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RESEARCH REPORT

Effects of combined Adeli suit and neurodevelopmental treatment in children with spastic cerebral palsy with gross motor function classification system levels I and II

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KEYWORDS
Adeli suit;
balance;
gait;
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Abstract *Background:* Children with cerebral palsy (CP) exhibit diverse gait patterns depending on their neurological deficits and musculoskeletal problems. The Adeli suit treatment (AST) has been proposed as an intensive exercise protocol in the management of CP.
Objectives: The aim of this study was to compare the effects of a 6-week programme of combined AST and neurodevelopment treatment (NDT) with those of NDT alone on Gross Motor Function Measure (GMFM), balance, and gait in children with CP.
Methods: Twenty children with CP of Gross Motor Function Classification System levels I and II were randomly assigned to one of the following two groups: (1) NDT or (2) AST/NDT. The participants were assessed using the GMFM, Pediatric Balance Scale (PBS), Timed Up and Go (TUG) test, and spatiotemporal gait parameters.
Results: The GMFM, PBS, and TUG test for both groups showed a statistically significant increase ($p < 0.05$). Three children were excluded. Compared to the NDT group ($n = 9$), the AST/NDT group ($n = 8$) demonstrated a significant increase in spatiotemporal gait parameters ($p < 0.05$).
Conclusion: These results provide evidence for the greater effectiveness of combined AST/NDT than NDT alone in improving spatiotemporal gait parameters but not GMFM, PBS, and TUG test.

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Introduction

Cerebral palsy (CP) is a group of permanent disorders associated with the development of movement and posture due to activity limitation that are attributed to nonprogressive disturbances that occur in the developing foetal or infant brain. Motor disorders with cerebral impairment are often accompanied by disturbances in sensation, perception, cognition, communication, and behaviour [1]. Additionally, several factors include pathophysiology impairment, limitations on functional and social activities, and physical asymmetry [2]. Particularly noteworthy is that low muscle tone trunk creates problems of safety and mobility, and leg muscle spasticity affects the mobility of the lower body and delays motor development that is essential for independent standing and walking [3].

Children with CP exhibit diverse gait patterns depending on their primary neurological deficits and secondary musculoskeletal problems; in comparison with healthy children, those with CP walk at a slower speed and exhibit asymmetries and decreased balance [4]. Balancing and walking abilities serve as useful indicators that correlate with the functional level of children with CP [5]. Balancing requires maintaining a state of equilibrium with minimal change in posture. It is composed of multiple movements that require walking, sensory-motor input, proprioceptive input, and joint and muscle coordination. It requires an orientation response that positions one's head and body in an upright position and an equilibrium reaction for recovery of one's posture [6]. The equilibrium reaction results in a reduction of bilateral body asymmetries and shifting of weight to the lower extremities [6,7]. Spasticity and muscle weakness are the main factors affecting gait abnormality in children with CP [8,9].

The treatment methodologies adopted for CP, such as neurodevelopmental treatment (NDT) [10], constraint-induced movement therapy [11], and functional electrical stimulation [12], require a long duration (>8 weeks) to demonstrate improved muscle strength. NDT promotes proprioceptive input and is aimed at reduction of spasticity as well as facilitating normal motor development and improved activities of daily living [13,14]. NDT focuses on the promotion of normal and suppression of abnormal patterns in motor disturbances caused by central nervous system damage, with the aim of improving posture and movements performed with abnormal muscle tone. NDT is effective in improving the patient's body alignment and functional level, which normalises posture through key point of control on the patient's body and handling [15].

Use of the Adeli suit treatment (AST) has been proposed as an intensive exercise protocol in the management of CP as well as other neuromuscular disorders. The suit was developed for maintenance of muscle tone in a weightless environment such as that of an astronaut [16]. AST is based on three principles: (1) working against resistive loads, increased proprioception, and realignment; (2) intensive daily physical therapy; and (3) active motor participation by the patient [17]. The suit is composed of a cap, vest, shorts, knee pads, shoes attached with auxiliary equipment, and a bungee cord that connects the auxiliary equipment. The pieces are laced together with bungee-type cords. The cords are adjustable to allow varying degrees of tension to different muscle groups. The bungee cords are positioned to keep the body properly aligned and to forcibly encourage movement within a normal range of motion [18]. In an attempt to reposition limbs to correct abnormal muscle alignment, the bungee cords are adjusted by therapists to mimic normal flexor and extensor patterns of major muscle groups [16]. In a previous study of 24 children with CP [Gross Motor Function Classification System (GMFCS) levels II—IV], improvement in Gross Motor Function Measure (GMFM) was reported over a 4-week period comprising of 5 days (2 h/d) per week with a total of 20 sessions; however, in order to justify the higher costs of the suit treatment compared with that of NDT, more clinical base studies are needed [16]. AST incurs additional hospital visits that increases treatment programme costs and time spent [16]. More information demonstrating the effective treatment of CP is needed in order to obtain more concrete generalisations about AST.

In this study, we aimed to compare changes in Gross Motor Function Measure-88 (GMFM-88), Pediatric Balance Scale (PBS), Timed Up and Go (TUG) test, and spatiotemporal parameters in children with CP, who were categorised into two groups based on the type of treatment received for a period of 6 weeks. Participants in one group underwent standard NDT alone, whereas those in the second group underwent both NDT and AST.

Methods

Design

This study was conducted using a single-blinded randomised controlled trial with a pretest/posttest design conducted for a period of 6 weeks. The participants were randomly divided into AST/NDT and NDT groups, using a free random allocation software (Isfahan University, Isfahan, Iran). Participants in the AST/NDT group underwent NDT (30 min/session, 2 sessions/d, 5 d/wk) and suit treatment (30 min/session, 5 times/wk); participants in the NDT group underwent exclusive NDT (30 min/session, two 2 times/d, 5 times/wk). Pre- and postintervention assessments of 6 weeks were conducted by the same physical therapist experienced in paediatric rehabilitation and unaware of each child's treatment.

Participants and estimation of sample size

Twenty children with CP participated in this study. The inclusion criteria were as follows: (1) diagnosis of CP; (2) 4—7 years of age; (3) GMFCS level I or II; (4) no orthopaedic surgery or spasticity-reduction intervention in the past 6 months; and (5) parental consent for allocation of their child to either group through randomisation [19]. The exclusion criteria according to the contraindications for AST were as follows: (1) hip dislocation or progressive scoliosis; (2) poorly controlled epilepsy; and (3) use of medications for treatment of spasticity. All participants participated in the intervention at a children's hospital in the Republic of Korea. Data were collected between February 2011 and

September 2011. This study was approved by the Institutional Review Board of Sahmyook University, Seoul, Korea. All parents of the participating children were given detailed information about the research procedures and the scope and purposes of this study, and all signed a consent form.

In a previous study [20], the difference of gait velocity was 0.26 ± 0.07 m/s in the experimental group and 0.06 ± 0.05 m/s in the control group. The effect size was 3.28 and the power was 95%, with a two-tailed significance level of 0.05 assuming two groups having the same number of participants. The required sample size was eight children using the G*Power software (Franz Faul, Germany).

AST

The 30-minute AST session included putting on the Adeli suit, adjusting the belt, and taking it off. The mean exercise time using the Adeli suit was 15 minutes. The suit fit was based on each child's body size (Figure 1). Each child's therapeutic programme was individualised with the goal of advancing the patient to the next level of function. Each session involved performing multiple movements based on the child's functional abilities; these included sitting to standing, playing with balls while standing, walking on different surfaces, and climbing stairs or ladders [21].

NDT

Participants in both the AST/NDT and the NDT groups underwent NDT. The programme involved NDT based on the Bobath concept, which uses both traditional kinetic theory and motor learning theory. This programme uses techniques aimed to promote normal patterns of movement and reduce spasticity as a framework for treatment [2]. It includes functional motor activities consisting of sitting on a chair, standing, and walking. Children in the NDT group were treated by physical therapists trained in basic and advanced NDT courses.

Outcome measures

GMFM-88

The GMFM is a tool that measures and records changes in gross motor function in children with CP [22,23]. The GMFM-88 consists of 88 items grouped into the following five dimensions: dimension A (lying and rolling, 17 items), dimension B (sitting, 20 items), dimension C (crawling and kneeling, 14 items), dimension D (standing, 13 items), and dimension E (walking, running, and jumping, 24 items). Scores for each dimension are expressed as a percentage of the maximum score for that dimension, adding the scores for all dimensions, and dividing by 5 to obtain the total score.

TUG test and PBS

The TUG test is widely considered a reliable and valid objective test as a measurement of change in functional mobility over time in children [24]. The patients were instructed to flex both knees to 90°, and place their feet on the floor for support. The walking distance and halfway point were marked on the floor with a tape, and the time

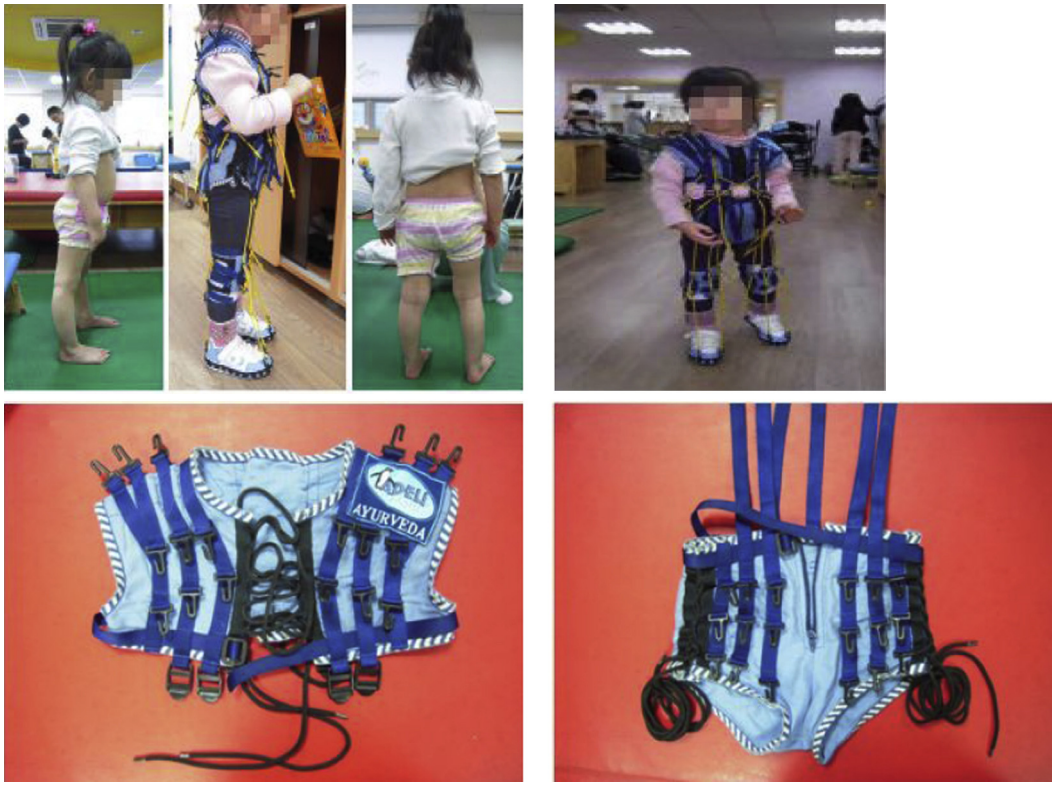

Figure 1. The children with cerebral palsy using the Adeli suit and its parts.

from when the patient stood up from the chair, walked 3 m and back, until their hip touched the chair was measured. The average of three measurements was obtained [24,25].

The PBS, a modification of the Berg Balance Scale, was developed as a measure of balance. PBS is a reliable test for children 5–15 years of age with mild to moderate motor impairment [26]. The PBS is a simple, valid scale for examining functional balance capacity in children 4–10 years of age with spastic CP and highly correlated with GMFM total score and dimensions D and E of the GMFM [27]. This test has been shown to have good test–retest and interrater reliability in CP in the 4–9 years age bracket [28]. In this study, four children (2 in the AST/NDT group and 2 in the NDT group) representing four different ages among the 17 children participated. PBS is composed of 14 items. Each item is scored on a 5-point scale, and the scores range from a minimum of 0 points to a maximum of 4 points. The total score for 14 items is 56 points. Higher scores indicate better stance balance ability [26,29].

Spatiotemporal parameters

All children underwent gait analysis using the GAITRite walkway system (CIR Systems Inc., Sparta, NJ, USA), which consists of an electronic walkway (90 × 460 cm). Data were sampled at the walkway data frequency of 80 Hz. The spatiotemporal characteristics measured using the GAITRite system have demonstrated good reliability (intraclass correlation coefficient, 0.82–0.92) [30]. The procedure was explained and demonstrated to each participant. Each participant was then instructed to walk barefoot at a self-selected walking speed with the head facing forward and eyes looking straight ahead. Three walking trials were collected and used in the analysis. The participants were allowed adequate rest if there were any signs of fatigue. Data on spatial (step length, stride length) and temporal (walking speed, cadence) gait parameters were obtained using the GAITRite version 3.2b [30,31]. Velocity was calculated by dividing the distance with the ambulation period, and was expressed in cm/s. Stride length was defined and measured on the line of progression between the heel points of two consecutive footfalls of the same foot, and was expressed in cm. Cadence was defined as the number of footfalls in 1 minute. A symmetry index (SI) was calculated with reference to these variables, using the following equation adapted from Lythgo et al [32]:

$$\mathrm{SI} = \mathrm{Absolute}\left[\left(L_{\mathrm{right}} - L_{\mathrm{left}}\right)/\left(L_{\mathrm{right}} + L_{\mathrm{left}}\right) \times 100\%\right] \quad (1)$$

The SI is a measure of symmetry. An SI of 0 represented perfect symmetry. L denotes the mean length of a gait variable.

Statistical analysis

SPSS version 17.0 statistical software (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. GMFM-88, PBS, TUG test, and spatiotemporal parameters did show normal distribution using the Kolmogorov–Smirnov test. The general characteristics of two groups were analysed using Chi-square analysis. The interaction effect between group and time was assessed using repeated-measures analysis of variance. Paired t tests were used for comparison of pre- and posttest results within each group. The statistical significance was set at $p < 0.05$.

Results

Demographic characteristics

Seventeen patients with quadriplegia or diplegia (8 in the AST/NDT group, 9 in the NDT group; 8 girls and 9 boys; age 5.64 years, range 4–7 years) participated in the study. One participant from the NDT group was excluded because of refusal to attempt a test after intervention, and two participants from the AST/NDT group who received botulinum toxin injections during the intervention period were excluded. Participants in the AST/NDT and NDT groups were similar in age, height, and weight. The demographic characteristics of the participants are shown in Table 1.

GMFM outcomes

Baseline scores for the GMFM and the A, B, C, D, and E dimensions of the GMFM did not differ statistically between the two groups. Statistically, there were significant time factor effects on GMFM and C, D, and E dimension ($p < 0.05$), but not on group and time × group interaction. Paired t tests revealed statistically significant improvement in GMFM, D and E dimension in AST group ($p < 0.05$). Additionally, a statistically significant improvement in GMFM, C, D, and E dimension in NDT group was discovered ($p < 0.05$; Table 2).

Table 1 General characteristics ($N = 17$).

	AST ($n = 8$)	NDT ($n = 9$)	Z	p
Boys/girls	2/6	6/3		
Age (y)	5.71 ± .89	5.57 ± 1.08	−0.290	0.772
Height (cm)	106.25 ± 6.61	107.89 ± 12.88	−0.048	0.961
Weight (kg)	17.15 ± 2.21	19.33 ± 5.45	−0.582	0.560
GMFCS (level I/II)	3/5	2/7		
Quadriplegia	5	6		
Diplegia	3	3		

Data are presented as n or mean ± standard deviation.
AST = Adeli suit treatment; GMFCS = Gross Motor Function Classification System; NDT = neurodevelopment treatment.

Table 2 Changes in Gross Motor Function Measure score after NDT/AST and NDT.

Variable (dimension)	Pre	Post	Pre & post within group		Time		Group		Time × Group	
			t	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Total										
NDT/AST ($n = 8$)	80.56 ± 12.93	85.42 ± 11.58	4.089	0.005	34.508	<0.001	0.152	0.702	<0.001	0.985
NDT ($n = 9$)	78.29 ± 11.63	83.18 ± 12.00	4.237	0.003						
Lying and rolling (A)										
NDT/AST ($n = 8$)	98.78 ± 1.80	99.51 ± 0.91	2.049	0.080	3.774	0.071	0.307	0.588	0.249	0.625
NDT ($n = 9$)	97.88 ± 4.20	99.13 ± 1.99	1.377	0.206						
Sitting (B)										
NDT/AST ($n = 8$)	97.76 ± 4.61	100.00 ± .00	1.372	0.212	3.908	0.067	0.126	0.728	0.078	0.783
NDT ($n = 9$)	97.55 ± 4.87	99.24 ± 1.75	1.421	0.193						
Crawling and kneeling (C)										
NDT/AST ($n = 8$)	87.89 ± 10.04	92.26 ± 9.67	1.965	0.090	10.801	0.005	0.355	0.560	0.071	0.793
NDT ($n = 9$)	84.73 ± 14.67	88.44 ± 13.49	3.042	0.016						
Standing (D)										
NDT/AST ($n = 8$)	62.55 ± 22.35	71.76 ± 21.92	2.759	0.028	22.890	<0.001	0.191	0.668	0.344	0.566
NDT ($n = 9$)	56.17 ± 25.32	67.95 ± 27.03	4.084	0.004						
Walking, running and jumping (E)										
NDT/AST ($n = 8$)	55.34 ± 28.36	63.91 ± 28.34	6.027	0.001	29.883	<0.001	0.379	0.547	0.015	0.905
NDT ($n = 9$)	47.92 ± 23.94	56.12 ± 21.83	3.160	0.013						

Data are presented as mean ± standard deviation.
AST = Adeli suit treatment; NDT = neurodevelopment treatment.

TUG test and PBS

Statistically significant time factor effects on TUG and PBS ($p < 0.05$) were revealed, but not on group and time × group interaction. TUG test and PBS revealed statistically significant improvement in all groups ($p < 0.05$; Table 3).

Gait parameters

Statistically significant time × group interaction effects on walking speed, cadence, and stride length ($p < 0.05$) were observed, but not on step length, SI of step length, and SI of stride length. Paired *t* tests revealed statistically significant

Table 3 Changes in Timed Up and Go test and Pediatric Balance Scale after NDT/AST and NDT.

Variable	Pre	Post	Pre & post within group		Time		Group		Time × Group	
			t	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Timed Up and Go test										
NDT/AST ($n = 8$)	18.43 ± 5.89	14.77 ± 4.15	−5.705	0.001	42.771	<0.001	2.204	0.158	7.970	0.513
NDT ($n = 9$)	20.62 ± 4.44	19.17 ± 3.97	−3.103	0.015						
Pediatric Balance Scale										
NDT/AST ($n = 8$)	33.00 ± 12.39	37.63 ± 13.67	7.083	<0.001	61.086	<0.001	0.151	0.703	0.621	0.443
NDT ($n = 9$)	35.67 ± 10.86	39.44 ± 10.89	4.554	0.002						

Data are presented as mean ± standard deviation.
AST = Adeli suit treatment; NDT = neurodevelopment treatment.

Table 4 Changes in spatiotemporal parameters after NDT/AST and NDT.

Variable	Pre	Post	Pre & post within group		Time		Group		Time × Group	
			t	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Walking speed (cm/s)										
NDT/AST ($n = 8$)	84.12 ± 16.08	98.15 ± 16.07	12.997	<0.001	72.639	<0.001	2.637	0.125	41.577	<0.001
NDT ($n = 9$)	72.70 ± 26.85	74.64 ± 26.02	1.313	0.226						
Cadence (step/min)										
NDT/AST ($n = 8$)	105.95 ± 12.36	118.91 ± 14.79	4.482	0.003	12.514	0.003	2.008	0.177	12.730	0.003
NDT ($n = 9$)	102.02 ± 18.97	101.97 ± 15.16	0.024	0.981						
Step length (cm)										
NDT/AST ($n = 8$)	33.38 ± 8.56	38.82 ± 6.38	2.270	0.057	2.765	0.006	1.246	0.282	2.765	0.117
NDT ($n = 9$)	33.24 ± 7.37	36.18 ± 7.18	3.695	0.006						
Stride length (cm)										
NDT/AST ($n = 8$)	69.85 ± 25.15	78.76 ± 26.06	0.442	0.672	10.200	0.845	0.050	0.826	4.847	0.044
NDT ($n = 9$)	71.19 ± 16.52	72.83 ± 17.24	−1.962	0.085						
Symmetry index of step length										
NDT/AST ($n = 8$)	8.30 ± 4.93	9.67 ± 6.16	2.797	0.027	0.039	0.321	0.546	0.834	1.170	0.297
NDT ($n = 9$)	9.56 ± 4.65	7.57 ± 4.81	1.245	0.248						
Symmetry index of stride length										
NDT/AST ($n = 8$)	2.96 ± 6.55	1.61 ± 1.47	0.540	0.606	1.053	0.985	2.792	0.115	3.976	0.065
NDT ($n = 9$)	5.40 ± 7.16	9.61 ± 9.77	2.975	0.018						

Data are presented as mean ± standard deviation.
AST = Adeli suit treatment; NDT = neurodevelopment treatment.

improvements in walking speed, cadence, SI of step length, in the AST group ($p < 0.05$). Additionally, statistically significant improvement in step length and SI of stride length in the NDT group was detected ($p < 0.05$; Table 4).

Discussion

This study focused on children with CP, who were treated with either combined NDT and AST or NDT only based on the Bobath concept, for a period of 6 weeks; the effects were compared on the basis of pre- and posttest GMFM, TUG test, PBS, and spatiotemporal parameters on gait.

The Adeli suit provides resistance to movements and makes performance of intensive exercise possible [16]. Intensive rehabilitation demonstrated a significant correlation to improved motor skills in children with CP [33]. The suit treatment relies on changes of proprioceptive senses from joints, muscles, and tendons, reduction in pathologic reflection, and improvement in physiological movements of muscles. Increase in input of proprioception and significant information from the vestibular organs can affect body position, balance, and posture tension. Suit treatment seems to improve body alignment through trunk stability, along with walking patterns. It becomes effective in helping patients develop their muscles and balancing abilities, especially when patients execute the exercise programme while wearing the suit [16].

Muscle strengthening exercises performed for a short duration can improve GMFM in children (6—12 years) with spastic paraplegia and hemiparalysis. Improvements seen in the GMFM dimension E were mainly related to skills that involved lower extremity strength such as walking [34]. The loaded sit to stand home exercise programme performed three times a week over a 6-week period can improve motor abilities, functional muscle strength, and walking efficiency in children with mild CP [35]. Even if walking were improved as a result of strengthening exercises or intensive sit to stand exercise, differences in spasticity would still persist in extremities, and it is unknown what other factors contribute to motion and stability [34]. AST was not devised for the purpose of muscle strengthening. However, AST possibly improves motion and postural stability during activities [36]. AST used in a therapy

programme provides some resistance. In this study, children in the AST/NDT group participated in the AST programme lasting 30 minutes per session. AST is more beneficial when administered several hours a day. A comparison between the AST and NDT groups demonstrated improvement in GMFM in both groups. A significant improvement in GMFM was observed in both groups, as reported in a previous study [17].

With respect to gait, dynamic balance training improves walking function more than static standing training, and the ability to control balance improves quality of life by enabling performance of movements required for daily living [5]. The suit treatment affects the level of postural tension in dynamic situations and provides more stability to the trunk, intense tactile and proprioceptive sensation to the wearer and to realign the body parts by resisting the spastic muscles and positioning the antagonists into the middle of joint range so that all of the muscles can contact in a biomechanically sound position [37]. The suit allows the wearer to relearn the correct movement patterns and is considered intensive therapy.

Significant improvement was observed in GMFM (total, standing, and walking), the TUG test, and PBS in the AST/NDT group, and in GMFM (total, crawling, standing, and walking), the TUG test, and PBS in the NDT group. In the absence of central nervous system regulation due to a brain injury, children with CP exhibit an equine or crouch gait, knee hyperextension, hip internal rotation, and lumbar lordosis [38]. The TUG test shows a significant correlation with PBS. Stability in standing and walking correlates with faster walking speeds [5]. In addition, because of the significant negative correlation ($r = -0.52$) between the TUG test and GMFM-D and E [24], the TUG test has become an indicator of changes in movement speed and GMFM in children with mild motor impairment (GMFCS levels I and II) [39]. Slow walking speed owing to incomplete control reflects a decrease in balance and muscle strength and walking asymmetries [5]. When a patient moves his body quickly because the centre of the body is stable on a base of support, a new base of support is formed, and static balance control changes to dynamic control. Balance abilities can be improved by these dynamic assignments [38].

Walking speed is used as a measure for assessment of independent walking ability during daily living activities and functional recovery [40]. As walking speed increases, cadence increases and dorsiflexion decreases, resulting in increasing stability [41]. Because of the excess levels of muscle tension and lack of ability to maintain normal body alignment, children with CP experience a decrease in walking speed and cadence. In previous research [21], after application of the suit treatment for measurement of changes in walking analysis for 3 weeks (4 h/d, 5 times/wk), improvements were observed in walking speed, cadence, ankle range of motion, and body alignment. In this study, in order to investigate walking variables before and after the tests, measurements of participants' walking speed, cadence, step length, stride length, SI of step length, and SI of stride length were performed. Participants in the AST/NDT group showed improvement in walking speed, cadence, and stride length; those in the NDT group showed improvements only in step length and an increase in SI of stride length. Proper positioning of feet during walking increases stability in standing and helps the participant to walk further [42]. Spasticity arises from a hyperactive stretch reflex mechanism, and it arises voluntarily and involuntarily from excess movements [1]. Treatment using the suit is believed to result in improvement of balance abilities through equal weight loads and reinforcement of antigravity muscles and walking speed. In the AST/NDT group, motor improvement of the lower extremity joints from repeated use of antigravity muscle by resistance is thought to cause an improvement in walking asymmetries along with walking speed and cadence, when patients move each part of their body that is connected to a bungee cord.

Compared to the NDT group, although no significant improvement in the TUG test and PBS was observed in the AST/NDT group, more significant improvements were observed in the spatiotemporal gait parameters. The spatiotemporal gait parameters are suitable for measurement of a more sensitive and minimal amount of change. According to the results of this study, participants in the AST/NDT group showed more statistically significant effects than their counterparts in the NDT group in terms of walking speed, cadence, and stride length. Despite the objective change in spatiotemporal gait parameters, the data have to be interpreted with caution, because the statistically significant differences between the two groups may be a result of the additional intervention time and repetition.

Even if AST can improve posture and balance abilities, further studies are required to investigate the maintenance of treatment effects when the suit is not worn. Therefore, a long-term study on the application of AST is recommended. Additionally, to enable children wearing the Adeli suit to participate in the treatment, additional development of feedback-enabled programmes is needed.

Limitations

In this study, a relatively low number of children with CP participated; thus, generalisation of the results may be compromised. In addition, the quantitative standards of treatment between the two groups were different because the suit was applied only to the AST group. AST is regarded as an additional complimentary therapy, whereas NDT is a generalised treatment applied to children with CP; therefore, the individual effects of AST could not be proven.

Conclusion

This study aimed to establish the effects of the AST on GMFM, PBS, TUG test, and spatiotemporal parameters through the performance of concentrated training exercises in 17 children with CP.

In conclusion, NDT was effective in improving the performance of patients in GMFM, PBS, and TUG test, whereas AST/NDT was effective in improving the patients' performance not only in GMFM, PBS, and TUG but also spatiotemporal gait parameters.

Conflicts of interest

No conflicts of interest were declared by the authors.

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