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Review Article

Comprehensive Physiotherapy Approaches for Children With Cerebral Palsy: Overview and Contemporary Trends

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Cerebral palsy (CP) is a prevalent neurodevelopmental disorder characterized by motor and postural impairments caused by central nervous system dysfunction. It significantly impacts children's daily functioning and quality of life. Physical therapy is a crucial intervention for children with CP that aims to improve motor skills and functional abilities. This study aimed to provide a comprehensive overview of holistic physical therapy approaches methods specifically designed for children with CP and examine recent research trends and their implications for optimizing outcomes in this population. This study employed a narrative review approach, conducting a comprehensive examination of the current literature pertaining to physical therapy methods for children with CP. The review encompassed studies exploring assessment techniques, evidence-based interventions, and innovative approaches in the field. It was discerned that encompassing physical therapy strategies, which encompass individualized treatment plans, evidence-based interventions, and the integration of innovative techniques, yield a favorable influence on the motor skills and functional capacities of children with CP. This review synthesizes the current knowledge on effective physical therapeutic strategies for children with CP. Furthermore, this review highlights the need for continued research and innovation in the field of pediatric physical therapy for CP.

INTRODUCTION

Cerebral palsy (CP) is a developmental disorder characterized by permanent motor and postural impairments caused by central nervous system dysfunction. It is the most common motor disability in childhood, affecting the daily functioning and functional abilities of a child [1]. Individuals with CP often experience functional challenges, such as walking, balance, and muscle control, which limit their independence and social participation [2].

Physical therapy, also known as physiotherapy, plays a pivotal role as one of the crucial treatment modalities for children with CP, which aims to improve motor skills and functional abilities in daily life [3]. Recent studies have revealed that a comprehensive approach to physical therapy positively affects the functional improvement and quality of life of children with CP [4,5].

The imperative for a contemporary review of assessment techniques, evidence-based interventions, and innovative approaches in the context of CP arises from the dynamic nature of the field and the ever-evolving landscape of medical knowledge and technology.

Firstly, assessment techniques are the cornerstone of effective treatment planning and progress monitoring for children with CP. In recent years, there has been a notable shift towards more sophisticated and nuanced assessment tools that provide a more comprehensive understanding of an individual's specific needs and capabilities. Staying current with these advancements ensures that practitioners are equipped with the most accurate and insightful information to guide their therapeutic interventions.

Furthermore, evidence-based interventions represent the gold standard in healthcare practice. As the body of research surrounding CP interventions expands, it is essential to critically evaluate and synthesize the latest evidence to ascertain the most effective and efficient treatment modalities. By doing so, we can ensure that children with CP receive interventions that are rooted in the best available evidence, ultimately lead-

ing to improved outcomes.

Innovative approaches, on the other hand, signify the frontier of progress in CP management. With rapid technological advancements and novel therapeutic modalities emerging, it is imperative to scrutinize these innovations for their potential to revolutionize care for children with CP. By exploring these cutting-edge approaches, we have the opportunity to push the boundaries of what is currently achievable in CP treatment.

Despite these advancements, there exists a pressing need for an in-depth understanding of the evolving landscape of comprehensive physical therapy interventions for children with CP. This review aims to address this gap by providing a detailed overview of the latest strategies employed in physical therapy. By doing so, we endeavor to not only augment the quality of life for children grappling with CP but also lay the groundwork for future research endeavors in this critical area.

MAIN BODY

1. Assessment and Individualized Treatment Planning

1) Assessment methods for cerebral palsy

One commonly employed assessment tool is the Gross Motor Function Classification System (GMFCS). GMFCS categorizes individuals with CP into one of five levels based on their gross motor function, thereby providing valuable information for treatment planning and prognosis [6,7]. Additionally, the Manual Ability Classification System (MACS) is a classification system designed to assess the manual abilities of individuals with CP based on their self-initiated use of hands when handling objects in daily activities [8].

The use of standardized tests, such as the Pediatric Evaluation of Disability Inventory (PEDI) and the Canadian Occupational Performance Measure (COPM), further helps identify specific areas of difficulty and track progress over time [9-11].

2) Individualized treatment planning for children with cerebral palsy

Children with CP often have diverse needs and functional abilities. Individualized treatment planning is essential to resolve their unique challenges and facilitate optimal outcomes [12-15]. This process begins with a comprehensive assessment that considers factors such as motor function, muscle tone, and functional mobility, as discussed in Section 1.1. Specific goals and intervention strategies are established based on the assessment findings to target areas that require improvement.

2. Evidence-based Approaches in Physical Therapy

Evidence-based physical therapy practice involves integrating the best available research evidence with clinical expertise and patient preferences to make informed decisions about patient care and treatment [16]. This approach ensures that physical therapists are using interventions and techniques that have been demonstrated to be effective through rigorous scientific research.

The critical appraisal of research studies is an important part of evidence-based practice. Physical therapists depend on high-quality, peer-reviewed studies published in reputable journals. These studies undergo thorough scrutiny to assess their methodology, results, and overall validity [17-19].

3. Innovative Techniques and Technologies

Technological advancements have significantly influenced the field of pediatric physical therapy, providing new avenues for enhancing treatment outcomes in children with CP and other motor disorders. Innovative techniques and technologies are being integrated into clinical practice to supplement established approaches enhance more effective interventions. In the context of physical therapy, innovative techniques refer to novel and advanced methods employed by practitioners to assess, treat, and rehabilitate patients with CP. These techniques often involve creative and specialized approaches that may encompass a range of manual therapies, exercise regimens, and movement retraining strategies. They are designed to target 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 patients with CP. These technologies encompass a diverse array of devices such as wearable sensors, virtual reality systems, and assistive robotics. By leveraging the capabilities of modern technology, physical therapists can provide more precise and personalized care, ultimately leading to improved outcomes for individuals with CP. By leveraging the capabilities of modern technology, physical therapists can provide more precise and personalized care, ultimately leading to improved outcomes for individuals with CP (Table 1).

Table 1. Innovative techniques and technologies for pediatric physical therapy

Treatment approach	Description
Virtual reality rehabilitation	Virtual reality is a technology that generates interactive, computer-generated environments, offering controlled and customizable settings for therapeutic exercises in rehabilitation, simulating real-world scenarios or specific tasks aligned with individual goals.
Robot-assisted therapy	Robot-assisted therapy employs specialized robots with advanced sensors and controls to enhance rehabilitation for children with CP, targeting motor function aspects like mobility, strength, coordination, and range of motion, under the supervision of trained healthcare professionals.
Neuromuscular electrical stimulation	Neuromuscular electrical stimulation applies electrical impulses to muscles, aiding activation and strengthening, benefiting children with CP who may struggle with muscle recruitment and strength.
Wearable sensors for movement analysis	Wearable sensors for movement analysis refer to devices that can be worn on the body to capture and analyze motion patterns, providing valuable data for assessing and improving physical movements in various applications, including sports, rehabilitation, and healthcare.
Neurofeedback training	Neurofeedback training is a non-invasive technique that involves providing real-time feedback to individuals about their brainwave activity, allowing them to learn how to self-regulate and improve cognitive functions or emotional states.
3D printing for customized orthotics	3D printing for customized orthotics refers to the use of advanced technology to create personalized, precise, and comfortable orthopedic devices tailored to an individual's specific anatomical needs and requirements.
Telehealth and remote monitoring	Telehealth and remote monitoring involve the use of technology to provide healthcare services and monitor patients' conditions from a distance, allowing for convenient access to medical care and timely interventions, especially useful in situations where in-person visits may be challenging.
Biofeedback systems	Biofeedback systems provide real-time information about physiological functions, enabling individuals to learn self-regulation techniques for improving physical or mental well-being.
Transcranial direct current stimulation	Transcranial direct current stimulation is a non-invasive brain stimulation technique that involves applying a low-level electrical current to the scalp to modulate neuronal activity, potentially leading to cognitive or motor improvements.

CP, cerebral palsy; 3D, three-dimensional.

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 engage in therapeutic exercises. This technology allows for the creation of virtual scenarios that mimic real-world situations or specific tasks relevant to the individual's rehabilitation goals [20].

The use of VR in sensorimotor training involves designing exercises and activities that require the integration of sensory and motor skills within the virtual environment. For example, a patient with CP may engage in tasks that involve reaching, grasping, balance, or gait training using VR simulations [21].

One of the key advantages of VR-based training is its ability to provide immediate and precise feedback to the user. The virtual environment can track the user's movements in real-time, allowing for accurate assessment and adjustment of their performance. This feedback loop helps individuals with CP refine 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 a patient's focus and participation, which is especially important for maintaining interest and adherence to rehabilitation programs over time. Additionally, VR allows for the customization of exercises based on the individual's specific needs and abilities. Therapists can adjust parameters such as difficulty level, speed, and complexity of tasks to match the patient's current skill level and gradually progress as their abilities improves [22].

Research studies have shown promising results in the effectiveness of VR-based training for individuals with CP. It has demonstrated improvements in areas such as balance, coordination, muscle strength, and functional mobility [23].

2) Robot-assisted therapy

Robot-assisted therapy involves the use of specialized robotic devices that are designed to support and enhance the rehabilitation process. These robots are equipped with sensors and advanced control systems, allowing them to interact with patients in a controlled and precise manner. For children with CP, robot-assisted therapy can target various aspects of motor function, including mobility, muscle strength, coordination, and range of motion. The therapy sessions are typically supervised by trained healthcare professionals, such as physical therapists, who work alongside the robot to guide and monitor the child's progress [24].

One of the key advantages of robot-assisted therapy is its ability to provide repetitive and consistent movements. The robot can perform precise motions repeatedly, which is essential

for promoting neuroplasticity, especially in individuals with neurological conditions like CP. Additionally, robot-assisted therapy offers a level of customization that allows therapists to tailor the treatment to each child's specific needs. The therapy parameters, such as the range of motion, resistance levels, and speed of movements, can be adjusted to match the child's current abilities and gradually progress as they improve [25].

The robotic devices used in therapy are equipped with sensors that provide real-time feedback on the child's performance. This immediate feedback helps therapists monitor progress and make necessary adjustments to optimize the therapy sessions. It also allows for objective measurement of improvements in motor skills over time. Moreover, robot-assisted therapy can be engaging and motivating for children. The interaction with the robot often feels like a game or play, which can increase the child's willingness to participate in therapy and maintain their interest and enthusiasm throughout the sessions [26].

Research studies have shown promising results in the effectiveness of robot-assisted therapy for children with CP. It has demonstrated improvements in areas such as muscle strength, motor control, functional mobility, and overall quality of life [27].

3) Neuromuscular electrical stimulation

Another innovative technique used in pediatric physical therapy is neuromuscular electrical stimulation (NMES). NMES involves the application of electrical impulses to specific muscles, which promote muscle activation and strengthening. This technique can be particularly beneficial for children with CP who may have difficulties with muscle recruitment and strength development. Yiğitoğlu and Kozanoğlu [28] investigate the effectiveness of electrical stimulation following the administration of botulinum toxin in children with spastic diplegic CP. The study is a prospective, randomized clinical trial, meaning it involved a controlled experiment where participants were randomly assigned to different treatment groups. The focus of the study was to assess the impact of combining electrical stimulation with botulinum toxin treatment on children with spastic diplegic CP. The findings of the study suggest that the addition of electrical stimulation, when used in conjunction with botulinum toxin, may have positive effects on the motor function and overall well-being of children with spastic diplegic CP. The authors recommend further research in this area to validate and expand upon these promising results.

4) Wearable sensors for movement analysis

A systematic review by Rozin Kleiner et al. [29], conducts a comprehensive review to assess the feasibility and effectiveness of using wearable sensors for gait assessment in individuals with CP within real-world, everyday environments.

The authors focus on the application of wearable sensors, which encompass a variety of devices capable of capturing data related to motion, posture, and other relevant parameters. These sensors are used to monitor gait patterns and assess motor function in individuals with CP. The systematic review scrutinizes existing studies to evaluate the practicality and validity of employing wearable sensors in everyday settings. This includes activities and environments encountered in daily 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 tracking progress in individuals with CP. However, the paper also addresses 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.

5) Neurofeedback training

This is a training that applies neurofeedback technology, which provides real-time feedback on brain activity using cutting-edge neuroimaging technology, to children with CP. 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 demonstrates its effectiveness in improving motor outcomes and corroborates previous findings suggesting the potential for enhancing neuroplasticity in adults recovering from stroke [30].

Recently, associative learning paradigms have gained prominence and are considered particularly viable and efficient methods for neurorehabilitation. However, it is imperative to note that there is a notable scarcity of research focused on children with CP. This underscores the urgent need for further studies in pediatric neurorehabilitation, not only to refine methodologies and dosages but also to compare them with other evidence-based training strategies.

6) Three-dimensional printing for customized orthotics

Previous research has examined the use of three-dimensional (3D) printing technology to create customized orthodontic appliances tailored to the unique needs of children with CP [31]. This provides a more precise fit and improved support. It discusses the development and assessment of a customized 3D-printed dynamic upper extremity orthosis for children with CP and severe hand impairment. The study involved five participants with CP and unilateral upper extremity involvement. The intervention included the use of the custom orthosis in combination with occupational therapy sessions. The results showed improvements in various assessments of upper extremity function. The study concludes that the 3D-printed orthosis, when used alongside occupational therapy, holds promise for enhancing upper extremity function in children with severe hand impairment.

7) Telehealth and remote monitoring

Telehealth and remote monitoring can be utilized in physical therapy for children with CP by employing digital communication technologies and specialized equipment. This allows healthcare professionals to remotely assess, monitor, and guide therapy sessions. Through video conferencing, therapists can observe the child's movements, provide instructions, and offer real-time feedback on exercises. Additionally, wearable sensors and smart devices can track the child's progress, providing valuable data for tailored treatment plans. These technologies enhance accessibility, convenience, and continuity of care for children with CP, facilitating more effective and personalized rehabilitation interventions.

Previous study examines the use of telehealth for treating children with CP, a practice that had shown promise before 2020 but gained significant traction due to the COVID-19 pandemic [32]. The research conducted a scoping review, systematically searching literature in MEDLINE and PubMed in July 2021. Inclusion criteria encompassed primary research and systematic reviews focusing on telehealth interventions for children with CP, published between 2010 and 2021, and written in English. Some evidence suggested that telehealth requirements may vary based on children's developmental stage and functional level. Telehealth was reported to alleviate caregiver burden, although there was mixed evidence regarding children's compliance with telehealth. Overall, telehealth interventions for treating children with CP yielded positive results, indicating comparable or improved outcomes compared to traditional face-to-face care.

8) Biofeedback systems

Biofeedback systems can be effectively employed as a physical therapy modality for children with CP. These systems utilize electronic or computerized instruments to provide real-time information about physiological processes, such as muscle activity or body movements. In the case of CP, biofeedback can be used to improve motor control and coordination.

One way to utilize biofeedback is by incorporating electromyography sensors. These sensors measure muscle activity, allowing therapists to provide immediate feedback to the child about their muscle engagement patterns. This information helps the child learn how to activate specific muscles more effectively, improving their ability to perform tasks [33].

9) Transcranial direct current stimulation

Transcranial Direct Current Stimulation (tDCS) is a non-invasive brain stimulation technique. It involves applying a low-amplitude electrical current to the scalp to modulate neuronal activity. This is done using a direct current stimulator, which generates a low-level electrical current. The stimulation is achieved with two electrodes: 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, often 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 brain regions and have varying effects on neuronal activity. The intensity of the current typically ranges from 1 to 2 mA, and the duration of stimulation can vary from a few minutes to over an hour. Safety measures are crucial in tDCS, including avoiding contact with metal objects during stimulation and monitoring for any discomfort or skin irritation. In research studies, a control group is often included, receiving a sham stimulation condition to account for placebo effects. After tDCS sessions, researchers assess the effects on various outcome measures, such as changes in motor function or cognitive abilities, depending on the study's objectives [34].

While these evolutionary techniques and technologies have enormous potential, their implementation must be approached with caution. Additionally, there is not much research on these treatments, so pediatric physical therapists must ensure that

these tools are safely and developmentally used appropriately and that they complement, rather than replace, traditional therapeutic interventions.

4. Long-term Management and Follow-up

Long-term management and follow-up are crucial components of improving the outcomes and well-being of children with CP undergoing physical therapy interventions. This phase of care extends beyond the initial treatment period and focuses on maintaining and further enhancing functional abilities as the child grows and develops [35].

The essential components of long-term management include regular and structured follow-up assessments. These assessments serve multiple purposes, including monitoring progress, identifying emerging challenges, and adjusting treatment plans accordingly. Furthermore, they provide an opportunity to address any concerns or questions that may appear over time [36].

5. Psychosocial Aspects and Family Involvement

Crucial components of effective pediatric physical therapy for children with CP include addressing the psychosocial aspects and involving families. This comprehensive approach highlights the interdependence between a child's physical well-being and their emotional, social, and familial context [37,38].

DISCUSSION

The lack of direct experimental outcomes in this study warrants a focused discussion on the broader implications and contextualization within the existing body of research on CP interventions.

1. Literature Synthesis and Comparative Analysis

Drawing upon the extensive literature review, a multidimensional approach to physical therapy in children with CP is well-established. The combination of assessment tools, such as GMFCS, MACS, PEDI, and COPM, provides a holistic understanding of the functional capacities and limitations of these individuals. This comprehensive assessment framework stablished the cornerstone of personalized treatment planning.

2. Individualized Treatment Planning

The emphasis on individualized treatment planning coincides with the consensus in the literature. Designing specialized interventions to address specific impairments, goals, and preferences of each child has consistently shown positive outcomes. This person-centered approach not only addresses the unique needs of the child but also promotes a sense of empowerment and ownership in the therapeutic process.

3. Technological Innovations in Physical Therapy

The integration of innovative technologies and techniques in pediatric physical therapy represents a progressive transition in treatment paradigms. Robot-assisted therapy, VR rehabilitation, wearable sensors for movement analysis, neurofeedback training, 3D Printing for customized orthotics, telehealth and remote monitoring, biofeedback systems, tDCS have demonstrated the potential to improve engagement and facilitate motor learning. These technological advancements open new avenues for personalized and engaging interventions.

4. Long-term Management and Follow-up

The imperative of long-term management remains a critical aspect of pediatric CP care, although the current studies do not provide direct outcomes. Regular follow-up assessments and the adaptability of treatment plans are crucial for sustaining and optimizing functional gains over time.

5. Evidence-based Practice and Future Directions

The broader trend towards evidence-based practice in pediatric physical therapy highlights the need for rigorous research methodologies and the integration of the best available evidence. Future research should continue to build investigate based on this foundation, while emphasizing refining intervention protocols and exploring emerging technologies.

6. Psychosocial Aspects and Family Involvement

Essential components of comprehensive care include consideration of the psychosocial well-being of children with CP and the involvement of families in the therapeutic process. A holistic approach that addresses not only physical function but also the emotional and social aspects of well-being is integral to optimizing outcomes.

In conclusion, this discussion summarizes the crucial findings from the literature review, emphasizing the importance of a comprehensive and individualized approach to physical therapy for children with CP. Although the current study

revealed no direct results, it lays the groundwork for future research to build upon and refine intervention strategies. The integration of innovative technologies and a holistic consideration of psychosocial well-being are crucial components of advancing pediatric physical therapy practices.

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CONFLICTS OF INTEREST

No potential conflicts of interest relevant to this article are reported.

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