THE EFFECTIVENESS OF SENSORY MOTOR STIMULATION ON BALANCE AND GAIT IN CHILDREN SUFFERING FROM TRAUMATIC BRAIN INJURY

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Abstract

Background: Traumatic brain injury (TBI) is a significant contributor to mortality and disability among children. The condition is a disruption in the brain's normal function caused by a mechanical impact on the head. Depending on the nature and location of the lesion, sensory, Cognitive, motor, behavioral and emotional deficits can emerge. Therefore, rehabilitation should be initiated as soon as possible, targeting motor, sensory, cognitive and affective functioning. This work aimed to know the methodological characteristics and effects of sensory motor programs on balance, gait and gross motor skills in children suffering from traumatic brain injury.

Methods: This randomized controlled study was carried out on 44 patients, aged from 8 to 14 years old, both sexes, with traumatic brain injury. Patients were randomly assigned into two equal groups. Control group: received traditional physiotherapy program only. Study group: received sensory motor integration program in addition to the traditional physiotherapy program. The evaluation was done before treatment, and after 6 months of treatment using pediatric balance scale to assess balance and Kinovea software to assess gait.

Results: In control group, Terminal stance and initial Swing were significantly higher in pre-treatment than post treatment (P<0.05). PBS and terminal swing were significantly different between study and control group. While other PBS and gait parameters without significant difference.

Conclusions: Sensory motor integration program has a positive impact on balance and gait parameters and gross motor skills in children suffering from traumatic brain injury.

Keywords: Traumatic Brain Injury, Children, Balance, Gait Parameters, Sensory Motor Integration Therapy

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Introduction

Traumatic brain injury (TBI) is a serious public health concern and is the most frequent cause of disruption to normal childhood development. Traumatic brain injury occurs when a sudden trauma triggers the brain to move rapidly within the skull leading to neuronal damage [1].

TBI can result from the head suddenly hitting an object, from a non-impact force such as blast waves or rapid acceleration and deceleration or from an object puncturing the skull and penetrating the brain tissue. Although TBI can occur across the lifespan this type of brain insult can be particularly devastating for the developing brain. This interruption of normal brain development and the cascading effects of TBI may alter the course of brain development and its functioning [2]. Children with TBI typically experience major developmental disruptions and long-term functional impairments [3].

TBI has more severe and persistent effects in children than adults presumably due to the immaturity of the child's brain and potential for early injury which interferes with ongoing brain development and disrupts related sensory, motor and cognitive functions [4, 5].

The majority of children with TBI have disrupted balance performance and walking ability that limit their activities [6]. Moreover, they are more prone to gait instability and repeated head injury in the presence of sensory and motor impairments and cognitive deficits [7]. Most children with TBI present with spatiotemporal deviations in gait including decreased gait velocity, decreased step length, a broad-based gait and increased double – limb support time compared to typically developing children [8, 9]. Walking is a fundamental function of mobility in daily life that requires various forms of concurrent sensory, motor and cognitive tasks. Safe walking requires some degree of attention and complex processes that involve the ongoing integration of visual, proprioceptive and vestibular sensory information [10, 11].

These limitations in sensory and motor functions and cognitive deficits can cause TBI to become more dependent on their caregivers and reduce their community and social participation, reducing their quality of life [12, 13].

This study aimed to investigate the effect of sensory motor stimulation on balance during independent and safe walking which are crucial for children with TBI to ensure that they can be independent at home and in the community.

Patients and Methods

This randomized controlled study was carried out on 44 patients, aged 8 to 14 years, both sexes, at least one month post-TBI, Glasgow coma scale (6 CS) score < 10 at first admission, ability to stand and walk in dependently even without those, ability to obey one – step instructions, admitted to physical therapy clinic, faculty of physical therapy, Kafr Elsheikh University, Egypt. The study was done from July 2024and March 2025 after approval from Faculty of Physical Therapy, Kafr Elsheikh University, Egypt with an ethical code stated in Helsinki Declaration 1995 and registration of clinicaltrials.gov (ID: KFSIRB 200 – 534). An informed written consent was obtained from relatives of the patients.

The exclusion criteria were patients receiving botulinum toxin, visual field defects, undergone Orthopedic surgery after traumatic head injury and uncooperative children.

Randomization

An online randomization program (http://www.randomizer.org) was used to generate a random list and each patient's code was kept in an opaque sealed envelope. Patients were randomly allocated with 1:1 allocation ratio into two groups in a parallel manner: Control group: received a designed physical therapy program. Study group: received the same designed physical therapy program as control group in addition to sensory motor stimulation program.

Intervention

Physical therapy program

Children in this group underwent a designed physical therapy program for 60 minutes, three sessions per week for six consecutive months. This physical therapy program was based mainly on the neurodevelopmental technique and directed toward improvement of normal patterns of postural control. They also received stretching exercises in order to preserve the length and elastic recoil of all soft tissues that could become tight and strengthening exercises to help children become more functional.

Sensory motor stimulation program

Exercise 1

The child is standing on balance (vestibular stimulation) inside the spider cage and inserts a small ball into the holes of the spider cage. We change the small ball that we insert inside the spider cage with something different in size, shape and weight (proprioception stimulation) And other things that differ in texture (tactile stimulation). The opening is at shoulder level, sometimes enters the right, sometimes the left, sometimes above shoulder level, and sometimes below shoulder level (visual tracking). We place a weight above the wrist joint, perhaps a quarter or half a kilogram (proprioception simulation). We can specify the frame of the hole in a specific color to improve visual attention.

Exercise 2

The child is standing on a balance and throwing a ball into a basket. The edges of the basket in which the ball would place would color, and if the child likes a certain color, we make it that color.

Exercise 3

Place the child in quadruped position (proprioceptive stimulation) on the swing, (vestibular stimulation) move the swing, and ask him to pull one of the chain rings. The chain of rings is colourful and luminous (visual attention) while the room is dark, and we attach a weight to the wrist joint (proprioceptive stimulation).

Exercise 4

The child walks on the balance board, forward and sideways, and there is a rope with colored clips on it. We ask the child to walk and remove the clips of a specific color.

Exercise 5

The child is sitting on the swing, and we move the swing forward and he places the ring in the lighted ring column while the room is dark. Then we move the swing again and the child takes the ring out of the ring column.

Exercise 6

The child is sitting on the balance board (vestibular stimulation) and playing the fishing game while the fish are placed on a lighted board (visual attention). Then he puts the fish in a small box.

Exercise 7

The child is standing on a trampoline, and we make shadows for objects of different shapes and colors, and the child was asked to place his hands in a specific shape or colour.

Exercise 8

The child is standing on trampoline and holds a board with luminous edges and a luminous ball with a hole in the middle. The child was asked to move the board so that the ball moves until it falls into the hole.

Exercise 9

The child is sitting on the ball and pressing on coloured, illuminated bubbles in front of child. The child was asked to press a specific color each time.

The evaluation was done before treatment, and after 6 months of treatment using Pediatric balance scale (PBS) to assess balance and Kinovea software to assess gait.

Pediatric balance scale (PBS)

PBS is a standardized tool for testing balance. This tool developed by modifying the Beng balance scale to test the functional balance of the school-age population with mild to moderate motor impairment. The tool has been confirmed to be reliable in terms of both intra-rater reliability (intraclass correlation coefficient (ICC) = 0.99) and inter-rater reliability (ICC = 0.99). The items can be measured within 15 minutes and don't require the use of specialized equipment. PBS consists of 14 items that are scrod from 0 points to 4 points with a maximum score of 56 points. The scale examines many of the functional activities such as sitting standing, transfers and stepping [14].

Evaluation of gait using Kinovea software, Kinovea is a free 2D motion analysis software for computers that can be used to measure kinematic parameters. This software allows to analyzed video without markers although its reliability may improve with the use of passive markers [15]. Evaluation was done at the base line after six months following the intervention.

Sample Size Calculation

Sample size calculation done by G power (version 3.1.9.2; Germany) was used to compute the sample size a prior using these values and our assumption (alpha = 0.05). As a result, the total estimated sample size for children with traumatic brain injury was 44 subjects.

Statistical analysis

For data analysis, SPSS V.12.0 (SPSS Inc; Chicago, TL, USA) was used. The normality of variables was assessed by the Shapiro Wilks Test. Data of paediatrics balance scale and gait parameters were analyzed by using the paired t-test for comparison between parameters obtained with and without sensory motor integration therapy. A two-tailed P value < 0.05 was considered statistically significant.

Results

Fifty- Four patients were assessed for eligibility; 10 patients did not meet the criteria. The remaining patients were randomly allocated into two equal groups (22 patients in each). All allocated patients were followed up and analyzed statistically (Figure 1).

General characteristics were insignificantly difference between both groups (Table 1).

In control group, Terminal stance and initial Swing were significantly higher in pre-treatment than post treatment (P<0.05). while the other parameters without significant (Table 2).

PBS and terminal swing were significantly different between both groups. While other PBS and gait parameters are without significant (Table 3).

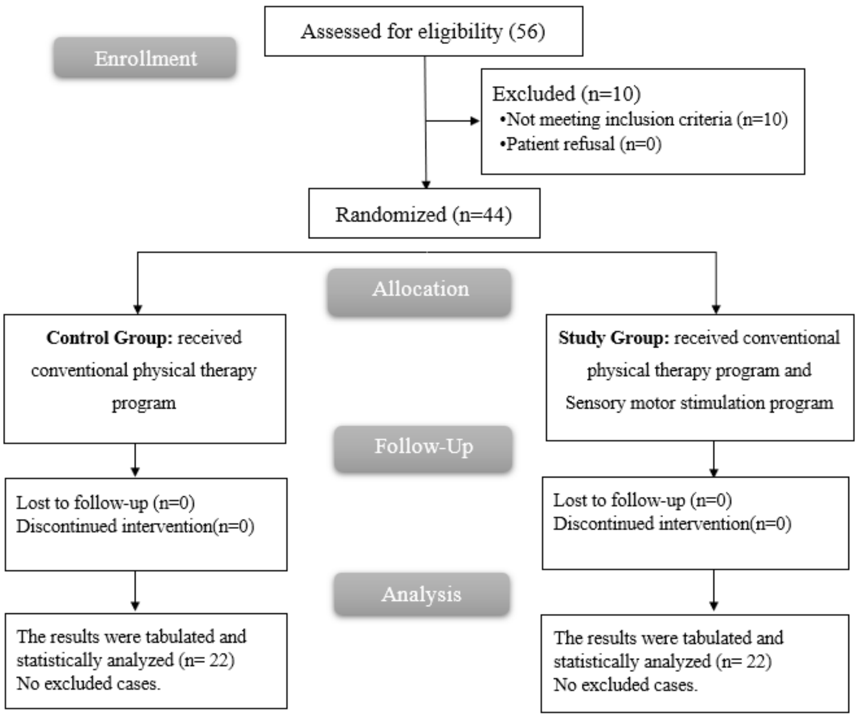

Figure 1. ONSORT flowchart of the enrolled patients.

Table 1. General characteristics of both control and study groups.

	Control group (n=22)	Study group (n=22)	t - value	P
Age (year)	11.62±1.88	11.46±2.0	1.7	0.756
Body weight (kg)	40.64±12.35	41.83±16.93	0.215	0.802
Height (m)	1.415±0.18	1.421±0.17	0.214	0.909
BMI (kg/m²)	20.20±5.26	19.90±5.43	1.9	0.847

Data are presented as mean ± SD. BMI: body mass index.

Table 2. Comparison between pre and post treatment of PBS and gait parameters in both groups.

		Pre- treatment	Post treatment	t-value	P
PBS	**Control group**	25.47±2.9	27.4±3.25	10.854	1.8 E-6
	Study group	25.93±2.81	41.2±3.47	9.099	7.8 E-6
Initial contact	**Control group**	17.3±3.1	12.5±2.7	24	1.8 E-9
	Study group	17.5±2.4	3.3±1.2	28.549	3.9 E-10
Loading response	**Control group**	16.2±2.7	11±2.9	43.5	9 E-12
	Study group	16.8±2.6	6.2±2.1	25.198	1.2 E- 9
Midstance	**Control group**	10±1.1	6.2±1.3	18.419	1.9 E- 8
	Study group	10.2±1.2	1.3±0.4	34.714	6.7 E- 11
Terminal stance	**Control group**	10.6±1.4	5.9±1.7	6.417	**0.00012***
	Study group	10.5±1.5	1.0 ±0.2	15.895	6.8 E8
Pre swing	**Control group**	39.2±4.4	30.2±3.3	18.719	1.9 E- 8
	Study group	38.8±4.5	22.7±3.2	34.714	6.7 E- 11
Initial Swing	**Control group**	30 ± 3.6	20 ± 2.3	6.417	**0.00012***
	Study group	30±3.5	12.252±2.1	15.895	6.8 E- 8
Midswing	**Control group**	22.6±2.5	12.8±3.1	29	3.4 E- 10
	Study group	22.5±2.4	2.2±1.1	19.125	1.3 E- 8
Terminal swing	**Control group**	20.6±2.2	11.6±1.9	31.423	1.6 E- 10
	Study group	20.7±2.4	2.1±1.3	24.832	1.3 E- 9

Data are presented as mean ± SD. * Significant p value <0.05. PBS: pediatric balance scale

Table 3. Comparison between control and study groups post treatment regarding PBS and gait parameters.

	Control group (n=22)	Study group (n=22)	t - value	P
PBS	27.4±3.29	41.2±3.47	3.08	**0.001***
Initial contact	12.5±2.7	3.3±1.2	5.232	5.6 E-5
Loading response	11±2.9	6.2±2.1	4.604	4.9 E-5
Midstance	6.2±1.3	1.3±0.4	5.364	4.3 E-5
Terminal stance	5.9±1.7	1±0.2	5.1	4.09 E-5
Pre swing	30.2±3.3	22.7±3.2	5.155	6.6 E-5
Initial Swing	20±2.3	12.2±2.1	24	1.8 E-9
Midswing	2.8±3.1	2.2±1.1	20.959	6 E-9
Terminal swing	11.6±1.9	2.1±1.3	4.882	**0.0001***

Discussion

The present study was conducted to study the effect of sensory motor integration on balance and walking abilities in children suffering from traumatic brain injury. The present study was performed on forty- four children post traumatic brain injury, divided randomly into two groups of equal number. All patients were assessed before starting the treatment program by Pediatric balance scale and kinovea software to measure kinematic gait parameters.

Treatment was performed for six successive months; the control group received the designed physical therapy program only while the study group perceived sensory motor stimulation program in addition to the designed physical therapy program.

Choosing the age of the children to be from eight to fourteen years agreed with Westcott et al. [16] confirmed that at 7 to 10 years of age, children are able to resolve a sensory conflict (mismatched information coming from somatosensory and visual receptors) and appropriately utilize the vestibular system as a reference. Comparing the pre-treatment values of the two groups revealed insignificant differences in all variables (Pediatric balance scale & gait parameters). Children with brain injuries present with a variety of walking and balance difficulties, this supported by Thorpe et al. [17] stated that broad based gait, prolonged time of double limb support and increased step length variability, all of which indicate postural instability which have been observed in children post TBI.

It is well established that individuals who sustain TBI can experience temporary or permanent deficit in static or dynamic balance [18]. These disorders of balance and equilibrium having a widespread impact on activities of daily living, community living skills, social and recreational pursuits [19]

A statistically significant improvement in Pediatric balance scale and gait parameters in study group which received sensory integration program in addition to the designed physical therapy program

The results of this study show that providing children with traumatic brain injury with sensory integration therapy enhances their balance and gait abilities.

Sensory integration therapy (SIT) is defined as the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment. Sensory integration is viewed as necessary to maintain a personal map of one' body (i.e being aware of the body and what it is doing and to perform sophisticated cognitive activities e.g planning, attending to the environment and using language. Sensory integration dysfunction is the inefficient neurological processing of information received through the senses causing problems with learning, development and behaviour [20]

This study in accordance with the interpretation of shamsoddin and Hollisaz [21] emphasized that sensory integration approach had a considerable beneficial impact on gross motor functioning in children with CP.

The results of this study come in agreement with the findings of Mahaseth and Choudhary [22] concluded that SIT improves a children's capacity to analyze and integrate sensory data by incorporating various visual processing, kinaesthetic awareness, tactile awareness, visumotor coordination development and vestibular and proprioceptive activities.

The results of this study agree with the findings of Batool et al. [23] investigated in a pilot study whether cerebral palsy patients would benefit from SIT combined with virtual reality (VR) and traditional physical therapy. They came to the conclusion that adding virtual reality to sensory integration therapy had significant impacts on improving patients gross motor skills, balance and mobility.

These results are consistent with those of Raipure et al. [24] concluded that SIT has a positive impact on gait parameters, balance and gross motor function in children with spastic diplegia [25].

Conclusions

Adding sensory integration therapy to the designed physical therapy program can be an effective modality for improving balance, gait parameters in children post traumatic head injury and this study recommends this procedure in conducting podiatric rehabilitation protocols.

The limitations of this study include the relatively small sample size, which may affect the generalizability of the findings. Additionally, the study was conducted in a single center, which limits the diversity of the sample. The lack of long-term follow-up data also prevents the assessment of the sustainability of improvements in balance and gait over time. We recommended future multicentre research with larger sample size and longer follow-up periods to explore the long-term effects of sensory motor stimulation therapy.

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Conflict of Interest: Nil

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