Chapter

Cerebral Palsy

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Abstract

Cerebral palsy is one of the most common neurodevelopmental and musculoskeletal problems in the world. Two or four out of 1000 births each year are born with this disease. Cerebral palsy, with its various etiologies impacting different areas of the brain, adds to a broad spectrum of clinical findings that may result in secondary problems like hip pain or dislocation, balance issues, hand dysfunction, joint deformities, and social challenges. Children with cerebral palsy have difficulties in providing trunk postural control and balance, which is critical for independence in daily living activities. Treatment requires a multidisciplinary approach, and the aim is for the child to continue daily life and education with maximum independence. With the development of technology, new technological methods are applied in the rehabilitation process and contribute to the improvement of activity and participation.

Keywords: cerebral palsy, childhood disability, rehabilitation, quality of life, education

1. Introduction

Cerebral palsy (CP) is a permanent childhood disease that affects the functionality, participation in social life, and independence of the person from the earliest periods. Health professionals make important contributions to increase the level of participation and independence of children in home, school, and social environments at every stage of their lives. Recent research results have shown that new technological treatment options also have important contributions in this field.

2. Definition

Cerebral palsy is a group of disorders that can be defined as an overarching term. It constitutes a persistent condition, albeit not inherently fixed, marked by deficits in both movement and/or posture as well as motor functionality. It results from a non-progressive response/impairment/abnormality that occurs in the developing/immature brain. These "five essential elements" provide a clear and concise definition of CP and reflect the main features of the definitions to date [1–4]. CP is a physical and developmental disability caused by disorders in the brain before or during birth. CP causes permanent impairments in movement and posture. Described in 1861, ideas and knowledge about CP have evolved over time. In 2006, an international panel reached a consensus definition of CP as a condition associated with non-progressive impairments. CP is a common developmental disorder encountered by many pediatric healthcare providers.

This update reviews current knowledge on the diagnostic methods, prevalence, risk factors, genetic research, and clinical management of CP. These data are evaluated with the aim of providing better healthcare for patients with CP and their families [3–5].

3. Prevalence of cerebral palsy

Epidemiological studies indicate that the prevalence of CP varies between 2 and 4 per 1000 live births. However, it is important to note that the data contain geographical differences and that there are different rates between countries [6, 7]. In a meta-analysis conducted by Oskoui et al., the total prevalence of CP worldwide was reported to be 2.11 per 1000 live births [8]. In a comprehensive study conducted to determine trends and current estimates regarding the regional and global prevalence of CP, 27 countries and 41 regions from five continents were included in the study. The study concluded that the prevalence rate for CP of prenatal and perinatal origin in high-income countries was 1.5 per 1000 live births, and when postneonatal CP was included, this rate was 1.6. In contrast, the prevalence of CP in low- and middle-income countries was reported to be significantly higher at 3.4 per 1000 live births. It has been reported that the prevalence trends in low- and middle-income countries cannot be measured at the moment. However, it is evident that prevalence tends to decrease in high-income countries [9].

4. Etiology

Cerebral palsy is a condition with various etiologies, resulting in a variety of clinical manifestations due to brain damage. CP can occur as a result of risk factors and associated conditions in the prenatal, perinatal, and postnatal periods of the developing brain. Initially, CP was thought to be caused by hypoxia at birth or during the perinatal period. However, in most cases, the initial event of CP cannot be determined. Studies have indicated that the cause of CP is often difficult to determine. In approximately 30% of children with CP, no known etiology or risk factor can be identified. Approximately 75% of cases are associated with a prenatal cause, while perinatal and neonatal risk factors are responsible for 10–18% of cases. However, it is observed that most children with risk factors do not develop CP [10–12].

Risk factors associated with CP include maternal infection, difficult delivery, arterial defects, and asphyxia in the prenatal period, as well as trauma and cerebrovascular events in the postnatal period. Preterm birth is one of the greatest risk factors for the development of CP, with preterm children accounting for approximately 35% of CP cases. A neonate born prior to 28 weeks of gestational age is 50 times more likely to develop CP than a neonate born at term. Multiple births carry a fivefold increased risk of CP compared to single births. Other risk factors for CP include male gender and low socioeconomic status. Previously, genetic factors were thought to have a 1–2% effect on CP. However, recent studies have indicated that genetic factors are involved in approximately 30% of children diagnosed with CP [13–15].

5. Diagnosis

The diagnosis of CP is based on a combination of neurological examinations, neuroimaging findings, and clinical risk factors. Recent advances in technology

have enabled earlier and more accurate diagnosis of CP, allowing early diagnosis and initiation of treatments that can improve long-term outcomes. It is noted that early diagnosis allows for the initiation of treatments and can improve long-term outcomes. Population studies indicate that parents generally prefer to find out earlier whether their child has CP or is at high risk for CP. A variety of screening tools and neurological assessments are employed to diagnose CP, with the objective of enabling earlier detection of high-risk children in the neonatal period and closer follow-up. Prior to 5 months of age, neonatal magnetic resonance imaging (MRI) is reported to be among the tools with the best predictive validity for the detection of CP [16, 17]. Consequently, it is imperative to implement more effective measures for early diagnosis and initiate treatments at an earlier stage. Neonatal MRI, Prechtl General Movement Assessment, and Hammersmith Infant Neurological Examination are important tools used for the diagnosis of CP in newborns. A standardized neurological examination and neuroimaging is recommended for CP in newborns. It is recommended to use the label 'high risk for CP' for babies with suspected CP. MRI findings indicating high risk for CP in newborns include white matter damage, damage to deep gray matter structures, cerebellar hemorrhage, and developmental brain malformations [18]. Some children with CP may have normal MRI or ultrasonography results in the neonatal period. In children with normal neuroimaging but persistent neurologic abnormalities, underlying genetic or metabolic causes should be investigated. In patients with CP, imaging is crucial for determining the types and extent of brain damage, as well as for assessing the risk of neurodevelopmental disability [19–21].

The assessment of spontaneous infant movements is a method employed in the diagnosis of motor dysfunctions. The General Movement Assessment (GMA), developed by Heinz Prechtl, is a predictive model used to describe infants' movements. A recent review of the GMA identified two movement patterns that are highly sensitive and specific for the diagnosis of spastic paresis: restricted synchronized general movements, which are characterized by rigid contraction and relaxation of muscles, and the lack of small amplitude fidgety movements that should be present in normal newborns. Other reviews have also reported that assessment with GMA in high-risk neonates provides high sensitivity and specificity in predicting spastic paresis. It is recommended that GMA be performed by providers who have completed standardized training in order to ensure accuracy and reliability [19, 22–24].

6. Early symptoms and classification

Early detection of cerebral palsy in infancy is paramount for initiating timely interventions and improving long-term outcomes. Several key indicators can aid in the recognition of CP during this critical period:

1. Neurobehavioral signs: Suspicious neurobehavioral signs may include excessive irritability, lethargy, poor sleep patterns, frequent vomiting, difficulty in being held or cuddled, and impaired visual attention.

2. Developmental reflexes: Monitoring the disappearance of developmental reflexes is crucial. Delayed or exaggerated disappearance of these reflexes, such as the tonic labyrinth reflex or abnormal response to vertical suspension, can serve as early indicators of motor disability.

3. Motor tone and posture: Evaluation of motor tone and posture provides valuable insights. Observing for poor head control, persistent or asymmetric hand fisting, and abnormal oromotor patterns (e.g., tongue thrusting or facial gestures) can help identify early motor signs. However, it's important to note that elevated neck extensor and axial tone may falsely indicate superior head control.

4. Motor milestones: Regular assessment of motor milestones is recommended by the American Academy of Pediatrics. Conducting developmental screenings at 9, 18, 30, and 48 months enables the early detection of any delays or abnormalities, facilitating prompt intervention and support.

By incorporating these systematic assessments into clinical practice, healthcare professionals can enhance their ability to detect CP in infancy, leading to earlier interventions and improved outcomes for affected children [25].

6.1 Cerebral palsy surveillance group of Europe (SCPE) classification system

The SCPE classification system is currently the most widely used classification system for the classification of CP. It classifies children with CP according to their clinical characteristics as follows:

a. Spastic type (unilateral or bilateral)

b. Dyskinetic type (dystonic, chorea-athetoid)

c. Ataxic

d. Unclassifiable (Mix)

A recent study by Himmelmann et al. reported that 40% of children with cerebral palsy exhibited unilateral spasticity (hemiparetic), 39% exhibited bilateral spasticity (diparetic and quadriparetic), 16% exhibited dyskinetic features, and 5% exhibited ataxic features [26–28]. It is not uncommon for one type of CP to exhibit features belonging to other types. In such cases, classification is based on the dominant feature. The "Classification Tree," created by the SCPE, facilitates the process of classification, making it more straightforward and accurate [26]. Although hypotonic CP has been previously defined, it is not included in contemporary classifications. The evolution of CP from hypotonia in early infancy to other subtypes such as spastic, dyskinetic, or ataxic CP is a common phenomenon. However, it's important to recognize that not all children follow this typical progression. In some cases, children may continue to exhibit hypotonia due to specific involvement of cerebro-cerebellar or extrapyramidal circuits. These circuits play crucial roles in motor control and coordination, and their impairment can result in persistent hypotonia.

6.1.1 Spastic cerebral palsy

Patients with spastic cerebral palsy present with upper motor neurone findings, including spasticity, hyperreflexia (with or without clonus), and an extensor plantar response [27–29]. Children with CP may exhibit various spastic syndromes, including spastic diplegia, characterized by gross motor problems primarily affecting the lower

limbs but with preserved fine motor function in the upper limbs, often associated with periventricular leukomalacia and periventricular hemorrhagic infarction; spastic quadriplegia, presenting severe motor impairments affecting both upper and lower limbs equally, with minimal speech and language development, visual impairment, epilepsy, and feeding difficulties, often accompanied by multicystic encephalomalacia on magnetic resonance imaging; and spastic hemiplegia, featuring asymmetric motor impairment with the arm more affected than the leg, sometimes accompanied by athetotic posture, and commonly associated with sensory deficits reflected as poor muscle mass on the affected side without motor deficits [29].

In addition, mental impairment, hemianopia, and other visual problems may also be observed. Furthermore, behavioral problems including anxiety, defiance, and specific phobias are common among children with hemiplegic CP.

6.1.2 Dyskinetic syndromes

Dyskinetic CP can be further subclassified as choreo-athetoid and dystonic. Choreo-athetoid CP is characterized by rapid, irregular, unpredictable contractions of individual muscles/muscle groups, involving the face, bulbar muscles, proximal extremities, and fingers. In addition, there are slow writhing movements involving the distal muscles. Oropharyngeal difficulties may result from grimacing. Primitive reflexes usually persist into childhood. Dystonic CP is characterized by the simultaneous contraction of agonist and antagonist muscles. Pyramidal findings and dysarthria are frequently observed in conjunction with one another.

6.1.3 Ataxic CP

Ataxic CP represents a relatively infrequent manifestation necessitating careful differentiation from progressive neurodegenerative conditions. Delayed attainment of motor and language milestones commonly characterizes its clinical presentation. Notably, the ataxic symptoms tend to ameliorate with time, emphasizing the dynamic nature of this subtype within the spectrum of CP [29, 30].

7. Classification by functional ability

In addition to the SCPE classification method, functional classification systems are another classification method currently used for children with CP. These classification systems have been developed to provide information about the functional status of children with CP, to categorize the level of independence of children in different areas, to provide a holistic view, and to provide a common language within multidisciplinary and interdisciplinary study models. They make the classification using a simple ordinal scale. They classify Gross Motor Function Classification System (GMFCS), Manual Ability Classification System (MACS), Communication Function Classification System (CFCS), Eating and Drinking Function Classification System (EDACS), Visual Function Classification System (VFCS), and Speech Function System (VSS).

Of these classification systems, GMFCS, MACS, CFCS, EDACS, and VFCS consist of five levels, while VSS consists of four levels. However, all classification systems categorize functions with a similar logic. Level 1 refers to the level at which children are most functionally independent [31].

7.1 Gross motor function classification system

The GMFCS is a measure used to classify the gross motor function of people with cerebral palsy. This simple and sequential grading system provides a common language used in conjunction with the GMFCS. The GMFCS describes the mobility of the individual and the assistive devices used for mobility (walkers, crutches, canes, wheelchairs). This classification system is used to distinguish clinically significant differences in the assessment of motor function in children with CP. The GMFCS was originally designed for children aged 2–12 years but was later extended to the age range 12–18 years, making the levels more detailed. This revision allows age-appropriate classifications to be made, taking into account developmental milestones [32–34].

7.2 Manual ability classification system

In 2006, Eliasson et al. introduced the Manual Ability Classification System (MACS) as a counterpart to the Gross Motor Function Classification System (GMFCS), focusing specifically on upper extremity function. This simple ordinal classification system consists of five points and is tailored for children aged 4–18 years. The MACS serves as a validated tool for categorizing a child's habitual use of their hands and upper limbs in cases of cerebral palsy [28, 35].

7.3 Communication function classification system

The CFCS is a communication classification system developed by Hidecker et al. in 2011. This system is designed to assess the daily communication of people with cerebral palsy. It is estimated that 31–88% of people with CP have a comorbid communication disorder [36]. The CFCS is a five-point rating system and is designed to be compatible with other classification systems such as the GMFCS and MACS. The CFCS is a system that assesses both how information is expressed and how it is received. It covers all methods of communication and is suitable for people who cannot express themselves. The CFCS assesses a variety of communication methods including voice, manual signs, eye gaze, pictures, communication boards, and voice generating devices. The CFCS also considers both familiar and unfamiliar communication partners. In this way, the CFCS provides a comprehensive and descriptive assessment of communication [37].

7.4 Eating and drinking ability classification system

The Eating and Drinking Ability Classification System has been developed as a valid measure to assess the eating and drinking ability of children with cerebral palsy. People with CP are thought to have difficulties with eating and drinking. In 2014, Sellers et al. devised the EDACS, aimed at evaluating the nutritional skills of children diagnosed with cerebral palsy aged 3 years and older. The system assesses the safety and efficiency of eating and drinking. There is also an additional three-point ordinal scale to determine the level of assistance required: independent, requiring assistance, or dependent for eating. EDACS is similar and supplementary to the GMFCS, MACS, and CFCS. This classification system provides a comprehensive assessment of the eating and drinking needs of people with CP [38, 39].

8. Problems seen in cerebral palsy

The problems seen in cerebral palsy are quite complex, and different pictures can occur.

8.1 Range of motion problems

Although spasticity is a common finding in people with cerebral palsy, most people with CP have limb deformities and limited range of motion rather than spasticity. It is generally accepted that such movement limitations are caused by secondary changes in the muscles and soft tissues. In these patients, the limited range of motion, known as contracture, is treated by splinting, botulinum toxin type A injections, surgical lengthening of the spastic muscles, or tenotomy [40].

8.2 Muscle tone problems

Cerebral palsy is usually associated with developmental delay and muscle tone problems such as hypotonia, dystonia, and spasticity. The peripheral and central nervous systems produce muscle tone by reflex mechanisms. In hypotonia, the mechanism of muscle contraction is slower. It is characterized by a decrease in muscle tone, stretch reflexes, and primitive reflex patterns. Hypotonia can often be seen as a transitional stage to spasticity. The most prominent feature of these individuals is joint hypermobility. Motor problems in these individuals are usually characterized by inadequate head and trunk control, balance, and corrective and protective responses. In dystonia, involuntary muscle contractions are repeated continuously or intermittently, resulting in hypertonic movements and prolonged muscle contractions. This leads to abnormal posture in the proximal parts of the extremities, trunk and neck. Spasticity, another muscle problem, is known to be the main cause of CP in children. When a muscle is stretched, the neuromuscular system can respond automatically by changing muscle tone. This modulation of the stretch reflex is important for controlling movement and maintaining balance. Lance et al. defined spasticity as "a speed-dependent increase in the stretch reflex." Prolonged spasticity can lead to changes in anatomical structures, such as bone dislocation or transformation of muscle into fibrous tissue. Ineffective management of spasticity can lead to severe immobilization in addition to these detrimental effects [41–44].

Spasticity stands out as the predominant issue in cerebral palsy, demonstrating a tendency to affect the entirety of the body. Nonetheless, it typically exhibits heightened severity in the lower limbs among individuals with bilateral involvement, while in those with unilateral impairment, it is more prominently observed in the upper limbs. In children with CP, the gastrocsoleus, hamstrings, rectus femoris, adductors, and psoas muscles are usually affected in the lower limbs, while in the upper limbs, spasticity is seen in the shoulder external rotators, elbow, wrist and finger flexors, and elbow pronators. Spasticity impairs voluntary control, increases energy expenditure, and contributes to the development of secondary muscle and soft tissue contractures and skeletal deformities by preventing normal muscle stretching. Muscle contractures and skeletal deformities can lead to abnormal joint moments during gait [45–50].

8.3 Selectivity

People with cerebral palsy often experience problems such as reduced muscle strength, increased muscle tone/spasticity, and loss of motor control. Selectivity is a very important aspect of human movement and provides independent control of joint movement. Loss of selectivity can be described as "impaired isolated muscle activation during movement." Impaired selectivity is the inability to activate certain muscles without simultaneously activating other muscles. This can lead to a lack or excess of muscle activity and an inability to perform expected movements. Although impaired selectivity is associated with significant loss of function, the possible causes are not fully understood. However, it is thought that mirror movements occur due to bilateral cortical activation resulting from preserved ipsilateral corticospinal projections or insufficient interhemispheric inhibition. Impaired selectivity may interfere with isolated joint movements of flexor or extensor synergies, which may adversely affect functional movements such as walking and reaching. It is not clear which method is the most effective in treating selectivity [51–53].

8.4 Trunk stability and movement problems

One of the most important factors affecting the independence and quality of life of people with cerebral palsy is trunk control. Trunk control can be defined as the ability of the trunk muscles to maintain static and dynamic balance and to keep the body upright. In people with cerebral palsy, problems such as increased kyphosis, lumbar lordosis, and scoliosis can be seen with reduced head and trunk control. It has been reported that people with cerebral palsy increase their head and trunk movements during walking compared to their healthy peers, which may be due to reduced trunk stability. At the same time, trunk control is very important in situations that require upper and lower extremity activity, such as walking. Impaired trunk control may lead to increased trunk mobility during walking. In addition, trunk mobility may increase during upper extremity movements. Although there are studies reporting that poor upper extremity function limits postural control, it has been reported that there are many studies investigating upper extremity function in people with CP but a limited number of studies investigating the relationship between upper extremity function and trunk control. Therefore, the relationship between trunk control and upper extremity remains unclear [54–57].

8.5 Problems with functional independence

Causes such as spasticity, selectivity and sensory problems, muscle weakness, and secondary musculoskeletal problems negatively affect the level of functional independence of people with CP. Dressing, bathing, mobility, and bladder/bowel problems are reported to reduce the independence of people with cerebral palsy [58]. Therefore, it is also important to investigate the effect of a method used in people with CP on quality of life and functional independence.

8.6 Quality of life problems

Quality of life is a broad and multidimensional concept that encompasses the assessment of all positive and negative aspects of life. The World Health Organization

defines quality of life as "an individual's expectations, goals, standards, concerns and perceptions of his or her position in life within the culture and value system in which he or she lives" [59, 60].

Given the diversity of problems associated with cerebral palsy, it is not surprising that these problems have a profound impact on the physical, social, and emotional health and well-being of people with CP and their parents. Children with cerebral palsy are four times more likely than their peers to experience physical problems such as muscle weakness and spasticity, as well as emotional and behavioral problems. Therefore, quality of life is very important as it is a subjective indicator of the well-being of children with CP in their life domains. The individual's well-being and functioning in daily life is becoming an important part of clinical assessment and can help determine the individual's quality of life and help health professionals decide how best to plan appropriate and individualized care interventions [61, 62].

9. Innovative therapeutic techniques and technologies

Technological advances have had a significant impact on the field of pediatric physiotherapy, providing new ways to improve outcomes for children with CP and other motor and movement disorders. Innovative techniques and technologies are being integrated into clinical practice to improve established techniques and provide more effective interventions. Innovative techniques in the context of physiotherapy refer to new and advanced methods used by practitioners to assess, treat, and rehabilitate patients with CP. These techniques frequently entail creative and tailored approaches that may encompass a spectrum of manual therapies, exercise regimens, and movement retraining strategies designed to address specific impairments and optimize functional outcomes for individuals with CP. Innovative technologies pertain to the utilization of cutting-edge tools, equipment, and digital resources to enhance the assessment, intervention, and monitoring of individuals with CP. These technologies encompass a vast array of wearable sensors, virtual reality systems, and assistive robots. The utilization of contemporary technology enables physiotherapists to provide more precise and personalized care, which in turn leads to enhanced outcomes for individuals with CP [63].

9.1 Virtual reality rehabilitation

Virtual reality (VR) is a technology that creates immersive, computer-generated environments that users can interact with. In the context of rehabilitation, VR provides a controlled and customizable environment for individuals to participate in therapeutic exercises. This technology allows the creation of virtual scenarios that mimic real-world situations or specific tasks related to the individual's rehabilitation goals [64]. The utilization of virtual reality in sensorimotor training entails the design of exercises and activities that necessitate the integration of sensory and motor skills within a virtual environment. For instance, a patient with cerebral palsy may utilize VR simulations to perform tasks involving reaching, grasping, balance, or gait training [65]. One of the principal advantages of VR-based training is the capacity to provide immediate and accurate feedback to the user. The virtual environment monitors the user's movements in real time, allowing for accurate assessment and adjustment of performance. This feedback loop helps people with CP to develop their motor skills and improve their coordination. Furthermore, VR can create a motivating and

engaging therapy experience. The immersive nature of the technology can increase patient focus and engagement, which is particularly important for maintaining interest and adherence to rehabilitation programs over time. Furthermore, VR enables the creation of exercises that are tailored to the specific needs and abilities of the individual. Therapists can adjust parameters such as the level of difficulty, speed, and complexity of tasks to align with the patient's current skill level, with gradual progression as their abilities improve [66]. Research studies have demonstrated the efficacy of VR-based training for individuals with CP. Improvements have been observed in areas such as balance, coordination, muscle strength, and functional mobility [67].

9.2 Robot-assisted therapy

Robotic therapy is a form of rehabilitation that employs specialized robotic devices. These devices are designed to support and enhance the rehabilitation process. They are equipped with sensors and advanced control systems, which allow them to interact with patients in a controlled and precise manner. Robotic therapy for children with cerebral palsy can target different aspects of motor function, including mobility, muscle strength, coordination, and range of movement. Therapy sessions are typically supervised by trained healthcare professionals, such as physiotherapists, who work with the robot to guide and monitor the child's progress. One of the main advantages of robotic therapy is its ability to provide repetitive and consistent movements. The robot can repeat precise movements, which is essential to promote neuroplasticity, especially in individuals with neurological disorders such as CP. Furthermore, robotic therapy offers a level of customization that allows therapists to tailor treatment to the specific needs of each child. Therapy parameters such as the range of motion, resistance levels, and speed of movement can be adjusted to suit the child's current abilities and gradually increased as they develop [68]. The robotic devices used in therapy are equipped with sensors that provide real-time feedback on the child's performance. This immediate feedback enables therapists to monitor progress and implement necessary adjustments to optimize therapy sessions. Furthermore, it allows for objective measurement of improvements in motor skills over time. Additionally, robot-assisted therapy can be engaging and motivating for children. Interaction with the robot often resembles a game or play, which can enhance the child's willingness to participate in therapy and maintain interest and enthusiasm throughout the sessions [69]. A number of research studies have demonstrated the efficacy of robot-assisted therapy for children with cerebral palsy. These studies have indicated that robot-assisted therapy can improve muscle strength, motor control, functional mobility, and overall quality of life [70, 71].

9.3 Neuromuscular electrical stimulation

Another innovative technique employed in aediatric physical therapy is neuromuscular electrical stimulation (NMES). NMES involves the application of electrical impulses to specific muscles, which promotes muscle activation and strengthening. This technique may be particularly useful for children with cerebral palsy who may have difficulties with muscle recruitment and strength development. Yiğitoğlu and Kozanoğlu [72] conducted a prospective, randomized clinical trial to investigate the efficacy of electrical stimulation following botulinum toxin administration in children with spastic diplegic CP. The study randomly assigned participants to different treatment groups and evaluated the effect of combining electrical stimulation with

botulinum toxin therapy on children with spastic diplegic CP. The findings of the study indicate that the addition of electrical stimulation when used in combination with botulinum toxin may have positive effects on motor function and general well-being of children with spastic diplegic CP. The authors therefore recommend further research in this area to confirm and extend these promising results [72].

9.4 Wearable sensors for movement analysis

A systematic review by Rozin Kleiner et al. [73] conducted a comprehensive evaluation of the feasibility and effectiveness of using wearable sensors to assess gait in people with CP in real-world, everyday settings. The researchers focused on the use of wearable sensors, which included a variety of devices that could collect data related to movement, posture, and other relevant parameters. These sensors were used to monitor gait patterns and assess motor functions in people with CP. The systematic review examines existing studies to assess the practicality and validity of the use of wearable sensors in everyday settings. This includes activities and environments encountered in everyday life rather than just controlled clinical or laboratory conditions. The review explores the potential benefits of wearable sensor technology, including its ability to provide continuous, objective, and ecologically valid data on gait performance. The authors discuss the relevance of such data for optimizing intervention strategies and monitoring progress in people with CP. However, the paper also addresses the challenges and limitations associated with the use of wearable sensors in real-world scenarios. Factors such as sensor placement, data processing, and participant compliance are considered [73].

9.5 Neurofeedback training

This is a training program that applies neurofeedback technology to children with CP. Neurofeedback provides real-time feedback on brain activity using the latest neuroimaging technology. This approach can be used to train specific brain functions related to motor control in children with CP. Previous research on brain-computer interface-based neurofeedback training demonstrated its effectiveness in improving motor outcomes and supported previous findings suggesting its potential to enhance neuroplasticity in adults recovering from stroke [74]. In recent times, associative learning paradigms have gained prominence and are recognized as particularly feasible and effective methods for neurorehabilitation. However, it is important to note that there is a notable lack of research focusing on children with CP. This highlights the urgent need for more studies in the field of pediatric neurorehabilitation, not only to improve methods and dosages but also to compare them with other evidence-based educational strategies.

9.6 Three-dimensional printing for customized orthotics

Previous research has investigated the use of three-dimensional (3D) printing technology to create customized orthodontic appliances to meet the specific needs of children with cerebral palsy [75]. These devices provide a more accurate fit and improved support. A study to develop and evaluate a customized 3D-printed dynamic upper limb orthosis for children with CP and severe hand impairment involved five participants with CP and unilateral upper limb involvement. The intervention involved the use of the customized orthosis in combination with occupational therapy

sessions. The results demonstrated improvements in several assessments of upper limb function. The study concluded that the 3D-printed orthosis, when used in combination with occupational therapy, has the potential to improve upper limb function in children with severe hand impairment.

9.7 Telehealth and remote monitoring

Telehealth and remote monitoring can be employed in the physiotherapy of children with cerebral palsy using digital communication technologies and specialized equipment. This enables healthcare professionals to assess, monitor, and guide therapy sessions remotely. Video conferencing allows therapists to observe the child's movements, give instructions and provide real-time feedback on exercises. In addition, wearable sensors and smart devices can track the child's progress and provide valuable data for customized treatment plans. These technologies enhance accessibility, comfort, and continuity of care for children with CP, facilitating more effective and personalized rehabilitation interventions. A previous study examined the utilization of telemedicine in the management of children with CP, an application that demonstrated promise prior to 2020 but has received significant attention due to the COVID-19 pandemic [76]. A scoping review of the literature was conducted by systematically searching MEDLINE and PubMed in July 2021. The inclusion criteria were as follows: Primary research and systematic reviews focusing on telehealth interventions for children with CP, studies published between 2010 and 2021, and articles written in English. Some evidence suggested that the need for telehealth may vary depending on the child's developmental stage and functional level. Although there is mixed evidence on children's adherence to telehealth, telehealth has been reported to reduce carer burden. In general, telehealth interventions for the management of children with CP have demonstrated favorable outcomes, with comparable or improved outcomes compared to traditional face-to-face care.

9.8 Biofeedback systems

Biofeedback systems can be employed as an effective method of physical therapy for children with CP. These systems utilize electronic or computerized tools to provide real-time information about physiological processes such as muscle activity or body movements. In CP, biofeedback can be utilized to enhance motor control and coordination. One method of utilizing biofeedback is to incorporate electromyography sensors. These sensors measure muscle activity and allow therapists to provide the child with immediate feedback on muscle interaction patterns. This information assists the child in learning how to activate specific muscles more effectively, thereby enhancing their capacity to perform tasks [77].

9.9 Transcranial direct current stimulation

Transcranial direct current stimulation (tDCS) represents a non-invasive method of brain stimulation whereby a mild electrical current is applied to the scalp, seeking to regulate neuronal activity. This is done using a direct current stimulator, which produces a small electrical current. Two electrodes are used for stimulation: an anode (positive electrode) and a cathode (negative electrode). The anode is placed over the target area of the brain, while the cathode is placed elsewhere, usually on the opposite side of the head. The specific arrangement of the electrodes, known as the

montage, depends on the desired outcome, as different montages can target different areas of the brain and have different effects on neuronal activity. The intensity of the current is typically between 1 and 2 mA, and the duration of stimulation can vary from a few minutes to an hour. Safety precautions are very important with tDCS, including avoiding contact with metal objects during stimulation and monitoring for any discomfort or skin irritation. Research studies often include a control group that receives a sham stimulation condition to account for placebo effects. After tDCS sessions, researchers assess effects on various outcome measures, such as changes in motor function or cognitive ability, depending on the aims of the study [78, 79].

10. Daily activities and participation in social life

The severity of motor impairment, sensory involvement, and cognitive and behavioral problems among children with CP is different for each child. Consequently, activity and participation levels of children with CP will also vary greatly. In the ICF-CY classification, activity and participation are included in the same domain, while in some studies, they are evaluated separately; in others, they are analyzed under a single heading [80–82].

Children with physical or neurological problems participate in activities and have similar demands as children with normal development. Children's participation in age-appropriate activities is an important indicator of quality of life and a fundamental right of every child. Children who actively participate in school life can gain educational and social benefits through this participation. Children with CP face more limitations in daily activities and social life compared to their typically developing peers. Consequently, participation in activities of daily living and appropriate education for children with CP represents a shared objective among parents, health professionals, service providers, and relevant organizations [82–84].

During the first 6 years of life, children discover themselves and the world by using their bodies and senses, moving and exploring their environment [85]. The period during which the child actively orientates toward their environment, attempts to explore the external world full of stimuli, and acquires the most basic skills of human life is referred to as the preschool period (24–60 months) [86]. This period represents a critical period during which the child develops at the highest level and learns with curiosity and thinking potential. The experiences acquired by the child through learning form the basis of their life in adulthood [87]. In this period, the rate of physical development is slower than in infancy. The acquisition of self-care skills, such as dressing, toileting, and using language, becomes a part of daily life in this period. The development of motor skills between the ages of 3 and 6 is closely related to physical development. In the preschool years, the child's primary means of expression is movement [88]. Therefore, movement is both meaningful and functional.

Preschool children with CP exhibit lower levels of body structure and function and activity and participation compared to their typically developing counterparts [89]. According to the ICF-CY, the number and impact of impairments in body structure and function are higher in children with CP compared to their typically developing peers. A multitude of factors, including socioeconomic level, gender, motor function, and CP type, influence activity and participation in these children [90]. They engage in a multitude of recreational and leisure activities, such as playing with toys, listening to stories, and drawing and coloring, which require minimal parental preparation and utilize few materials. These activities are sedentary and may

not provide the same level of physical activity as swimming, gymnastics, and team sports. The level of participation in recreational activities of preschool children with CP is lower than that of children with normal development. The preschool children with CP who participate in the highest number of recreational activities are those who are able to walk independently and engage in activities that require physical exertion both at home and in their social environment. In contrast, the preschool children with CP who participate in the least number of activities are those with GMFCS IV and V levels, who are unable to move independently [91].

In order to fulfill activities of daily living, the child must possess physical and cognitive competence, as well as active skills. The term "activity" is a broad term that encompasses a multitude of concepts. "Ability" refers to the skills and abilities that the child can utilize in the daily environment. "Performance" refers to the child's optimal ability in a structured, standardized, and controlled environment in which the test is administered. Performance describes the skills and abilities that are a'tually used in daily life [92, 93]. Participation can be defined as being involved in life and being present in life. Participation can be modified by factors such as the child's preferences, motivation, and internal structure. Factors within the child, such as the child's ability to perform an activity and the physical and social environment affecting this activity, cause participation to be limited. For instance, participation can be analyzed in a multitude of domains, including participation in domestic activities, participation in educational and social settings, participation in everyday life, participation in social activities, and participation in leisure activities [92, 93].

It is of great importance to consider the participation of children with CP in social, daily life, and leisure time activities. Such participation is essential for the child to maintain their development in a healthy manner, to increase motivation, to interact with peers and other people in society, to develop functional abilities and social skills, to enjoy life, and to become more independent [94, 95]. It is of great importance to evaluate children with CP from a holistic perspective. The ICF-CY provides guidance on how to address this holistic perspective when evaluating and planning treatment approaches. It is of the utmost importance to ensure that children with CP are able to participate in social, daily, and leisure time activities, as this is a fundamental aspect of maintaining healthy development, increasing motivation, interacting with peers and other people in society, developing functional and social skills, enjoying life, and becoming more independent [94, 95]. In studies conducted with children with CP, it has been found that children have limitations in activity and participation due to difficulties in many activities, including mobility, personal care, play, and school activities [96–98]. Furthermore, studies have demonstrated that children with CP experience more limitations in social activities and participation in leisure time activities compared to their typically developing peers. The aforementioned limitations experienced by children may be dependent on a multitude of factors, including the level of impairment, motor and sensory problems, problems in body structure and function, age, environmental factors, functional abilities, and personal characteristics [88, 92, 97–99].

The ICF framework encompasses a plethora of parameters, including body structure and function, activity, participation, and environmental and personal factors. The body structure and function category encompasses a range of features, including selective motor control, muscle tone, pain, muscle strength, muscle structure, range of motion, posture, and trunk control. The activity category encompasses both fine and gross motor functional activities, such as self-care activities and activities of daily

living. The participation category encompasses participation in social, community, and school life. In addition, the environmental factor category encompasses factors such as the physical condition of the home and the external environment, family, and friends. Personal factors encompass the child's fundamental characteristics, including age, personality traits, cognitive status, and motivation level. These five areas interact with each other, and it is evident that numerous factors converge to influence the health and functionality level of the child [88, 97–99].

Children with spastic CP exhibit a range of structural and functional impairments. These impairments result in activity limitations, hindering their ability to perform various activities. Furthermore, these children experience severe participation limitations, which prevent them from engaging in activities with their peers, writing in class, or going to the cinema. Participation limitations can be attributed to impairments in body structure and function, activity limitations, or personal and environmental factors. For instance, a child's ability to write in the classroom with the assistance of appropriate equipment represents a factor that facilitates participation. Conversely, for a child who is unable to attend the cinema due to a lack of suitable transportation, this constitutes a barrier to participation. Consequently, it is imperative to conduct a comprehensive assessment utilizing the ICF framework in order to make accurate determinations [88, 97–99].

11. Conclusions

- Neurological disorders such as cerebral palsy have varying effects on children's motor skills, sensory abilities, cognitive functions, and behavioral patterns. Therefore, the activity and participation levels of each child should be assessed individually.

- The participation of children with CP in daily life activities and education should be a shared goal among healthcare professionals, families, and relevant organizations.

- The preschool period is a critical phase where children undergo rapid development and acquire fundamental skills. Activities and participation during this period lay the foundation for the child's life.

- Children with CP in the preschool years tend to have lower body structure and function compared to typically developing peers, which can impact their activity and participation.

- The involvement of children with CP in social, daily, and leisure activities supports their development and enhances their enjoyment of life.

- Spastic CP children may experience activity and participation restrictions due to impairments in body structure and function. These limitations can be mitigated or eliminated with appropriate support and environmental factors.

These conclusions provide a foundational basis for evaluating and improving various aspects of the lives of children with CP.

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