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Full Length Research Paper

Efficacy of insole foot stimulation in improvement standing equilibrium in hemiplegic C. P. Children

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The aim of this work was to investigate the Efficacy of insole foot stimulation in improvement of standing equilibrium in hemiplegic C .P. children. Thirty children were enrolled in this study and randomly assigned into two groups; group A (foot stimulation plus traditional physiotherapy program), and group B (traditional physiotherapy program only). GMFM was used to evaluate and follow standing equilibrium development also stopwatch was used to detect and follow stability of standing balance. This measurement was taken before treatment and after 12 weeks of treatment for all patients. The children parents in both groups A and B were instructed to complete 3 hours of home routine program. Data analysis were available on the 30 hemiplegic cerebral palsy children participated in the study. No significant difference was recorded between the mean values of all parameter of the two groups before treatment. By comparison of the two groups results after treatment there was significant improvement in GMFM in favor of the study group. The difference between pre and post treatment results of each group was significant. According the results of this study supported by the relevant literature it can be concluded that the combined effect of physiotherapy training program in addition to foot insole stimulation can be recommended in improvement of standing balance in hemiplegic cerebral palsy children.

Keywords: Insole foot stimulation- standing equilibrium - hemiplegic C. P.

INTRODUCTION

Balance is the ability to maintain equilibrium by positioning the centre of gravity over the base of support. it changes according to changes in positions and movements of the body segments. Postural adjustments occur in order to maintain equilibrium. These postural adjustments which maintain balance are known as equilibrium reactions which carried out by a complex process involving afferents from the sensory system, integration of the afferents by the central nervous system (CNS), and the efferents being sent from the CNS to the musculoskeletal system. Balance is affected when part of the control system is not working correctly for example if the vestibular system is damaged or if the CNS is not integrating the information correctly (Wenson, 2008).

Impaired postural control is a key characteristic of the mobility problems in hemiplegic children and is caused by a complex interplay of motor, sensory, and cognitive impairments. in addition to reduced loading on the paretic lower limb, increased postural sway during quiet standing

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as well as delayed and disrupted equilibrium reactions and impaired anticipatory postural adjustments to body perturbations, especially in the affected leg. Together with a general slowness of information processing this combination of postural deficits causes slow and inflexible motor behavior during various activities of daily life (Shumway et al., 1988).

Stroke is a major cause of postural imbalance in terms of static (eg, weight distribution, foot-pressure distribution) and dynamic (eg, equilibrium reactions ,weight shifting control). Although stroke patients may suffer from postural instability in all planes .Frontal plane balance is disproportionally affected because the ability to initiate and control voluntary weight shifts toward either leg is a prerequisite for independent walking, learning to load and unload the affected leg while standing is an important step in the balance and gait training of stroke patients. Hence, making self-generated weight shifts in the frontal plane within the base of support seems an essential ability to train and monitor in these patients (Winstein et al., 1989).

The foot is an anatomical wonder: with 26 bones, 33 joints, over 100 muscles and ligaments, tendons and fascia, evolution has clearly produced a remarkable functioning unit of strength and elasticity. In connection with the nervous system and the overlapping cranial muscle groups, the foot forms the prerequisite for an erect body. it is considered the main source of information for sensori-motor signals in the body's information flow. Feet constantly transmit information to the brain and make coordinated movement and posture control. The sensori-motor function of foot includes the recording and processing of bodily sensations as well as the ensuing response of the muscles and the musculoskeletal system to these sensations. The feet present essential basic information in the sensori-motor information flow. They determine the beginning and end of the kinematic chain of functionality (Mizrahi et al., 1989).

MATERIAL AND METHODS

Subjects

Thirty children from both sexes with hemiplegic cerebral palsy children were enrolled for this study, aged 3 to 7 years at time of recruitment because the children in this age are able to participate in graduations tests of GMFM, children are able to stand with support, cannot stand alone. Children who otherwise met the inclusion criteria were excluded if they had: previous BoNT-A injections in the lower limb in the past 12 months or prior lower limb surgery (i.e. tendon transfer/tendon lengthening).

Children randomized to the experimental group (A) received foot insole electrical stimulation plus traditional physiotherapy program. Children randomized to the control group (B) received traditional physiotherapy program only. The individual-based foot insole electrical stimulation treatment sessions of 45 to 60 minutes were conducted three times weekly for 12 weeks in physiotherapy treatment room after the traditional physiotherapy session for group (A). In addition, children in the experimental group were exposed to home routine program 3 hours daily for the 12 week treatment period. Control group (B) received a traditional physiotherapy program only.

Outcome measurements

The clinical evaluation included history, and stage of standing development and balance. All children were assessed for stage of standing development using GMFM and the standing balance by using time stopwatch. All measurements were taken at baseline (pre) and after 12-week of intervention (post).

1-Assessment of standing development stage:

GMFM (GROSS MOTOR FUNCTION MEASURE):

1-On the floor

Pull to stand at large bench.

2-On standing

Maintain arm free 3 seconds.

Holding on to large bench with one hand, lift R foot, 3 seconds.

Holding on to large bench with one hand, lift L foot, 3 seconds

Maintain arm free 20 seconds

Lift L foot, arms free, 10 seconds.

Lift R foot, arms free, 10 seconds

Lowers to sit on floor with control, arms free.

Attain squat arms free.

Picks up object from floor arms free, return to stand

3-Sit on small bench:

Attain standing without using arms

4-High knee:

Attain standing through half kneeling on R knee, without using arms

Attain standing through half kneeling on L knee, without using arms

The GMFM was developed to measure changes in gross motor function over time in children with CP. . The GMFM is a reliable scale to evaluate gross motor function. It measures the child’s skill in lying, rolling, sitting, crawling, kneeling, standing, walking, running, and jumping. It can be used for children from birth to 16 years of age. stages of standing from pull to stand to quadruped to kneeling to half kneeling to standing with support to standing with holding on to standing alone were evaluated

The GMFM is used to assess motor function, i.e., how much of an activity a child can accomplish, rather than the quality of the motor performance, or how well the child accomplishes the activity. The scoring key is provided as a general guideline. Initiation (1) is usually less than 10% completion. Partially completes (2) is from 10% to less than 100% completion. Completes (3) is 100% completion.

The child is allowed a maximum of 3 attempts or trials for each items. The spontaneous performance of any item is acceptable and is included as one of the 3 trials. The score assigned is based on the best performance over a maximum of 3 trials. If the child achieves the task in the first trial, no subsequent testing of the item is needed (Sackley, 1991).

2-Assessment of standing balance:

STATIC STANDING BALANCE**:**

By stop watch time in seconds was measured of independent standing pre and post treatment program and show the changes in standing equilibrium. Balance is comprised of the dynamic reactions of involuntary sensations and impulses that maintain an upright stance and is necessary for most functional movements (Rode et al., 1997)

BASE OF SUPPORT(BOS):

The CNS has an internal representation of stability limits and uses it to determine how to move and maintain balance. Postural stability can be understood as the ability to keep the center of gravity (COG) within the limits of the BOS, or stability limits; The more decrease of BOS width will demand a great effort of postural stability and gaining of balance . So we measure BOS pre and post treatment and show the changes in postural stability.

The most important biomechanical constraint to standing balance is the quality and the size of the BOS. In hemiparetic patients, weakness and impaired muscle control of the affected lower limb, decreased range of motion, and pain can lead to changes in the BOS .The center of pressure (CP) can be displaced anteriorly in the paretic leg because of anteroposterior muscle imbalance in the ankle joint (equinus foot) (Di Fabio, 1987).

Intervention

For all children, the programs were conducted three times weekly, for a period of 12 weeks. Each session lasted for 45 to 60 minutes in a physical therapy room, in addition to 3 hours of home program, 7 days a week during the treatment period.

Both groups (A and B) received a traditional physiotherapy program, as the following

1. Hot packs to improve circulation and relax muscle tension applied on the wrist flexors for 20 minutes.
2. Facilitation of anti-spastic muscles (wrist extensors): tapping at the dorsal surface of the forearm followed by movement, quick stretch, triggering mass flexion, biofeed back, weight bearing, compression on bony prominence, approximation, vibration, irradiation to weak muscles by strong muscles, and ice application for brief time.
3. Prolonged stretch to wrist flexors to gain relaxation as prolonged stretch positioning and night splint also via techniques use as reflex inhibiting pattern Bobath technique for 20 minutes.
4. Slow Passive stretching of the tight muscles (wrist flexors) to regain mobility of the muscles and sheath. It must be slow, gentle and gradual lasting 20 second then relaxation 20 second repeated 3-5 times per session then maintain the new range by using adjustable wrist splint after the session for two hours then release for using the hand in ADL activity.
5. Graduated active exercise for upper limb muscles with special emphasis on wrist extensors.
6. Gait training using aids in closed environment using obstacles side walking
7. Balance training program which include static and dynamic training.
8. Faradic stimulation for the wrist and elbow extensors to modulate muscle tone. Wrist and finger flexors should be fully stretched to prevent cross electricity to reach wrist flexors because these spastic muscles are more sensitive to electric stimulation than anti-spastic muscles. The Mother was asked to support wrist and finger in extension during electrical stimulation for 15 minutes.

9-Faradic stimulation for ant-tibial muscles to improve their efficiency and inhibit spastic planter flexors by reciprocal inhibition.

The experimental group (group A) received specialized training program as the following

The main physical problem with hemi paretic child is that they have excess muscle tone at the upper limb flexors and lower limb extensors on the affected side . This hypertonia lead to loss of normal reciprocal inhibition between agonist and antagonist which lead to loss of motor control on the affected half of the body which lead to imbalance in standing equilibrium and decreased weight and foot-pressure distribution in addition to decreased equilibrium reactions and weight shifting control this may lead to decreased of proprio-ceptive stimulation which play an important role in maintaining of standing balance. we stimulate cutaneous receptors by TENS (afferent) for increase postural awarness and decrease its sway. we apply TENS on sole of the foot aiming for modulation of cutaneous receptors excitability.

For transcutaneous electrical stimulation (TENS) subjects were standing barefoot, feet side by side at a distance of 5cm. high-frequency low-amplitude alternating current(TENS) of the plantar soles has been shown to produce postural reactions, subjects stood with their hands at their sides. They were instructed to stand relaxed and to keep their bodies upright (Badke and Duncan, 1983).

Table 1. Patients' characteristics.

Variables	Study group N=15	Control groupN=15	P-value
Age	4.87±1.46	4.93±1.71	0.9093
Sex N%			
Boys	3(20%)	7(46.66%)	0.1967
Girls	12(80%)	8(53.33%)	
Hand dominance N%			
Right	7(46.66)	8(53.33%)	0.4814
Left	8(53.33%)	7(46.66%)	

Table 2. The average test of standing level in both groups.

Standing level	Study group Mean±SD	Control group Mean±SD	P-value (within groups)
Pre-treatment	2.07±1.03	1.33±0.49	0.6054
Post-treatment	2.71±0.73	1.57±0.65	0.0406
Improvment%	31%	18%	0.125
P-value (within groups)	0.0001	0.0401	

RESULTS

Patients characteristics

Table 1 shows the demographic and clinical characteristics of all patients. There were 10 boys (33.33%) and 20 girls (66.66%). and in term of Right hand dominance reported in 15 patients (50%), and also15 patients (50%) were left hand dominance. There was no significant difference between the two groups in terms of age (p=0.9093), in term of sex (p=0.1967) and in term of hand dominances (p=0.4814).

Changes in standing level

Mean test scores and standard deviations for both groups are shown in the table 2. The mean value of standing level in both groups (assessed by GMFM) at baseline measurement (pre-treatment) was insignificant (p>0.05). while both groups had a significant improvement in hand grip strength post-treatment (p<.05). The average improvement of standing level tended to being highly significant in the study group (2.07±1.03 versus 2.71±0.73, p=0.0001) than in the control group (1.33±0.49 versus 1.57±0.65, p=0.0401). The percentage of improvement of standing level was (31%) in the study group compared to the (18%) n control group.

DISCUSSION

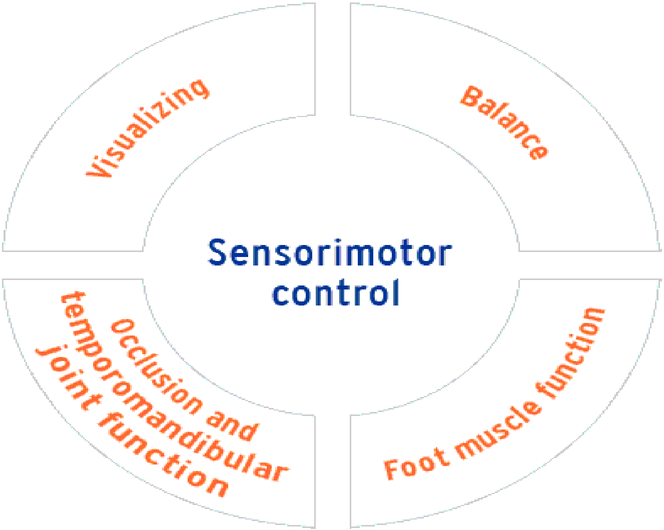
The results of this study show a significant impact of TENS as insole foot stimulation producing joint position sense and balance control in hemiplegic cerebral palsy children. TENS could be used to promote motor performance or recovery in people with disabling neuromotor conditions. Cortical excitability changes can alter the individual experience to interact with the environment (Badke and Duncan, 1983).

Foot and ankle complex is the only segment which is in direct contact with supporting surface and has an important role in collecting somatosensoy feedbacks and regulating balance control .Sensory impairments in the foot and ankle complex contribute to balance and activity problems in hemiplegic C.P. If effective, the application of TENS as insole foot stimulation has the potential to be a highly beneficial intervention as facilitation of joint position sense and balance control contribute to the decrease risk of falls and limited mobility associated with hemiplegia (Badke and Duncan, 1983).

Sensori-motor insoles receptors and its role in maintaining of upright standing posture

The brain detects the new stimuli and activates a newly adapted movement. The foot actively rights itself to a new coordination of the musculoskeletal system. Stronger feet emit stronger signals and harmonize the entire balance of the body: a very active flow of information travels from the foot to the brain and back again.

Control circuits of the sensorimotor control are as well: Visualizing, Balance, Occlusion and temporo-mandibular joint function, Function of the foot muscles and muscle groups from the head to the feet. Weak foot muscles send weak afferent signals. They lead to an insufficient efferent feedback and cause malfunctions and muscular imbalances. However, if the afferents of the foot muscles are strengthened, the sensori-motor integration and resulting posture and movement control will change. Children without static balance lack the stabilizing framework that is necessary to develop normal functional activities (Ilum and Pfaltz, 1985).



Sensorimotor insoles receptors and its role in maintaining of upright standing posture (Allum and Pfaltz, 1985)

Sensorimotor insoles stimulate the receptors of the foot's sole. The brain detects the new stimuli and activates a newly adapted motion sequence. The foot actively rights itself and the musculoskeletal system's muscle tensions can therefore be newly coordinated. The strengthened feet send stronger signals and harmonize the entire balance of the body. A more active flow of information from the foot to the brain originates (Allum and Pfaltz, 1985).

Afferent impulses from muscle spindles, tendon receptors, joint receptors and Mechanoreceptors of foot make up the sum of the proprioceptive information from the periphery of the musculoskeletal system to the brain. Among other things, effective control of movement requires that important information related to the composition of the ground, slope and temperature be transmitted. Afferents from the vestibular, visual and cranio-mandibular subsystems in the brain and cerebellum are interconnected to control the head. For all incoming signals, the brain creates the reflex-neuromotor response as efference to the (foot) muscles (lum et al., 1989).

Somatosensory input from the lower limb has long been recognized as an important source of sensory information in controlling standing balance. Although the specific source of this essential input remains to be determined, there are several classes of receptors in the lower limb that may provide feedback related to stance and movement. Proprioceptive information from muscle spindles in muscles from around the knee and ankle may code for the change in joint angle relative to the trunk while Golgi tendon organs may be esponsible for force feedback about the loading of the body . skin receptors in the foot sole are sensitive to contact pressures and may be sensitive to potential changes in the distribution of pressure Together, the integration of all these somatosensory inputs appears to provide important information about the body's position with respect to the supporting surface (Allum et al., 1993).

There are several lines of evidence in the recent literature that suggest a contributing role of cutaneous receptors from the foot sole in controlling standing balance. For example, mechanical stimulation of the plantar skin during quiet stance has been shown to evoke postural sway that is highly correlated with the cutaneous stimuli. Reduction of this cutaneous information, either by cooling or placing a cuff on the leg, is associated with an increase in postural sway. Furthermore, compensatory stepping reactions to sudden postural perturbations are also affected by reduced plantar support information. Skin receptors may therefore be able to detect not only the movement of the centre of pressure as it moves towards the boundaries of the base of support, but may also be able to initiate postural reflexes that promote a more stable standing position (Allum et al., 1994).

Sensory information is regulated dynamically and modified by changes in environmental conditions .Despite the availability of multiple sources of sensory information, in a given situation, the central nervous system (CNS) gives priority to one system over another to control balance in the orthostatic position. Nondisabled adults tend to use somato-sensory information from their feet in contact with the surface while standing in a controlled environment with a firm base of support (BS) .Under this condition, somato-sensory afferents account for 70 percent of the information required for postural control, while vestibular afferents account for 20 percent and visual input for 10 percent (Allum et al., 1995).

Visual and vestibular inputs are likely to be more relevant sources of information when proprio-ceptive information is unreliable, for instance, during sway. The ability to choose and rely on the appropriate sensory input for each condition is called sensory reweighting When one is standing on an unstable surface, for instance, the CNS increases sensory weighting to vestibular and visual information and decreases the dependence on surface somato-sensory inputs for postural orientation. On the other hand, in darkness, balance control depends on somato-sensory and vestibular feed-back. The ability to analyze, compare, and select the pertinent sensory information to prevent falls can be impaired in hemiparetic stroke patients (Allum et al., 1995).

In patients with stroke, balance impairments and decreased foot proprio-ception are positively correlated .Abnormal interactions between the three sensory systems involved in balance (somato-sensory, vestibular feedback and vision) could be the source of abnormal postural reactions .In situations of sensory conflict, a patient with stroke can inappropriately depend on one particular system over another .Laboratory measurements of sensory organization demonstrate that patients with chronic stroke perform worse in conditions of altered somato-sensory information and visual deprivation or inaccurate visual input .Excessive reliance on visual input may be a learned compensatory response that occurs over time .Relying on a single system can lead to inappropriate adaptations and, hence, balance disturbances (Fitzpatrick et al., 1992).

The components of the nervous system, which play a major role in the maintenance of static standing balance, must integrate information of proprio-ceptive, vestibular, and visual sources. Proprio-ceptive feedback mechanisms, serving to correct externally or internally induced errors in position, velocity, and force of movement, have been suggested as supporting the fundamental process of coordinated accurate movements These mechanisms are the main source of sensory information in normal people for balance maintenance when the feet were on a fixed surface Therefore, the nervous system may weight the importance of proprio-ceptive information for static standing balance more than information from visual and vestibular sources (Sackley, 1991).

Human sensory control of upright stance is known to involve, in addition to visual, vestibular, and proprioceptive cues, also somatosensory inputs from mechanoreceptors at the body site where support forces have impact. Clinically, distal sensory neuropathy in the feet is known to impair postural control .Experimentally, cooling or anaesthetising the plantar soles of upright standing human subjects leads to increased postural sway. Furthermore, responses to support perturbations change after ischaemically blocking afferent above the ankles. Additionally, limiting the foot support surface from a broad base to a narrow beam changes the intersegmental coupling. However, it is not clear to date, which of the foot mechanoreceptors are providing the different pieces of information that are relevant for the various aspects of postural control (Allum et al., 1989).

Stroke patients have difficulties in all planes but mostly in the direction of their paretic leg. Also, when shifting from a 2-legged to a 1-legged stance or when stepping on stairs of various heights, stroke patients show the greatest difficulties with transferring weight toward their paretic leg. On the other hand, loading the nonparetic leg may be troublesome as well which could be due either to subtle neuromuscular impairments ipsilateral to the brain lesion or to a reduced ability to control weight shifts toward the nonparetic side using the leg and hip muscles of the paretic body side (Allum et al., 1994).

Five mechanical factors determine stability and mobility

1- Height of the center of gravity above the base of support: standing up straight raises the center of gravity above the base of support and decreases stability.

2- Location of the center of gravity projection within the base of support: the center of gravity has a greater distance to travel before leaving the base of support on the opposite side and causing you to fall.

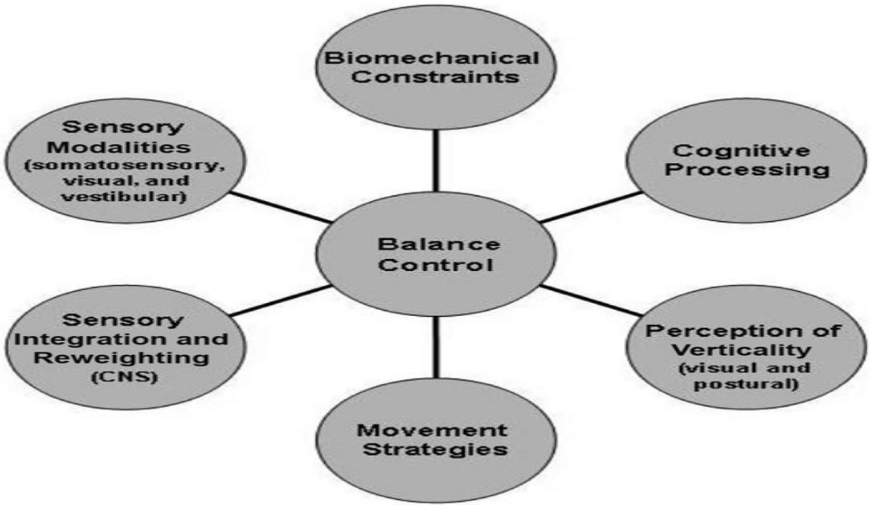
3- Body mass or body weight: A body’s mass (or weight) contributes to stability. Simply stated, heavier bodies are harder to move and hence are more stable. Lighter bodies are moved more easily and are less stable.

4- Friction: The amount of frictional resistance at the interface between the ground and foot or shoe contributes to stability and mobility. low friction would be more likely to slip and fall.

5- Size of the base of support in the direction of force or impending force: In general, increasing the size of the base of support increases stability. In preparation for an impact, we tend to spread our feet apart.

High stability (low mobility) is characterized by a large base of support, a low center of gravity, a centralized center of gravity projection within the base of support, a large body mass, and high friction at the ground interface. Low stability (high mobility), in contrast, occurs with a small base of support, a high center of gravity, a center of gravity projection near the edge of the base of support, a small body mass, and low friction.

The base of support is the area on the supporting surface i.e. floor, ground, etc. included around and within your child’s feet and knees if kneeling; feet, knees, and hands if creeping; and feet if standing, walking, or running. The area within the base of support varies during movement, at times shortening or lengthening and narrowing or widening. It also changes with the development of motor skills. As an infant gains strength and balance, for example, his or her sitting base of support narrows allowing movement out of the position. Also, when a child begins to walk, his or her base of support is initially wider than when, with increased balance, a narrowing of the base occurs.



Important resources required for postural control (Fitzpatrick et al., 1992).

Functional balance has a direct reliance on lumbar/pelvic stabilization and articulation. “Stability of the spine is proposed to be dependent upon active (muscles), passive (skeletal/noncontractile), and control (neural) subsystems.” The main function of spinal orientation is to balance external loads applied to the trunk so that residual forces transferred to the lumbar spine can be handled by the local muscles. vertical loading of the lumbar spine (axial compressions) occurs during upright standing or sitting postures. It is important to be aware of the constant compression forces that are occurring throughout the vertebra, the intervertebral discs, and the facet joints (Fitzpatrick et al., 1992).

CONCLUSION

The combined physiotherapy program which include (traditional physiotherapy program + transcutaneous insole foot stimulation) is recommended in standing balance delay, to improve the ability to upright posture in standing, normal distribution of weight bearing during standing, provide sensory feedback via gaining of equilibrium reaction so this combined program may be used as a therapeutic intervention for improving standing balance in children with hemiplegic cerebral palsy children

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