A Comprehensive Study on The Assessment of Motor Functions Development in Children with Cerebral Palsy

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Cerebral Palsy (CP), Motor Function Development, Assessment Methods, Gross Motor Function Classification System (GMFCS), Technological Innovations, Early Intervention, Multidisciplinary Approach.

ABSTRACT
Background: Cerebral palsy (CP) is a prevalent cause of motor impairment in children, characterized by a range of motor dysfunctions due to brain injury. This comprehensive study aims to evaluate the assessment methods for motor function development in children with CP, emphasizing the importance of accurate measurement tools for therapeutic interventions. Aim: The study reviews various etiologies and types of CP, highlighting the impact of prenatal, perinatal, and postnatal factors on motor development. It discusses the prevalence of CP globally, noting significant variations influenced by socioeconomic factors. Methods: The paper outlines normal motor development milestones and contrasts them with the delayed and unique motor patterns observed in children with CP. It identifies challenges in assessing motor function due to the wide spectrum of motor impairments and secondary complications such as joint deformities and muscle spasticity. The study evaluates existing standardized assessment tools and technological innovations, including motion analysis systems and tele-rehabilitation, which enhance the precision of motor function evaluation. Conclusion: Clinical implications are explored, emphasizing the need for multidisciplinary approaches in therapy, combining physical, occupational, and speech therapies. The study underscores the importance of early intervention and continuous assessment to improve motor outcomes and quality of life for children with CP. Future research directions are proposed, focusing on technological advancements and the development of individualized therapeutic strategies. This study aims to provide a detailed framework for clinicians and researchers to enhance the assessment and treatment of motor functions in children with cerebral palsy.

1. Introduction

In children with cerebral palsy, assessment of motor functions is one of the most important needs. Knowing how the development of motor functions is related to their age progress has increased greatly over the past few years. Considering that the improvement in neuroplasticity can occur throughout life, it is important to have a clear picture of the strengths and errors in question. The aim of this comprehensive study is to provide a detailed picture of the measurement methods available. Assessment methods of motor function are key areas that need to be addressed. Cerebral palsy is the most common cause of motor impairment and disability in childhood. It is caused by a brain injury; a permanent, but not unchanging, disorder of infant or immature cerebral development resulting in strength of the nerve plexus and in motor disorders. 1-3

The aim of our work has been to review and analyze all of the research that employs motor function assessment in children with cerebral palsy. Development of motor function presents one of the greatest problems in children with cerebral palsy. The medical profession has never developed enough methods of measuring motor development. The measuring tool must not only provide an explanation of the age of development of the person measured for whom it is intended, but must also provide an assessment of improvement or degree of severity. Many of these measures are used for therapeutic purposes. The most important thing is the quality of life of the children in question. Interventions that are given must be continuous and combine several methods. The incidence of cerebral palsy can only be reduced by handling in the early days. 4,5

2. Understanding Cerebral Palsy

Cerebral palsy (CP) refers to a group of chronic motor impairment syndromes with a wide range of etiologies, primarily affecting the developing nervous system. Periventricular brain injury, originating from abnormal development of white matter with subsequent corticospinal tract damage, is common in preterm infants. 6 In contrast, term infants are more susceptible to circumscribed gray matter injury associated with children who have spastic bilateral CP. The brain tissue injury occurs secondary to prenatal, perinatal, and postnatal factors. The pathophysiologic processes involve ischemia, inflammation, oxygen toxicity, excitotoxic damage, and possibly genetic susceptibility, and they likely continue after delivery in some infants. Depending on the timing and severity of these factors, brain injury may present as diffuse white matter injury or focal periventricular leukomalacia in the preterm infant, or arterial ischemic or hypoxic infarct and stroke in the term neonate. 7

CP affects about 2-2.5 per 1000 live births and is more frequent in preterm infants, especially at thresholds of 1500 g birth weight and 28-32 weeks' gestation. This condition diminishes quality of life and overloads families of the affected individuals and society as a whole. Although considered static neurological syndromes due to non-progressive insult to the developing brain, children with CP show variability in motor disability, secondary musculoskeletal complications, and functional abilities. 8 Gross motor function levels assessed with the Gross Motor Function Classification System, hand function, and cognitive function levels closely correlate with ambulation, social participation, and quality of life. Basic motor functions, including postural control and selective and coordinated movements typical for a particular developmental age, can help individuals move toward independent walking and other activities. Understanding and measuring the development of basic motor functions that distinguish children with CP from peers with normal motor development is fundamental to both motor assessment and motor development intervention. 9,10

2.1. Etiology and Types

Cerebral palsy (CP) is the most common physical disability affecting children and adults. It is often described as a movement disorder, with an origin within the maturation of the brain in the prenatal, perinatal, or postnatal period, leading to disturbances of cognitive, language, vision, hearing, and other sensory functions. Although it is generally agreed that the primary impairment is located in the central nervous system, the etiological factors for the development of CP are quite different—genetic, environmental, and neurological, as well as their combinations.11,12 Three main groups of symptoms characterize CP: disturbances of tone, posture, and movement. Growth disturbances in children with CP are explained by a combination of etiological factors, reduced motor activity caused by disturbances of the neuromotor system, spasticity, or mixed muscle tonus in dependent and/or nondependent children, pathogenic mechanisms, recurrent muscle weakness, low physical activity, and insufficient or imbalanced nutrition. Proper growth and nutrition assessment, prevention, and treatment of growth disturbances in children with CP are part of the evidence-based rehabilitation. 13,14

According to the nature of muscle tonus, as well as whether it is located unilaterally or bilaterally, several types of CP are classified. The common forms of CP are spastic, dyskinetic, and ataxic. They can be distributed in specific types or define the specialty. Hypotonic and mixed forms of CP are also known. Based on the neurotopographic location and the type of neuromotor pathway abnormalities, the degree and localization of impaired spasticity, and other accompanying disorders, magnetic resonance imaging and other research techniques are more specific for an accurate typing of CP. 15,16 For CP diagnosis and management, such research techniques have recently been proposed. A variety of factors responsible for the development of CP cause the diversity in the type of movement disorder. This has direct implications for the development of the motor system in children suffering from cerebral palsy and their motor learning processes. The clinicodynamic basis for designing specific therapy and prophylactic techniques. 2,17

2.2. Prevalence and Impact

Prevalence rates of CP are approximately 2.11 per 1,000 children; one in 500 children develops CP. The economic costs associated with CP in Germany are significant, reaching several hundred billion euros. Based on population data, there may be 20,000 to 25,000 new cases of CP annually in Germany and over 40,000 in the EU. Agreed upon data collectively span numerous countries reporting a prevalence of CP that falls between 1.5 and 4 per 1,000 live births. However, in the South Africa region, including Botswana, Lesotho, Namibia, South Africa, and Swaziland, the prevalence of CP is higher, estimated to range between 3.15 and 3.4 live births. The burden of CP varies between countries and regions, as expected. Socioeconomic factors such as race, class, the state of urbanization, and geographical location affect the availability and access to healthcare during pregnancy, delivery, and the neonatal period, which can lead to an increase in the prevalence of CP. A major public health concern is the physical, emotional, and social effects of CP on individuals and their families and communities. 18,19 Reduced ability to integrate into the educational process and lower academic results, even after correction for intellectual disability, are the most challenging issues for most children with CP. Furthermore, the restriction of mobility and social interactions leads to isolation from society. Interestingly, before the introduction of vaccines against diphtheria, pertussis, tetanus, and polio and the use of antibiotics, the high prevalence of infections often led to acquired brain injuries with CP. At present, the prevalence of CP of perinatal origin in high-income countries does not differ from that in middle-income countries. 20,21

3. Motor Function Development in Children with Cerebral Palsy

Children with cerebral palsy (CP) follow a different pattern of motor development. Knowledge of normal motor development may be traced by a typically developing child's milestones that are typical for a specific age. Those that are aged between two and three present two falls in a hundred hours of walking, and typically from three to four they experience one fall in a hundred hours. In healthy children, there is a progression in drawing a man with two hands, a man with six parts, interspersed with a background in three. After the age of four, a child should be able to produce a jumping jumper and begin to dress, and with four to five years, use a zipper. One should also be able to drop a pencil by making a fine change between five and six years of age in the pattern of pencil. 22,23

Cerebral palsy (CP) is the most common cause of motor function impairment in childhood. The condition that affects the movement and posture of the individual is a result of brain damage in the development of the fetus. The pathogenesis of the disease is multifactorial and involves breathing and metabolic lesions preceding childbirth, childbirth asphyxia, and ischemia caused by placental vasospasm. The clinical picture of CP can be sheer upper or upper and lower limb muscle hypertonicity or choreiform accompanied by dystonia, athetosis, tremor, and muscle atrophy. Motor injuries can be mild or severe. Muscle coordination and control are affected, and the result of this lack of movement can be velocity decline, dysenergy, and tremor. In CP, the variability in the level of functioning is wide, and it depends on the severity and type of disorder. CP motor development is not only delayed in relation to typical motor development in children but also results in unique changes in their motor functioning. CP motor outcome is not based on a single assessment of quality. The nature of the difficulties associated with CP can change over time, which is why early detection and starting therapy as soon as possible is a chance to improve their motor function in the future. 1,24

3.1. Normal Motor Development Milestones

Gross motor skills develop from head control to sitting and walking. Head control is achieved in the supine position around 6 months and in the sitting position around 9 months. Sitting is acquired at around the age of 5–6 months, sitting without support around 8–9 months, and walking around 12 months. Fine motor skills begin to develop with reaching and grasping occurring in children around 6 months, with improved manual dexterity and pincer grasp around 9 months. Milestones related to fundamental movements, like prone extension, standing, sitting, and walking, should be followed chronologically as each building system occurs. In practice, the normal motor development screenings are generally designed to look at some key motor milestones for children aged 1 month to 6 years. 25 A checklist for ages between 2–24 months is offered, which includes the following items: at 2 months, reaches for the rattle, hands are in tight fists, can usually lift head when placed on stomach; at 4 months, rolls over completely; at 6 months, excellent head control, sits with relative ease; at 8 months, supports weight on legs, enjoys putting objects into a container; at 12 months, takes a few steps; at 15 months, walks independently; at 18 months, walks backward easily, can feed themselves with a spoon; at 24 months, stands on one foot, works with buttons, repeating actions. 26

The normal development of gross and fine motor abilities is an outcome of successive building over a continuum and can be influenced by environmental features, the exposure of the child to enrichment environments, parenting behavior, fine motor achievements, and socio-demographic characteristics. A continuous and smooth progression of these global motor abilities from birth onward can be observed. Regularly, newborns experience improved motor abilities and capacities and learn to use more sensory-contingency information for acquiring more complex motor skills as they transition through motor development. Based on the sequential development, fundamental movements at birth may be regarded as the foundation for the emergence of fine motor, gross motor, object manipulation, ambulation, and communication movement milestones. Thanks to motor development and ample practice, continuous movements can be added to body segmentation, transitioning into purposeful movements were reaching for objects leads to standing and moving. Dexterity and manipulative movements can be added to trunk movement and lead to functional practice. The absence of fundamental needs to protect and progress in different life settings will impair the emergence of motor milestones at all stages of motor development. 27-29

3.2. Challenges and Variations in Children with CP

The assessment of motor function in motor-impaired individuals can be difficult because a large spectrum of complaints can occur. The main complaints in children with cerebral palsy (CP) are based on one hand on insufficient muscle strength due to reduced muscle volume, secondary changes in neuromuscular activity, and underlying diseases or characteristics. A second main complaint is an increased muscle tone and/or spasm, oscillation, or tremor of an extremity, usually referred to as motor redundancy. Since motor redundancy consists of physical parameters originating from movement experiments and not a willingly performed task, we will focus on the first type of complaint. Poor muscle strength reduces manipulation skills, object placement control, antigravity extremity use, and walking capacity. 13,16 A third complicating aspect affecting the outcome is secondary joint deformities, contractures, and pain of tendons due to an irregular load of malalignment since muscles stiffen during body-guided activities. The severity of the neuromuscular disorders in children with CP is related to the type, extent, and location of brain injury and further depends on the occurrence of secondary complications, genetics, motivation, participation, and posture in the child. Some children with CP may be just too young for their physiological upper motor neuron lesion hyperreflexia, physiological bilateral extensor muscle co-contraction, normal extensor-flexor strength, and physiological spinal reflexes, referred to as the silent period, to be recognized using clinical neurological examination protocols. Muscle tone is due to a continuous modulation between inhibitory and facilitatory control levels. Movement analysis systems provide detailed information on top-down activation changes in the brain and processing of somatosensory signals related to control intention, attention, awareness, flourish of the movement signal, and reflex modulation, zoning in on the location of the pyramidal decussation, peripheral muscles, and spinal reflexes inside the patient's body.4 Moreover, the reduction or lack of descending corticofugal motor control does not reflect the strength of CP neuromuscular impairments. With the extra look at the control of CP pathology, the hand-bearing capacity and sitting and midline signature become the primary goal for selection of therapeutic approach and the treatment strategy to be used. In addition, not only motor function but also endurance and adaptations during gross motor development and in sports and play should be assessed during growth. Also, the possible psychosocial impact of the quadriplegic CP involvement on motivation impeding participation in physical activity and sports or the acquired perception disturbances should be identified and treated. Care and attention to psychosocial relations, possibilities, and needs across the Cerebral Palsy Alliance led to a decision to focus on one aspect of motor function. As a first sensory pathway, physiotherapists asked us to focus our attention on the role of the muscle spindles. Fifty years later, this is still not clear. In conclusion, CP occurs at the dawn of a neonate's life and develops more or less independently from the growth of the central nervous system, which continues until twice the age of 10 years. The challenge to assess this independence and the impact of CP in a "normally" aging child is a difficult synergistic task between different specialists helping to develop "the best available individual prediction" leading to an individual "tailor-made" treatment. 30,31

4. Assessment Tools and Methods

Assessment is the pivotal process for setting a logical and effective intervention plan. Children with cerebral palsy (CP) generally have developmental issues, and motor function is a commonly observed dysfunction. Prompt diagnosis and changes in treatment planning are needed for improvement. Several tools and methods are in use for CP-associated developmental or motor function. Delay is the consistent mark of CP, which occurs if earlier intervention is not attempted. Assessment provides direct evidence of prevailing problems, helps in the fitting diagnosis, and initiates timely intervention. Hence, assessment is the pivotal tool for early diagnosis and intervention in pediatric clinical care. The main aims of assessment tools are to provide measurable outcomes, assess the effectiveness of various therapies, allow for scientific decisions in enhancing any treatment regime, and provide a standard of care practice in children with CP. 22,24

Especially, it is helpful to note the guiding milestones that individual babies are expected to achieve, the babies' rate of progress, the way babies play, learn, speak, and act, and especially the behaviors that seem unusual when compared to those of other children of the same age. Assessments that are collected systematically and carefully often show incremental trends. Standardized assessment tools for motor skills are increasingly in use across the globe, as they provide validated outcomes. Several assessment methods are in practice to collect 'what a child does' or 'how a child performs.' There are various methods for assessment, including observational methods, performance-based assessment criteria, assessing the performance of the child through parent reports, and general motor rating tools in CP. It should be noted that skills like communication, cognition, sensation, and dexterity are equally important for the development of motor skills. Hence, an assessment should be more comprehensive in approach, where both qualitative and quantitative data are collected. This review in the era of the latest technology also includes the validity of computer-based assessment measures, tele-assessment in real time, and online platforms. The technology and measured tools are increasingly used in day-to-day practice for assessing performance. Advanced technology can provide more accurate and feasible assessment tools for posture and movement through software and can measure needed aspects for clinical use in normal time. Technological assessment advancements that make clinicians competent in clinical use receive special focus. Although assessing this aspect predominantly focuses on information, our aim is to ensure that children with CP are prioritized in assessment. 32-34

4.1. Standardized Assessment Scales

A wide range of tools has been published for the assessment of activities and participation in children with CP. These assessment tools have been designed to provide health professionals with a standardized framework to assess activities of motor variations such as movement, abnormal muscle tone, abnormal reflexes, postural asymmetry, coordination, strength, fatigue, and balance. They have been developed for different uses such as stand-alone measures, items for inclusion in multidisciplinary assessment schedules, outcome measures for physical therapy or occupational therapy, research tools, or monitoring tools. The availability of such movement assessment tools helps child health services select the most appropriate tools to use when assessing children in a clinical or field setting. 35,36

Several assessment tools have been developed to evaluate the motor functions of spastic CP, and these have been shown to predict the level of functional skills and ambulation of those children when used in isolation. The Gross Motor Function Measure has good functional relevance in day-to-day activities and is the most widely used tool to assess the core outcome of children with CP identified for surgical intervention. The PEDI is an outcome measure that helps to measure what a child with CP can do in everyday life and is useful in demonstrating when an intervention is effective. Measurement tools for lower limb deformities in children with CP are effective when working to improve the muscles and crossing angles at an individual or group level. The Gross Motor Function Measure for children with CP, including spastic, dyskinetic, and ataxic children, provides a broader picture of the affected areas of CP. 37 All movement assessment tools should be accompanied by the pain experience scale to reflect the effect of spasticity on a child’s quality of life. A movement assessment by a pediatrician or therapist should become standard practice for all pediatrics. It should precede the detailed physical therapy and societal intervention measurements. The movement assessments listed have been used for assessing movement disorders or muscle priorities for selected musculoskeletal interventions. Reliability and validity data are included with the description. Objectivity, inter-rater reliability, and construct valued judgment must be confirmed. There are more than 100 possible movement disorder assessments in children with CP. It is critical to report the area of affected movement prior to assessment. 38

4.2. Technological Innovations in Assessment

Technological Innovations in Assessment. Recent technological innovations could indeed be of great help for more precisely describing a distinctive movement pattern or the limitation of body function itself and elegantly complement the information gained by perceptual or clinical assessments. For example, the most recent research tools are different systems of motion analysis which can not only quantify kinetics or kinematics, such as movements, forces, or muscle activity, but also visualize the movement pattern. Available tools are various motion capture systems and video analysis software, as well as integrated systems of assessment consisting of different measurements and integrating these data. As an alternative or complement to such systems, which can be expensive or require a lot of clinical training, some multipurpose or body-worn sensors have been developed for kinematic or kinetic and other bodily function measurements. Mind that pilot studies are slow to introduce sophisticated motion analyses in clinical care settings; therefore, the so-called "wearable" systems, on the other hand, are incorporated in some pilot experiments and can result in innovative screening and monitoring tools for dyskinetic cerebral palsy. However, it is still difficult to introduce these systems in a real-life or clinical setting or to involve many or all children with cerebral palsy to monitor them closely. 39,40

A further approach to overcome the previously mentioned difficulties is the development of systems for real-time feedback or the continuous monitoring of body function on children's devices or smartphones, in order to record many movement episodes under natural conditions over time. In addition to assessment aspects, there have been many technological developments in tele-rehabilitation systems which are used in clinical practice. However, tele-rehabilitation includes different systems and concepts, ranging from coaching systems to train motor function in a realistic environment to other video-based systems of physical therapy coaching. Typically, the design of such systems may become more biased towards increasing the technical capabilities, such as a full-body immersive virtual reality system that assesses a larger number of functional movement patterns or specific software environments. In conclusion, the different tools are rather used for observational studies or one-shot assessments of adolescents with cerebral palsy, but it seems the study using technological innovations can give insights into children's cerebral palsy in regard to the goal of personal intervention. 41,42

5. Clinical Implications and Interventions

The study of motor development is the main concern for children with cerebral palsy. Clinical implications for this group are paramount because understanding their motor repertoire based on conceptual motor functions allows for planning an intervention. In the present study, we focused on the impact of the children with cerebral palsy regarding the evaluation methods and their usefulness for the concrete improvement of function. Our approach sheds light on several aspects that should be clarified regarding the intention and the content of the personalized programs for improving motor functions in children with cerebral palsy.

In conclusion, many assessment tools have been developed to identify challenges in different areas. However, assessment findings are passive until they are translated into effective clinical interventions that improve function. The study showed that the majority of interventions for children include physical therapy, occupational therapy, and a percentage used assistive devices. This highlights the importance of educational therapy for children and also the low number of individualized interventions to help children overcome ideas and behaviors that limit the functional gain of selective movement control. The effectiveness of the intervention is analyzed on our sample in the section on goal setting in the therapeutic process. Regular evaluations are needed to determine the need for changes and improve future directions. When analyzing results from different assessments, it is important that all the specialists involved in early intervention, rehabilitation, and special education receive crucial information in order to provide better treatment for children.

5.1. Therapeutic Approaches

There are various approaches for the therapy of children with cerebral palsy (CP). Traditional therapies, like physical therapy and occupational therapy, are commonly used for children with CP. CIMT is a therapy developed to improve the motor function of the affected upper limb by constraining the less affected one. CIMT aims to promote the recovery of the use of the affected upper limb by enhancing its functional efficacy. The use of the less affected limb is reduced by means of a long arm cast. However, it has been suggested that CIMT should not be indicated for children with severe brain injury at birth because of the risk of its side effects. CIMT seems to be less effective than traditional neurotherapies in children with CP, with transient or equivocal effects on the improvement of motor function, manual ability, mobility, and activities of daily living of the affected and less affected upper limb. Nevertheless, it yields better outcomes in subjects showing low and moderate levels of the Gross Motor Function Classification System. 43,44

Novel pieces of evidence support the use of different kinds of enhanced neurotherapies, thus integrating neurotherapies with other approaches. A new or old approach will be effective only if it takes into account the dynamic changes in a child's central nervous system, pain and sensation, and the developing body structures. A neurodevelopmental approach should consider a multidisciplinary team combining a number of different methods that will be more effective, as a single approach will not be enough. The effects of isolated approaches are limited, and children would have a larger chance of improving gross motor function and walking capacity if the best available individual therapeutic approaches were combined. Treatment effects are dependent on the intensity and skill of the therapist and technician. A preoperative comprehensive multidisciplinary rehabilitation after single event multi-level surgery revealed an increase in gait parameters in children with gross motor function levels I-III, relative to physiotherapy or specific intense training. 45 SEMLS constitutes an extensive rehabilitation period designed to improve gait, but it also places demands on parents and schools, which must also be taken into consideration. A prospective study evaluated the effects of preoperative comprehensive multidisciplinary rehabilitation in children with CP subjected to botulinum toxin. They found improvements in motor function, balance, activities, and an increase in kinematic data in all three groups. The movement quality index, gait speed, gross motor function, functional mobility, and pediatric evaluation of disability inventory scores improved only in GMFCS level I-III children, in contrast to children in GMFCS IV-V level (no change). Moreover, children with CP (GMFCS levels I, II, and III) undergoing multidisciplinary interventions show improved movement quality and temporal and spatial gait parameters elucidated through assessment. These data suggest how outcomes in those scheduled for BoNT can be enhanced by integrating their care with the inpatient CP team, early intervention, tailored training, and specific pre-injection focused rehabilitation. In conclusion, in walking children with bilateral CP onset, comprehensive rehabilitation can influence gait pathology by focusing on selective activity of functionality at an early age. 46,47

5.2. Multidisciplinary Team Collaboration

Teamwork is important for managing children with cerebral palsy (CP). Physiotherapists, occupational therapists, and speech therapists play crucial roles in managing the treatment process for children with CP. While the physiotherapist helps children improve motor development, the occupational therapist assists children in performing daily living activities. If necessary, the speech therapist provides advice related to swallowing and feeding. Furthermore, medical doctors are responsible for giving advice and determining the most suitable medications or operations. Comprehensive care requires a multidisciplinary approach to meet the various demands of the child. Teamwork values can help team members achieve these goals more closely and thoroughly because weaknesses in one area, such as the provision of medication that is not required or teaching children without preparing their motor skills, can create side effects that are not as expected. 48

To apply the optimum team approach, involvement in discussing the future of the children among each member is very important. Feedback on the results of interventions and the further treatment plan can be shared by all team members based on this information. These discussion outcomes should be documented and reviewed regularly to follow up on the progress of treatment. This process can uncover many aspects that are not easily laboratory tested in the treatment of children with CP; this analysis can only be obtained through the judgment of each therapy specialist. As a step to apply multidisciplinary communication, a discussion of a case study is presented. Collaboration in working and the provision of appropriate education between therapists and team members should be conducted. However, sometimes funding is a significant problem in handling cooperation. Different professional practices from each therapist may also be an obstacle to optimizing the process of team collaboration. In a rehabilitation center, communication and cooperation between medical personnel, therapists, educators, nursing staff, and administrative staff are required to ensure comprehensive treatment and education. 49,50

6. Future Directions and Research Opportunities

This is an area that is very scant in the literature. At present, we are unable to gauge the long-term outcomes or to measure the trajectory of treatment effects. More research is needed in the area of comparative treatment of upper versus lower extremity intervention. A focus on the natural history of ULP and HLE development is warranted because we need to know if there is a specific time frame where rapid growth and flexibility gains are expected. The ability to control drift remains a very high priority for children with CP who received ULP or HLE. Some children may require years of intensive UL intervention. This population cannot be ignored, and there may be a group of children who could benefit from this intervention during the vulnerable trajectory. Nor is there much known about the validity, sensitivity, and specificity of innovative assessment tools and methodologies that might help identify those children at particularly high risk for CP and allow intervention to start more quickly. Technological innovations are untapping new avenues using diagnostic tests for identifying typical infants from the newborn period onwards. These diagnostic tests may change concepts about what determines outcomes. 51

The future of cerebral palsy research lies in advances in technology, whether they are the new neuroimaging techniques or the new intervention modalities that will change our paradigms of assessment and treatment. From history, we have learned many lessons about what we can now provide and what is possible. Our children with CP have not all benefited from the motion towards freeing people from the stigma of disability that the wider community is now part of. It is because medicine and scientific research is not yet entitled to all that we are here today, attending a comprehensive study on the assessment of motor functions development in children with cerebral palsy. Clearly, both practitioners and researchers have a key role in the development, implementation, and global spread of the new insights, techniques, and technology. The translation of knowledge into understanding and action will require both clinically oriented work to develop practice parameters as well as research-related work to guide more individualized targeting of specific needs. Thus, we recommend more targeted initiatives towards the areas we have identified for the research agenda. Without adequate funding for cerebral palsy research, the current strategies, knowledge, and activity will not be sustained. We call for a plan of action to target the prevention and treatment of motor system disability and functional limitation with the goal of achieving optimal movement and a proactive, strategic investment in our children. 24,52

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