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# Effect of Minds in Motion program on vestibular function and balance in children with hemiplegia: A randomized controlled study

*Wpływ programu Minds in motion (Umysł w ruchu) na funkcjonowanie układu przedsionkowego i równowagę u dzieci z porażeniem połowiczym: randomizowane badanie kontrolowane*

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**Abstract**

Purpose. To investigate the effect of Minds in Motion (MiM) program on vestibular function and dynamic balance in children with hemiplegia.
Methods. Thirty children with hemiplegic cerebral palsy (CP) of both genders with age ranged from 6-12 years were randomly assigned into two groups of equal number; Group (A) (control group), received specially designed physical therapy program for 3 months, Group (B) (study group), received MiM vestibular exercise program in addition to the specially designed physical therapy program given to the control group for 3 months. Vestibular functions and stability indices were assessed for all children before and after treatment using cervical vestibular evoked myogenic potentials (cVEMPs) device and biodex balance system (BBS) respectively.
Results. The results of the present study showed statistically significant improvement within both groups when comparing their pre and post-treatment mean values of stability indices and VEMP amplitude. Post-treatment significant improvement was also observed in the amplitude asymmetry ratio (AAR) in the study group compared with the pre-treatment mean values while no significant change was detected in the control group. Also, no significant changes were detected in P1, and N1 latencies in both groups after treatment. Statistically significant differences were observed in all measured variables between both groups in favor of the study group while there was no significant difference between both groups when comparing the post-treatment mean values of P1 and N1 latencies.
Conclusion. Minds in motion program is an effective modality that can be used for improving the vestibular functions and balance capabilities in children with hemiplegic CP.

**Key words:**

cerebral palsy, hemiplegia, minds in motion, vestibular function, balance

**Streszczenie**

Cel. Zbadanie wpływu programu Minds in Motion (MiM) na funkcjonowanie układu przedsionkowego i równowagę dynamiczną u dzieci z porażeniem połowiczym.
Metody. Trzydzieścioro dzieci z połowicznym porażeniem mózgowym (CP) obu płci w wieku od 6 do 12 lat zostało losowo przydzielonych do dwóch równych grup; Grupa (A) (grupa kontrolna) była poddawana specjalnie opracowanemu programowi fizjoterapii przez 3 miesiące, Grupa (B) (grupa badana), oprócz specjalnie opracowanego programu fizjoterapii przez 3 miesiące wykonywała program ćwiczeń przedsionkowych MiM. Funkcjonowanie układu przedsionkowego i wskaźniki stabilności oceniono dla wszystkich dzieci przed i po leczeniu za pomocą miogennych przedsionkowych potencjałów wywołanych (cVEMP) i platformy Biodex Balance System (BBS).
Wyniki. Wyniki niniejszego badania wykazały statystycznie istotną poprawę w obu grupach, porównując średnie wartości wskaźników stabilności i amplitudy VEMP przed i po leczeniu. Znaczącą poprawę po leczeniu zaobserwowano również we współczynniku asymetrii amplitudy (AAR) w grupie badanej w porównaniu ze średnimi wartościami przed leczeniem, podczas gdy nie wykryto istotnej zmiany w grupie kontrolnej. Nie wykryto również istotnych zmian w latencji P1 i N1 w obu grupach po leczeniu. Statystycznie istotne różnice zaobserwowano we wszystkich mierzonych zmiennych między obiema grupami na korzyść grupy badanej, podczas gdy nie było istotnej różnicy między obiema grupami przy porównywaniu średnich wartości latencji P1 i N1 po leczeniu.
Wniosek. Program Minds in motion jest skuteczną metodą, którą można wykorzystać do poprawy funkcjonowania układu przedsionkowego i równowagi u dzieci z porażeniem połowiczym.

**Słowa kluczowe**

porażenie mózgowe, hemiplegia, minds in motion, funkcjonowanie układu przedsionkowego, równowaga

## Introduction

Cerebral palsy (CP) is commonly used to refer to a neuro developmental condition beginning in early childhood and persisting through the lifespan resulting in disorganized and delayed neurological mechanisms of postural control, balance and movement which leads to functional limitations, especially when there is head and trunk involvement [1]. Hemiplegia is the most frequent type of CP among preterm infants. It is the second type of CP among preterm infants and constitutes 33% of CP children. Children with hemiplegia experience various impairments including spasticity, paralysis, muscle weakness in the half of the body and have higher weight on the healthy limbs when standing putting more weight on certain limbs directs the center of pressure on the healthy limb. More use of healthy limb causes shortness of the involved limb, reduction of bone density, and exposure to instability and frequent falls [2].

The vestibular sensory function, which is important for head movement, provides important information to the postural control system as well as to the visual sensory function. Among these, the vestibuloocular reflex and the vestibulospinal reflex activations particularly play an important role in the vestibular function needed for postural control [3].

Minds in motion program is an exercise circuit, or maze, that is developed to provide vestibular stimulation exercises in a fun atmosphere. The goal of this developmental program is improving children's motor skills and visual processing. The premise of MiM is that there is a link between early afferent neural stimulation and cognitive abilities. Specifically, movement activities that stimulate the vestibular system can have an impact on children's academic and physical domains [4]. Minds in motion program is a sensory motor circuit that involves physical activities focused on dynamic balance (i.e. equilib¬rium), basic motor skills (e.g. hopping, jumping, turning, and walking backward and sideways), and eye–hand coordination through juggling and eye-tracking activities [5].

## Materials and methods

### Study design

A randomized control trial was conducted to investigate the effect of MiM program on vestibular function and balance in children with hemiplegia. Data were collected pre and post treatment from October 2019 to February 2021. Research Ethics Committee before study commencement was approved by Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (No.: P.T.REC/012/003066).

### Participants

Thirty children of both genders with age ranged from 6 to 12 years classified as hemiplegic CP were randomly divided into two groups of equal number and recruited from the physical therapy department of The National Institute of Neuromotor System, Giza, Egypt. Exclusion criteria included children with musculoskeletal abnormalities in both upper and lower limbs, history of convulsions, seizures, visual or auditory disorders and history of congenital abnormalities in the head and neck.

### Randomization

The recruited children were randomly assigned, after signing consent form, into two groups of equal number of 15 children each using sealed envelope method. The randomization process was conducted by an independent researcher who did not take any part of the study. These two groups named as group (A) (control group), received specially designed physical therapy program, group (B) (study group), received MiM vestibular exercise program in addition to specially designed physical therapy program given to the control group. Figure 1 shows the recruitment process and the flow chart of the experimental design of the study.

### Outcome measures

All children were evaluated at baseline (pre-treatment) and at the end of 3 months of treatment (post-treatment). Dynamic balance was assessed for all children participated in this study using the BBS and vestibular function was measured using the cVEMPs device. All children were given an explanatory session before the evaluation procedures to be aware about the different test steps.

### Procedures for evaluation

***Assessment of Dynamic balance***

Biodex balance system is a multiaxial device that objectively measures an individual's ability to stabilize the involved joint under dynamic stress and to test the child's ability to control the platform's angle of tilt. It uses a circular platform that is free to move in the anteroposterior and mediolateral axes simultaneously. The BBS allows up to 20° of foot platform tilt. The BBS measures, in degrees, the tilt about each axis during dynamic conditions and calculates MLSI, APSI, and OASI.  It composed of a movable balance platform that provides up to 20° of surface tilt in a 360° arc of motion. These indexes were the standard deviations assessing sway around the zero point at the center of the platform in which high scores indicating worse postural stability [6]. The system has 8 stability levels. Level 8 has the highest platform stability, whereas level 1 has the lowest stability.

Child's age, weight, and height were introduced into the device and all children were tested on stability levels 4 and 2 for 20 seconds in each trial. From standing position each child was asked to achieve a centered position on a slightly unstable platform by shifting the foot position until it was easy to keep the cursor centered on the screen grid. After centering, the child was asked to maintain the foot position until the platform was stabilized. The test began after introducing heel coordinates and foot angles into the BBS. The child was instructed to concentrate on the visual feedback screen, hold both arms at the side of the body without grasping the handrails, and attempt to maintain the cursor in the middle of the bull's-eye on the screen [7]. Children performed three attempts for each stability level and the average value of these attempts was used for analysis as shown in Fig (2).

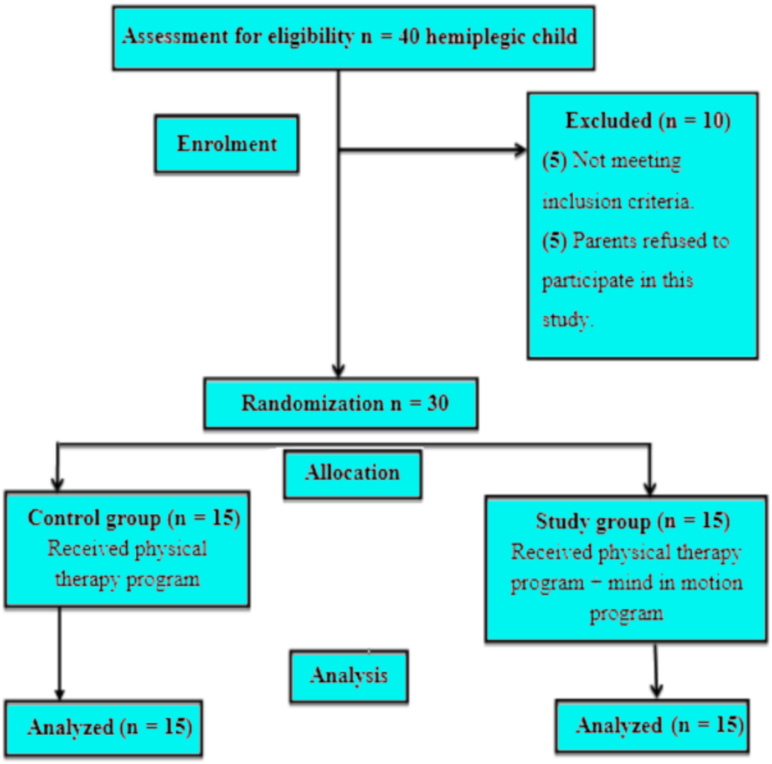


**Figure 1. Flow chart showing the experimental design of the study**

**Fig. 2. Child position during dynamic balance testing**

**Assessment of vestibular function**

The cVEMPs is one of the clinical tests used to evaluate the saccular function of the vestibular system and to assess functions of the inferior vestibular nerve. This test used to assess the sacculocollic reflex in healthy newborns and children [8].

VEMP tests consist of putting muscles in extreme positions then stimulating the reflex by sound which occur in (cVEMPs) and the response is ipsilateral, producing head turn in the direction of an external sound by sternocleidomastoid (SCM) inhibition. This results in an instantaneous head turn in the direction of the threat [9]. This test was conducted in a sound treated room with an acceptable ambient noise level (less than 40 dBA). Equipments used include: labtop, the VEMP device, electrodes (active- reference - ground), scrub gel, marker to mark the location for the electrodes placement, headphones and a chair [10].

The child wore the headphones and asked to turn the head about 90 degrees to one side to increase the tension of the SCM muscle. To ensure the stability of the recording, the child was instructed to face a target (i.e. red dot) that was marked symmetrically on the left and right wall in the tested room. cVEMPs was measured on the right and left sides. To record cVEMPs, surface electrodes are used, placing active electrodes

symmetrically on the middle third of the SCM, indifferent electrodes on the lateral end of the upper sternum and the ground electrode is placed in the midline on the forehead [11]as shown in Fig (3).
The measured variables includes; cVEMPs amplitude, AAR and P1 latency and N1 latency. P1 is the first positive peak of the VEMP, N1 is the first negative peak following P1. Latency is the time from the onset of the stimulus to the peak. The amplitude ratio between the two ears was calculated as follows: (AR − AL) / (AR + AL) × 100 where AR Amplitude of the right ear, AL Amplitude of the left ear. Values above 36 % were considered abnormal [12].

**Fig. 3. Electrodes placement during cVEMPs testing**

**Procedures for treatment**
***Interventions***
Group (A) (control group) included 15 children who received specially designed physical therapy program, group (B) (study group), received MiM vestibular exercise program in addition to specially designed physical therapy program given to the control group.
Physical therapy program
All children in both groups received the specially designed physical therapy program (1 hour, three sessions/week) for three months. The selected exercises according to Levitt [13] included:
- Gait training exercises including gait training at open environment by using obstacles; like rolls and wedges across walking way or track and walking training on different surfaces like soft mat, carpet, or hard surface was used. Gait training exercises in different directions including in different directions including sideway, forward and backward;
- Strengthening exercise for the muscles of the affected lower limb and upper limb;
- Balance training from standing position in all directions using wooden balance board;
- Walking along a body rocker;
- Bridging exercise to strength the back muscles;
- Stretching exercises to maintain the elastic properties of the muscles which are liable for shortening;
- Facilitation of protective reactions from standing position by pushing the child in different directions to improve the child's ability to take protective steps forward, backward or sideways;
-Training of weight shift on both sides with concentration on the affected side.
- Facilitation of righting and equilibrium reactions to improve postural mechanisms through specific exercises like tilting at different directions using medical balls and balance board;
- Training of active trunk extension for improving postural control and balance.

***Minds in motion program***
Children in the study group received MiM program for 3 months, 3 sessions/ week for 30 minutes which includes the following 15 exercises according to Carter et al. [4].
Strong Arm Push: the child stood facing a wall, one foot ahead of the other, arms stretched forward with palms pressed flat on the wall at shoulder height. Children were instructed to push the wall with as much force as possible for 10 seconds. The verbal cue was "push the wall down"
1. Eye Can Convergence: A 5 feet length of string held at the children's eye level, between the therapist and the child, parallel to the floor. Three 1½ inch foam balls attached evenly spaced along the string. While holding the string children cue was to "focus on each ball one at a time for a count of ten".
2. Eye to Eye: the child stood 14 inches in front of the physical therapist and followed the top of a pencil with their eyes, without moving their head. The pencil was moved in two vertical motions, two horizontal motions, two circlesclockwise, two circles counterclockwise, and end with the pencil moved towards the child's nose twice.
3. The Beam Team: the child walked along a 2 ½ in. × 5in. × 10 ft. balance beam with arms extended out to the side. Children cue was to focus on a specific point in front of him
4. Jelly Roll: the child lay on a 4 ft. × 8 ft. tumbling mat with legs straight and arms stretched above the head, then rolled the length of the mat keeping the body straight

5. Puppy Dog Crawl: the child kneeled on a 4 ft. × 8 ft. tumbling mat with palms flat on the floor. The instruction was to crawl across the mat, moving the opposite arm with the opposite leg.
6. Monster Mash: Six 9 inch circular pads placed on the floor in a straight line touching each other. Children stumped one foot at a time with as much force as possible on each circle.
7. Climb Every Mountain: children stepped over 3 plastic hurdles set at heights of 6 in., 8 in., and 10 in. leading with their preferred foot and placing both feet on the ground before starting the next hurdle.
8. Balance Board Bash: children placed their feet equal distance from the center of a balance board and maintained the board in a horizontal position as long as possible.
9. Electric Slide: children stood with their body facing, but not touching, a wall. Without turning their head or body the children moved sideways along the length of the wall by taking a side step with the lead foot, sliding the following foot along until it touched the lead foot.
10. Skip to My Lou: children skipped across the room, swinged their arms laterally across the body in an exaggerated fashion raising knees as high as possible.
11. Cross Walk: children walked across the room lifting knees high while touching alternating knees with opposite elbows.
12. Bean Bag Boogie: children tossed a bean bag in the air and caught it while walking in a straight line across the room. Children was instructed to "follow the bean bag with their eyes".
13. Jumping Jack Flash: children stood behind a line and jumped over a second line placed 3 ft. away, taking off and landing on both feet.
14. Step Back: children walked backwards up 3 stairs, then forward down 3 stairs, then backwards up 3 stairs looking straight ahead. The therapist stood directly in front of children for safety


**Fig. 4. Monster Mash exercise**

**Fig. 5. Step Back exercise**

**Statistical analysis**

The statistical analysis was done by using statistical package of social studies sciences (SPSS) version 25 for windows. Descriptive statistics as the mean and standard deviation were calculated for demographic characteristics including age, weight, height, BMI and also for all measured variables. Inferential statistics as paired t-test was used for within group comparison before and after the intervention. Independent t-test was used to compare the demographic data of both groups as well as the pre- and post-treatment mean values in all measured variables. The statistical significance level set at 0.05.

At baseline, comparing the general characteristics of the subjects of both groups revealed that there was no significant differences between groups in the mean values of age, weight, height and BMI ($P > 0.05$) (Table 1).

Comparing the pre and post-treatment mean values of OASI, APSI, and MLSI of the control and the study group, there was a significant decrease in the post-treatment mean values of OASI, APSI, and MLSI at levels 2 and 4 compared with the pre-treatment mean values ($P < 0.05$) (Table 2). Comparing the pre and post-treatment mean values of cVEMP amplitude, latency and AAR of both groups, there was a significant increase in the post-treatment mean values of cVEMP amplitude of the right and left sides compared with the pre-treatment mean values ($p = 0.0001$), there was no significant change in P1, N1 latencies and AAR when comparing the pre and post-treatment mean values ($p > 0.5$) (Table 3).

There was a significant decrease when comparing the post-treatment mean values of OASI, ASSI and MLSI at levels 4 and 2 of the study group with that of the control group ($P < 0.05$) (Table 4). Moreover, when comparing the post-treatment mean values of the study group with that of control group, there was a significant increase of cVEMP amplitude of the right and left sides, a significant decrease of AAR ($P < 0.05$), and there was no significant difference of N1 and P1 latencies ($p > 0.5$) (Table 5).

**Table 1. Comparison between the mean values of demographic characteristics in both groups**

| Variable | Control group (n = 15) Mean ± SD | Study group (n = 15) Mean ± SD | p-value |
|---|---|---|---|
| Age [years] | 9.04 ± 2.09 | 8.4 ± 1.94 | 0.38 |
| Weight [kg] | 29.4 ± 13.42 | 29.25 ± 10.29 | 0.97 |
| Height [cm] | 124.06 ± 12.01 | 126.43 ± 14.44 | 0.62 |
| BMI [kg/m²] | 18.33 ± 4.39 | 17.73 ± 2.26 | 0.63 |
| **Gender** | | | |
| Girls | 8 (53%) | 9 (60%) | 0.71 |
| Boys | 7 (47%) | 6 (40%) | |

*SD: Standard deviation, p value: Probability value, BMI : Body mass index*

**Table 2. Comparison between pre and post-treatment mean values of stability indices of the control group and the study group**

| Variable | Stability indices | Level | Pre treatment Mean ± SD | Post treatment Mean ± SD | p-value |
|---|---|---|---|---|---|
| Control group (n=15) | OASI | 4 | 1.88 ± 0.6 | 1.48 ± 0.19 | 0.008 |
| | | 2 | 3.68 ± 0.96 | 2.58 ± 0.64 | 0.0001 |
| | APSI | 4 | 1.47 ± 0.66 | 1.34 ± 0.49 | 0.02 |
| | | 2 | 2.95 ± 0.89 | 1.96 ± 0.86 | 0.0001 |
| | MLSI | 4 | 1.62 ± 0.3 | 1.42 ± 0.33 | 0.0001 |
| | | 2 | 2.27 ± 0.67 | 1.82 ± 0.44 | 0.0001 |
| Study group (n=15) | OASI | 4 | 2.04 ± 0.34 | 1.28 ± 0.14 | 0.0001 |
| | | 2 | 3.86 ± 0.78 | 2.11 ± 0.52 | 0.0001 |
| | APSI | 4 | 1.68 ± 0.46 | 1.02 ± 0.3 | 0.0001 |
| | | 2 | 3.01 ± 1.11 | 1.44 ± 0.27 | 0.0001 |
| | MLSI | 4 | 1.71 ± 0.38 | 1.14 ± 0.23 | 0.0001 |
| | | 2 | 2.55 ± 0.7 | 1.41 ± 0.32 | 0.0001 |

*SD: Standard deviation, p value: Probability value, OASI: overall stability index, APSI: anteroposterior stability index, MLSI: mediolateral stability index*

**Table 3. Comparison between pre and post-treatment mean values of cVEMP latency, amplitude, AAR of the control group and the study group**

| Variable | cVEMPs parameter | | Pre treatment Mean ± SD | Post treatment Mean ± SD | p-value |
|---|---|---|---|---|---|
| Control group (n=15) | Amplitude [mV] | Right side | 44.76 ± 16.26 | 57 ± 18.92 | 0.0001 |
| | | Left side | 43.3 ± 19.55 | 57.12 ± 19.27 | 0.0001 |
| | Latency [msec] | P1 | 13.34 ± 1.23 | 14.76 ± 4.13 | 0.15 |
| | | N1 | 19.34 ± 1.16 | 20.98 ± 4.14 | 0.11 |
| | AAR [%] | | 9.79 ± 4.07 | 9.08 ± 3.51 | 0.56 |
| Study group (n=15) | Amplitude [mV] | Right side | 41.92 ± 13.15 | 76.09 ± 16.25 | 0.0001 |
| | | Left side | 48.42 ± 16.92 | 79.81 ± 17.96 | 0.0001 |
| | Latency [msec] | P1 | 13.65 ± 1.59 | 13.39 ± 2.94 | 0.76 |
| | | N1 | 18.79 ± 1.33 | 20.07 ± 3.03 | 0.13 |
| | AAR [%] | | 9.89 ± 5.57 | 4.36 ± 2.02 | 0.002 |

*SD: Standard deviation, p value: Probability value, AAR: amplitude asymmetry ratio*

**Table 4. Comparison of the post-treatment mean values of stability indices between the control and study groups**

| Stability indices | Level | Control group (n = 15) Mean ± SD | Study group (n = 15) Mean ± SD | p-value |
|---|---|---|---|---|
| OASI | 4 | 1.48 ± 0.19 | 1.28 ± 0.14 | 0.003 |
| | 2 | 2.58 ± 0.64 | 2.11 ± 0.52 | 0.03 |
| APSI | 4 | 1.34 ± 0.49 | 1.02 ± 0.3 | 0.03 |
| | 2 | 1.96 ± 0.86 | 1.44 ± 0.27 | 0.03 |
| MLSI | 4 | 1.42 ± 0.33 | 1.14 ± 0.23 | 0.008 |
| | 2 | 1.82 ± 0.44 | 1.41 ± 0.32 | 0.007 |

*SD: Standard deviation, p value: Probability value, OASI: Overall stability index, APSI: anteroposterior stability index, MLSI: mediolateral stability index*

**Table 5. Comparison of post-treatment mean values of cVEMP amplitude, latency, and AAR between the control and study groups**

| cVEMPs parameter | | Pre treatment Mean ± SD | Post treatment Mean ± SD | p-value |
|---|---|---|---|---|
| Amplitude [mV] | Right side | 57 ± 18.92 | 76.09 ± 16.25 | 0.005 |
| | Left side | 57.12 ± 19.27 | 79.81 ± 17.96 | 0.002 |
| Latency [msec] | P1 | 14.76 ± 4.13 | 13.39 ± 2.94 | 0.29 |
| | N1 | 20.98 ± 4.14 | 20.07 ± 3.03 | 0.48 |
| AAR [%] | | 9.08 ± 3.51 | 4.36 ± 2.02 | 0.0001 |

*SD: Standard deviation, p value: Probability value, AAR: amplitude asymmetry ratio*

## Discussion

Vestibular dysfunction may be found as comorbidity with developmental disorders and has been reported in children with CP, Down's syndrome (DS), attention deficit hyperactivity disorder (ADHD)and autism. The vestibular system can be affected by various diseases during childhood, and this can have a major impact on a child's development [14]. It has been hypothesized that children with CP have impaired function of the peripheral vestibular system, but there is a paucity of studies employing vestibular testing in this population [15].

The results of the present study showed significant changes in both groups in most of the measured variables but with more significant improvements in favor of the study group. There was a significant decrease in the post-treatment mean values of OASI, APSI, MLSI at levels (4,2) compared with the pre-treatment in both study and control groups. There was a significant increase in the post-treatment mean values of cVEMPs amplitude of the right and left sides compared with the pre-treatment in both study and control groups and. Also, there was a significant decrease in the mean values of AAR in the study group compared with the pre-treatment mean values while no significant change was detected in the control group. There was no significant change in P1, and N1 when comparing the pre and post-treatment mean values in both the study and the control group.

The results of the study group showed that MiM program vestibular based might improve balance functions and might improve vestibular function. These findings comes in agreement with findings of Sunderman et al.[16] who study the effect of MiM vestibular stimulation exercises on balance in children with DS and found improvement in balance, upper limb coordination, speed and agility.

Also, the results of the present study come in agreement with Carter et al.[4] who study the effect of MiM on balance, coordination and agility in children with DS. They found that vestibular stimulation exercise program could increase balance and agility in children with DS and possibly assist in increasing their functional ability.

Similar results were obtained by Vidoni et al. [17] who study the effectiveness of implementing the MiM Maze in the preschool setting. Their study was based on a 30 minute daily physical activity intervention lasting 11 weeks. They found that the MiM intervention resulted in significant changes in preschoolers motor skills, specifically in balance and coordination. After intervention, balance and coordination improvements that were observed in the experimental group were significantly greater than what was observed in the control group.

On the contrary, the results of a study conducted by Vargas [18] who investigates the effect of MiM on balance and motor skills in middle school aged students did not show a statistical significance of participating in MiM and improving balance and motor skills.

There are primary factors that contribute to the success of MiM program in rehabilitation as it includes variety of activities.

Some activities provide vestibular input to initiate neck and trunk musculature firing. This maintains posture and improves head and trunk control. Other activities were selected to provide proprioceptive input. Proprioception helps to understands own body, its relation to its environment and coordinated movements. The activities were designed to give active stretch, strengthening of muscles, weight bearing on hands, knees and feet and improved bilateral coordination Tahir et al.[19].

The results of the study group provide insight into how MiM program influences balance and vestibular functions. This could be explained by Watson et al. [20] who concluded that individuals who particpate in the MiM program report improved mental functioning following a MiM session, gains in their confidence and comfort with their life, as well as improved balance, mobility, strength, endurance, and increased flexibility. The physical activity program is gentle and easy, and focuses on building mobility, balance, and flexibility. It is completed in a social environment with others, so it increases connectivity and confidence as well.

In the current study, there was a significant decrease in the stability indices of the study group compared with that of the control group post treatment, this improvement may be due to vestibular and proprioceptive activities achieved through MiM which develop sense of positioning and balance. These activities are crucial for sensory motor development in which child learns to coordinate large muscles of the legs, trunk, and arms, and the smaller muscles of the hands through different sensory experiences. Explore through sensory motor stimulation has a great impact on gross and fine motor functioning [21].

The activities included in MiM program are joyful. The children enjoyed and actively participated in initiating and completing the tasks. The activities were designed to give active stretch, strengthening of muscles and weight bearing on hands, knees and feet. The child's body was brought into different positions which gave active stretch and improved bilateral coordination These activities gave the child opportunity to experience its body in different positions and in relation to its environment which they does not do due to their restricted body movements [19].

The significant improvement in the study group in the measured variables may be related to children's engagement in a playful and joyful environment and application of a just right challenge. Moreover, the children were able to regulate the intensity and type of balance tasks, attempt to maintain their body alignment in the midline, learn the balance strategies during the task, and to generalize these experiments to the other balance situations [22].

The post treatment significant improvements in the study group could be explained by the process called sensory reweighting in which to compensate for the loss of sensory information such as vestibular input in children with balance dysfunction, the developing brain may rely on information from other sensory systems. The children may have learned how to properly reweight the available sensory information (i.e. vestibular, proprioceptive, and visual) for producing motor actions that maintained their balance [23].

The post-treatment improvement in the study group may be due to stimulation of the vestibular system which elicits change in the tonic state of the skeletal muscle, specifically, the antigravity muscles in which normal muscular tone of the skeletal muscle obtained, thereby normalizing the postural tone [24]. Researchers are discovering that stimulating a child's brain through specific movement activities increases the functioning of the brain, making children more prepared to learn [17].

The results of the present study showed that there was a significant increase in the amplitude of P1 and N1, and there was a significant reduction in the asymmetry ratio in children who practice MiM compared to the control group. This could be explained by the findings of Sinha et al. [25] who reported that the increased amplitude, reduced asymmetry ratio indicate a possible vestibular plasticity of sacculo-collic pathway with regular practice of MiM.

The amplitude of cVEMP responses also depends on the strength of SCM muscle. Thus, the increased muscular strength because of practicing MIM might have also contributed for enhanced cVEMP responses [26]. There was no significant improvement in P1 and N1 latencies of both control and study groups when comparing their pre and post treatment. Also, there was no significant difference in N1 and P1 latencies when comparing post-treatment mean values between both groups. This comes in agreement with Mirzadeh et al. [27] who examined the effect of rock climbing training on cervical vestibular evoked myogenic potential, balance, body composition, and functional index in quasi-experimental study including 10 sighted and 10 blind girls aged 7-12 years. They found that the difference between the pretest and post-test of latency of the myogenic potentials in both the groups was not statistically significant ($p>0.05$) and intergroup variations showed that there is no significant difference between the effect of the training on the latencies of P1 and N1 of the sighted and blind girls ($p< 0.05$).

According to Akbarfahimi et al. [28], non significant change in the latency of (P1, N1) in both groups before and after treatment may be due to different aspects as P1 wave latency is related to the frequency, intensity, and type of stimulation, while the latency of the N1 wave largely depends on the nerve conduction velocity.

The results of the present study comes on the same line with findings of [29] who study the effect of auditory training on cVEMPs in primary school age deaf children. In this study, the study group were children with profound hearing loss received six months of regular auditory training. The control group of children with profound hearing loss had no history of auditory training. Both groups were evaluated by cVEMPs test. The results showed no significant difference between the two groups in the time delays of waves P1and N1. However, the difference of the peak-to-peak amplitude of waves P1-N1 was significant.

**Study limitations**

The limitations of this study includes lack of cooperation of some children during the application of the testing procedures of cVEMPs due to difficulty maintaining the optimal SCM muscle tension during cVEMPs testing. Conducting the study during Covid-19 pandemic was more difficult than the usual circumstances as extra effort, precautions and cost were required for optimal hygiene.

## Conclusion

It was concluded that, MiM program alongside a specially designed physical therapy program may be useful to improve vestibular function and dynamic balance in children with hemiplegic CP.

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