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Integrated intensive proprioceptive and visuomotor rehabilitation program for treatment of spastic diplegic Children

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ABSTRACT

Although so many rehabilitation programs have been addressed for rehabilitation of diplegic children, it still a challenging task to attain a satisfactory functional recovery. The purpose of the study was to investigate the efficacy of an intensive proprioceptive and visuomotor training program in the treatment of diplegic children in term of spatiotemporal gait parameters, postural stability, and quality of life. In a prospective randomized controlled trial, convenient sample of forty ambulant diplegic children were randomly distributed to either control (n=20) or study (n=20) groups; the control group received a traditional rehabilitation program for 1 hour, 5 times/week for 3 successive months, while the study group received the same program with intensive proprioceptive and visuomotor integration. Vicon 3D motion analysis system, Technobody balance system and Pediatric Quality of life Inventory were used to measure spatiotemporal gait parameters, stability indices and quality of life respectively. all parameters were similar in both groups at inception ($p>0.05$). Children within both groups showed improvement of gait function, postural stability and quality of life ($p<0.05$) and the integrated proprioceptive and visuomotor rehabilitation program achieved better gain ($p<0.05$). Integrated proprioceptive and visuomotor rehabilitation might improve gait function, postural stability, and quality of life in diplegic children.

Key words: Spastic Diplegia, Rehabilitation, Proprioceptive training, Visuomotor exercises

INTRODUCTION

Spastic diplegia is a common pattern of motor impairments in children with brain insult. Impairment of motor function is due to poor muscle control, weakness, spasticity and impaired postural stability **[1]**. Diplegic patients are usually independent ambulant but most have identified gait deviations **[2]**. The diplegic gait pattern may be true equinus pattern (ankle in plantar flexion while hip and knee joint in extension), jumping pattern (the body center of gravity displaced upward in mid stance phase as the child jumps), apparent equinus (toe walking, and equinus is apparent), and crouch pattern (calcaneal ankle with excessive hip and knee flexion **[3]**. Their walking pattern is typically slow and they have difficulty in the performance of daily living activities such as walking, running and stair climbing. Walking is a major concern of their parents. Improvement or maintenance of walking ability is often primarily considered by most of the treatment interventions addressing the motor problems in diplegic children who develop abnormal walking and abnormal motor learning **[4]**. Spasticity and deformities as ankle plantar flexion, knee flexion hip adduction, and internal rotation are contributing factors of functional limitation and balance problems in cerebral palsied children **[1]**.

Standing balance is usually traditionally measured by the duration of maintenance of standing or by postural stability **[5]**. The posture considered in equilibrium when the center of body mass is controlled relative to the base of support either in static or dynamic situations **[6]**. Postural control could be a reaction to external forces that disturb the position of the center of body mass or a proaction to an anticipated internal destabilizing forces produced by the body's own movements. Both external forces and internal forces ultimately act to disturb the postural control by accelerating its center of mass. The nervous system detects and predicts postural instability and produces the appropriate muscle forces to control COM **[7]**.

Postural correction suit has been proposed as an alternative therapy to treat the functional impairments in diplegic children. It is also known as thera suit, Adeli suit, polish suit, and penguin suit. The suit originally designed by the Russians astronauts to minimize the effect of weightlessness in space **[8, 9]**. The theory behind the therapy suit is that it induces a strong afferent proprioceptive input, which stimulates neural reorganization of the brain whose post-natal development has been delayed **[10]**.

Proprioceptive and visuomotor feedback augmentation is often used as an adjunct to the traditional rehabilitation programs to reinforce performance rather than being used as a primary intervention for rehabilitation. Children have to gain in the real-time settings to get benefits from the proprioceptive and visuomotor training **[11]**.

Meaningful life and social participation are important aspects of life for children with cerebral palsy **[12]**. Motor limitation often associated with cognitive, perceptual, behavioral, and communication problems **[13]**. Understanding the sufferance of cerebral palsied children expand beyond the physical limits to the perception of their position in life in the context of the culture and value they live in. such perception is defined by the World Health Organization (WHO) as the Quality of life (QoL) **[14]**. Average to a good quality of life is a key outcome for both the society and the children themselves **[15]**.

The current study aims to investigate the efficacy of integrated intensive proprioceptive and visuomotor rehabilitation program for treatment of children with spastic diplegia.

MATERIALS AND METHODS

Methods and procedures

Subjects: A sample of 40 ambulant diplegic children were conveniently recruited to participate in the study. Their ages ranged from 6 to 8 years. Children were eligible if they were ambulant diplegic, had crouch gait pattern, had spasticity of grade 1 or 1+ according to modified Ashworth's scale, had a developmental level of grade I or II according to gross motor function classification system and if they had no auditory or visual disorders. Children were excluded if they had structured musculoskeletal deformities, hip dislocation, spinal deviations, cardiopulmonary problems or uncontrolled convulsions.

Children were recruited from the outpatient clinic of the college of applied medical sciences, Prince Sattam bin Abdulaziz University and King Khalid hospital, Al-Kharj, Saudi Arabia. Children were randomly distributed to two groups of equal numbers; control group (n=20) and experimental group (n=20). Block randomization with a fixed block size was used to ensure the creation of two equal groups, each block has a sequence of 5 consecutive patient's numbers. An independent person was asked to pick up a closed envelope from the 8 blocks. When a child was enrolled the next children in the sequence were then enrolled. Children assigned to the control group received a traditional rehabilitation program while those assigned to the study group received the same program as control group with employment of an integrative proprioceptive and visuomotor feedback. The sample size was calculated by G. power 3.0.1, means and standard deviation of step length of 10 patients in two groups were collected from a pilot study, alpha level 0.05, desired power was 80 %. A sample of 18 children was created upon the previous assumptions for each group with a total of 36 children. 40 children were recruited for possible withdrawal.

Assessment

- 3D motion analysis system with Vicon Clinical Manager software was used to measure the kinematic gait parameter. It consists of 12 cameras that capture 200 frames/second, an Active wand kit for system calibration, six meters long walkway with an embedded force platform, and a computer with Vicon Manager Software. After preparation of the system (camera volume setup and system calibration) and subject preparation (marker setup), subject's demographic and anthropometric data were submitted to the system (age, weight, height and the anthropometric measurement of the pelvis and lower extremity segments) and static subject calibration was conducted. Then, capture phase started by asking each child to walk freely along the walkway for 3 trials before data collection. Finally, a complete gait cycle was selected for analysis and the spatiotemporal gait data (step length, step width, stride length, cadence, velocity and stance %) were then collected.

- Techno-body PROKIN system was used for measurement of postural stability. A number of tests were conducted for both groups. Anteroposterior stability index (AP-SI), mediolateral stability index (ML-SI) and overall stability index (OSI) were measured at stability levels 4 and 8. After explanation of the test procedure, the test entry data were submitted (age, weight, height and foot replacement landmarks on the test platform). The test goal was to quantify the maximum distance the child can intentionally displace COG without losing balance or stepping. The test repeated for 3 times for each trial and the mean AP-SI, ML-SI and OSI were recorded.

- Pediatric Quality of life inventory (PedsQL^{TM} 4.0) generic core scale will be used to measure health-related quality of life (HRQOL). The PedsQL generic core scale consists of 23 items. It includes four subscales physical functioning (8 items), emotional functioning (5 items), social functioning (5 items), and school functioning (5 items), each item has five possible responses ranges from 0-4. Row scores transformed linearly to 0-100 scale. The mean score for the physical functioning, psychosocial functioning (social + emotional + school functioning score) and the total score were calculated in the present study. Better HRQL is indicated by higher scores **[16]**.

The assessment was carried out by independent subjects who were blinded to the treatment assigned for children in both groups prior to and after the intervention.

Intervention

Control group: A traditional physical therapy program was implemented for children in this group. Children in this group were not engaged in a rigorous rehabilitation program. Instead, the functional goals were carefully identified for each child and children were directed to properly react to normal movement patterns throughout the program. Generally, the treatment protocols were individually constructed and were aiming for:

- Inhibition of abnormal motor patterns and facilitation of normal pattern. Neurodevelopmental techniques (NDT) were basically used to achieve this goal.
- Promotion and enhancement of the existing postural reactions during standing and walking milestones (equilibrium, protective and locomotion reactions).
- Development of postural mechanisms such as; changing position from one to another and return to the original one (rising mechanism), maintenance of the posture against gravity (anti-gravity mechanism), fixation of body parts on the shoulder and pelvic girdles (postural fixation mechanism), and moving one body part while fixing the other parts (counterpoising mechanism).
- Correction of abnormal gait pattern and building up a normal walking pattern. Children were encouraged to walk independently or even with minimal assistance on even and uneven surfaces, walk across obstacles, walk in different directions and treadmill gait training.
- Finally, preservation of the flexibility and functional joint mobility. Muscles that have a tendency to develop tightness or contractures were monitored. For instance, hip flexors, knee flexors, and ankle plantar flexors. Then, active or passive stretching exercises was applied when necessary.

The treatment protocol was conducted by three professional NDT therapists who had an experience of at least five years. The duration of each session was an hour with intervals of rest every 15 minutes and frequency was five times/week for three successive months.

Experimental group: An integrated proprioceptive and visuomotor rehabilitation program was employed for this group. They received the same treatment as the control group while the postural correction suit was worn. This suit was made up of the vest, short, knee cuffs, and shoe attachments. Its parts were connected to each other with elastic bungee bands to correct abnormal trunk posture, anterior pelvic tilt, hip and knee flexion and ankle plantar flexion. The tension of these bands was adapted to each exercise and position assumed by each child during the training program. Moreover, the tension of the bands was measured and calibrated each week to ensure maintenance of the amount of tension and consistency of the proprioceptive feedback throughout the program. Tension Formula was: $T = (m \times g) + (m \times a)$, where T: is the tension of the cord, m: is the mass of the object attached to a vertically hanged cord (kg), g: is the gravitational force (9.8 m/s^2), and a: refers to acceleration of the mass (m/s^2).

In addition, the visuomotor training was addressed for children in this group by providing a virtual intuitive interface during the real time treadmill training while wearing the postural correction suit that offers an intensive proprioceptive stimulation. This was accomplished using (ZebrisRhawalk® Platform System, Germany). The system includes an instrumented treadmill synchronized with a unit for adaptive visual cueing through the projection of the actual footprints and gait pattern on the treading surface. Also, Virtual feedback training provided simultaneously, with the help of a large monitor mounted in front of the treadmill. During training, an initial gait analysis was carried out without any measuring preparations to be done for each child. On the basis of the initial evaluation, the target parameters were adjusted and individual training parameter was created to each child's capability. Then a virtual training environment in the form of a straight path in a forest was displayed. In the virtual walking environment, children were asked to walk and position their feet as accurately as possible over the predetermined projected footprints. Also, walking across obstacles was planned.

Treatment was conducted by three physical therapists that were trained on the use of the intervention assigned for this group. Each session was for an hour of which 20 minutes were specified for gait training, five sessions/week, and treatment duration was for three consecutive months.

Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) software, version 23. Descriptive statistics were computed for gait and postural stability measures as mean ± standard deviation and for HRQL measures as Median and interquartile ranges. Paired and unpaired t-test were used to calculate the mean differences of spatiotemporal gait parameters and stability indices within and between both groups respectively. While HRQL measures were compared within each group using non-parametric Wilcoxon Signed-Rank test and between groups using Mann-Whitney U test. Data were considered significant at ($P<0.05$).

RESULTS

Baseline demographic characteristics

The demographic and anthropometric features for children in both control and experimental groups are demonstrated in table 1. Data analysis indicated non-significant differences between both groups in term of their age, gender, weight, height and developmental level on GMFM ($p>0.05$).

Spatiotemporal gait parameters

The baseline scores and those collected after intervention are presented in table 2. No significant differences were recorded between control and experimental groups at entry regarding all measuring variables ($p>0.05$). While analysis of the post treatment scores of both groups reported a significant difference of all variable in favor of the experimental group ($p<0.05$).

Also, as summarized in table 3, after three months of treatment, data analysis revealed a significant difference between the pre and post-treatment spatiotemporal gait parameters (step length, step width, stride length, cadence, velocity and stance phase percentage) within both control and experimental group ($p<0.05$).

Postural stability indices

Mean A-P stability index, M-L stability index and overall stability index for both groups are presented in table 4 across the two measurement points**.** No significant difference was recorded between control and experimental group pre-treatment regarding the aforementioned three indices of postural stability ($p>0.05$). Contrariwise, a significant difference between the two groups post-treatment in favoring the experimental group was indicated ($p<0.05$)**.** Also, pre and post treatment scores of all stability indices showed significant differences with both the control and the experimental groups ($p<0.05$).

Health-related quality of life

Table 5 presents the descriptive results concerning three domains of children HRQL (physical functioning, psychosocial functioning, and total score) for both groups prior to and after the intervention. Before the intervention, all median scores were > 50. Both groups were similar ($p>0.05$). Whereas, after the intervention, all median scores were > 0.05 and a statistically significant difference in the physical health scores, psychosocial health scores, and the total HRQL scores was revealed between both groups in favor of the experimental groups ($p<0.05$).

DISCUSSION

Although a huge number of studies were conducted to determine the efficacy of different therapeutic options for promotion or reclamation of the functional recovery for cerebral palsied children, it is perpetually important to extend the range of application of these therapeutic interventions. The present study focused on the integration of proprioceptive feedback (postural correction suit) and visual feedback (sustained multi-source feedback during the real time walking on a treadmill) to enhance the efficacy of the traditional rehabilitation programs for cerebral palsied children.

This study targeted the diplegic children aged from six to eight as the development of independent standing and walking may delay beyond the age of five years **[17]**. The variables of interest were the spatiotemporal gait function, postural stability, and the HRQL. It has been identified that diplegic children develop abnormal spatiotemporal gait parameters (step length, stride length, stance and swing time) compared to their typically developed counterparts **[18]**. The adapted abnormal gait and postural instability might be attributed to abnormal tone, lack of movement dissociation, failure of development of postural reaction and abnormal muscle co-activation of the lower limb muscles **[19]** and difficulty with timing to motor response to perturbation of the supporting surface and difficulty in organizing the anticipatory postural adjustments associated with voluntary movement during standing and walking **[20]**. Consequently, they develop secondary compensatory mechanisms that result in alteration of the forces acting on the lower limb muscles, abnormal motor control, muscle tightness, muscle weakness, contractures and movement incoordination **[21]**. Also, cerebral palsied children have been reported to have a lower quality of life than the general population and strongly associated with their impairment **[22, 23]**.

The findings of the present study indicated a significant improvement of the gait function, postural stability and the health related quality of life for children were engaged in either the traditional rehabilitation program or the integrated proprioceptive and visuomotor rehabilitation program. Increasingly, in comparison to the traditional program, the integrated proprioceptive and visuomotor program yielded a better gain of gait function, postural stability and the HRQL.

It has been reported that the application of the postural correction suit provides an intensive dynamic proprioceptive correction of the abnormal crouch posture of diplegic children, reduces abnormal muscular synergies and restore normal synergies and improve postural control through normalization of the afferent proprioceptive and vestibular input by the load it places on the muscles **[9, 24]**. A possible mechanism of the postural correction suit is the provision of intensive exteroceptor and proprioceptor feedback from muscles and joints through the control of the tension of the elastic bands that attaches parts of the suit **[25]**. Thereafter, it promotes and enhances the neuromuscular control, correct postural deviation and abnormal crouching pattern. Also, Rosenbaum et al. explained the efficacy of the postural correction suit to assist diplegic children to re-train the central nervous system by allowing the child to overcome complex pathological movement and to perform and repeat movement patterns that were not previously unknown, enhance postural control and plain movement activities **[26]**. In the same context Bar-Haim, et.al explained that postural correction by the suit provides an opportunity to perform aggressive movement therapy that helps in building up and recognition of proper movement pattern in the brain **[27]**. Further, the postural suit allows a controlled resistive exercises and improve muscular strength and imposes a stretching force to tight muscles and changes the postural alignment **[25]**. Additionally, improvement of spatiotemporal parameters and postural stability are optimized by the use of continuous visual cueing of the walking pattern simultaneously with the proprioceptive training offered by the postural correction suit. Sensory visual input helps children to enhance their physical performance during walking by creating a meaningful, challenging environment and stimulation of cognitive function **[28]**. Kott et al. reported of improvement of walking performance of cerebral palsied children when a playful context was created through a virtual reality **[29]**. Also, Brien et al. reported significant improvement of functional balance and mobility in adolescents with cerebral palsy and the improvement retained for one month later after short duration virtual reality intervention **[30]**. Visuomotor exerts a detectable effect on the neural excitability and helps to reorganize the neural motor pathway, generate effective synaptic potentiation and produce a remarkable gain of motor function caused by repetitive practice induced neural plasticity **[31]**.

Our perspective, diplegic children repetitively use abnormal movement pattern during functional activities and has a tendency to build up abnormal engram in the motor cortex that contributes in limitation of the sensorimotor processing of normal movement patterns. Therefore, the functional recovery of the experimental group might be attributed to the proprioceptive feedback from assuming an optimal posture that has the potential to enhance the central control and functional execution. Further, sustained visual feedback related to correction of both the posture and the walking pattern probably considered as an additional supporting mechanism.

Notwithstanding the positive results of the present study, several limitations should be acknowledged for consideration in the forthcoming studies**.** First, gait assessment was limited to the spatiotemporal parameters of gait without exposure to gait kinematics. Second, no follow-up assessment was conducted to identify the long-term effect of the intervention. So, the results of the present study are not conclusive. Finally, potential bias may arise from recruiting children with two different developmental levels. Future studies should consider gait kinematic and follow-up assessment as well as cross-sectional studies for clearer insight about the efficacy of the rehabilitation program.

Table 1: Demographic characteristics of the patients

		Control group	Experimental group	P-value
Age (years)		7.25 ± 0.85	6.80 ± 0.80	0.099
Gender	**Boys**	13 (65%)	15 (80%)	0.294
	Girls	7 (35%)	5 (20%)	
Weight (kg)		27.20 ± 5.35	30.32 ± 6.89	0.121
Height (cm)		127.72 ± 7.31	125.65 ± 8.71	0.420
GMFM	**I**	11 (55%)	14 (70%)	0.334
	II	9 (45%)	6 (30%)	
Age, weight, and height expressed as (mean ±SD). Gender and GMFM classification expressed as n (%), kg: kilogram, cm: centimeter				

Table 2: Spatiotemporal parameters between both groups

Gait measures	Pre-treatment			Post-treatment		
	Control	**Experimental**	**P-value**	**Control**	**Experimental**	**P-value**
Step length	32.32±4.62	33.56±3.79	0.386	34.97±3.17	37.80±3.60	0.011*
Step width	19.87±2.33	18.84±1.98	0.099	20.33±2.49	22.53±2.88	0.036*
Stride length	77.95±8.01	82.35±6.29	0.060	79.50±9.84	86.35±8.77	0.034*
Cadence	99.70±6.01	100.50±2.80	0.202	104.25±5.96	107.40±3.30	0.015*
Velocity	46.42±4.76	44.82±5.14	0.256	47.80±4.04	50.47±4.68	0.045*
Stance %	64.30±3.45	66.25±4.23	0.143	62.50±2.91	60.60±2.37	0.035*
*Step length, step width and stride length expressed in (centimeters), cadence as (step/minute), velocity as (meter/minute), * significant*						

Table 3: Spatiotemporal parameters within both groups

Gait measures	Control group			Experimental group		
	Pre	**Post**	**P-value**	**Pre**	**Post**	**P-value**
Step length	32.32±4.62	34.97±3.17	0.001*	33.56±3.79	37.80±3.60	0.000*
Step width	19.87±2.33	20.33±2.49	0.011*	18.84±1.98	22.53±2.88	0.001*
Stride length	77.95±8.01	79.50±9.84	0.039*	82.35±6.29	86.35±8.77	0.008*
Cadence	99.70±6.01	104.25±5.96	0.003*	100.50±2.80	107.40±3.30	0.000*
Velocity	46.42±4.76	47.80±4.04	0.006*	44.82±5.14	50.47±4.68	0.002*
Stance %	64.30±3.45	62.50±2.91	0.015*	66.25±4.23	60.60±2.37	0.001*
*Step length, step width and stride length expressed in (centimeters), cadence as (step/minute), velocity as (meter/minute), * significant*						

Table 4: Pre and post treatment mean values of stability indices for both groups

Postural Stability		Control group	Experimental group	p-value
A-P stability	Pre	4.08±0.52	3.78±0.42	0.085
	Post	3.54±0.81	3.10±0.30	0.017*
	p-value	0.046*	0.001*	
M-L stability	Pre	3.75±0.45	3.57±0.47	0.171
	Post	3.45±0.47	3.10±0.35	0.015*
	p-value	0.012*	0.011*	
Overall stability	Pre	4.45±0.65	4.14±0.70	0.093
	Post	4.06±0.45	3.59±0.49	0.005*
	p-value	0.003*	0.002*	
** significant*				

Table 5: Parents reported HRQL for both groups.

HRQL measures		Control group		Experimental group		p-value
		Median	IQR	Median	IQR	
Physical health	Pre	58.5	51.2 – 67.7	55.5	50.3 – 63.8	0.330
	Post	64.5	54.3 – 71.8	68.6	65.2 – 76.5	0.039*
	p-value	0.035*		0.001*		
Psychosocial health	Pre	68.5	57.5 – 69.5	71.2	66 -79.5	0.176
	Post	70.2	65.1 – 77.3	78.9	75.7 – 83.4	0.009*
	p-value	0.004*		0.001*		
Total score	Pre	64.2	58 - 69.5	63.9	61.6 – 67.7	0.882
	Post	68.6	62.6 – 71.4	75.3	71.5 – 79.6	0.001*
	p-value	0.002*		0.001*		
*IQR: Interquartile rank, * significant*						

CONCLUSION

Upon the findings of the present study, it could be concluded that integrated proprioceptive and visuomotor rehabilitation program has the potential to improve gait function, postural stability and HRQL of diplegic children.

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REFERENCES

[1] Hagglund G, Lauge-Pedersen H, Wagner P. Characteristics of children with hip displacement in cerebral palsy. BMC Musculoskelet Disord. 2007;8(1):1.
[2] Novacheck TF, Stout JL, Tervo R. Reliability and validity of the Gillette Functional Assessment Questionnaire as an outcome measure in children with walking disabilities. J Pediatr Orthop. 2000;20(1):75-81.
[3] Rodda J, Graham HK. Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm. Eur J Neurol. 2001;8 Suppl 5:98-108.
[4] Effgen SK, Magee S, Scalzo K. Meeting the physical therapy: needs of children. Rio de Janeiro, RJ: Guanabara Koogan. 2007:159-208.
[5] Winter DA, Patla AE, Frank JS. Assessment of balance control in humans. Med Prog Technol. 1990;16(1-2):31-51.
[6] Rha DW, Kim DJ, Park ES. Effect of hinged ankle-foot orthoses on standing balance control in children with bilateral spastic cerebral palsy. Yonsei Med J. 2010;51(5):746-52.
[7] Elnaggar RK. Static and Functional Balance in Diplegic Children Submitted to Botulinum Toxins Type A and Reciprocal Electrical Stimulation. Int J Physiother Res. 2014;2(1):372-77.
[8] Shvarkov SB, Davydov OS, Kuuz RA, Aipova TR, Vein AM. New approaches to the rehabilitation of patients with neurological movement defects. Neurosci Behav Physiol. 1997;27(6):644-7.
[9] Semenova KA. Basis for a method of dynamic proprioceptive correction in the restorative treatment of patients with residual-stage infantile cerebral palsy. Neurosci Behav Physiol. 1997;27(6):639-43.
[10] Elshafey MA. Efficacy of Postural Correction Suit on Gait Parameters and Executive Mobility Activities in Diplegic Children. Int J Physiother Res. 2014;2(3):495-01.
[11] Wang M, Reid D. Virtual reality in pediatric neurorehabilitation: attention deficit hyperactivity disorder, autism and cerebral palsy. Neuroepidemiology. 2011;36(1):2-18.
[12] Schneider JW, Gurucharri LM, Gutierrez AL, Gaebler-Spira DJ. Health-related quality of life and functional outcome measures for children with cerebral palsy. Dev Med Child Neurol. 2001;43(9):601-8.
[13] Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, et al. A report: the definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl. 2007;109(suppl 109):8-14.
[14] WHO. The World Health Organization quality of life assessment (WHOQOL): position paper from the World Health Organization. Soc. Sci. Med. 1995;41(10):1403-9.
[15] Dickinson HO, Parkinson KN, Ravens-Sieberer U, Schirripa G, Thyen U, Arnaud C, et al. Self-reported quality of life of 8-12-year-old children with cerebral palsy: a cross-sectional European study. Lancet (London, England). 2007;369(9580):2171-8.

[16] Varni JW, Limbers CA, Burwinkle TM. Parent proxy-report of their children's health-related quality of life: an analysis of 13,878 parents' reliability and validity across age subgroups using the PedsQL™ 4.0 Generic Core Scales. Health Qual Life Outcomes. 2007;5(1):1.
[17] Pountney TE, Mulcahy C, Green E. Early development of postural control. Physiotherapy. 1990;76(12):799-802.
[18] Boyd RN, Pliatsios V, Starr R, Wolfe R, Graham HK. Biomechanical transformation of the gastroc–soleus muscle with botulinum toxin A in children with cerebral palsy. Dev Med Child Neurol. 2000;42(01):32-41.
[19] Damiano DL, Martellotta TL, Sullivan DJ, Granata KP, Abel MF. Muscle force production and functional performance in spastic cerebral palsy: relationship of cocontraction. Arch Phys Med Rehabil. 2000;81(7):895-900.
[20] Girolami GL, Shiratori T, Aruin AS. Anticipatory postural adjustments in children with hemiplegia and diplegia. J Electromyogr Kinesiol. 2011;21(6):988-97.
[21] Kalirathinam D, Arumugam J. Gait training On Spastic Diplegic children-A physiotherapy Approach. Journal of Nursing and Health Science (IOSR-JNHS) ISSN.2320-1959.
[22] Varni JW, Burwinkle TM, Sherman SA, Hanna K, Berrin SJ, Malcarne VL, et al. Health-related quality of life of children and adolescents with cerebral palsy: hearing the voices of the children. Dev Med Child Neurol. 2005;47(9):592-7.
[23] Arnaud C, White-Koning M, Michelsen SI, Parkes J, Parkinson K, Thyen U, et al. Parent-reported quality of life of children with cerebral palsy in Europe. Pediatrics. 2008;121(1):54-64.
[24] Turner AE. The efficacy of Adeli suit treatment in children with cerebral palsy. Dev Med Child Neurol. 2006;48(05):324-.
[25] Liptak GS. Complementary and alternative therapies for cerebral palsy. Ment Retard Dev Disabil Res Rev. 2005;11(2):156-63.
[26] Rosenbaum P. Controversial treatment of spasticity: exploring alternative therapies for motor function in children with cerebral palsy. J Child Neurol. 2003;18(1 suppl):S89-S94.
[27] Bar-Haim S, Harries N, Belokopytov M, Frank A, Copeliovitch L, Kaplanski J, et al. Comparison of efficacy of Adeli suit and neurodevelopmental treatments in children with cerebral palsy. Dev Med Child Neurol. 2006;48(5):325-30.
[28] Sveistrup H. Motor rehabilitation using virtual reality. J Neuroeng Rehabil. 2004;1(1):1.
[29] Kott K, Lesher K, DeLeo G. Combining a virtual reality system with treadmill training for children with cerebral palsy. J Cyber Ther Rehabil. 2009;2(1):35-43.
[30] Brien M, Sveistrup H. An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy. Pediatr Phys Ther. 2011;23(3):258-66.
[31] You SH, Jang SH, Kim Y-H, Hallett M, Ahn SH, Kwon Y-H, et al. Virtual reality–induced cortical reorganization and associated locomotor recovery in chronic stroke an experimenter-blind randomized study. Stroke. 2005;36(6):1166-71.