International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(REVIEW ARTICLE)

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Exploring the interplay between cognition and cerebral palsy: A comprehensive review

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International Journal of Science and Research Archive, 2024, 12(01), 1086–1094

Publication history: Received on 18 April 2024 revised on 24 May 2024; accepted on 27 May 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.12.1.0939

Abstract

Cerebral palsy (CP) is a group of permanent movement disorders that appear in early childhood which is termed as ‘‘motor-oriented’’, in the clinical setting, but the nonmotor co-morbidities often account for a substantial part of the disability and functional limitation experienced by the patient, rather than the motor component.

Despite being primarily associated with motor impairments, there is a significant interplay between cerebral palsy and cognitive functions. Besides the visible motor impairments, cognitive abilities are frequently affected but might remain unrecognised in children with mild forms. On the other hand, some severely disabled children with presumed intellectual disabilities might demonstrate normal-range reasoning capacities. Most studies on this topic have emphasized a variety of cognitive profiles (cognitive level) related to the type of cerebral palsy and the underlying brain lesions (biological level).

This comprehensive review examines the multifaceted relationship between cognition and cerebral palsy, highlighting the complexities of cognitive deficits, the impact on daily functioning, and the importance of early intervention. Also discusses about the prevalence and types of cognitive impairments. Through an extensive review of current literature, this article aims to provide a holistic understanding of how cerebral palsy affects cognitive development and functioning and cognitive functioning in children with CP from a developmental perspective.

The objectives of this study were to describe the epidemiology of cognitive impairment in CP in terms of clinical and neuroimaging associations, and to report the impact of cognitive impairment on utilization of health services and longevity would provide a basis for future decision-making around health care delivery for this group.

Keywords: Cerebral Palsy; Cognition; Cognitive Functioning; Cognitive Impairment; Children

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1. Introduction

Cerebral palsy (CP) is one of the most common causes of physical disability in childhood. Population-based studies from around the world report prevalence estimates of CP ranging from 1.5 to more than 4 per 1,000 live births or children. (1)

Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication, behaviour, by epilepsy and by secondary musculoskeletal problems."(2)

The classification of CP is typically based on the type and distribution of motor abnormalities and the functional status of the individual. The common types include spastic, dyskinetic, ataxic, and mixed forms of CP. While the motor impairments associated with CP are well-documented, the cognitive aspects of the disorder are less frequently discussed yet equally significant. cognition plays a greater role for communication, academic functioning, participation, and social functioning, it has been less focused upon. (3)

Cognitive impairments in children with CP can range from mild to severe and can impact various domains such as attention, executive function, memory, and learning. This review aims to elucidate the relationship between cerebral palsy and cognition, exploring the underlying neurobiological mechanisms, the types and prevalence of cognitive impairments, and the implications for intervention and management.

The etiology of CP is multifactorial, with causes ranging from prenatal, perinatal, to postnatal factors. Prenatal causes include genetic abnormalities, intrauterine infections, and placental pathologies. Perinatal factors often involve birth asphyxia, preterm birth, and neonatal stroke. Postnatal causes might include infections, traumatic brain injury, and severe jaundice. The pathophysiology of CP involves damage to the developing brain's white matter, grey matter, or both, leading to impaired transmission of neural signals and subsequent motor and cognitive deficits. (4)

1.1. Cognitive impairments in cerebral palsy

Cognitive impairments are prevalent in individuals with CP, though the degree and nature of these impairments vary widely. Studies suggest that approximately 30-50% of children with CP have some level of cognitive impairment. (7) These impairments can affect several cognitive domains, including:

- Attention and Executive Function: Difficulties in sustaining attention, inhibitory control, and working memory are common. Executive dysfunction can manifest as problems with planning, organizing, and flexible thinking.
- Memory: Both short-term and long-term memory can be affected. Children with CP may struggle with encoding, storage, and retrieval of information.
- Language and Communication: Language impairments, such as delayed speech development and difficulties with expressive and receptive language, are frequently observed.
- Visual-Spatial Skills: Problems with visual perception and spatial awareness can impact everyday tasks and academic performance.(2)

1.2. Cognitive level

All domains and functions such as global intelligence (as expressed by IQ), memory, language, executive and attentional resources, visual perceptual and visuoconstructional skills, might be affected in various combinations in children with CP, resulting in heterogeneous profiles. Among all children with CP, approximately 50% have intellectual impairment. Most studies show that intelligence is strongly (but not absolutely) correlated with the degree of motor impairment and with epilepsy. (7)

Visual perceptual impairment is considered a core feature in all forms of CP, affecting about half of children with CP and not solely those with predominant white-matter injuries [8,9]. The aetiology of cerebral visual impairment in CP is related to the vulnerability of the posterior white-matter tracts, particularly but not exclusively in preterm children with periventricular leukomalacia (10). These children feature a range of observable deficits, independent of intellectual levels, that reflect both dorsal and ventral stream dysfunction (9).

Right-hemispheric lesions are associated with impaired visuospatial memory and navigation strategies. (11) Finally, abnormal uni- or bilateral sensorimotor motor development, reduced hand-eye coordination, abnormal body part

representation (finger gnosia), and limited digital use might reduce play and exploration and lead to altered spatial cognition (12,13,14). With respect to activity and participation, visual perceptual impairment is associated with everyday motor skills such as bimanual coordination and motor planning (15) as well as academic achievements, especially the acquisition of literacy and arithmetic skills (16,17).

One quarter of all children with CP are nonverbal (18). In most ambulant individuals with CP, preserved basic language ability is the rule, (19,20) but speech and language problems are common in children with more severe forms of CP Severe speech and language impairment is most frequent in children with diplegia, most featuring severe impairment of communication (21). In these individuals, receptive language is often better preserved, likely related to distinct affected cerebral structures (22–24). In bilateral spastic CP, more than one third of individuals have severe speech and language impairment (21). In quadriplegic spastic CP, both expressive speech (ranging from anarthria to dysarthria) and receptive language are typically affected (22–24). Gross linguistic impairment is rare in people with unilateral spastic CP, for whom robust language network plasticity has been well described after left hemispheric damage (25,26,27).

Language development, especially receptive language, is associated with general cognitive abilities (28,29,30). Oromotor, speech and expressive language functions are well correlated with gross motor functioning (31,32,33). Impaired communication grossly affects academic and social participation, and even the more subtle receptive language problems of youth with unilateral spastic CP may prevent them from full participation because of a lack of comprehension in conversation or in understanding text.

Several studies have been recently dedicated to attentional and executive functions that encompass multiple domains, including attentional control, working memory, cognitive flexibility, goal-setting, and information processing. These higher-order cognitive functions that mature progressively during childhood and adolescence rely on a complex cerebral network involving multiple, predominantly anterior, and cortico-thalamo-basal ganglia loops, which are particularly vulnerable to early brain injuries. Despite the diversity of tests to assess executive function in children with CP(34), there is a convergence across studies suggesting that most children with CP exhibit mild to moderate deficits in attention and executive functions culminating in attention deficit/hyperactivity disorder in many(10,35-39).The presence of attention deficit/hyperactivity disorder does not seem associated with the severity of motor impairment (21).

Across CP subtypes, processing speed is impaired in the visual and motor domain, whereas stimulus evaluation and performance monitoring seem intact (40). In children with unilateral spastic CP, visual-spatial attention seems abnormal (41). Such problems in attention and executive functions directly affect daily life, not only at school but also in the environment, affecting adaptive behaviour, social participation and quality of life (10).

Data regarding memory capacities in children with CP are sparse and essentially limited to short-term and working memory, which affect learning capacities and predict academic achievements (42-44). Both visual-spatial and verbal working memory seem impaired in all forms of CP (45-47) but to a lesser degree in diplegic CP than spastic CP [84]. In spastic CP, visualspatial working memory was not found associated with gross motor impairment, (46,48) whereas verbal working memory was associated with motor speech impairment and narrative abilities (48,49).

Deficits in visual-spatial working memory have been associated with lesion size in the right hemisphere (11) but also left hemispheric lesions in UCP, indicative of compromised visuospatial skills in the context of language reorganization (45). Long-term memory has been mostly studied in hemiplegic children with epilepsy, which per se might be responsible for memory impairment (50).

Seminal publications from Vargha-Khadem and co-workers have reported on selective severe episodic memory impairments (i.e., developmental amnesia) in children who experienced perinatal hypoxic-ischemic events. These children exhibited bilateral hippocampal atrophy as well as volume reduction in deep grey-matter structures compatible with the presumed mechanism; nevertheless, none had CP and all were attending mainstream schools, with good academic achievements (51,52).

Similar findings were found in 2 recent studies of children with hypoxic-ischemic encephalopathy (53,54). Bi-hippocampal atrophy was identified on MRI in a large proportion of diplegic children with declarative-episodic impairment (54). Furthermore, when comparing children with and without CP who had hypoxic-ischemic encephalopathy, the memory problems were more ‘‘pronounced’’ in children with than without CP (53). However, these 2 studies did not provide any data regarding academic achievements but recommended careful monitoring of educational achievement.

1.3. Factors influencing cognitive outcomes

Several factors influence the cognitive outcomes in children with CP, including:

- Severity of Motor Impairments: More severe motor impairments are often associated with more significant cognitive deficits.
- Type of CP: Different types of CP are linked with varying cognitive profiles. For instance, children with spastic quadriplegia are more likely to have severe cognitive impairments compared to those with spastic hemiplegia. (5,10)
- Associated Conditions: The presence of additional conditions such as epilepsy, sensory impairments, and other comorbidities can exacerbate cognitive difficulties.
- Socioeconomic and Environmental Factors: Access to early intervention, educational resources, and a supportive environment plays a crucial role in cognitive development.

Table 1 Types of CP – Brain Involvement: (6)

Clinical forms of cp	**Unilateral cp**	**Spastic (diplegia)**	**Spastic cp (quadriplegia)**	**Dyskinetic cp**
Structural level (predominant cause)	Periventricular venous infarction Unilateral arterial ischemic stroke Unilateral brain malformation	Periventricular leukomalacia (preterm >> term)	Extensive periventricular white-matter changes. Diffuse cortical and subcortical perinatal injuries Bilateral brain malformation	Predominantly deep grey matter injury
Cognitive level Intellectual abilities	Intelligence most often preserved Verbal > non-verbal	Intelligence often preserved Verbal > non-verbal	Intelligence often mild to severely affected	Intelligence preserved in > 50%
Speech and language	Subtle to mild deficit in basic and high-order linguistic components	Limited data, but no evidence of clinical overt deficit	Heavily impaired expressive speech and reduced comprehension	Heavily impaired speech, normal comprehension
Visuospatial functions	Mild deficit	Marked visuoperceptual and visuomotor deficit	High risk of cerebral visual impairment	Often spared
Working memory	Deficit	Deficit	Deficit	Limited data
Executive functions	Deficit	Deficit	Deficit	Mildly affected
Attention	Deficit	Deficit	Deficit	Limited data
Behavioural level Learning impairment	High prevalence of subtle mild learning disabilities (Reading disability and Mathematical disability)	Mathematical disability >> Reading disability	Rudimentary learning skills	Limited access to academic skills despite potentially preserved intelligence
Exacerbating factors for cognitive impairment	Epilepsy, antiepileptic drugs, socioeconomic status	Gestational age, socioeconomic status	Epilepsy, antiepileptic drugs, socioeconomic status	Insufficient access to assisting technology, socioeconomic status

2. Neurobiological mechanisms underlying cognitive impairments

2.1. Brain Lesions and Cognitive Deficits

The neurobiological basis of cognitive impairments in CP is often related to the location and extent of brain lesions. Lesions in specific brain regions, such as the frontal lobe, parietal lobe, and basal ganglia, can lead to deficits in executive function, memory, and motor control, respectively. White matter damage, particularly periventricular leukomalacia, is strongly associated with cognitive impairments due to disrupted neural connectivity. (2)

2.2. Neuroplasticity and Compensation

Despite the early brain injury associated with CP, the developing brain exhibits a remarkable capacity for neuroplasticity. Neuroplasticity refers to the brain's ability to reorganize itself by forming new neural connections. In children with CP, neuroplasticity can lead to functional compensation, where unaffected brain regions may partially take over the functions of damaged areas. However, the extent of compensation varies, and the early critical periods of brain development underscore the importance of timely interventions. (2)

2.3. Impact on daily functioning and quality of life

2.3.1. Educational Implications

Cognitive impairments in children with CP can significantly affect their educational performance. Challenges with attention, memory, and executive function can hinder academic achievement, necessitating individualized education plans and specialized support services. Early identification and intervention are crucial to address learning difficulties and promote academic success.

2.3.2. Social and Emotional Functioning

Cognitive deficits can also impact social interactions and emotional well-being. Children with CP may experience difficulties in social communication, understanding social cues, and forming peer relationships. These challenges can lead to social isolation, low self-esteem, and increased risk of mental health issues such as anxiety and depression.

2.3.3. Activities of Daily Living

The ability to perform activities of daily living is often compromised in children with CP, particularly those with more severe cognitive impairments. Tasks such as dressing, feeding, and personal hygiene require both motor skills and cognitive planning. Occupational therapy and adaptive technologies can help enhance independence and improve quality of life.

2.4. Intervention and management strategies

2.4.1. Early Intervention

Early intervention is critical for optimizing cognitive and motor outcomes in children with CP. Multidisciplinary approaches that involve physical therapy, occupational therapy, speech-language therapy, assistive devices and special education services are essential. Early intervention programs focus on enhancing developmental skills, promoting neuroplasticity, and supporting families.

Early intervention can significantly enhance the development of motor skills, cognitive abilities, and overall quality of life. Initiating therapy as soon as possible can maximise the child’s potential and reduce the severity of complications associated with cp.

2.4.2. Cognitive Rehabilitation

Cognitive rehabilitation aims to improve cognitive functioning through targeted exercises and activities. Techniques such as cognitive-behavioural therapy, computer-based cognitive training, and task-specific training can be effective. The goal is to strengthen cognitive skills, compensate for deficits, and improve overall functioning.

2.4.3. Assistive Technologies

Assistive technologies play a vital role in supporting cognitive and daily functioning in individuals with CP. Tools such as augmentative and alternative communication devices, computer-based learning programs, and adaptive equipment can facilitate communication, learning, and independence.

2.4.4. Pharmacological Interventions

Pharmacological interventions may be used to manage associated conditions such as epilepsy, attention-deficit/hyperactivity disorder, and mood disorders, which can indirectly impact cognitive functioning. Medications should be carefully monitored for efficacy and potential side effects.

2.5. Future directions and research

2.5.1. Advances in Neuroimaging

Advances in neuroimaging techniques, such as functional MRI and diffusion tensor imaging (DTI), offer new insights into the neural correlates of cognitive impairments in CP. These technologies can help identify specific brain networks involved in cognitive processes and guide targeted interventions.

2.5.2. Genetic and Molecular Research

Ongoing research into the genetic and molecular underpinnings of CP holds promise for understanding the mechanisms of brain injury and potential therapeutic targets. Identifying genetic risk factors and biomarkers can lead to earlier diagnosis and personalized treatment approaches.

2.5.3. Longitudinal Studies

Longitudinal studies are needed to track cognitive development and outcomes over time in individuals with CP. Such studies can provide valuable information on the long-term effects of early interventions, the progression of cognitive impairments, and factors influencing positive outcomes.

3. Conclusion

Cerebral palsy is a complex disorder with significant cognitive implications that extend beyond motor impairments. Understanding the interplay between cognition and CP is crucial for developing effective interventions and improving the quality of life for affected individuals. This comprehensive review highlights the prevalence and types of cognitive impairments, underlying neurobiological mechanisms, and the impact on daily functioning. Early identification, multidisciplinary intervention, and ongoing research are essential for addressing the cognitive challenges associated with CP and promoting optimal development and well-being. The different treatment principles mentioned in any system of medicine are to be incorporated and a holistic approach for cerebral palsy.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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