

## EFFICACY OF CONCURRENT COGNITIVE-MOTOR TRAINING ON GAIT IN HEMIPARETIC CEREBRAL PALSY: A RANDOMIZED CONTROLLED TRIAL

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### ABSTRACT

**Background:** Interference between cognitive tasks and motor control activities such as walking is crucial for functional enhancement in patients with neurological disorders. Therefore, both cognitive and motor training should be addressed in planning physical therapy programs.

**Objective:** To assess the efficacy of concurrent cognitive-motor training on gait in children with hemiparetic cerebral palsy.

**Materials and Methods:** Thirty children with hemiparetic cerebral palsy of both sexes (10-14 years) shared in this study. They were randomly assigned into two equal groups; experimental and control groups. Children in the experimental group received a traditional physical therapy exercise program in addition to a gait training program given concurrently with cognitive tasks. Those in the control group received the same traditional physical therapy and gait training programs without any concurrent cognitive tasks. Treatment was provided three times per week for three successive months. The participants received baseline and post-treatment assessments for dimension E of Gross Motor Function Measure (GMFM) and some gait parameters including: step length, walking speed, ambulation index and time of support on the affected side (% of gait cycle).

**Results:** Children in both groups showed significant improvement post treatment in GMFM scores and all measured gait parameters ( $p < 0.05$ ) with a higher improvement in the experimental group. After the intervention, between-group comparison revealed significant differences for ambulation index ( $t=3.16$ ,  $p=0.004$ ) and time of support on the affected side ( $t=3.61$ ,  $p=0.001$ ) in favour of the experimental group. No significant between-group differences were found in GMFS scores, step length and walking speed ( $p > 0.05$ ).

**Conclusion:** Concurrent cognitive-motor training increased the chance of improving walking ability in children with hemiparetic cerebral palsy as compared to the motor training alone.

**KEY WORDS:** Cognitive-Motor Intervention, Cerebral Palsy, Hemiparesis, Gait, Concurrent Tasks.

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## INTRODUCTION

Cerebral palsy (CP) is a non-progressive motor disorder with functional disability that occurs in about 2 per 1000 live births [1]. It results from a static injury to the developing brain [2]. Hemiplegia accounts for 35% of these children and results in abnormal motor control with associated delay in the onset of walking and an abnormal gait pattern [3].

Gait among children with hemiparetic CP is often characterized by longer gait cycle and support phase, slower walking speed and reduced stride length and endurance during gait as compared to healthy children [4]. Hence, this may produce a less efficient automatic control during walking and subsequently increases the need to pay more attention while walking and might be more vulnerable to the effect of an imposed concurrent task than their normal peers [5].

The control of human walking has traditionally been considered an automatic process that only requires minimal cognitive effort. However, recent research showed evidence that the control of locomotion requires cognitive resources [6]. A child with CP may walk successfully in the clinical setting, but have difficulty walking at school or on the playground. Differences in the cognitive and perceptual demands of different settings may contribute to the lack of carryover as most environments are characterized by obstacles and various distracting auditory and visual stimuli [7].

Children often encounter situations involving the concurrent performance of a cognitive task while walking. For example, they may need to identify signs and signals on their way to school or talk to a friend and carry a book while walking. Research concerning people's ability to perform two tasks concurrently has referred to these types of situations as dual-task or multi-task situations. During these situations, the attention needs to be divided [8].

Cognitive-motor interference refers to the decrement in performance that occurs when cognitive and motor tasks are performed simultaneously [9] and it has been well established in children with CP [5]. Studies have proved that children with CP, besides their

motor impairments, have some executive and attention problems [10] in the form of having limitations in their attentional processing abilities as indicated by a reduced ability to inhibit responses to irrelevant stimuli when performing a task [11]. Additionally, they may also have a smaller working memory capacity than their normal peers [12].

Motor performance is the result of an interaction among cognitive, perceptual, mechanical and neurologic mechanisms [13]. Subsequently, interference between cognitive tasks and motor control activities (such as walking) is important for functional improvement in patients with neurological deficits such as CP. Therefore, the physical therapist must address both cognitive and motor training in planning rehabilitation therapy [14].

According to the task integration hypothesis, single-task training (such as motor training alone) has lower demands than simultaneous cognitive-motor training. Single task training does not permit the concurrent performance of two or three tasks, whereas concurrent cognitive-motor training allows the coordination of various tasks via the simultaneous performance of two or more tasks [15].

However, the majority of gait training for children with CP focuses on functional recovery via motor training alone (single-task), rather than simultaneous cognitive-motor training. To the best of our knowledge, no research has yet been conducted on the effects of concurrent cognitive-motor training on gait in children with hemiparetic CP. Therefore, the therapeutic approaches available currently fall short of addressing cognitive impairment. Thus, the present study aimed to investigate the efficacy of concurrent cognitive-motor training on gait in children with hemiparetic CP.

## MATERIALS AND METHODS

**Subjects:** Thirty children with hemiparetic CP were recruited from the paediatric physical therapy outpatient clinic of the Faculty of Physical Therapy, Cairo University, Egypt after parental agreement to the participation in this study. Their ages ranged from 10 to 14 years old and they had a mild degree of spasticity in the affected lower limbs (Modified Ashworth Scale

score <2) [16]. The children were categorized as level II of the Gross Motor Function Classification System (GMFCS) scale [17]. Children classified as level II of this scale climb stairs hold onto a railing and encounter constraints in walking on uneven surfaces, inclines and walking in crowds or confined spaces. The categorization of GMFCS was initially determined by parental report and then affirmed by a qualified physical therapist after observation of walking for each child.

All children were assessed for intelligence and general cognitive functioning by the use of Wechsler Intelligence Scale for Children (WISC), 4th edition [18]. They all had Intelligence Quotient (IQ) ranged from 85 to 110 according to WISC. Additionally, all children had normal vision and hearing and attended primary school in Egypt.

Children were excluded if they received botulinum toxin injection within the last six months or had deformities in the spine or the extremities. Also, they were excluded if they had previous neurological or orthopedic problems or surgeries of the spine or the lower extremities within one year, auditory or visual agnosia or marked language deficits.

Children were randomly assigned to one of two groups; experimental or control group using a computer-generated random number list. Children in the experimental group received a traditional physical therapy exercise program in addition to a gait training program given concurrently with cognitive tasks. Children assigned to the control group received the same traditional physical therapy and gait training programs without any concurrent cognitive tasks. Ethical approval was obtained from the ethics committee of the Faculty of Physical Therapy, Cairo University and each parent signed an informed consent form authorizing the child's participation. Prior to the start of the study, all study personnel were trained on administration of all test measures by the use of standardized protocols.

## INSTRUMENTATION

a) Gross Motor Function Measure (GMFM) is a valuable observational standard for providing an estimate of gross motor function in children with

CP [19]. It was proved to have high levels of validity, reliability, and responsiveness in assessment of motor functions and effects of intervention in children with CP [20]. It consists of 88 items (GMFM-88) grouped into five dimensions. Each item of the test is scored on a 4-point scale and a percentage score is calculated for each dimension [21]. In the present study, dimension E (24 items) which evaluates the motor function during walking, running and jumping was selected as an outcome measure.

b) The Biodex Gait Trainer 2™ is a device used to evaluate and train walking ability in patients with gait impairments. It consists of a treadmill with an instrumented deck that evaluates some kinematic gait parameters. A high resolution colour touch screen is connected to the device to control the device settings. Furthermore, the device is supported by a serial interface which permits download of patient's data to the computer.

## Procedure

**a) For evaluation:** The children in both groups were assessed before the start of training and at its end (after three months). This was done by the same evaluator who was blinded to which group each participant was allocated.

For evaluation of the gross motor function, GMFM-88 test was administered bare feet without assistive aids. In the present study, dimension E (24 items) was used to evaluate the motor function during walking, running and jumping for all children participated in the study. The test was applied according to its user's manual [22].

The Biodex Gait Trainer 2™ was used to assess gait parameters before and after intervention including: speed of walking (m/sec), step length (m), time of support on the affected side (recorded as % of gait cycle) and ambulation index. Ambulation index is a compound score relative to 100 which depends on average step cycle and foot-to-foot time distribution [23].

Initially, each child was permitted to be acquainted with the gait trainer set up. The children's recognition with the device was guaranteed to stay away from any misinterpretation of any difference of the outcomes between the

two groups which might be clarified by unfamiliarity of the children with the device. This was accomplished through asking each child to practice walking over the gait trainer and follow the movement of the tread belt for 3-5 minutes. This was repeated 2-3 times until the child became familiar with the device.

To begin the assessment procedure by the gait trainer, the tread belt of the device was permitted to increase gradually to 0.3 meter/hour. The speed was then increased slowly to a comfortable pace for each child. Once a comfortable pace was reached, data recording process was begun. The assessment session lasted for continuous 3 minutes where each child was instructed to walk continuously over the tread belt. At the end of the evaluation, the tread belt was allowed to slow gradually till it stopped. The results then can be shown on the display. This process was repeated 3 times, with a rest period in between. For each child, gait parameters were averaged over the trials for further data analyses.

**b) For treatment:** All children in both groups underwent a designed physical therapy exercise program (two hours, three sessions / week) over a period of three months. Each physiotherapy session was divided into two parts; conventional exercises and gait training exercises, each part lasted for one hour with a 15-minutes rest in between. The first part of the session included inhibition of abnormal movement pattern and facilitation of normal movement pattern based on neuro-developmental technique (NDT). Specific strengthening exercises were also given for weak muscles in the affected side. Exercises for improving postural reactions from standing position were also applied as a part of training. Stretching exercises to restore flexibility of tight muscles in the affected side were also part of the routine rehabilitation. These exercises were based on passive range of motion therapeutic exercises described by Kisner and Colby [24]. As regarding to the second part of the session, gait training exercise program was applied for all children in both groups for 60 minutes. Children in the experimental group received gait training program concurrently applied with selected cognitive tasks (dual & triple-task conditioning), while those in the control group

received the same gait training program but as a single task (without dual or triple-task conditioning). The gait training exercise program was as follows:

- Training to stand alone with one limb support to shift the weight onto the affected side
- Training to walk overcoming obstacles of different sizes (forward, backward and sideward).
- Training to walk between steppers.
- Training to walk on rollators.
- Training to walk on balance beam.
- Training to walk over ground with narrow base of support, with tandem and semi tandem walking (forward, backward and sideways).
- Training to walk over foam ground (forward, backward and sideways).
- Training to walk on wooden and soft ramps.
- Training to ascend and descend stairs, without holding, on alternate feet.
- Training to go down stairs with two feet per stair without holding on, if possible.

For the experimental group, cognitive tasks were given concurrently while performing the previous gait training exercises. They were selected according to related dual and triple-task research [25-31] and they were given as follows:

1. For the 1<sup>st</sup> two weeks: the children were instructed to do the following tasks:

a. Naming things such as animals, governorates, and men's names (e.g., mention name of men starts with letter "A", so the answers are: Ahmed, Ashraf, Ayman,.....etc) (naming things & words task). This task was given concurrently with the gait training exercises for the first two weeks of the treatment period.

b. Imagining and telling the road direction (e.g., the road direction from home to the supermarket, stationary, mosque,....etc) (imagining task)

2. For the 3<sup>rd</sup> and 4<sup>th</sup> weeks: the children were instructed to do the following tasks:

a. Listening to a list of five different digits (comprising two numbers each) from a lab top with a loud speaker followed by listening to a word list composed of five different words (comprising five letters each). Then, the child was asked to recall the digits (digits task).

b. Identifying voices or sounds heard from a lab top with a loud speaker such as identifying voices

(child, woman, man) and identifying sounds (door close, hand clap, cat meow,....etc) (auditory discrimination task).

3. For the 5th and 6th weeks: the children were instructed to do the following tasks:

a. Reciting numbers, days, or months backward (e.g., from Friday to Saturday,.....etc) (N-Back task).

b. Randomly mentioning the numbers between 100 and 200 (random digit generation task)

4. For the 7th and 8th weeks: the children were instructed to do the following tasks:

a. Counting backward from specific start number (e.g., from 40) and subtracting two or three each time (counting backward by twos and threes task).

b. Naming the opposite direction of his action (e.g., to name "right" when he/she steps by the left foot) (opposite direction task).

For the next four weeks, the children were instructed to perform triple-task walking where they were instructed to walk and simultaneously do the following:

5. For the 9th and 10th weeks:

a. Naming things & words while carrying a tray (40 × 30 cm) loaded with seven table tennis balls (naming/tray) followed by naming things & words while unfastening and fastening a button having a diameter of 1 cm (naming/button).

b. Performing visual imaginary spatial task while carrying a tray (imaginary/tray) followed by performing the same task while unfastening and fastening a button (imaginary/button).

c. Instructing the child to perform the N-Back task while carrying a tray (N-Back /tray).

6. For the 11th and 12th weeks:

a. The child was instructed to perform the digits task while carrying a tray (digits/tray) followed by performing the same task while unfastening and fastening a button (digits/button).

b. Instructing each child to do the auditory discrimination task while carrying a tray (auditory/tray) followed by performing the same task while unfastening and fastening a button (auditory/button).

c. Each child was asked to perform the counting backward task (by twos and threes) while

carrying a tray (counting/tray)

To familiarize the children with the gait training tools, exercises and concurrent cognitive tasks, each child was given one demonstration before starting the treatment sessions. Afterwards, each child was instructed to perform the gait training exercises concurrently with a) one cognitive task (dual-task conditions, for the first eight weeks of the treatment period) and b) two cognitive tasks (triple-task conditions, for the 9th till 12th weeks of the treatment period). To perform dual-task walking, the children were asked to walk and simultaneously perform one cognitive task such as naming animals. While triple-task walking, each child was instructed to walk and simultaneously do the following 1) name animals and carry a tray with balls (animals/tray), 2) listen to and memorize digits and carry a tray with balls (digits/tray) and 3) listen to and memorize digits and unfasten and fasten a button (digits/button). During performing the dual- and triple-task conditions, the children were not asked to prioritize any of the tasks.

**Statistical analysis:** Statistical analysis was conducted using SPSS for windows, version 23. Normal distribution of the data was confirmed using the Kolmogorov-Smirnov normality test. Mann-Whitney signed-rank test was utilized to compare the baseline evaluation of the degree of spasticity between the two groups. To accommodate the (1<sup>+</sup>) modification for numeric analysis, grade (1<sup>+</sup>) of spasticity according to Modified Ashworth Scale was recorded as 1.5 [32]. Paired student *t*-test was used to compare between the mean values of GMFM scores, gait parameters pre and post treatment within the same group. Comparison between the mean values of these variables as regarding to pre and post treatment in the two groups was performed using unpaired student *t*-test. A *p*-value < 0.05 was considered as statistically significant.

## RESULT

Fifty children were evaluated for potential enrolment. Of these, 15 were excluded as they did not meet the inclusion criteria and five children's parents declined to share in the study. Thus, of the original pool, thirty children with hemiparetic CP were included in the study (13 males and 17 females). Analysis of baseline values between

the two groups revealed non-significant differences as regarding to age ( $p=0.85$ ), weight ( $p=0.45$ ), height ( $p=0.66$ ) and the degree of spasticity ( $p=0.72$ ). The demographic and clinical characteristics of children in the two groups are listed in Table 1.

There were statistically non-significant differences in the mean values of pre- treatment data of all variables being tested (dimension E of GMFM scale and gait parameters) between the two groups ( $p>0.05$ ). As regarding to dimension E of GMFM scale, it was assessed in this study to evaluate the motor function during walking, running and jumping. Comparison of the pre and post-treatment values of GMFM scores revealed a significant improvement of dimension E in both groups ( $p<0.05$ ) (Table 2). On the other hand, there was a statistically non-significant difference in dimension E scores between both groups

post treatment ( $p=0.06$ ) (Table 3).

When comparing the baseline and post-treatment values of gait parameters (measured by the gait trainer) within each group, the results revealed a significant improvement of all parameters in both groups including: step length for both the affected and non-affected sides, walking speed, time of support on the affected side (recorded as a percent of gait cycle) and ambulation index ( $p<0.05$ ) (Table 2).

The analysis of gait parameters post treatment between both groups revealed significant differences in ambulation index ( $p=0.004$ ) and time of support on the affected side ( $p=0.001$ ). On the contrary, there were non-significant differences in walking speed ( $p=0.32$ ) and step length of both the affected ( $p=0.33$ ) and non-affected ( $p=0.18$ ) sides (Table 3).

**Table 1:** Demographic and clinical data of participants in both groups.

	Experimental group (n=15)	Control group (n=15)	t-value <sup>c</sup> /Z-value <sup>d</sup>	p-value
Age (years) <sup>a</sup>	12.10 ± 1.16	11.09 ± 0.85	-0.18 <sup>c</sup>	0.86
Height (cm) <sup>a</sup>	122.67 ± 3.74	123.4 ± 5.17	-0.45 <sup>c</sup>	0.66
Weight (kg) <sup>a</sup>	36.60 ± 2.64	35.27 ± 2.05	-0.77 <sup>c</sup>	0.45
Gender <sup>b</sup>				
Male	6 (40%)	7 (46.66%)		
Female	9 (60%)	8 (53.33%)		
Modified Ashworth Scale <sup>a</sup>	1.25 ± 0.25	1.5 ± 0.50	-0.35 <sup>d</sup>	0.72
Affected side <sup>b</sup>				
Right	9 (60%)	7 (46.66%)		
Left	6 (40%)	8 (53.33%)		

Values are mean ± SD<sup>a</sup> or frequency (%)<sup>b</sup>. Method of statistical analysis is in the form of independent sample t-test<sup>c</sup>. Method of statistical analysis is in the form of U Mann-Whitney signed-rank<sup>d</sup>.

**Table 2:** Descriptive statistics and within group comparison of GMFM scale and gait parameters in both groups.

	Experimental group (n=15)		Control group (n=15)		Change score	
	Pre	Post	Pre	Post	Experimental	Control
GMFM (dimension E)	67.22 ± 3.59	80.36 ± 3.92*	67.49 ± 2.56	77.30 ± 4.53*	13.14 ± 1.15	9.81 ± 5.23
Step length (m)						
Affected side	0.37 ± 0.06	0.43 ± 0.07*	0.36 ± 0.05	0.41 ± 0.05*	0.06 ± 0.02	0.05 ± 0.02
Non-affected side	0.33 ± 0.06	0.41 ± 0.07*	0.32 ± 0.04	0.38 ± 0.05*	0.08 ± 0.03	0.05 ± 0.02
Speed of walking (m/sec)	0.55 ± 0.10	0.65 ± 0.10*	0.54 ± 0.09	0.62 ± 0.08*	0.10 ± 0.03	0.08 ± 0.04
Ambulation index	61.46 ± 7.03	72.20 ± 6.27*	61.8 ± 7.15	64.93 ± 6.3*	10.73 ± 3.19	3.13 ± 3.44
Time of support on the affected side (%)	36.40 ± 4.1	44.2 ± 3.36*	35.13 ± 5.31	38.13 ± 5.56*	7.8 ± 1.7	3.0 ± 2.4

Values are mean ± SD.

GMFM: Gross Motor Function Measure scale.

Pre: Pre-treatment evaluation.

Post: Post-treatment evaluation.

\* Significant at  $p < 0.05$ .

**Table 3:** Comparison between both groups pre and post treatment (between group comparisons).

	Pre		Post	
	t-value	p-value	t-value	p-value
GMFM (dimension E)	-0.24	0.81	1.97	0.06
Step length (m)				
Affected side	0.61	0.54	0.98	0.33
Non-affected side	0.33	0.74	1.35	0.18
Speed of walking (m/sec)	0.41	0.67	1.02	0.32
Ambulation index	-0.13	0.89	3.16	0.004*
Time of support on the affected side (%)	0.73	0.47	3.61	0.001*

GMFM: Gross Motor Function Measure scale.

Pre: Pre-treatment evaluation.

Post: Post-treatment evaluation.

\* Significant at  $p < 0.05$ .

## DISCUSSION

Exercise interventions that incorporate exercises to improve walking abilities have been often recommended for children with CP [33]. However, with physical exercise alone the additional cognitive requirements of safe walking cannot be addressed. Two recent reviews discussed the interplay between physical functions and cognition [34,35]. Both brought out the importance to combine physical and cognitive training into clinical practice to enable safer movement in physical environment. Thus, cognitive elements should be taken into account when designing an exercise regimen with the aim to preserve or improve walking performance in children with CP.

This study was conducted to assess the efficacy of concurrent cognitive-motor training on walking ability in children with hemiparetic CP as compared to motor training alone. The children were randomly assigned into experimental and control groups. Children in the experimental group received a traditional physical therapy exercise program in addition to a gait training program given concurrently with cognitive tasks (cognitive-motor training). However, children assigned to the control group received the same traditional physical therapy and gait training programs but without any concurrent cognitive tasks (motor training alone). Pre-training and post-training were compared within and between the two groups.

The findings in this research revealed a significant improvement post-treatment in both

groups as regards to gait in terms of GMFM scale (dimension E) and all measured gait parameters including step length of the affected and non-affected sides, walking speed, ambulation index and time of support on the affected side with greater improvement in the experimental group.

The significant improvement in GMFM scores and all measured gait parameters post treatment in both groups might be attributed to the effect of the designed physical therapy exercise program which was performed by the children in both groups. This exercise program included conventional exercises (based on NDT) followed by gait training program. The exercise program was directed to improve voluntary control on the muscles of the affected lower limb and trunk, control the unnecessary muscle activity, facilitate normal movement pattern, improve balance and maintain flexibility of the tight muscles in the affected side. This comes in agreement with the findings of a previous study which proved the efficacy of NDT on the walking abilities of children with CP who are ambulatory in terms of improving step length, stride length and velocity [36]. Also, Dodd et al [37] reported that proper training programs can lead to lasting changes in the strength of lower-limb muscles that may impact on the daily function for children with CP. Moreover, the program focused on improving weight bearing on the affected side and challenging balance while walking. This helped the child to achieve a better postural control during walking. Subsequently, this allowed further control over the muscles of the affected lower limb during both concentric and eccentric activity needed during gait. This facilitated the child to produce a longer step length, increase walking speed and time of support on the affected side and consequently improve ambulation index and GMFM scores. This explanation is in consistent with the findings of Cage and Novacheck [33]. Also, Kamm et al [38] reported that the development of postural control during locomotion, force the child to utilize the appropriate systems and sub-systems to promote the most efficient progress towards stability and control.

After the intervention, between-group comparison revealed non-significant differences for

GMFM score, step length of the affected and non-affected sides and walking speed. However, there was a significant difference between both groups as regards to the ambulation index and time of support on the affected side in favour of the experimental group. This might be attributed to the effect of concurrent cognitive-motor training given to the participants in the experimental group. Thus, this substantiates the hypothesis that an additional cognitive challenge should be preferably part of a training program aiming to improve physical functioning in children with CP.

Yet, to our knowledge, no other research has investigated training-specific effects on gait after concurrent cognitive-motor training in children with hemiparetic CP. Nonetheless, other studies have been conducted on adult patients with stroke to determine the efficacy of concurrent cognitive tasks on their walking abilities [39,40] and similar findings had been achieved. It was reported that 4 weeks of a dual-task training program effectively improved balance, and walking abilities of patients with stroke-induced hemiplegia [39]. Moreover, Kim et al [40] conducted a study to determine the effects of dual-task training on cognitive and walking abilities of chronic stroke patients. They concluded that dual-task training subjects' performance was better than single-task training subjects' performance. Both training groups exhibited significant improvements in walking speed in the Timed Up and Go Test and 10-Meter Walk Test. However, dual-task group showed higher increases in dynamic gait index than the single-task group. On the other hand, Plummer et al [41] conducted a case series study to evaluate the efficacy of cognitive-motor dual-task gait training in patients with chronic stroke. They found that some of the participants did not demonstrate remarkable improvements in single-task walking speed after the intervention. This can't affect the results of our study because of the nature of the case series that limits the generalizability of the findings to other individuals.

The difference in the response pattern to concurrent tasks between children with CP and other patients with acquired brain damage (such as adult hemiplegia) can be explained by the

suggested motor learning model which includes three phases; the cognitive, associative and automatic phase. Perfection in a motor skill is associated with a decline in the attention resources needed to perform the skill. In the third and final phase, the motor skill requires only a minimal amount of attention and the skill becomes automated [42]. For patients who have to (re)learn a lost motor skill such as walking, for example patients with stroke induced-hemiplegia, higher levels of attention are required to perform this skill [43]. On the contrary, children with CP aged 10-14 years with level II on GMFCS, who experienced walking for years, the attention required for walking is rather low. Therefore, concurrent cognitive-motor training programs can be beneficial in generating attention at the start of the task which continues till its end. They are effective in triggering the conscious control mechanisms and attention strategies and reduce automatic control during activities [44].

Research has proved that attention is effective in generating cortical plasticity in the primary somatosensory and motor cortex and improvement in the motor memory. Consequently, these produce enhancement of the neural processing mechanisms required for proper task performance [45,46]. This comes in agreement with Wright and Shea [47] who concluded that attention is critical for the development of motor control. This is because both of attention and perception provide the stimulus for motor activity and vice versa. Additionally, it was reported that cognitive abilities together with physical practice has been appeared to have a beneficial effect in enhancing motor performance than physical practice alone. This implies that cognitive abilities cause priming of the motor cortex and appropriate activation of the neuromotor pathways [48]. This was affirmed by the conclusion that cognitive training may assist the child to enhance attention and concentration subsequently improves his motor performance. This type of training can be considered as a kind of feedback during motor performance till its end, which permits the child to pass to motor learning process and keep away from any errors during the motor planning process [49].



Reason and Mycielska [50] reported that dual task training let the threshold of attention to be low which mean that the central nervous system becomes ready enough for correction of motor errors. Therefore, practice of cognitive tasks concurrently during walking feed the central nervous system with enough flow of impulses help to correct the motor disturbance during walking and improve the walking performance.

Additionally, the concurrent cognitive-motor training given to the experimental group in this study was high intensity task specific training with much more difficulty than single-task motor training that was given to the participants in the control group. Therefore, the walking abilities of the participants in the experimental group were continually challenged, and this may have resulted in improved motivation, self-efficacy and confidence in performing the post-treatment GMFM and gait assessments at the end of the treatment period. This comes in accordance with the conclusion drawn by Silsupadol et al [51].

There are specific limitations of the study that should be considered in the interpretation of the results. First, the small size of the studied sample may limit the generalization of the study results. The age of the children who shared in this study was between 10-14 years. Future studies are recommended to target different age groups to help comparison of the results across different ages. The lack of follow-up for the participants in both groups might be considered another limitation. Therefore, similar studies are suggested to detect the long term effects of concurrent cognitive-motor training on gait. Also, during the application of this study, we did not include cognition as a variable to be assessed pre and post intervention. In future, it would be of interest to determine whether concurrent cognitive-motor training has any effect on cognitive domains in children with hemiparetic CP, such as executive function. Additionally, other studies are advocated to evaluate the effects of concurrent cognitive-motor training in children with CP from different viewpoints depending on activities of daily living.

## CONCLUSION

In conclusion, the findings of this study revealed

the potential benefits of concurrent cognitive-motor training in the rehabilitation of children with CP. The concurrent cognitive-motor training improved the walking ability of children with hemiparetic CP more than the motor training alone in terms of improving GMFM score and gait parameters. Therefore, concurrent cognitive-motor training should be included in the comprehensive management for children with CP.

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**Conflicts of interest: None**

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