Faculty Of physical Therapy
Cairo University

Cairo University

A Sensorimotor Program for Improving Kinematic Gait Parameters in Diplegic Children

Nahla M.Ibrahim[1], Kamal E. Shoukry[1], Nanees E. Mohamed[1]

[1]Department of Physical Therapy for Disturbance of Growth and Development in Children and itsSurgery, Faculty of PhysicalTherapy, Cairo University, Egypt

ABSTRACT

Background: Improvement or maintenance of walking ability in children with spastic cerebral palsy is a primary goal of most therapeutic interventions.**Purpose**: The purpose of this study was to determine the effect of a sensorimotor program on kinematic gait parameters in diplegic children. **Materials andMethods:**Thirty spastic diplegic cerebral palsy children from both sexes participated in this study, their ages ranged from 10 to 12 years.They were divided randomly and equally into two groups: control and study. Control group received a designed physical therapy program included gait training exercises, whilestudy group participated in the same designed physical therapy program with gait training exercise based on sensorimotor program. Treatment was applied for three successive months for both groups. The average speed and average step length were assessed using the Biodex gait trainer for children of both groups before and after three successive months of treatment. **Results:**2x2 Mixed Design MANOVA showed non-significant improvement in the average step length and speed in control group, while statistically significant improvement was recorded in the measuring variables for the study group. **Conclusion:**It may be concluded that gait training exercise program based on sensorimotor approach may result in positive outcomes in kinematic gait parameters including step length and speed.

Keywords: Spastic Diplegia, Kinematic Gait Parameters, Biodex Gait Trainer II, Sensorimotor.

INTRODUCTION

Cerebral palsy (CP) is a heterogeneous group of permanent, non-progressive motor disorders of movement and posture caused by chronic brain injuries that originates in the prenatal, perinatal, or postnatal period [1]. It is also the clinical presentation of a wide variety of cerebral cortical or sub-cortical insults which appears early in life and is considered as the most common cause for children handicapping representing nearly 2 per 1000 live births [2]. There are many categories and types of CP (spastic, hypotonic, athetoid and mixed type).The spastic type is the most common type of CP[3].Spastic diplegic children have increased tone in theirlower extremities while their upper extremities are usually affected to some less degree[4].Diplegic children have difficulty in independent standing, they start walking with narrow base of support, cannot abduct their legs and cannot walk sideways also they have no standing balance without support as their lower limbs show a mixed pattern of flexor and extensor spasticity that is as co-contraction makes balance difficult [5].

Children with spastic diplegia can walk independently but with abnormal pattern which may include deviations such as toe walking, flexed-stiff knees, flexed hips and an anteriorly tilted pelvis with lumbar lordosis. They walk at a reduced speed, with increased energy expenditure when compared with their peers [6]. In order to improve walking abilities in children with spastic diplegia, therapists usually emphasize on tone inhibiting maneuvers, balance training and gait preparatory tasks during crawling, sitting, and standing[7].

Gait is a complex process characterized by rhythmic, cyclic, alternating movements of the legs and arms. However, gait also requires the movement of other body segments, since the single- and dual-stance actions of the legs is associated with slight rotations of the head and the trunk around the anteroposterior and mediolateral axes [8]. Walking is the most functional human movement. Stability in stance, sufficient foot clearance in swing, appropriate pre-positioning of the foot for initial contact, adequate step length and energy conservationis essential for normal gait.Defects in them have

gait impairment, or the inability to walk or walking with abnormal pattern [9, 10].

Sensory system is responsible of receiving different sensory information from the body, the environment and surroundings that help the brain to receive this information, and interpret them to organize the purposeful responses[11].Sensory integration refers to the ability of the brain to interpret external stimulus such as sight, sound, touch, movement, and body awareness, then organize them into functional outcome [12]. Sensory integration dysfunction occurs when a person's brain cannot organize sensory input messages from the skin, muscles and joints, inner ear and the environment [13]. Sensory integration therapy helps children to improve their sensorimotor skills, by combining different forms of sensation (vestibular, proprioceptive, and tactile stimulation) with motor activity during an individual therapy [14].

Occupational therapists use music as preparation for therapeutic activities on the basis of the sensory input through the auditory system can be organizing to children.Extensive musical training resulted in multi-regional changes in the brain (gray matter). Even simple movements, repeated over a short period of time, are effective in inducing cortical representational changes [15,16,17]. The aim of the present study was to determine the effect of a sensorimotor program for improving kinematic gait parameters in diplegic children.

MATERIALS AND METHODS

Subjects

Upon approval of Cairo University's supreme council of postgraduate studies and research,ethical approval was granted from the University Ethical Committee prior to the commencement of the study. Thirty spastic diplegic CP children of both sexes (14 boys and 16 girls)with ages ranged from 10 to 12 years were divided randomly and equally into two groups(using computer programming);control and study group.They were selected from the outpatient clinic, Faculty of Physical Therapy, Cairo University.

Subjects were included if they had gait problems identified by Gross Motor Function Classification System (GMFCS) (Level II or III). Their heights were more than one meter to be able to see the screen of the Biodex Gait Trainer 2TM. They had abnormal gait kinematics assessed by Biodex Gait Trainer 2TM. They have normal visual and auditory functions and able to follow the instructions. Subjects were excluded ifthey had convulsions,history of surgical interferenceor IQ below 65 according to Stanford Binet test. Informed consent was obtained from all subject's parents prior to their voluntary participation in the study.

Instrumentation

For Evaluation

a. A universal weight and height scale was used to determine the children's weight and height in both control and study groups.Data were entered to the Gait Trainer 2 to determine the defaults of study parameters.

b. Biodex Gait Trainer 2TM

Biodex Gait Trainer 2TM is a device used to assess and train walking performance. It is composed of a treadmill with an instrumented desk that monitors and records kinematic gait parameters including: average step length (m)"linear distance from one heel to successive another heel", and average walking speed (m/sec) "how quickly a person can complete a stride"[18].

For Treatment

a. Square Puzzle Mat

Two different size square puzzle foam mat (total length 150 cm× 60 cm width and 125 cm length× 50 cm width). They consisted of ten puzzle foam square (each square is 30 cm×30 cm and 25 cm × 25 cm, respectively) attached to each other's. Every puzzle square contains a number from 0 to 9, with different colors: red, blue, yellow, orange, green and purple.The colors of numbers are different from squares colors. That contrast in colors provided visual feedback that enabled the child concentrate more in the target foot position.These divided squares helped the child to correct his step length, width and velocity by giving visual feedback during his walk. Different small rubber musical toys were added above the numbers on the mat to allow auditory feedback when the child pressed on them.

b. Twist and move playmat (Square Musical Playmat)

Twist and move playmat is a musical square playmat, contains 20 squares with five different shapes (star, diamond, heart, circle and rectangle). Squares differ in shapes andcolorswith white borderline e.g. the star square is purple, the diamond is yellow, the heart is blue, the circle is green and the rectangle is red. Also there was an auditory feedback provided when the child pressed correctly on each shape (the name of the shape was heard by the child when he pressed down correctly on the shape) i.e. when the child pressed on the heart shape, he could hear "heart" as a voice feedback. Those visual and auditory feedbacks could help the child to correct his step length.

Procedure

For Evaluation

Biodex Gait Trainer 2TM

The assessment conducted for each child of both groups individually before and after three successive months of treatment. The protocol of the work explained to children before conducting this study. Each child was asked to perform two test trials before specific teststo befamiliar with the instrument. Each child was instructed to walk over the gait

trainer and to follow the tread belt movement for three to five minutes.

To start the evaluation process, the tread belt was ramp up slowly. The speed setting then increased gradually to a comfortable speed. Once the child was comfortable, the data recording was started. Each child was allowed to walk continuously for three minutes, then the evaluation session was ended and the gait trainer was slow down gradually until it stops. The results then were displayed on the display screen. That procedure was repeated three times (with a rest period in between) and the average was taken for each gait parameter.

For Treatment

Children of both groups received the designed physical therapy exercise program included gait training exercises. While study group participated in gait training exercise based on sensorimotor approach. For both groups treatment was applied one and half hours three times weeklyfor three successive months.

Physical therapy exercises program included gentle passive stretching to hamstring and calf muscles, facilitation of dynamic standing, stoops and recover from standing position, balance training exercises, ascending and descending stairs.

Gait training exercises for control group included walk between parallel bars, using stepper, using obstacles, and walk in open environment.

Gait training based on sensorimotorapproach:

Study group participated in gait training exercise with different visual and auditory feedback.

a- Square puzzle mat:

1-Gait training with visual feedback:

Children of the study group were asked to stand in front of the square puzzle mat then start walking while looking at the mat by pressing the right foot on the first number at the right side (for example number 0) and the left foot on the number at the left side (for example number 1).Then they were asked to press their right foot on the next number and follow it by the left foot. Different colors numbers of the squares puzzle mat could help the child to use his visual sense as a visual feedback to correct his motor output (correct position of the foot on the target number helped the child to correct his step length, and speed with each foot pressed correctly on each number). Then exercise was progressed to make the child increase his step length by pass a square and press at the next one.Also children were instructed to use reciprocal arm movement while walking to improve walking pattern.

2- Gait training with visual and auditory feedback:

Different small rubber musical toys were added to the different numbers of square puzzle mat.Then children of the study group were asked to walk correctly while pressing down on each toy over the number which allow visual and auditory feedback when the child press correctly on the target toy.

b-Twist and move playmat(Square Musical Playmat)

Childrenof the study group were asked to walk on the musical playmat while looking at its shapes (visual feedback) and then press their foot down on the target shape (for example red rectangle by the right foot then the left foot on the other red rectangle). Correctly pressing down the target shape correctly gave them auditory feedback by hearing the name of the shape (rectangle for example). Controlled step length, and speed could be achieved by selecting the target shape and square, therapist verbal commands could help the child to control his step length, and increase or decrease the walking speed.

2.4 Data Analysis

All statistical measures were performed through the Statistical Package for Social Studies (SPSS) version 18 for windows, (SPSS, Inc., Chicago, IL). Prior to final analysis, data were screened for normality assumption, homogeneity of variance, and presence of extreme scores. This exploration was done as a pre-requisite for parametric calculations of the analysis of difference.

The current test involved two independent variables. The first one was the (tested group); between subjects factor which had two levels: control group and study group. The second one was the (training periods); within subject factor which had two levels (pre, post). In addition, this test involved three tested dependent variables (average speed, right step length, and left step length). Accordingly, 2x2 Mixed Design MANOVA was used to compare the tested variables of interest at different tested groups and training periods. 2x2 Mixed Design MANOVA was conducted to compare average speed, right step length, and left step length between both groups in the "pre" and "post" tests. In addition, it was intended to compare between the "pre" and "post" tests for each variable at each tested groups and finally test the interaction between the two independent variables (tested group & time factor). The alpha level was set at 0.05 for analysis.

RESULTS

Baseline characteristics of the subjects are shown in **Table 1**. No statistically significant differences existed between groups recording age, height, weight, and IQ level.

Table 1: Demographic characteristics of subjects

	Control group No.=15	**Study group No.=15**	**t-value**	**p-value**	**S**
	$\overline{X}$ **±SD**	$\overline{X}$ **±SD**			
Age (years)	10.76± 0.67	10.93±0.86	-0.588	0.561	NS

Weight (kg)	22.02± .93	21.56±1.09	1.215	0.234	NS
Height (cm)	137.2±0.94	137.33±1.17	-0.343	0.734	NS
IQ	80.06± 6.82	82.53±6.85	-0.987	0.332	NS

(*) Significant where alpha level of significance is set at p< 0.05

Statistical analysis using 2x2 Mixed Design MANOVA indicated that there was insignificant effects of the tested group (the first independent variable) on the three tested dependent variables; average speed, right step length, and left step length (F= 1.265, P=0.312). However, there were significant effects of the training periods (the second independent variable) on the three tested dependent variables; average speed, right step length, and left step length(F= 34.731, P<0.001*). Also, the interaction between the two independent variables was significant, which indicates that the effect of the tested group (first independent variable) on the dependent variables was influenced by the training periods (second independent variable) (F= 22.683, P<0.001*).

Regarding the average step length, Multiple pairwise comparison tests (Post hoc tests) revealed that the mean values of the "pre" test between control group and study group showed there was no significant differences in both right and left sides (P=0.764, P=0.248) respectively. However, they revealed that the mean values of the "post" test between both groups showed there was a significant reduction of right and left step length in favor of study group (P=0.006*, P=0.005*) respectively.

When comparing the pre and post treatment mean values of right and left sides in control group statistically analysis revealed that there was no significant difference (p=0.939, p=0.422), respectively. While, in the study group when comparing the pre and post treatment mean values of right and left sides statistically analysis revealed that there was a significant reduction of both right and left step length (P<0.001*, P=0.005*), respectively,(Table 2, Figure 1)

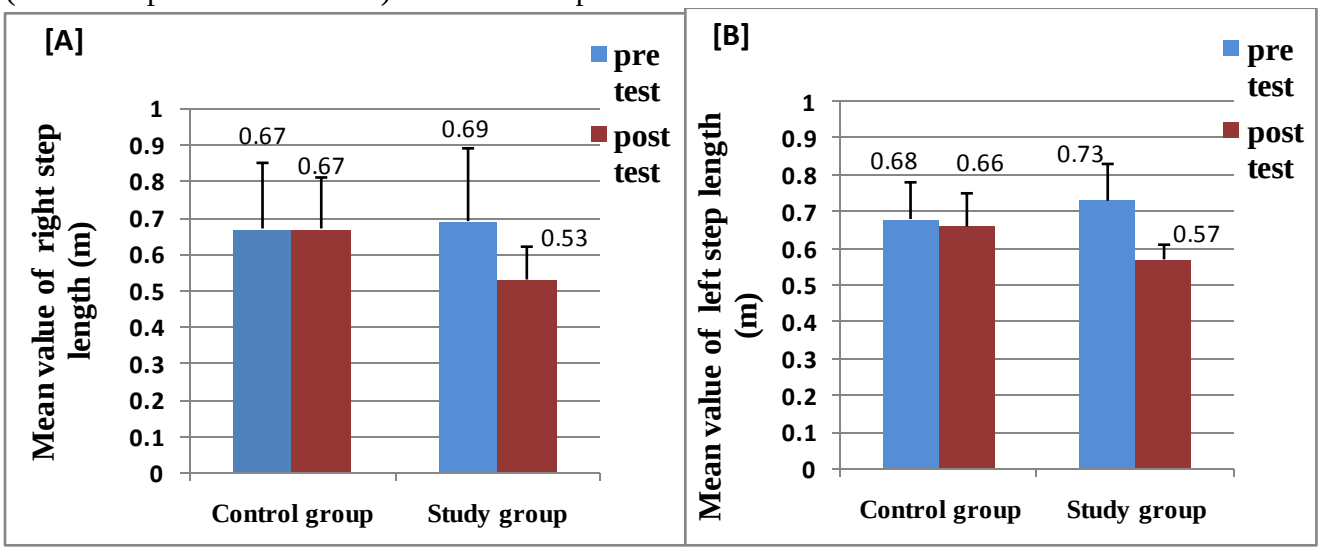

Figure (1): Mean values of step length (m) pre and posttest in control and study groups.[A] Right step length. [B] Left step length.

Considering the average speed, Multiple pairwise comparison tests (Post hoc tests) revealed that the mean values of the "pre" test between control group and study group showed there was no significant differences (P=0.135). However, they revealed that the mean values of the "post" test between both groups showed there was a significant increase of average speed in favor of study group (P<0.001*).

When comparing the pre and post treatment mean values in control group statistically analysis revealed that there was no significant difference (P=0.107). While in the study group, when comparing the pre and post treatment mean values statistically analysis revealed that there was a significant increase of average speed (P<0.001*), (Table 2, Figure 2

Table 2: Pre and post treatment mean values of average steplength (m) and average speed (m/sec) in both control and study groups

	Average Step Length (m)		Average Speed (m/sec)	
	Control Group No.=15	Study Group No.=15	Control Group	Study Group

	Right $\overline{X}$ (SD)	Left $\overline{X}$ (SD)	Right $\overline{X}$ (SD)	Left $\overline{X}$ (SD)	No.=15 $\overline{X}$ (SD)	No.=15 $\overline{X}$ (SD)
Pre treatment	0.67 (0.18)	0.68 (0.1)	0.69 (0.2)	0.73 (0.1)	0.39 (0.06)	0.36 (0.04)
Post treatment	0.67 (0.14)	0.66 (0.09)	0.53 (0.09)	0.57 (0.04)	0.41 (0.05)	0.51 (0.05)
% of improvement	0	0	23.18	23.18	5	41.66
P-value	0.939	0.422	< 0.001*	0.005*	0.107	< 0.001*

(*) Significant where alpha level of significance is set at p< 0.05.

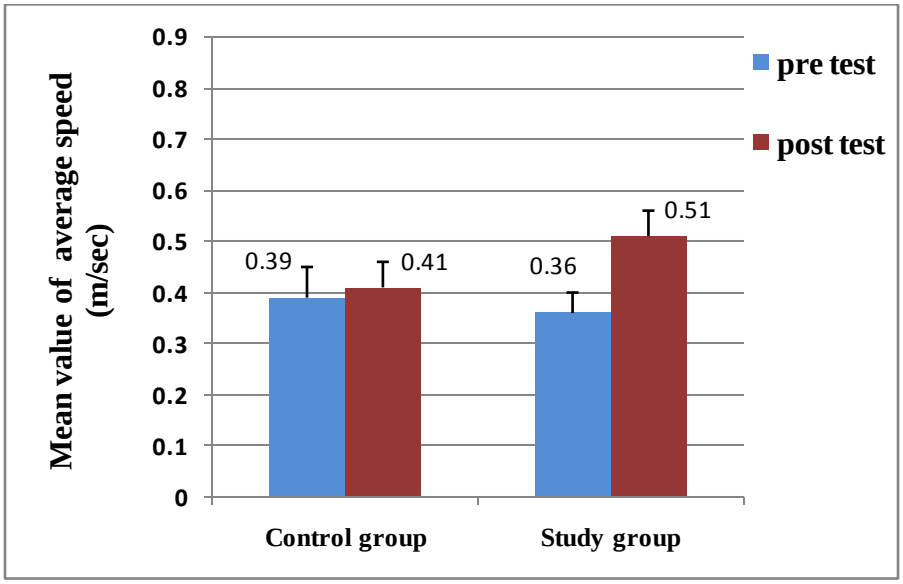

Figure (2): Mean values of average speed (m/sec) pre and posttest in control and study groups.

DISCUSSION

Cerebral palsy is a syndrome of non-progressive disturbances in the developing fetal or infant's brain. It is characterized by increased muscle activity to sustain posture, co-contraction of agonist/antagonist muscles, and restricted voluntary and selective control of movement which interferes with both the performance of functional activities, and the participation in leisure, community and school activities [19]. The most common form of CP is spastic diplegia and in this form both legs are more involved than the arms so that walking ability is affected [20]. The imbalance of muscle strength and tone causes muscle weakness and atrophy over time, as well as soft tissue contracture and eventual joint deformity [21]. Children with spastic diplegia typically walk slowly and have difficulty in performing activities such as walking up and down steps or running. The most common gait patterns are characterized by excessive knee and hip flexion, implicating weakness of the ankle plantar flexors, knee extensors, and hip extensors. They usually walk independently but most have gait disorder that is known as spastic diplegic gait. This gait disorder makes them walk at a decreased speed with high energy expenditure and restricted functional capability when compared with their healthy peers[22]. Improving the ability to walk or perform other functional activities is often the primary therapeutic goal for spastic diplegic children [23].

Gait represents the manner of walking. Formally it uses a repetitive sequence of limb motion to move the body forward while simultaneously maintaining stance stability[24].In the child, balance control and independent gait develop with motor learning, as the body ages and the structures involved mature. Gait is thus both an ontogenetic process and the product of a learning process that is generally interpreted as a marker of the child's physical and neurological integrity. In fact, gait requires certain levels of bone strength, muscle tone and center nervous system maturity [25].

This study aimed to investigate the effect of gait training exercises using sensorimotor approach on selected gait parameters (step length and speed) in diplegic cerebral palsied children. Subjects contact their environment and become aware of themselves and their emotions through their senses (seeing, hearing, smelling, tasting and touching) [26]. Sensory integration is a process by which information from our senses is interpreted by the brain so that we can respond to our environment in an organized way. For most of us effective sensory integration occurs automatically, subconsciously and effortlessly [27].

As managing children with CP the physical therapy aimed to promote motor learning through motor and functional

training with multiple sensory stimuli. Different approaches have been used to favor selective control and the coordination of muscle contractions during gait [28].

The use of sensory feedback (visual and auditory) by different shapes and colors on the play and puzzle mat which was distributed at equal distance resembling equal length for the child step, also the auditory feedback by the musical toys placed on the puzzle mat contributed to the significant improvement observed in the study group when comparing the pre and post results of the measured variables,that may be as a result of the central nervous system abilities to organize different sensory input (vision, hearing and touch) to improve the motor output and the execution of function [29].Also the motor learning process that help the child to learn specific task by repetitive practice, that was done by teaching the child to take his step by certain pattern, and control his speed by controlling his step [30].

The use of auditory feedback by the hearing the name of the shape when the child put his foot correctly in the target shape, help to improve the attention and arousal level for the children, that could improve their sensory motor coordination.It could be reflected in improving the step length and speed. According to Frick and Hacker[31] the therapeutic-listening program influences children's arousal and potentially enhances spatial–temporal organization resulting in improvements in task attention, visual–motor skills, handwriting, and timing of coordinated movements as part of a sensory integrative approach.Also, itmay prepare the child to attend to and focus on perceptual–motor activities.

The multiple repetitions of the steps of the gait cycle in a rhythmic pattern, may improve control between agonist and antagonist muscles and resulting in improved functional and static balance, gait speed and endurance, and gross motor function [32].Also gait training might stimulate sensorimotor system toward regaining normal function by facilitating weight-bearing to improve limb alignment [33].

Auditory cues are one of the most common treatment modalities used in neurological rehabilitation [34],possibly because the sound cue improves attention and guides movements.A neurologic technique used the physiological effects of auditory rhythm on the motor system.It was used to improve the control of movement in rehabilitation and therapy. It is mostly used in gait therapy to aid in the recovery of functional, stable, and adaptive walking patterns in patients with significant gait deficits [35].Music has long been known to have therapeutic value in recent years, occupational therapists, speech-language pathologists, and psychologists have adopted the use of music and sounds as therapy, and a variety of auditory intervention techniques have become available [36].Non-significant improvement noticed in the control group when comparing their pre and post treatment results might be due to the lack of improvement in the step length which could be due to the lack of the environmental stimulation that help improving motor process.

Finally the significant improvement in step length and speed came in agreement withWall et al.[37] who reported that walking speed is a function of both cadence and step length. Changes in walking speed are usually linked to changes in both step length and cadence. An increase in either cadence or step length contributes to increase walking speed. Also,it came in agree withDamiano et al.[38] who reported also that both stride length and cadence are linearly related to speed.

Limitation

The limitation of this study was that the small sample size as all subjects must have the cognitive ability to recognize different numbers, shapes and colors.

CONCLUSION

In this study, it was concluded that gait training based on sensorimotor program (using visual and auditory feedback) is effective in improving selected gait parameters in children with spastic diplegia.

CONFLICT OF INTEREST STATEMENT

There are no potential conflict of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

REFERENCES

[1] **Kothari R, Singh R, Singh S, Jain M, Bokariya P, Khatoon M**. Neurophysiologic findings in children with spastic cerebral palsy. J Pediatr Neurosci 2010;5:12–7.

[2] **Jan MMS.** Cerebral palsy: comprehensive review and update. Ann Saudi Med 2010;26:123–32.

[3] **Soleimani F, Vameghi R, Rassafiani M, Akbar Fahimi N, Nobakht Z.** Cerebral Palsy: Motor Types, Gross Motor Function and Associated Disorders. Iran Rehabil J. 2011;9:21-31.

[4] **Morrissy RT,Weinstein SL.** Pediatric orthopedics. 5th ed.PP,741-750,565-575,2001**.**

[5] **Damiano DL, Kelly LE,Vaughn CL.**Effect of quadriceps femoris muscle strengthening on crouch gait in children with spastic diplegia. Phys.Ther1995;75 (8):658-57.

[6] **Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R**. Sagittal gait patterns in spastic diplegia. J Bone Joint Surg Br 2004; 86:251–258.

[7] **Schindle-Ivens S,Shields PK.** Low frequency depression of H-reflex in humans with acute and chronic spinal cord injurey. Exp Brain Res2000; 133:233-241.

[8] **Imai T, Moore ST, Raphan T, Cohen B.** Interaction of the body, head, and eyes during walking and turning. Exp Brain Res 2001;136(1):1–18.

[9] **Rowland L.** Gait disorders: In: Merritt's Neurology (Lippincott, ed). Philadelphia: Williams and Wilkins, 1st ed. Baltimore, New York, PP:45-50,2000.

[10] **Gage J.**A qualitative description of normal gait. In: Gage J (Ed.). The Treatment of Gait Problems in Cerebral Palsy. London: Mac Kieth Press. PP: 42-70**,** 2004.

[11] **Krantz J.** Experiencing Sensation and Perception. Pearson Education, Limited. p. 12.3, 2009.

[12] **Heilbroner P.** Why "Sensory Integration Disorder" Is a Dubious Diagnosis. Quackwatch. May 1,2005.

[13] **Heller S.** Too loud too bright too fast too tight. New York: Quill2003.

[14] **Salokorpi T, Rautio T, Kajantie E, et al.**Is early occupational therapy in extremely preterm infants of benefit in the long run? Pediatr Rehabil 2002;5(2):91-98.

[15] **Frick SM, Hacker C.***Listening with the whole body.* Madison, WI: Vital Links, 2001.

[16] **Gaser C, Schlaug G.**Brain structures differbetween musicians and non-musicians. J. Neurosci2003; 23: 9240–9245.

[17] **Classen J, Liepert J, Hallett M, CohenL.**Plasticitv of movement representation in the human motor cortex.Electroencephalogr Clin Neurophysiol Suppl 1999; 51: 162–173.

[18] **Gharib NM, AbdElMaksoud G,Rezk-Allah SS.** Efficacy of gait trainer as an adjunct to traditional physical therapy on walking performance in hemparetic cerebral palsied children: a randomized controlled trial, Clin. Rehab 2011; 25: 924 – 934.

[19] **Prosser LA, Lee SC, VanSant AF, Barbe MF, Lauer RT.** Trunk and hip muscle activation patterns are different during walking in young children with and without cerebral palsy. Phys Ther2010; 90(7):986-97.

[20] **Watt JM, Robertson CMT, Grace MGA.** Early prognosis for ambulating of neonatal survivors with cerebral palsy. Dev Med Child Neurol 1989;31:766–73.

[21] **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 Pediatric Orthop 2000;20:75–81.

[22] **Karen J , Dodd .**A randomized clinical trial of strength training in young people with cerebral palsy. Developmental Medicine & Child Neurology2003**;**45:652-657.

[23] **Koman LA, Smith BP, Shilt JS.** Cerebral palsy. Lancet 2004;363:1619–31.

[24] **Kharb A, Saini V, Jain YK, Dhiman S.** A reviewofgait cycle andits parameters. International Journal of Computational Engineering & Management, 2011; Vol. 13, July.

[25] **Ledebt A, Bril B.** Acquisition of upper body stability during walking in toddlers. Dev Psychobiol 2000;36(4):311–24.

[26] **Schoeman JP.** Building a Therapeutic Relationship, Assessment and Treatment Planning. In Blom, R. The Handbook of Gestalt Play Therapy.Practical Guidelines for Child Therapists. London: Jessica Kingsley Publishers 2006.

[27] **Richardson M, Domingos P.** Building large knowledge bases by mass collaboration. Proceedings of the Second International Conference on Knowledge Capture (pp. 129–137). Sanibel Island, FL: ACM Press 2003.

[28] **Chagas PSC, Mancini MC, Barbosa AP, Silva PTG.**Analysis of the interventions used for gait promotion in children with cerebral palsy: a systematic review of the literature. Rev Bras Fisioter 2004; 8(2):155-63.

[29] **Shumway-Cook A, Woollacott MH.**Motor Control: Theory and Practical Applications, 2nd ed.; Lippincott Williams & Wilkins: Philadelphia, PA, USA, 2001.

[30] **Levitte S.** Treatment of cerebral palsy and motor delay.4th ed. Blackwell publishing, PP: 1-15 2004.

[31] **Frick SM, Hacker C.** Listening with the whole body. Madison, WI: Vital Links.Graphics-based model of the lower extremity to study orthopaedic surgical procedures. IEEE Trans Biomed Eng 2001; 37:757–767.

[32] **Johnston TE, Watson KE, Ross SA, Gates PE, Gaughan JP, Lauer RT.** Effects of a supported speed treadmill training exercise program on impairment and function for children with cerebral palsy. Dev Med Child Neurol2011;53(8):742-50.

[33] **Ghalwash MA, El-Shennawy SAW, Abd-Elwahab MS.** Efficacy of adhesive taping in controlling genu recurvatum in diplegic children: a pilot study Egypt J Med Human Genet 2013;14 pp. 183–188

[34] **Lim I, van Wegen E, de Goede C, Deutekom M, Nieuwboer A.** Effects of external rhythmical cueing on gait in patients with Parkinson's disease: a systematic review. Clin Rehabil 2005; 19: 695-713.

[35] **Thaut MH.** Rhythm, music, and the brain: Scientific foundations and clinical applications. NY. Routledge 2005.

[36] **Ferguson SL, Voll KV.** Burn pain and anxiety: The use of music relaxation during rehabilitation. Journal of Burn Care and Rehabilitation 2004; 25(1), 8–14.

[37] **Wall JC.** Walking, In: Durward BR, Baer GD and Rowe PJ: Functional human movement: measurement and analysis. Butterworth Heinemann, Oxford, PP: 94-105 2000.

[38] **Damiano DL, Kelly LE, Vaughn CL.**Effect of quadriceps femoris muscle strengthening on crouch gait in children with spastic diplegia. Phys.Ther 1995;75 (8):658-667.