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Relationship of cognitive functions and gross motor abilities in children with spastic diplegic cerebral palsy

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ABSTRACT

Spastic diplegic cerebral palsy can be accompanied by a myriad of symptoms affecting other body systems including cognitive dysfunction. The purpose of this study was to determine whether a relationship exists between cognitive functions in the form of selective attention and figural memory domains with standing and walking motor abilities in children with diplegic cerebral palsy. The research design was a correlational study. Tasks assessing cognitive function and gross motor abilities were carried out with a sample of 50 children. The data demonstrated the presence of correlation between selective attention and figural memory domains of cognitive function with standing, walking running, and jumping subscales of the Gross Motor Function Measure (GMFM) scale at different ages, and this correlation was significant between selective attention domain and gross motor abilities. The outcome measurements of the current study provide original evidence based on the necessity of including cognitive and physical impairments in the examination and evaluation of children with diplegic cerebral palsy in research and clinical settings.

KEYWORDS

Cerebral palsy; cognition; diplegia; figural memory; gross motor function; selective attention

Introduction

Cerebral palsy (CP) is a group of disorders affecting the development of movement and posture, causing activity limitation and is attributed to nonprogressive disturbances in the developing fetal or infant brain (Krigger, 2006). Although CP is primarily a disorder of movement and posture, it often involves disorder of other developing functions, such as perception and cognition including deficits in attention and reduced executive functions, which, in turn, include different aspects of the memory cognitive domain. CP varies substantially in type and severity of symptoms (Rosenbaum, Paneth, Leviton, Goldstein, & Bax, 2007).

Spastic diplegia is the most prevalent type of CP; it accounts for about 44% of the total incidence of CP (Yokoshi, 2012). Spastic diplegia is characterized by a pyramidal motor syndrome predominantly in the lower limbs commonly due to perinatal hypoxic-ischemic insult causing lesions in the white matter adjacent to the lateral ventricles of the brain, or periventricular leukomalacia (Stamer, 2012). It is particularly common in children born preterm (Volpe, 2008). In preterm children, tracts and networks of neural connections in the brain are particularly susceptible to damage due to reduced perfusion and oxygen supply to the periventricular water-shed areas in deep white matter (Volpe, 2009).

Injuries in these areas, where projectional cortico-spinal motor tracts, especially to the lower extremities, are passing through and may be damaged, explain the motor impairment. However, such diffuse or focal white matter injuries may also lead to problems of perception, cognition, attention, memory, and other higher brain functions caused by damage to commissural and association tracts with compromised connectivity and networking (Skranes et al., 2008). Attention and executive function were examined with standardized neuropsychological measures in a group of children with diplegic CP. Impairments in attention and executive functions were present in those children and may help to explain why these children have increased social and learning problems (Bottcher, Flachs, & Uldall, 2010). Also, a study by Løhaugen et al. (2010) on CP young adults born very preterm with a low birth weight showed that memory function may be especially impaired, even into adulthood.

There is extensive research examining potential relations between cognitive and motor performance in healthy individuals. A prominent explanation for these correlations is the overlapping activation in the cerebellum and the prefrontal cortex during cognitive and motor tasks (Diamond, 2000; Rigoli, Piek, Kane, & Oosterlaan, 2012). While a positive relationship has been demonstrated between cognitive and motor performance
in healthy individuals, there are few studies illustrating this relation in children with diplegic CP. In order to prescribe a multifactorial integrated therapeutic approach for children with diplegic CP, therapists need to gather sufficient information and evidence regarding existing or potential problems with motor and cognitive functions, in children with diplegic CP. However, the way in which cognition interacts with the rehabilitation process is controversial, and opinions on this topic are largely uninformed by empirical evidence (Harvey, Robin, Morris, Graham, & Baker, 2008; Romeo, Cioni, Battaglia, Palermo, & Mazzone, 2011).

Cognitive assessment is an important component of diagnosing learning and behavior problems in children. Intellectual deficits and learning disabilities may have an adverse effect on a child’s ability to comprehend and retain information (Krishnamurthy et al., 2004). Cognitive assessment also plays an important role in academic placement decisions as it allows teachers, parents, and clinicians to gain an understanding regarding a particular child’s capabilities in order to facilitate academic and training decisions. Success in school requires attention and memory skills. For example, for children to navigate school settings effectively, they need to be able to focus their attention on their teacher and complete tasks in the context of many distractions. They also need to remember instructions and be able to complete tasks without forgetting critical information. The importance of these attention and memory skills for academic success is supported by both theory and research (Stipek & Valentino, 2015).

In the last decade, there has been a proliferation of studies demonstrating that several different facets of memory predict academic skills (Raghubar, Barnes, & Hecht, 2010; Rogers, Hwang, Toplak, Weiss, & Tannock, 2011; Savage, Lavers, & Pillay, 2007). In addition, extant studies have shown significant associations between children’s ability to regulate their attention and their academic performance (Duncan et al., 2007; Kos, Richdale, & Hay, 2006).

Cognitive assessment has traditionally been conducted with a paper-and-pencil test but, subsequently, cognitive testing methods have increasingly become computerized. Computerization has made scoring simpler and more accurate; it also allows for more complicated computations (Naglirei & Graham, 2003; Sattler, 2008).

The use of computerized neuropsychological assessment devices is receiving increasing attention in clinical practice, research, and clinical trials.

There are several potential advantages of computerized testing including: (a) the capacity to test a large number of individuals quickly; (b) availability of assessment services without advance notice; (c) the ability to measure performance on time-sensitive tasks, such as reaction time, more precisely; (d) reduced costs; (e) administering measures in different languages easily; (f) automated data exporting for research purposes; and (g) increased accessibility to patients in areas or settings in which professional neuropsychological services are scarce (Bauer et al., 2012).

RehaCom system manufactured by (Schuhfriedet, model No. 454V, D-14482 potsdam, Karl-Liepke, Austria) is a comprehensive and sophisticated system of procedures for computer-assisted cognitive assessment and rehabilitation. It is a software package that helps to evaluate and train different cognitive domains (RehaCom, 2011). It has been developed by and for neuropsychologists. In addition, it is evidence-based and clinically proven software (RehaCom, 2017).

RehaCom system was identified by a Korean study by (Heo & Kim, 2016) as a tool with a high degree of validity and reliability that can be effectively used to assess the cognitive functions of stroke patients by professional therapists. Also, it has sufficient flexibility, simplicity, accessibility, dynamics, clinical validity, and objectivity to make a useful contribution to clinical practice (Yang et al., 2014). The study by Abdelazeim and Ameen (2014) applied on normally developing children with age ranging from 6 to 12 years suggests the usability of the computerized cognitive assessment tool “Rehacom” to detect the level of cognitive ability and variability of cognitive development patterns in school aged children.

Different types of memory modules are available in Rehacom system including working memory, topological memory, physiognomic memory, memory for wards, figural memory, and verbal memory. Therefore, in this study, we intended to assess only one type of memory cognitive function presented in this system which is “figural memory” (Schuhfried, 2017). Also, Rehacom system has different attention modules that can assess different domains of cognitive attention including alertness, vigilance, perceptive-visual spatial attention, cognitive-visual spatial attention, selective attention, and divided attention. Selective attention domain of cognitive function was assessed in our study using attention/concentration program according to information provided in Rehacom manual (Schuhfried, 2017).

Several recent neuropsychological studies used attention/concentration and figural memory programs either for assessment or intervention (Yang et al., 2014; Fernández et al., 2012).

The purpose of the present study is to evaluate the relationship between attention and memory cognitive functions with standing and walking motor abilities in children with diplegic CP at different ages.
Methods

Participants

Fifty children who had been diagnosed with spastic diplegic cerebral palsy with age ranging from 6 to 12 years, from both sexes (29 male and 21 female) were selected to participate in this correlation study. Initially, the study included 300 children, but 30 children were excluded; 10 children underwent surgical operation in their lower limbs, 5 children quit prior to termination of the assessment because time of the tests interfere with their school attendance and 15 children had IQ less than 65. Fifty children were randomly selected from 270 diplegic child using sealed envelopes. Selection of random sampling was supported by Rumsey (2016) who stated that random sampling avoid selection bias and that a small random sample is better than a large nonrandom one; no matter how large a sample is, if it is based on nonrandom methods, the results will not represent the population about whom the researcher wants to draw conclusions (Rumsey, 2016).

Subjects were divided into three groups according to their age; 6 < 8 years, 8 < 10 years, and 10 < 12 years to eliminate influence of age on results. The children enrolled in this study fulfilled to the following inclusion criteria: Their chronological age range from 6 to 12 years, able to follow verbal commands or instructions during testing procedures, degree of spasticity in affected lower limbs ranged between 1 + and 2 according to Modified Ashworth scale (MAS), their intelligence quotient (IQ) level range from 65 to 80 according to Stanford–Binet intelligence scale, their gross motor functional classification system Expanded and Revised (GMFCS E&R) selected Level II, III. The exclusion criteria were: Children who had visual or auditory problems that may interfere with cognition testing; patients who had contractures or fixed deformities related to the joints of the upper limbs that prevent them from using control panel of RehaCom system, injection with Botulinium toxin or any orthopaedic surgery in lower limbs within one year before study; and children who were subjected to any medicine that affect arousal and alertness status or children who were suffering from epilepsy. The general characteristics of the participating children are described in Table 1.

Table 1. General characteristics of the participating children.

<table>
<thead>
<tr>
<th>Age groups Items</th>
<th>6 &lt; 8 year (X ± SD)</th>
<th>8 &lt; 10 year (X ± SD)</th>
<th>10 &lt; 12 year (X ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex distribution</td>
<td>Male (n = 14) 6.62 ± 0.50 Female (n = 8) 8.50 ± 0.51 Male (n = 9) 11.27 ± 0.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GMFCS (II&amp;III)</td>
<td>II (n = 6) 6.62 ± 0.50 III (n = 8) 8.50 ± 0.51 II (n = 9) 11.27 ± 0.70</td>
<td></td>
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<tr>
<td>MAS (1 + &amp; 2)</td>
<td>1 + (n = 5) 8.50 ± 0.51 2 (n = 6) 8.50 ± 0.51 1 + (n = 9) 11.27 ± 0.70</td>
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</tr>
</tbody>
</table>

Prior to beginning testing, ethical approval for the study was given. Cognition of the selected children was measured in the cognition lab and their gross motor function was measured in outpatient clinic. Written informed consent was obtained from all parents prior to testing.

Testing procedures

All tests administered and scored in a manner that is consistent with the test manual directions as standardized procedures are critical to valid interpretation.

- Cognitive assessment: Two cognitive domains were assessed using RehaCom system (version 5); selective attention (in the form of attention/concentration program) and figural memory (in the form of figural memory program) with 20-minute break between two programs to avoid mental fatigue. The choice of figural memory program comes in agreement with Fernández et al. (2012) who select this type of memory to provide cognitive rehabilitation for children with acquired brain injury.

The children were given a brief demonstration of how the RehaCom programs are working in the two tested domains before starting the actual testing. All subjects performed a preliminary test to familiarize them with the sit up and testing procedures and practice trial was performed to ensure that the child understood the tests. All subjects were started with level 1 on RehaCom, which is the easiest level of difficulty and ends when tasks become too difficult so that child fall to previous level of difficulty. Visual feedback was activated to encourage child and make assessment session interesting. The administration of the tests should be based on the standardized procedures outlined in the testing manual (RehaCom, 2011). Each child was tested individually. The testing procedures were conducted in an environment free from any distraction and noise that may affects children’s cognitive performance with the child sitting on a suitable comfortable chair facing RehaCom system.

1. For assessment of selective attention, a separately presented picture was compared to a matrix of pictures and the child had to find the picture resembling it in every detail. The pictures in the matrix were harder to differentiate at the higher levels.
The training screen was divided into two parts. One part contained one separate picture of an object. The other part represented the matrix that contained a number of pictures that increase in number and difficulty according to the level reached by the child. The child had to recognize the picture shown separately and select the corresponding picture from the matrix that resemble it in every detail by means of the big buttons on the control panel.

2. For assessment of figural memory, several tasks had to be carried out. Each task consisted of an acquisition and a reproduction phase. In the acquisition phase, pictures of concrete objects were presented. The number of pictures increased with the level of difficulty. In the reproduction phase, the child had to recognize the pictures of concrete objects. The designation had to be picked out from a number of pictures moving over the screen.

- Gross motor function assessment: The Gross Motor Function Measure (GMFM) GMFM-88 is a valid and reliable tool especially designed for measuring gross motor function and the change over time in children with CP. The inter-rater reliability of this measure ranges from 0.92 to 0.99 for children with CP (Wei et al., 2006). The test contains 88 items of gross motor function distributed over five dimensions (Russell et al., 1989). The assessment in this study include standing (dimension D that include 13 items), and walking, running, and jumping subscale (dimension E that include 24 items) of GMFM scale. Each item is scored using a 4-point Likert scale; 0, does not initiate; 1, initiates; 2, partially completes; 3, completes (Wei et al., 2006). GMFM is constructed to measure quantitative aspects, that is, how much children can do, not the quality of their performance. All the items are considered to be achievable by 5-year-old with normal motor function (Palisano et al., 1997).

- Gross Motor Function Classification System Expanded and Revised for CP children between 6th and 12th birthday: The Gross Motor Function Classification System (GMFCS E&R) is a 5 level classification system that describes the level of gross motor function of children and youth with CP based on abilities and limitations in gross motor function, which has shown good validity and reliability for children. Distinction between different levels, ranging from level I (least limitations) to level V, are based on functional abilities and the need for assistive technology, including mobility devices and wheeled mobility rather than quality of movement (Palisano et al., 1997). Since the classification of motor function depends on age, for this study we used the descriptions provided for children 6–12 years. Level II and III were selected in this study.

- Modified Ashworth Scale (MAS): For grading degree of spasticity. Grade 1 + and 2 were selected in this study (Bohannon & Smith, 1987).

**Statistical analysis**

To assess the relationship between cognitive functions and gross motor abilities, a correlation analysis was used. For cognitive functions, two cognitive domains were assessed; selective attention (using attention/concentration program) and figural memory (using figural memory program) and for assessing gross motor abilities, section D and section E of the GMFM scale were assessed. For assessing selective attention, the maximum level reached by the child that represents intensity of attention (Yoo, Yong, Chung, & Yang, 2015) and reaction time (maximum and minimum reaction time) were used in correlation analysis. For assessing figural memory, the level child reached and acquisition time were used. For the GMFM scale, the raw score of section D and also section E was changed into a percentage score for analysis.

Statistical analyses were performed with predictive analytics software version 18.0 (PASW software). Pearson’s correlation coefficients were calculated to examine the relations when data were normally distributed and Spearman’s correlation correlations were used for data that were ordinal and not normally distributed. Correlations were considered significant for \( p \)-values <0.05.

**Results**

Participants were divided into three groups according to their age: 6 < 8 years, 8 < 10 years, and 10 < 12 years, trying to exclude influence of age on both cognitive and gross motor function results.

**Correlation between attention/concentration and figural memory level with standing, walking, running, and jumping subscales of the GMFM scale**

Spearman’s correlation coefficient was used to determine the relation between attention/concentration and figural memory level with section D (standing subscale) and section E (walking, running, and jumping subscales) of the GMFM scale as shown in Table 2. The results indicated that there was strong positive significant correlation between attention and concentration...
level with section D and also with section E of the GMFM scale at different ages, while there was nonsignificant correlation between figural memory level with section D and E of the GMFM scale at different age groups.

**Correlation between maximum, minimum reaction time, and acquisition time with standing, walking, running, and jumping subscales of the GMFM scale**

Pearson’s Correlation coefficient was used to assess the relation between minimum, maximum reaction time of attention/concentration domain, and acquisition time of figural memory domain with section D and E of the GMFM scale as shown in Table 3. The results indicated that there was strong negative significant correlation between minimum reaction time of attention/concentration domain with section D and E of the GMFM scale at different age groups. Also, there was strong negative significant correlation between maximum reaction time of attention/concentration domain with section D and E of the GMFM scale at different age groups, while there was nonsignificant correlation between acquisition time of figural memory domain with section D and E of the GMFM scale at different age groups.

**Discussion**

The aim of this study was to investigate the relationship between selective attention and figural memory cognitive functions with standing and walking motor abilities in children with spastic diplegic cerebral palsy. The main findings of this study showed that there was a correlation between selective attention and figural memory domains of cognitive function with standing and walking motor abilities of 50 diplegic children who were divided into three age groups; 6 < 8 years, 8 < 10 years, and 10 < 12 years. This correlation was significant between selective attention and standing motor ability, and also between selective attention and walking. Although the correlation was nonsignificant between figural memory and standing and also nonsignificant between figural memory and walking, it approached significance (Kirkwood & Sterne, 2003) at different age groups. All correlation results did not significantly differ with age.

The correlation of this study was positive when dealing with level of either selective attention or figural memory as it was something good for the child who had higher scores in standing and walking to reach higher levels of selective attention and figural memory domains, while it was negative when dealing with reaction or acquisition time because the child who had higher scores in standing and walking could react to stimuli or acquire information in a shorter time, which was something good for him/her.

Growth and development can be affected by abnormal posture, muscle and joint contractures, malformation, visual impairment, sensory impairment, and other major dysfunctions (Molenaers, Calders,
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Most studies of children with neurological disorders have focused on their physical consequences and have used cognitive and perceptual functions to evaluate the effectiveness of therapeutic interventions in rehabilitation. It is important to examine cognitive impairment in CP, because cognitive deficits independently affect the performance of functional activities and integration with community and school surroundings (Hadden & von Baeyer, 2005). However, there have been insufficient studies on the relationship between physical and cognitive functioning in children with CP in general and diplegics in specific. Also, the studies illustrating this relationship examine the relationship using different types of CP children with a small number of diplegic types. Therefore, their results cannot be generalized for a specific type of CP.

The results of our study show that standing and walking gross motor functions were significantly correlated with selective attention, which is in agreement with findings of Song (2013), who found that the GMFM was significantly correlated with the Bayley Scales of Infant Development-Second Edition (BSID-II) cognitive scale ($r = 0.719$) and the BSID-II motor scale was significantly correlated with BSID-II cognitive scale ($r = 0.866$) in 68 children with different types of CP. Furthermore, our findings are in line with the results of Enkelaar, Ketelaar, and Gorter (2008) who found association between mental and motor functioning in 78 toddlers with different types of CP, as measured by the BSID-II mental and motor scale ($r = 0.67, p = 0.01$). They added that in almost two-thirds of the toddlers, motor and mental functioning seemed to be developing synchronously, and in those cases in which motor and mental functioning did not develop similarly, it was always in favor of mental functioning.

Although significant correlation was found between motor and mental functioning in the studies of Song (2013) and Enkelaar et al. (2008), which is in agreement with our findings. Direct comparison with our results seems problematic because they used different assessment tools, different ages, and assessed general types of CP and general cognitive and motor skills rather than specific types.

A link between motor and cognitive development was already revealed by Piaget in the 1950s (Piaget, 1952). More recent studies like that by Davis, Pitchford, and Limback (2011) confirmed a link between cognitive and motor components by tracing it back to visual processing and fine motor control. They examined the strength and nature of the interrelation between cognitive and motor development across age by measuring performance in each of these domains in a group of 4- to 11-year old children. Across the entire sample, a significant positive correlation of moderate strength was found between the overall cognitive and motor indices generated by the standardized measures, indicating that these domains are developmentally linked. Correlations between indices of the standardized measures and a principal component analysis revealed that visual processing and fine manual control largely accounted for the interrelation among the overall domains.

In general, our data showed consistent correlations across age between cognitive and motor ability, suggesting close and stable links throughout childhood. This accords with some previous research by Ahnert, Bos, and Schneider (2003) and Davis et al. (2011), but does not support the prediction by Ackerman (1988) that the strength of this relationship will decrease with age as motor skills require less attention with practice.

Wassenberg et al. (2005) studied the relation between cognitive and motor performance, statistically corrected for attention in large cross sectional sample drawn from a population of 5–6-year old children attending normal kindergarten. No relation between the global aspects of cognitive and motor performance was found. Specific positive relations were found between both aspects of motor performance, visual motor integration and working memory, and between quantitative aspects of motor performance and fluency.

Hartman, Houwen, Scherder, and Visscher (2010) found that primary school-age children with intellectual disability (ID) experience problems with qualitative motor performance, especially object control skills, and executive functions. Furthermore, the motor and executive deficits seem to be related: poorer motor control results in poorer executive function (EF) and vice versa. Many authors demonstrated that cognitive functions are not separate from sensory motor control (Cisek & Kalaska, 2010; Koziol & Lutz, 2013; Pezzulo, 2011). Movement is the “training ground” for anticipation and even in neonates, purposeful movement is associated with the anticipation of an outcome deficit in the suckling reflex, which, for example, are strongly predictive of neurodevelopmental abnormalities in the future (Poore & Barlow, 2009).

Diamond (2000) stated that both complex cognitive and motor development, in terms of fine motor control, bimanual coordination and visuomotor skills, continues into early adulthood, and that both cerebellum and prefrontal cortex reach maturity late (Luna & Sweeney, 2001; Rubia et al., 2006). This consequently implies that motor performance affects cognitive functioning in children, and vice versa. Our study was restricted to gross motor skills, which comes in agreement with
a longitudinal study by Murray et al. (2006) who found that early gross motor development was related to superior adult EF. Furthermore, Piek, Dawson, Smith, and Gasson (2008) found a relationship between early gross motor and later school aged cognitive development.

Contrary to the results of an investigation by Ziereis and Jansen (2016), who found a significant relationship between motor abilities and working memory performance in 50 children with attention deficit hyperactivity disorder (ADHD), we were not able to find evidence for a significant relationship between motor ability and figural memory in the current study although the correlation between them approached significance.

**Limitations**

The emphasis of this study was to establish the correlation between selective attention and figural memory cognitive functions with standing and walking motor abilities. Laboratory measures of cognitive function were used rather than assessment of cognitive function at home or at school. Thus, we are not able to state whether the obtained correlation also exists in day-to-day life. Beckung and Hagberg (2002) found that, in addition to gross motor function, IQ and bimanual fine motor function were important predictors of participation restrictions, making further research into the relationships between fine motor function and mental and motor functioning even more important. Moreover, other internal and external factors, such as epilepsy, communication problems, or family related factors, also might have influenced the relationship between mental and motor functioning and need to be further investigated. Another limiting factor is the use of a single tool for assessment of both cognitive function and motor ability. As a result, further investigations exploring cognitive function and motor performance in children with diplegic CP should use more than one assessment tool while assessing each domain of function. Finally, in our study, assessment of cognitive function includes only two cognitive domains of function: selective attention and figural memory. Therefore, further research is needed to assess correlation using other different cognitive domains and the global cognitive area. Also, other motor abilities such as sitting and crawling needed to be studied using smaller ages and different subtypes of CP.

**Conclusion**

The current study shows a significant relationship between selective attention domain of cognitive function and gross motor abilities; standing and walking in children with spastic diplegia. No significant correlation was found between figural memory and gross motor function in the tested children, although it approached significance. These results have important implications for clinical, educational, and experimental practice. The present study provides evidence for the necessity of including cognitive and physical impairments in the examination and evaluation of children with diplegic CP in research and clinical settings. Also, therapeutic intervention for selective attention should be carefully considered when designing a program to improve gross motor function for children with spastic diplegia.

**References**


