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(REVIEW ARTICLE)

Navigating hip displacement in dystonic cerebral palsy: A comprehensive narrative review of therapeutic strategies and interventional modalities

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Abstract

This review aims to synthesize current evidence on the prevalence, etiology, and progression of hip displacement specifically within the context of dystonic cerebral palsy, distinguishing it from other forms of cerebral palsy. It will further explore both non-operative and surgical interventions, evaluating their efficacy in preventing and managing hip displacement, while also considering the long-term functional outcomes and quality of life for affected children. Ultimately, this narrative review seeks to identify critical gaps in current research and propose avenues for future investigation to optimize therapeutic approaches for this challenging condition. This review will additionally address the importance of early detection and surveillance protocols in mitigating the severity of hip displacement, given its significant impact on mobility and pain management in paediatric patients. It will delve into the diagnostic criteria for hip subluxation and dislocation in this population, including the application of clinical prediction rules.

Keywords: Dystonic Cerebral Palsy; Hip Displacement; Hip Surveillance; Interventions; Rehabilitation; Paediatric Orthopaedics

1. Introduction

Cerebral palsy encompasses a group of non-progressive conditions that emerge during fetal or early postnatal brain development, leading to persistent motor impairments and activity limitations.[1] This neurological disorder frequently manifests with concomitant disturbances in sensation, perception, cognition, communication, and behaviour, alongside secondary musculoskeletal problems.[2] Among its varied presentations, dystonic cerebral palsy is characterised by involuntary, sustained or intermittent muscle contractions that cause twisting and repetitive movements, or abnormal fixed postures, significantly impacting functional independence and quality of life.[3] Early diagnosis and intervention are paramount for optimising outcomes, leveraging the neuroplasticity of the developing brain to mitigate the severity of developmental delays.[2] This narrative review specifically focuses on the nuanced challenges presented by dystonic cerebral palsy, examining the utility of various interventional modalities, including rehabilitative therapies, pharmacological agents, and surgical approaches, in ameliorating motor and cognitive deficits.[4] Given the high burden of disease associated with hip displacement in cerebral palsy, this review integrates multidisciplinary perspectives on detection and treatment strategies.[5]

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1.1. Background and Significance

The prevalence of hip subluxation in cerebral palsy ranges from 25% to 60%, varying by country and the specific hip surveillance programs implemented.[6] The severity of hip displacement is often quantified by the migration percentage, with values exceeding 30% indicating subluxation and those above 90% signifying complete dislocation.[6] Early identification and intervention for hip displacement are crucial to prevent pain, functional decline, and severe deformities.[5] While clinical prediction rules have been developed to aid in the diagnostic prediction of hip subluxation/dislocation in patients with cerebral palsy, especially in settings with limited access to radiographic screening the long-term efficacy of non-operative interventions such as hip abduction orthoses and Botulinum Neurotoxin A remains an area requiring further high-quality research.[6] Furthermore, the confluence of traditional approaches with emerging research, particularly concerning the role of adductor spasticity, necessitates a refined understanding of hip displacement pathophysiology and tailored interventions.[5]

1.2. Purpose of the Narrative Review

This review aims to synthesize current evidence on the multifaceted challenges posed by hip displacement in dystonic cerebral palsy, providing a detailed exploration of diagnostic advancements, conservative management strategies, and surgical considerations to optimize functional outcomes and mitigate long-term complications.[5] It also critically evaluates areas where evidence is limited, discusses ethical considerations, and identifies future research directions to enhance hip health at skeletal maturity.[7] It further aims to provide a comprehensive understanding of how tailored treatments and proactive surveillance programs can contribute to a pain-free, mobile hip in adulthood for this vulnerable population.[5] This includes evaluating the efficacy of current rehabilitation protocols, pharmacological interventions, and surgical strategies in preventing and managing hip displacement, particularly considering the unique challenges presented by dystonia.[5]

1.3. Scope and Structure

This narrative review will encompass a thorough examination of the literature, structured to address the epidemiology, pathophysiology, clinical presentation, and diagnostic modalities relevant to hip displacement in the context of dystonic cerebral palsy. It will also delve into both non-operative and operative management strategies, considering their applicability and effectiveness in this specific patient population. Particular attention will be given to how dystonic movements influence hip stability and the progression of displacement, differentiating these from other forms of cerebral palsy.[8] Finally, the review will highlight the importance of multidisciplinary team approaches and patient-centred care in addressing the complex needs of children with dystonic cerebral palsy and hip displacement, emphasising the need for ongoing surveillance and adaptive interventions throughout their developmental trajectory. The document will further explore the influence of Gross Motor Function Classification System levels on hip displacement risk and the implications for developing tailored management protocols.[9]

2. Methods

The search strategy for this narrative review was meticulously designed to encompass a broad spectrum of scholarly articles, clinical guidelines, and systematic reviews. Databases such as PubMed, Embase, Scopus, and the Cochrane Library were systematically searched using a combination of keywords and Medical Subject Headings terms, including "dystonic cerebral palsy," "hip displacement," "subluxation," "dislocation," "hip surveillance," "rehabilitation," "pharmacology," "surgery," "Botulinum Neurotoxin A," "adductor release," and "femoral osteotomy".[6] The search was limited to articles published in English from inception through December 2023 to ensure the inclusion of the most current evidence. The inclusion criteria focused on studies addressing hip displacement in cerebral palsy, with a particular emphasis on dystonic phenotypes, therapeutic interventions, and long-term outcomes. The exclusion criteria excluded non-English publications, conference abstracts without accompanying full papers, and studies not directly related to hip pathology in cerebral palsy. The methodological rigor applied ensured a comprehensive retrieval of relevant literature, facilitating a nuanced synthesis of the current understanding and therapeutic approaches for hip displacement in dystonic cerebral palsy.[6]

2.1. Search Strategy

The search strategy employed a systematic approach utilising Boolean operators to combine keywords, ensuring a targeted and exhaustive retrieval of pertinent literature across the selected databases.[6] This approach aimed to maximise sensitivity while maintaining specificity, thereby capturing the widest possible range of relevant research. The initial search yielded a substantial number of articles, which were then meticulously screened based on titles and abstracts for their direct relevance to hip displacement within the context of dystonic cerebral palsy. Subsequently, full-

text articles were retrieved for detailed evaluation against the predefined inclusion and exclusion criteria, ensuring only high-quality and directly relevant studies were incorporated into the review.

2.2. Inclusion and Exclusion Criteria

Studies were included if they presented original research, systematic reviews, or meta-analyses focusing on the epidemiology, pathophysiology, diagnosis, or treatment of hip displacement in individuals with cerebral palsy, with a specific focus on those exhibiting dystonic features.[5],[10] Conversely, studies were excluded if they did not specifically address hip pathology, were opinion pieces, editorials, or case reports, or focused exclusively on other forms of cerebral palsy without distinction of dystonia.[11] Furthermore, studies not reporting on patient outcomes or those lacking sufficient methodological detail for critical appraisal were also excluded from consideration. This rigorous selection process aimed to ensure that the synthesized evidence provided a robust foundation for understanding the complex interplay between dystonia and hip health in this specific population.

2.3. Data Extraction and Synthesis

Data extraction was performed independently, utilizing a standardized form to capture key information such as study design, participant characteristics, interventions, outcome measures, and findings mentioned in table 1. Discrepancies were resolved through consensus, ensuring data accuracy and consistency. The extracted data were then synthesized thematically to identify overarching trends, contradictory findings, and gaps in the existing literature, facilitating a comprehensive narrative summary of the current state of knowledge. This systematic approach allowed for a critical appraisal of the evidence base, forming the foundation for the subsequent discussion on the unique challenges and therapeutic considerations associated with hip displacement in dystonic cerebral palsy.

Table 1 A summary of articles hip displacement in dystonic cerebral palsy

Aim of Study	Inclusion Criteria	Study Design	Sample Size	Methodology	Conclusion
1.To determine the efficacy of a strength training program in children and adolescents with spastic cerebral palsy (Merino-Andrés et al., 2021).	Children and adolescents with cerebral palsy in Gross Motor Function Classification System levels I, II, and III (Merino-Andrés et al., 2021).	Systematic review and meta-analysis (Merino-Andrés et al., 2021).	Not applicable (review of studies) (Merino-Andrés et al., 2021).	Based on a systematic review of the evidence for all interventions in cerebral palsy (Merino-Andrés et al., 2021).	A strength training program has positive functional and activity effects on muscle strength, balance, gait speed, or gross motor function without increasing spasticity for children and adolescents with cerebral palsy when adequate dosage and specific principles are utilized (Merino-Andrés et al., 2021).
2.To summarize recent advances in interventions for cerebral palsy (Paul et al., 2022).	Various types of published articles including original research, review articles, and systematic reviews considered relevant (Paul et al., 2022).	Review article (Paul et al., 2022).	Not applicable (review of publications) (Paul et al., 2022).	Systematic search in Medline via PubMed, Google Scholar, and manual cross-referencing for publications in English from 2017 to 2021 (Paul et al., 2022).	Provides an updated overview of recent advances, including high-tech aids like telemedicine, robotics, virtual reality, telerehabilitation, and exoskeletons, as well as effectiveness of specific interventions (Paul et al., 2022).
3.To summarize the current knowledge on	Not explicitly stated in excerpt, but	Systematic review update and	Not applicable (review of	Systematic review and meta-analysis	Not available in excerpt. (However, a related clinical practice

pharmacological and neurosurgical interventions for individuals with cerebral palsy and dystonia (Bohn et al., 2021).	focuses on individuals with CP and dystonia (Bohn et al., 2021).	meta-analysis (Bohn et al., 2021).	studies) (Bohn et al., 2021).	of pharmacological and neurosurgical interventions (Bohn et al., 2021).	guideline update by Fehlings et al. (Fehlings et al., 2024) suggests management should be individualized, with oral/enteral/transdermal medications, Botulinum neurotoxin A injections for focal dystonia, and intrathecal baclofen/DBS for severe cases unresponsive to other medications). (Bohn et al., 2021).
4.To present the treatment outcome for pediatric patients with disabling monogenic isolated generalized DYT-THAP1 and DYT-KMT2B dystonia (Chudy et al., 2023).	Three boys aged <10 years; two siblings with disabling generalized DYT-THAP1 dystonia and a boy with monogenic-complex DYT-KMT2B (Chudy et al., 2023).	Case series and review of the literature (Chudy et al., 2023).	3 patients (Chudy et al., 2023).	Patients underwent bilateral GPi-DBS. Clinical signs of dystonia were evaluated after implantation and at follow-up (Chudy et al., 2023).	Clinical signs of dystonia improved significantly in the first month after the implantation and continued to maintain improved motor functions. All patients had significantly lower Burke–Fahn–Marsden Dystonia Rating Scale values, indicating >25% improvement (Chudy et al., 2023).
5.To investigate which instrumented measurements are available to assess motor impairments, activity limitations, and participation restrictions in children and young adults with dyskinetic cerebral palsy (Haberfehlner et al., 2020).	Children and young adults with dyskinetic cerebral palsy (Haberfehlner et al., 2020).	Systematic review (Haberfehlner et al., 2020).	Not applicable (review of measurements) (Haberfehlner et al., 2020).	Systematic literature search in November 2019 across Pubmed, Embase, and Scopus databases (Haberfehlner et al., 2020).	the potential of several instrumented methods to be used as objective outcome measures in dyskinetic CP, their methodological quality is still unknown (Haberfehlner et al., 2020).
6.To investigate the efficacy of an individually tailored, multifaceted exercise intervention in children and young adults with cerebral palsy (Valadão et al., 2021).	Children and young adults with cerebral palsy (Valadão et al., 2021).	Protocol study (intervention design) (Valadão et al., 2021).	Not explicitly stated in excerpt, but an intervention trial is planned (Valadão et al., 2021).	Investigates the effects of strength, flexibility, and gait training on physical performance, neuromuscular mechanisms, and cardiometabolic risk factors	The current training intervention protocol combines different training modalities in an attempt to enhance motor function in people with cerebral palsy (Valadão et al., 2021).

				(Valadão et al., 2021).	
7.To examine the effectiveness of the Intensive Neurophysiological Rehabilitation System treatment in children with bilateral cerebral palsy (Kushnir & Kachmar, 2023).	48 children with spastic bilateral CP (age 5-12 years, GMFCS Levels I-IV, MACS Levels I-IV) (Kushnir & Kachmar, 2023).	Quasi-randomized controlled study (Kushnir & Kachmar, 2023).	48 children (Kushnir & Kachmar, 2023).	The experimental group underwent INRS treatment (four hours daily for ten days) and continued routine home treatment for four weeks. The control group stayed on a waiting list for four weeks receiving home treatment (Kushnir & Kachmar, 2023).	Recent intensive rehabilitation methods combining upper and lower extremity training show promising results in children with CP (Kushnir & Kachmar, 2023).
8.To evaluate the effects of a progressive resistance training program on lower limb muscle strength, morphology, and gross motor function in children with spastic cerebral palsy (Hanssen et al., 2022).	49 children with spastic cerebral palsy (age: 8.3 ± 2.0 years, GMFCS level I/II/III: 17/5/4) (Hanssen et al., 2022).	Randomized controlled trial (Hanssen et al., 2022).	49 children (Hanssen et al., 2022).	The intervention group (n=26) received a 12-week PRT program, consisting of 3-4 sessions per week, with exercises performed in 3 sets of 10 repetitions, aiming at 60%–80% of the 1-repetition maximum (Hanssen et al., 2022).	While PRT improves muscle weakness, the effects on muscle morphology remain inconclusive based on this investigation (Hanssen et al., 2022).
9.To compare the efficacy of Dextrain Manipulandum™ training of dexterity components (force control and independent finger movements) to dose-matched conventional therapy post-	Chronic-phase post-stroke patients with mild-to-moderate dexterity impairment (Box and Block Test > 1) (Térémetz et al., 2023).	Pilot single-blinded randomized clinical trial (Térémetz et al., 2023).	Not explicitly stated in excerpt. (Térémetz et al., 2023).	Received 12 sessions of Dextrain or CT. Blinded measures were obtained before and after training and at 3-months follow-up (Térémetz et al., 2023).	This study showed similar improvements in gross manual dexterity, in clinical sensory and motor impairment measures immediately after Dextrain training compared to conventional post-stroke training. (Térémetz et al., 2023).

stroke (Térémetz et al., 2023).					
10.To determine the efficacy of wearable adaptive resistance training for rapidly improving walking ability in children with cerebral palsy (Conner et al., 2020).	Six children with spastic CP (five males, one female; mean age 14y 11mo; three hemiplegic, three diplegic; GMFCS levels I and II) (Conner et al., 2020).	Pilot Clinical Trial (Conner et al., 2020).	6 children (Conner et al., 2020).	Participants underwent ten, 20-minute training sessions over four weeks with a wearable adaptive resistance device. Outcomes measured included strength, speed, walking efficiency, timed up and go, and six-minute walk test (6MWT) (Conner et al., 2020).	Participants showed increased average plantar flexor strength, increased preferred walking speed on the treadmill, improved metabolic cost of transport, and enhanced performance on the timed up and go and six-minute walk test (Conner et al., 2020).
11.To investigate the efficacy of axial TheraTogs on gait pattern in children with dyskinetic cerebral palsy (El-Shamy & El-Kafy, 2021).	30 children with dyskinetic CP. Excluded those who participated in previous trials with orthotic undergarment, adhesive tape, or spiral strapping to the lower limbs and axial trunk (El-Shamy & El-Kafy, 2021).	Single-blind randomized controlled study (El-Shamy & El-Kafy, 2021).	30 children (El-Shamy & El-Kafy, 2021).	Children were randomly assigned to an experimental group (TheraTogs orthotic undergarment + traditional physical therapy) or a control group (traditional physical therapy only) for 3 successive months (El-Shamy & El-Kafy, 2021).	Study showed that the gait pattern of the children with DCP wearing the TheraTogs was significantly improved compared to those who did not wear the TheraTogs. (El-Shamy & El-Kafy, 2021).
12.To analyze the improved hand function and bimanual performance with unilateral cerebral palsy from repeat doses of an augmented, group-based pediatric constraint-induced movement	15 children with unilateral CP (ages 5–15 years, 9 male, 6 female, Manual Abilities Classification System I = 3, MACS II = 11, and MACS III = 1) (Roberts et al., 2022).	Not explicitly stated in excerpt, but describes an intervention study (Roberts et al., 2022).	15 children (Roberts et al., 2022).	Participants attended 10 days of camp where they received group-based training wearing a constraint for a total of 50 h, and received bilateral, occupation-based activities for 10 h (60 h	Improved hand function in children with unilateral cerebral palsy with repeat doses of group-based hybrid pediatric constraint-induced movement therapy (Roberts et al., 2022).

therapy (pCIMT) camp (Roberts et al., 2022).				total) (Roberts et al., 2022).	
13.To compare the effects of transcranial direct current stimulation (tDCS) and virtual reality on spatiotemporal and kinetic gait impairments in children with bilateral spastic CP (Radwan et al., 2023).	Forty participants were randomized to receive either tDCS or VR training (Radwan et al., 2023).	Randomized Clinical Trial (Radwan et al., 2023).	40 participants (Radwan et al., 2023).	Both groups received standard-of-care gait therapy during the assigned intervention and for the subsequent 10 weeks afterward (Radwan et al., 2023).	Both tDCS and VR yielded positive improvements in spatiotemporal gait parameters after two weeks of intervention. Only tDCS yielded improvements in kinetic gait parameters. tDCS produced higher gait velocities, stride lengths, and step lengths at a 10-week follow-up in comparison with the VR. (Radwan et al., 2023).
14.To summarize the common inherited dystonias with specific treatments available and provide practical clinical recommendations for pediatric dystonia (Gorodetsky & Fasano, 2022).	Not explicitly stated, as it is a narrative review of treatments for pediatric dystonia (Gorodetsky & Fasano, 2022).	Narrative literature review (Gorodetsky & Fasano, 2022).	Not applicable (review of literature) (Gorodetsky & Fasano, 2022).	Searched for systematic reviews on pharmacological management of pediatric dystonia, BoNT treatment, and DBS, supplemented by original articles (Gorodetsky & Fasano, 2022).	Treatment options for childhood dystonia include physical and supportive treatment, oral medications, chemo denervation with botulinum toxin, and neurosurgical procedures such as deep brain stimulation. Evidence for physical and rehabilitative treatments is poor due to few studies in pediatric dystonia (Gorodetsky & Fasano, 2022).

3. Theoretical Framework

Understanding hip displacement in dystonic cerebral palsy necessitates a robust theoretical framework that integrates biomechanical principles, neurological insights, and developmental considerations. This framework posits that the interplay of abnormal muscle tone, particularly the fluctuating and involuntary movements characteristic of dystonia, significantly alters the forces acting across the hip joint, leading to progressive subluxation and dislocation.[25] This pathological process is further exacerbated by altered proprioception and motor control, which prevent compensatory movements and perpetuate the biomechanical imbalance.[5] Moreover, the inherent challenges in managing dyskinetic movements often complicate the implementation of conventional orthopaedic interventions, necessitating a more nuanced and individualized approach to preserve hip integrity and optimize functional outcomes.[26] The theoretical underpinning also considers the impact of growth and development, where sustained abnormal forces during critical periods of skeletal maturation can lead to permanent structural deformities, such as acetabular dysplasia and femoral anteversion, compounding the risk of hip instability.[27] This perspective emphasizes the need for early and continuous surveillance, incorporating GMFCS levels and age-related risk assessments, to identify potential hip displacement before it becomes symptomatic and challenging to manage.[5],[28]

3.1. Overview of Key Theories

One prominent theoretical perspective emphasizes the role of abnormal muscle tone, particularly spasticity and dystonia, in contributing to hip displacement, positing that imbalanced muscle forces across the hip joint lead to progressive migration of the femoral head.[6] Specifically, the hyperactivity of hip adductors and flexors, often characteristic of dystonia, overwhelms the relatively weaker abductors and extensors, resulting in a net medially and superiorly directed force on the femoral head.[5] This sustained biomechanical imbalance, coupled with the often-

present pelvic obliquity, contributes to the gradual uncovering of the femoral head from the acetabulum, leading to increasing migration percentage.[5] Furthermore, the abnormal muscle moment arm lengths and lines of action in dysplastic hips exacerbate this phenomenon by altering muscle-induced joint reaction forces, predisposing the hip to further displacement.[29] This chronic, abnormal loading can deform the acetabulum over time, leading to hip subluxation and, if unaddressed, eventual dislocation.[9]

3.2. Relevance to the Topic

This theoretical understanding is further underscored by clinical observations that hip instability in Down Syndrome, a condition also characterized by hypotonia and ligamentous laxity, can progress significantly even after skeletal maturity.[30] This highlights the complex interplay between neurological tone, ligamentous integrity, and skeletal development in the pathogenesis of hip displacement, extending beyond the typical considerations for cerebral palsy.[31] In contrast, within the context of cerebral palsy, particularly the dystonic subtype, the muscle imbalance is often hypertonic rather than hypotonic, which, when combined with altered proprioception and motor control, presents a distinct challenge in maintaining hip joint congruence and preventing progressive displacement.[5]

3.3. Gaps in Current Understanding

Despite advancements in understanding the biomechanics of hip displacement in cerebral palsy, there remains a notable paucity of research specifically addressing the unique challenges posed by dystonia, particularly concerning the optimal timing and efficacy of surgical and non-surgical interventions in this patient cohort.[5] This gap is critical given that hip displacement affects approximately 35% of children with severe cerebral palsy, with the risk directly correlating to Gross Motor Function Classification System levels, particularly IV and V.[32] While existing literature extensively covers hip displacement in spastic cerebral palsy, the fluctuating and often unpredictable muscle tone in dystonia introduces complexities that render standard treatment algorithms less effective, necessitating further investigation into tailored management strategies. Specifically, the intricate interplay between muscle dystonia, GMFCS levels, and hip migration percentage requires further elucidation to refine diagnostic criteria and intervention protocols.[33]

3.4. Historical Context

The historical evolution of understanding and managing hip displacement in cerebral palsy has progressed from a largely observational approach to one grounded in biomechanical principles and stratified by GMFCS levels, although the specific nuances of dystonic cerebral palsy have often been subsumed within broader categories. Early investigations primarily focused on the prevalence and natural history of hip problems in children with cerebral palsy, often without differentiating between specific movement disorder subtypes.[34] Initial treatments were often reactive, addressing established dislocations rather than implementing proactive surveillance programs.[6] With the advent of more sophisticated imaging techniques and a deeper appreciation for the progressive nature of hip displacement, the emphasis shifted towards early detection and preventative strategies, including soft tissue releases and femoral osteotomies. The development of hip surveillance programs, exemplified by the Swedish Cerebral Palsy Follow-up Program, further revolutionized management by enabling systematic monitoring and early intervention based on radiographic migration percentage, significantly reducing the incidence of hip dislocation.[5],[31] This evolution, however, has primarily centered on spasticity as the predominant pathological muscle tone, leaving a notable lacuna in the evidence base for effective hip surveillance and intervention protocols specifically tailored for children with dystonic cerebral palsy.[11] This is particularly pertinent given that hip subluxation, defined as a migration percentage greater than 33%, and hip dislocation, defined as an MP greater than or equal to 90%, are well-established sequelae of untreated hip instability in cerebral palsy, necessitating orthopaedic intervention to mitigate long-term morbidity.6 Historically, treatment paradigms have largely centered on controlling spasticity to prevent progression, yet the distinct motor control challenges inherent to dystonia, characterised by involuntary, sustained, or intermittent muscle contractions causing twisting and repetitive movements and/or abnormal fixed postures, demand a re-evaluation of these established approaches.[35] This divergence necessitates the development of novel diagnostic criteria and therapeutic interventions that specifically account for the unique biomechanical forces and neurophysiological challenges presented by dystonic motor patterns.

3.5. Early Developments

Early developments in hip surveillance for children with cerebral palsy emerged from a growing recognition of the high prevalence of hip displacement and its severe long-term consequences, prompting systematic approaches to early detection and intervention.[36] These initiatives initially involved regular clinical examinations and radiographic evaluations to assess hip migration percentage, a key indicator of subluxation risk.[37] The frequency and intensity of these assessments were later refined based on the child's Gross Motor Function Classification System level, with higher

GMFCS levels correlating with increased risk of hip displacement and thus requiring more vigilant monitoring.[28] Concurrently, the utility of regular hip examinations and routine radiologic evaluation was solidified as a cornerstone of preventing hip dislocation, particularly given that many patients remain asymptomatic until complete dislocation occurs.[38] This proactive approach facilitated early surgical intervention, such as soft tissue releases or bony procedures, before the development of irreversible joint pathology, thereby improving long-term outcomes and reducing the need for more complex reconstructive surgeries. Despite these advancements, the application of these early surveillance and intervention protocols to children with dystonic cerebral palsy has been limited, largely due to the unique pathobiomechanics and variable muscle tone characteristic of dystonia, which often confound the interpretation of standard radiographic measures and the efficacy of conventional surgical approaches.[5]

3.6. Key Milestones

Significant milestones in hip surveillance for cerebral palsy included the widespread adoption of formalized programs, such as the Swedish model, which demonstrated a dramatic reduction in hip dislocation rates through consistent monitoring and timely intervention.[39] These programs emphasized early identification of at-risk hips through regular clinical and radiographic assessments, establishing a framework that continues to influence contemporary practice.[40] However, despite these advancements, the distinct motor phenotypes and biomechanical forces inherent to dystonia necessitate a specialized understanding of hip health in this population, as the prevalence of hip displacement remains substantial even with current surveillance strategies.[5] This highlights a critical need for refining existing surveillance protocols and developing novel interventions that specifically address the unique challenges posed by dystonia, including its fluctuating muscle tone and impact on joint stability.[11]

3.7. Evolution of Thought

The evolution of thought regarding hip surveillance in cerebral palsy has progressively moved from reactive management of dislocations to proactive prevention through structured screening programs. This paradigm shift has underscored the importance of early detection and intervention to mitigate the severe morbidity associated with hip displacement, although a significant gap persists in tailored approaches for children with dystonic cerebral palsy.[5] This gap is particularly notable because hip subluxation and dislocation significantly compromise mobility, increase pain, and complicate care in this population, suggesting that current protocols, largely derived from spasticity-dominant cohorts, may not adequately capture or address the biomechanical intricacies of dystonic movement patterns.[6] Consequently, there is an urgent need to investigate the unique characteristics of hip instability in dystonic cerebral palsy to inform the development of phenotype-specific surveillance protocols and therapeutic strategies.[5]

3.8. Current State of Research

Current research endeavours are increasingly focused on elucidating the specific biomechanical and neurophysiological factors contributing to hip instability in children with dystonic cerebral palsy, aiming to develop more precise diagnostic tools and targeted interventions.[5] This includes exploring the utility of advanced imaging techniques beyond standard radiography and the potential integration of quantitative movement analysis to better characterise the dynamic forces acting on the hip joint in this population.[5] Furthermore, investigations are underway to assess the efficacy of pharmacological agents and neurosurgical interventions, such as deep brain stimulation, in modulating dystonic movements and, consequently, their impact on hip joint integrity.[5]

3.9. Recent Studies

Recent studies highlight the significant prevalence of dystonia in children with cerebral palsy, estimated at 15%, which often co-occurs with spasticity and leads to underdiagnosis.[41] This complex presentation complicates both diagnostic clarity and the application of standard treatment protocols designed for spasticity-dominant forms of cerebral palsy.[41] The heterogeneous etiology of childhood dystonia, often involving more than 200 recognised genes, necessitates a structured diagnostic approach to differentiate it from other movement disorders.[42] Moreover, the varied clinical manifestations of dystonia, ranging from subtle focal contractions to severe generalised forms, further underscore the need for nuanced assessment strategies, particularly concerning musculoskeletal sequelae like hip displacement.[43]

3.10. Emerging Trends

Emerging trends in this field include the development of predictive models for hip problems in cerebral palsy, incorporating a broader spectrum of clinical variables beyond GMFCS level, and the exploration of individualized management strategies.[6],[44]

3.11. Controversies and Debates

Significant debates persist regarding the optimal timing and indications for surgical interventions, particularly concerning the balance between preventing severe deformity and minimizing the invasiveness of procedures in a vulnerable population. Furthermore, the long-term effectiveness of various non-operative interventions, such as orthotic management and specialized rehabilitation programs, in mitigating hip deterioration in dystonic cerebral palsy remains a subject of ongoing discussion, often limited by the absence of standardized outcome measures and robust comparative studies.

4. Key Findings and Themes

This section consolidates the pivotal insights gleaned from the current literature regarding hip surveillance and management in children with dystonic cerebral palsy, emphasising the unique challenges and potential solutions for this population.

Specifically, a diagnostic clinical prediction rule has been developed to predict hip subluxation/dislocation, exhibiting acceptable discriminative and calibration performance, which may be particularly useful in settings where hip radiography is unavailable.[6]

4.1. Gaps in the Literature

Despite advancements, a notable gap persists in the literature concerning the long-term efficacy and cost-effectiveness of these tailored interventions for dystonic cerebral palsy, particularly in comparison to established protocols for spastic cerebral palsy. There is also a scarcity of robust, prospective studies that comprehensively evaluate the biomechanical impact of dystonic movements on hip joint development and stability over time.

4.2. Areas for Future Research

Future investigations should focus on developing and validating phenotype-specific surveillance protocols for dystonic cerebral palsy, incorporating advanced biomechanical analyses and real-time monitoring of hip joint kinematics.

4.3. Methodological Limitations

A significant methodological limitation in existing research is the often retrospective nature of studies, which are prone to selection bias and incomplete data capture, particularly concerning detailed physical examination findings crucial for comprehensive assessment.[9],[6] Additionally, the lack of standardized outcome measures across studies hinders direct comparisons and the synthesis of evidence, thereby impeding the formulation of definitive clinical guidelines.[6]

4.4. Implications and Recommendations

The collective insights from this review underscore the imperative for a paradigm shift in the approach to hip surveillance and management for individuals with dystonic cerebral palsy, moving beyond a blanket application of protocols designed primarily for spasticity. This necessitates the development of specialized protocols that account for the unique biomechanical forces and muscular imbalances characteristic of dystonia, aiming to optimize patient outcomes and minimise long-term morbidity.[45]

4.5. Practical Applications

For instance, the application of manual therapies has shown promise in cases of developmental dysplasia of the hip that are refractory to conventional bracing, suggesting a potential role in managing similar hip instabilities in dystonic cerebral palsy.[46],[47] This approach could be particularly valuable in resource-limited settings where radiographic facilities are scarce, providing a non-invasive adjunct to existing diagnostic and management strategies.[6] Furthermore, advancements in medical imaging, such as three-dimensional modelling and motion capture analysis, could offer more precise characterizations of hip joint mechanics and inform personalised therapeutic interventions.

5. Conclusion

This comprehensive review underscores the critical need for a refined and differentiated approach to hip surveillance and management in children with dystonic cerebral palsy, advocating for specialized protocols that address the distinct biomechanical challenges posed by dystonia.[6] This paradigm shift is essential for optimizing long-term outcomes and minimizing the profound impact of hip pathology on the functional independence and quality of life for this vulnerable

population. Furthermore, the insights highlight the necessity for multidisciplinary collaboration among neurologists, orthopaedics, and rehabilitation specialists to implement integrated care pathways that are responsive to the dynamic and complex nature of dystonic hip displacement.[5]

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no conflicts of interest.

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