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ORIGINAL RESEARCH

Effects of Modified Adeli Suit Therapy on Improvement of Gross Motor Function in Children With Cerebral Palsy

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Abstract
Objective: This study aimed to investigate the effects of the Modified Adeli suit therapy (MAST) on improvement of gross motor function in children with cerebral palsy (CP).
Methods: Thirty-six children with CP assigned by match pairs to three equal groups such as the MAST, the AST, and the Neurodevelopmental Treatment. They were treated for 4 weeks, 2 hr/d, 5 d/wk. All children were tested by the Gross Motor Function Measure (GMFM) at baseline, immediately before and 16 weeks after treatments.
Results: All groups had improvement in the GMFM after treatment ($p < .01$) and there were significant differences among groups ($p < .01$). In the follow-up study, no significant improvement in the GMFM was seen within groups ($p > .05$), but again there were significant differences among groups ($p < .01$).
Conclusion: The MAST was more effective than using either the AST or the Neurodevelopmental treatment on improvement of gross motor function in children with CP after treatment and at follow-up.

Introduction

Cerebral palsy (CP) is characterized by nonprogressive abnormalities in the developing brain, which creates a cascade of neurologic, motor, and postural deficits in the developing child. The incidence of CP is estimated to be 1.4—2.4 per 1,000 live births, and although this rate has

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remained constant during a 30-year period, the causes have changed (Roger, 2005). One of the main problems in children with CP is impairment in gross motor function (GMF), which limits movement; therefore they depend on others in self-care and mobility. Therapists working with these children primarily attempt to improve their GMF to help them be more independent.

There is a plethora of therapeutic approaches toward improvement of GMF in children with CP. Neurodevelopmental treatment (NDT) is the most common approach, which is being used by physiotherapists and occupational therapists all over the world (Bobath & Bobath, 1984). This approach is based on the experience of Bobath and his wife in 1940 on children with CP, which has undergone a lot of changes since then (Bobath & Bobath, 1972). There is controversial research on the effectiveness of NDT approach in treatment of children with CP. Some studies admit NDT as a popular and internationally known method of treatment for optimizing motor function in children with CP (Barry, 1996; Campbell, 1990; Carlsen, 1975; Ketelaar, Vermeer, Hart, Petegem-van Beek, & Helders, 2001). However, some studies have not shown any significant improvement in motor function relating to the use of NDT approach (Butler & Darrah, 2001; Herndon, Troop, Yngve, & Sullivan, 1987).

New approaches towards the treatment of children with CP have been developed during the past 2 decades. One of these new approaches is the Adeli suit therapy (AST) that was introduced in 1991 by Semenova (1997). The treatment incorporates a device developed in Russia in the late 1960s to maintain neuromuscular fitness during weightlessness experienced by cosmonauts. The Adeli loading suit is essentially a system of supporting elements named special vest, shorts, knee caps, and footwear. Each pair of the supporting units is linked together with a set of adjustable elastic ties named Bungee. A loading suit acts as an elastic shell to make it more difficult for the patient to move for treatment purposes without restricting the amplitudes of movements. This treatment is based on the following principles: (a) the effects of the suit such as working against resistance loads, increases the proprioception, and improves alignment; (b) intensive daily therapy for 1 month, at least 2 hr/d, 5 d/wk; and (c) active motor participation of the child. In this method, the suit will not restrict the range of motion and active movements of the child so that the child can move actively inside the suit without any limitation (Adeli Bibliography, 1994). Semenova argued that this method, called as "dynamic proprioceptive correction," would reduce pathological synergies, improve normal muscular synergies, and apply loads to antigravity musculatures, which leads to normalization of the afferent vestibulo-proprioceptive input. Abnormal afferent input to central nervous system leads to abnormal movement patterns as an output in children with CP. The key sense of Adeli method is in normalizing and enforcing the flow of afferent impulses by active correction of position and movements of a patient with the help of suit for the purpose of directed influence on brain kinetic centres to restore its failed functions.

Shvarkov, Davydov, Kuuz, Aipova, and Vein (1997) conducted a study on the efficacy of the AST in an adult population with movement disorders caused by brain lesions and found that clinical effects in all patients were transient in the hyperkinetic syndrome but prolonged in patients with spastic paralysis. The relative effectiveness of this new treatment and its long-term effects when compared with other conventional therapies is open to discussion (Liptak, 2005; Rosenbaum, 2003). In the AST, the child was not really actively participating in the programme because the nature of exercises was passive and tedious; hence we decided to modify this method in a way that the child could move more actively. In the MAST, we applied joyful and purposeful activities and plays instead of exercises to fortify the effects. The aim of this study was to test the efficacy of the MAST compared with the AST, with the NDT on improvement of GMF in children with CP during intensive course and at follow-up.

Methods

Participants

This was a clinical randomized trial (true experimental) study carried out in eight rehabilitation centres in the city of Tehran in 2009 (January–June). Sixty-two children with spastic and dystonic CP were recruited for the programme. Their parents were informed about the aim and requirements of the study. All children were on usual programmes of occupational and physical therapy in different centres in Tehran before the study. The inclusion criteria were: (a) diagnosis of CP; (b) no orthopaedic surgery or spasticity reduction intervention in the last 6 months; (c) in Level 1, 2, 3, and 4 of the Gross Motor Function Classification System (GMFCS); (d) not a candidate for surgery or other intervention for at least 1 year; and (e) with parent's consent for child assignment in either group by randomization. According to the contraindications for the AST (Adeli Bibliography, 1994), the following exclusion criteria were taken into account, they were having (a) hip dislocation and marked scoliosis; (b) high degree of spasticity and disability (Level 5 of the GMFCS); (c) uncontrolled seizures; (d) hydrocephalous, progressive encephalopathies, and miopathies; and (e) systemic diseases such as renal or cardiac disorders.

Written consent to participate in the study was obtained from the parents. A paediatric neurologist screened the children's medical histories before soliciting their participation and verified the diagnosis of CP with no uncontrolled seizures and other excluding criteria. At the next stage, the intelligence status of the children was assessed using the Goodenough test and then the children were classified based on the GMFCS (Palisano et al., 1997). Among the 62 children, who participated in the study, 36 children (25 boys and 11 girls) met the criteria. Children were matched by the age and the GMFCS level and then assigned to three groups by match pairs. The characteristics of the samples are shown in Table 1.

Interventions

There are three training groups in this study: the MAST, the AST, and the NDT groups. All children in the three groups received daily treatment for 2 hr/d, 5 d/wk for a period of 4 weeks (20 sessions). During this period, the occupational or

Table 1 Characteristics of Children Treated in Three Groups of Therapeutic Protocols.

Variables	MAST (n = 12)	AST (n = 12)	NDT (n = 12)
Sex			
Male/female	9/3	8/4	8/4
Age (y)	7.78 ± 1.93	7.48 ± 2.13	7.40 ± 2.15
Type of CP			
Spastic diplegia	7	7	7
Spastic quadriplegia	3	3	3
Dystonic quadriplegia	2	2	2
GMFCS level			
I	2	1	2
II	1	2	1
III	2	3	2
IV	7	6	7
IQ score according to Goodenough scale	88 ± 11	89 ± 12	87 ± 15

Data are presented as mean ± standard deviation.
Note. AST = Adeli suit therapy; CP = cerebral palsy; GMFCS = gross motor function classification system; IQ = intelligence quotient; MAST = Modified AST; NDT = neurodevelopmental treatment.

Figure 1 Child wearing Adeli suit.

physical therapy sessions that they had previously received were stopped, whereas educational and recreational activities were continued.

The training in the AST group contained two separate sessions. The first hour was a preparation session and the next hour required the child to wear the Adeli suit (Figure 1). The Adeli suit was purchased from Ayurveda Corporation, Moscow, Russia. The classic AST was executed according to the original Russian protocol with the following instructions (Adeli Suit, 2007). The preparation stage consisted of two different protocols including (a) whole body massage with baby oil as a preparation before wearing the suit. Massage would take 30 min including 10 min for the trunk, 10 min for the upper limbs, and finally 10 min for the lower limbs and (b) Post isometric relaxation exercises. These exercises would take 30 min for each child. The suit wearing stage consisted of wearing the Adeli suit and fitting it to the child according to anthropometrical measures and applying loads to it according to child's tolerance and strength. This stage would take 1 hr. Vigorous exercises inside the suit were done for strengthening the weak musculatures and optimizing the correct posture and alignment. The type of exercises differed according to developmental stages of children.

The training in the NDT group consisted of 2 hr of actions, including the passive motions and active movements. These programmes were based on the instructions of Bobath concepts. In the passive part, which would take 1 hr, passive stretching of the shortened musculatures and stiff joints, positioning and techniques of reducing spasticity, facilitation, and inhibition techniques were applied. In the active part, functional activities depending on the child's neurodevelopmental stages such as sitting, standing up from sitting, and walking were applied for another hour. The normal movement patterns were facilitated through proper handling.

The training in the MAST group included passive stretching of shortened muscles followed by facilitating close to normal movement patterns through handling and facilitation techniques for 1 hr. This part was similar to the NDT protocols. At the next hour, the Adeli suit was dressed and the loading system was applied. Instead of doing nonmeaningful, tedious, and vigorous exercises that applied in the AST, the child was encouraged to do more functional and goal directed activities in the context of play, within the suit. All activities were selected according to the child's capabilities and interests so as to encourage the child to participate actively in the session.

After the intensive treatment, all children in three groups received traditional occupational therapy services for 16 weeks, 2 times a week, and 45 min/session. The contents of these programmes were stretching and flexibility, preventing deformities, facilitation of the GMF, and inhibition of abnormal movement patterns. These trainings were applied across all the children. Therapists delivering these treatments were blinded and did not know about the type of group that a child had previously participated.

Instrumentation

The Gross Motor Function Measure (GMFM-66) tool was used to test the children's functional status at baseline, after 4 weeks of intensive treatment, and after 16 weeks of regular treatment. All the tests were performed by an

occupational therapist, which were blinded about the grouping of children. The GMFM is an ordinal measure designed to valuate changes in GMF in children with CP in five dimensions: (a) lying and rolling, (b) crawling and kneeling, (c) sitting, (d) standing, and (e) walk-jump-run activities (Russell, Rosenbaum, Cadman, Hardy, & Jarvis, 1989). Each item is scored on a 4-point ordinal scale, as outlined in the manual (Russell, Rosenbaum, Avery, & Lane, 2002).

Statistical Analysis

Statistical analysis was conducted with SPSS (version 16.0; IBM corporation SPSS Inc., USA) software using analysis of variance (ANOVA) for repeated measurements to test the effect of each protocol on the obtained scores of GMF within each group. Tukey's post hoc analysis was used to determine the specific differences among groups. We also used the Kolmogrov Smironov test to test the normal distribution within groups. We compared the GMF scores among three groups at the baseline by ANOVA test to know if there was any difference among them. The significant p value level was determined as .05.

Results

A total of 36 children were treated in three groups and their characteristics were presented in Table 1. The mean age of children did not differ significantly among the three groups ($p = .886$). There was also no significant difference among children in the three groups regarding their intellectual status ($p = .935$).

The GMF was measured in three different stages (baseline, 4 weeks, and 16 weeks after the treatment). No significant difference in the GMF scores was noticed among groups at the baseline ($p = .965$). The repeated measures ANOVA test was used to measure the effects of each training protocol on the GMF scores during the treatment period (Table 2). Evaluating changes of the GMF score among groups during the therapy period revealed that there was a significant difference among three groups ($p = .000$). *Post hoc* analysis showed that the difference was between the MAST group with the AST group ($p = .000$) and between the MAST with the NDT group ($p = .000$), whereas no significant difference between the AST group and the NDT group ($p = .272$) was detected.

The follow-up study about the GMF scores, that is 16 weeks after the treatment, showed an increase in the GMF scores in the MAST group but a decrease in the NDT and the AST groups (Figure 2). Although changes were observed in the groups (Table 2), there was no significant difference in the GMF scores within three groups at follow-up ($p = .637$).

However, there was a significant difference between groups in the GMF scores at follow-up ($p = .000$). *Post hoc* study indicated a significant difference between the MAST group and the AST group ($p = .000$) and the MAST group and the NDT group ($p = .001$), whereas no significant difference was found between the AST group and the NDT group ($p = .379$).

Discussion

According to the results, there was no difference between the AST and NDT protocols in treatment of children with CP. To our knowledge, there was a few study on the effectiveness of AST and comparing it to conventional approaches in treatment of children with CP. Semenova (1997) compared two groups of children with CP treated with the AST or the NDT and reported major improvement in the AST group in comparison with the NDT group.

Another study was conducted by Bar-Haim et al. (2006) who compared the effectiveness of the AST and the NDT on improvement of GMF in two groups of children with CP. The study was conducted in Israel on 24 children with spastic diplegia and quadriplegia. They used GMFM-66 to test GMF in children of two groups at three stages, the baseline, after treatment, and 9 months at follow-up. They found no significant differences between the two groups after the treatment and at follow-up (Bar-Haim et al.).

In another study, at the Children's Hospital of Michigan, 57 children were assigned randomly into control and treatment groups. All children received an hour of physical, occupational, and speech therapies 3 times a week for a period of 8–10 weeks followed by a 4-week home programme. The experimental group wore the Adeli suit for the last 4 weeks of their therapy programmes. The study revealed constant improvement in both groups, but no statistical difference was found between the two groups. However, there was a trend for greater improvement in some functions with the Adeli suit. This study also disclosed that a period of intensive therapy in ambulatory children with CP could lead to improvement in a number of

Table 2 Gross Motor Function Scores and Level of Significant Differences Within Three Groups at Baseline, After Intensive Treatment, and at Follow-up.

Group	n	Baseline		After intensive treatment		p	After intensive treatment		Follow-up		p
		M	SD	M	SD		M	SD	M	SD	
MAST	12	85	33	118	41	.000	118	41	124	43	.054
AST	12	85	37	101	41	.000	101	41	98	42	.096
NDT	12	82	40	94	44	.000	94	44	91	45	.114

Note. AST = Adeli suit therapy; M = mean; MAST = Modified Adeli Suit Therapy; NDT = neurodevelopmental treatment; SD = standard deviation.

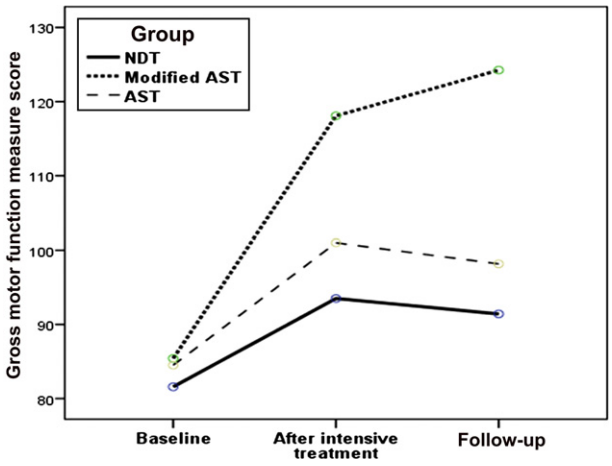

Figure 2 Changes of Gross Motor Function Measure in three treatment groups. *Note*. AST = Adeli suit therapy; NDT = neurodevelopmental treatment.

disabilities. However, they did not demonstrate that the Adeli suit was useful (United Cerebral Palsy, 2007).

There are investigations on the influence of the intensity and duration of intervention. Law et al. (1991, 1997) and Herndon et al. (1987) found no differences between various kinds of intensity in therapeutic programmes. However, Tsorlakis et al. (2004), Bower and McLellan (1992) and Bower, McLellan, Arney, and Campbell (1996) found in their studies that programmes providing a higher intensity of therapy yielded better results. Moreover, Bower et al. (2001) found that more intensive daily treatment led to a limited and temporary improvement. In another study, Trahan and Malouin (2002) found that an intermittent intensive NDT programme was less tiring and led to improvements in motor function. This study revealed that intensive therapeutic programmes were more effective than the regular ones as the GMF scores improved after all the intensive programmes; however, no significant improvement was noticed in any of the groups during follow-up. This finding showed the importance of intensive therapeutic programmes and identifying that improvement of GMF might not be the result of natural and spontaneous recovery in children.

At last, we compared the effectiveness of the MAST with that of the AST and the NDT, after the intensive treatment period and also at 16 week after the intensive programme. As shown in Figure 2, when the intensive programme discontinued in the MAST group, the progress trend slowed down but some regression was observed in both the NDT and the AST groups. There was no significant difference in GMF scores before and after the regular programme during the follow-up study. Results indicated that the MAST was more effective than the AST and the NDT programmes in both periods. To our knowledge no study has examined this issue so far and the results of our study worth further research. We think that the probable reasons making this modification more effective than the other two protocols could be related to integrating the goal directed activities of NDT with the biomechanical principles of the AST approach. According to the NDT approach, therapists have limitations in handling the child and they cannot simultaneously correct all the abnormal movement patterns of the child, especially in the severe ones. For instance, when therapists are trying to correct the head, neck, and upper trunk by handling, the limbs go to abnormal patterns easily. It is where the Adeli suit assists the therapist by working as a frame that corrects the child posture so that the therapist can focus more on facilitation of more normal movement patterns without emphasizing on correction of abnormal movement patterns.

The AST, on the other hand, applies the intensive exercises, particularly the passive ones, to the child to promote motor function regardless of the child's interests. The child gets tired, bored, and frustrated easily because of numerous, heavy, and vigorous exercises. In our modification, we did not apply heavy exercises, but recruited goal directed activities and functional movements with play to keep the child's motivation and encourage active participation.

Conclusion

The MAST was more effective than the AST or the NDT on treatment of children with CP. Intensive rehabilitation programmes, no matter they are the MAST, the AST, or the NDT, were more effective than regular training programmes in children with CP.

We recommend more investigation about the effects of this modification in children with CP with more cases and in different kinds of CP such as ataxic or athetoid, which we had not studied before. We also recommend a longer period of follow-up and examining the effects of this modified treatment on improvement of fine motor skills.

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