention phase of the trial from 3 to 9 months. This model resulted in significant coefficients for T2 and T3 with respect to baseline levels ($P<0.001$).

Because of missing data, only the linear mixed effects model was used for ME to assess treatment effectiveness. None of the main effects or the interactions were significant, however the directions of coefficients were similar to those of the GMFM-66 model with regard to effects over time and may indicate that motor learning coaching resulted in higher levels than neurodevelopment treatment after treatment at 9 months. Based on these analyses, motor learning coaching performed as well as neurodevelopment treatment, as measured by GMFM-66 and ME, with some evidence suggesting that motor learning coaching shows higher retention of GMFM-66.

Figure 2C and Figure 2D show that the motor learning coaching-treated subjects at level II had a lower mobility performance at baseline than the corresponding neurodevelopment treatment group in the two settings, but an opposite pattern was noted in the groups at level III (Figure 2E and Figure 2F). From baseline to 9 months for subjects at GMFCS-II, the 38% increase in mobility performance for motor learning coaching in the Outdoors + Community was significantly greater than the 7% decline for neurodevelopment treatment ($P < 0.03$).

Discussion

The main findings of our study are that retention of gross motor functions and mechanical efficiency are improved by motor learning coaching and that this corresponds to an increased transfer of mobility performance in outdoor environments by the motor learning coaching group. Our results also show significantly increased motor function measures following intensive therapy, in line with other studies. The significant increases in GMFM-66 over 3 months (Table 2) in both groups suggest that both treatments may have been beneficial, as changes >1.5 are considered clinically meaningful.[23]

We noted that 6-month retention of gross motor function improvements was maintained only following motor learning coaching treatment, as GMFM-66 declined following neurodevelopment treatment (Table 2). This suggests that true motor learning occurred with motor learning coaching; the 3-month treatment course may be where new motor functions were gained and practiced, but not incorporated or optimized, as shown by no immediate change in ME. Learning may be considered as a gradual refinement of movements toward the functional optimum, with optimum defined as movement patterns that maximize ME. According to Sparrow[24] and Gentile,[25] in early stages of learning, efficiency will be less than optimal but in later stages motor functions are developed and coordination refined to achieve efficient movement. Later, performance might plateau while efficiency improves.

We assumed that enhancing treatment by including motor learning principles would increase efficiency of ambulation and ME because the latter represents global mobility efficiency; it incorporates work output of a motor task and is implicit in definitions of skilled performance and sensitive to changes in coordination and motor control.[24] Stair-climbing ME was chosen as an ambulatory measurement to compare the effect of interventions on ME. For normally developed children it is approximately 20% and for children with CP typically <5%,[17,26] with changes >0.6% being significant.[27]

We noted reduced ME in the neurodevelopment treatment group from 3 to 9 months that correlated with the decline in gross motor performance. If new motor functions are not gained and practiced, as with earlier motor learning coaching, a lower ME is expected. The retention of gross motor functions (GMFM-66) in the motor learning coaching group following treatment may have allowed a process of practice, tuning and optimization of these functions to continue, indicated at 9 months by increased mechanical efficiency. Although fewer children were tested for ME than GMFM-66, we assume the ME measure is still valid because of its close relationship with GMFM-66 in all conditions; also, if the activities between 3 months and 9 months varied by site, the equal number of neurodevelopment treatment and motor learning coaching subjects came from each site would reduce the effect of this variation.

The GMFM-66 (computed from the GMFM-88)[12] is the gold standard measure designed to evaluate changes in gross motor function in children with CP.[28] This measurement is an indicator of capability, but does not measure day-to-day performance in different environments. Increases in mobility performance in both 'familiar and unfamiliar' environments at 3 months suggest that children became more adaptable in negotiating their environments following interventions. Specific mobility methods at baseline may be due to environmental, economic or personal factors and are demonstrated by the range of baseline values shown in Table 1 and agree with findings by Tieman *et al.*[18] The capability measurements were made at clinics under controlled conditions, whereas performance occurred in variable settings and locations. In more controlled home/school environments it is easier to motivate and coach performance to the upper limit of capability and baseline scores were higher ($P = 0.09$). The variable Outdoors + Community environments are more challenging for walking and may require additional mobility supports. The positive gain in mobility performance from 3 months to 9 months in Outdoor + Community environments in motor learning coaching-level II vs. neurodevelopment treatment-level II children suggests a transfer of learned motor functions to improve mobility performance.

Our results indicate that level II children treated with motor learning coaching benefited more than those treated with neurodevelopment treatment in terms of retention and transfer of learned motor functions in the outdoors/community, while the neurodevelopment treatment-level II group lost function during the retention trial. No improvement in retention or transfer of mobility was noted for children at level III, although they improved their motor function capabilities by 3 months (Table 2). These observations support our hypothesis that a 'motor learning' approach facilitates retention and transfer to everyday living. We speculate that the motor learning coaching intervention induces neuromotor flexibility that results in improved ability to adapt to non-structured and challenging environments.

Higher GMFCS levels indicate lower gross motor function,[11] increased energy cost of walking,[29] reduction in mobility and self-care,[30] reduced muscle strength and functional ambulation[31] and greater hip deformities.[32] However, the specific response to interventions of children with CP at different GMFCS levels is rarely reported. One report demonstrated that training with an 'Adeli suit' improved mechanical efficiency more in six participants who had higher motor function (mean GMFM-66 = 62) than in six with a lower mean score (44) at base line.[7]

One plausible reason for improved transfer and retention in the motor learning coaching at level II group is that they have less physical impairments than those at level III. Therefore, they were able to better practice and incorporate the learned motor tasks and generalize them to other tasks and environments. This view is supported by two studies showing that a principled motor learning technique increased retention and transfer of tasks in mild hemiparetic groups.[33,34] In one study, adult patients with hemiplegia exhibited impaired adaptation of the paretic arm to a laterally displacing force-field, indicating that these patients did not have a learning deficit *per se*, but rather a weakness-related time lag to develop required force to implement anticipatory control.[33] Another study of adult patients with mild hemiparesis, lacking upper extremity coordination, incorporated variability of repetitive practice by altering the task difficulty. The clinical trial demonstrated the benefits of this arm training compared with standard rehabilitation for increasing efficiency of arm function.[34]

The main limitation of the study was not being able to precisely control the treatment/therapy received during the 6-month retention trial. Another limitation is the generalizability of our results to children outside the 6–12 year age and/or GMFCS II–III range.

Although our numerical and statistical differences are of limited magnitude, our findings suggest benefits of motor function retention and improved mobility in non-structured environments in children with CP by the motor learning coaching approach and those children at higher functional levels will benefit more. Importantly, the present randomized controlled study is among the first to examine the impact of motor learning coaching on retaining gained functions, an aim that could not be attained by other approaches.

Clinical messages

- A 3-month motor learning coaching intervention and conventional neurodevelopmental therapy resulted in equivalent gains in gross motor function and mobility.
- Retention and transfer of these gains in gross motor function 6 months after treatment was higher following the motor learning coaching intervention.

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