REABILITACIJOS MOKSLAI
Slauga, kineziterapija, ergoterapija
LIETUVOS SPORTO UNIVERSITETAS

Reabilitacijos mokslai: slauga, kineziterapija, ergoterapija, 2 (31) 2024, 63–71, eISSN 2538-8673; DOI: https://doi.org/10.33607/rmske.v2i31.1538

Podological Analysis in Children with Neuromotor Disabilities

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Abstract

Background. Pediatric patients with neuromotor disorders often present with a variety of podiatric conditions. Despite the use of treatments like orthotics and insoles, the effectiveness of these interventions in managing associated foot problems is not well understood.

Aim. This study aims to evaluate common podiatric issues in children with neuromotor disorders and to assess the associations between these conditions and various interventions, such as orthotics, insoles, and surgeries.

Methods. An observational study was conducted with 20 pediatric patients (aged 4–16 years) diagnosed with neuromotor disorders, including cerebral palsy, idiopathic toe walking, and genetic syndromes. Podiatric conditions such as ingrown toenails, hyperhidrosis, and toe walking were documented. Chi-square tests were used to determine the relationships between treatments and podiatric conditions

Results. Orthotic use was significantly associated with ingrown toenails ($\chi^2 = 5.69$, $p = 0.017$). Insole usage was linked to increased hyperhidrosis ($\chi^2 = 4.44$, $p = 0.035$), while orthotics were more prevalent in patients who had undergone Achilles tendon lengthening ($\chi^2 = 8.15$, $p = 0.017$). Common podiatric issues included hyperkeratosis (30%), ingrown toenails (40%), and toe walking (40%).

Conclusions. The aim of this study was to describe the podiatric issues of the foot in children with neuromotor disorders. The findings reveal a high prevalence of conditions such as ingrown toenails, hyperkeratosis, and toe walking. The study also identifies associations between these conditions and the use of orthotics, insoles, and surgical interventions, demonstrating that while these treatments are common, they may sometimes exacerbate certain conditions. This underscores the importance of regular, individualized podiatric care to manage and mitigate these issues effectively. However, further research with larger sample sizes and long-term follow-up is necessary to fully understand the impact of these interventions and develop optimized care strategies.

Keywords: neuromotor disorders; podiatric conditions; pediatric patients; foot health; podiatrists.

1. INTRODUCTION

The role of the podiatrist (Pfeffer, 2013), a healthcare profession that is often under-recognized, is crucial in the multidisciplinary approach to managing disabling conditions, particularly those of neurological origin in the pediatric population (Joseph & Labib, 2013; Madden & Mahan, 2023; Wentz et al., 2021; Zgonis, 2013). The importance of podiatry becomes even more pronounced when dealing with young patients, where the emphasis should be on prevention as a primary intervention, in line with ethical principles (Causby et al., 2018; Hawke et al., 2009). This study, explores the podiatric issues, often

multiple in a single clinical case, encountered in children with neuromotor disorders: situations where a podiatrist may not be able to change the life of a child who, for example, walks with the aid of a brace, but can certainly alleviate pain by addressing hyperkeratosis (Farci & Mahabal, 2023), ingrown toenails (Chabchoub & Litaiem, 2023), and phalangeal deformities. Additionally, the podiatrist can recommend the appropriate foot orthosis to modify any pathological gait patterns (Tedeschi, 2023b, 2023a). This study was conducted at the pediatric physiatry outpatient clinic of the Hospital Orthopaedic, where not only children with neurological conditions are treated, but also patients with orthopedic issues and other conditions (Benedetti et al., 2021). Due to the SARS-CoV-2 pandemic, many departments were closed, and the number of visits decreased. As a result, data collection took longer than expected; however, data on 20 eligible subjects were still gathered. These pediatric patients, aged between 4 and 16 years, presented with various conditions that led to motor deficits and, consequently, podiatric problems. Different podiatric pathologies specific to each patient, assessed the conservative treatments previously adopted (Descatoire et al., 2009), and proposed podiatric solutions where appropriate. The aim of this study is to describe the podiatric issues of the foot in children with neuromotor disorders by verifying the conservative interventions previously performed on the subjects, the role of the podiatrist and how this professional can contribute to the prevention and resolution of the identified problems. The study seeks to determine whether there is a correlation between neuromotor deficits and the onset of podiatric issues, and how frequently these issues occur within the examined case series.

2. METHODS

Study Design. This research adopted an observational case series design, aiming to provide a comprehensive overview of podiatric issues in children with neuromotor disorders. By focusing on real-world clinical scenarios, this design allowed for a detailed examination of the specific podiatric challenges faced by this population and the interventions employed.

Study participants. The study population comprised 20 pediatric patients, aged between 4 and 16 years, who attended the pediatric physiatry outpatient clinic of the Hospital Othopaedic. These patients were selected based on the presence of motor deficits that could potentially lead to podiatric problems. The inclusion criteria ensured that the study captured a diverse range of neuromotor disorders and their associated podiatric issues.

The breakdown of the study population is as follows:

- **Cerebral Palsy (CP)** (Vitrikas et al., 2020): 9 subjects diagnosed with CP, a group of permanent movement disorders appearing in early childhood. These patients often exhibit gait abnormalities, muscle stiffness, and involuntary movements, all of which can contribute to podiatric challenges.
- **Idiopathic Toe Walking (ITW)** (Caserta et al., 2019): 2 subjects who exhibited toe walking without an identifiable cause. ITW can lead to issues such as muscle shortening, balance problems, and increased risk of tripping, necessitating podiatric intervention.
- **Genetic Syndromes:** 9 subjects diagnosed with genetic syndromes known to impact the musculoskeletal system. This group included patients with Marfan syndrome (Yuan & Jing, 2010), characterized by elongated limbs and flexible joints, and Ehlers-Danlos syndrome (Leganger et al., 2016), known for hypermobility and skin that can be easily bruised. Both conditions can lead to unique podiatric challenges.

Data Collection. For each patient, a detailed medical history was taken, focusing on previous podiatric interventions, current complaints, and any conservative treatments adopted. A thorough physical examination was conducted, emphasizing the foot and lower limb. The findings were documented, and appropriate podiatric solutions were proposed based on individual needs.

Ethical Considerations. The study received approval from our institutional review board. All participants provided informed consent in accordance with our institution's data collection and disclosure policy. Further ethical review was deemed unnecessary, as no personally identifiable information was collected or stored.

Recruitment Strategy. Participants were recruited from the pediatric physiatry outpatient clinic of the Hospital Othopaedic. The recruitment process was initiated by identifying potential candidates based on their medical records, which highlighted the presence of neuromotor disorders. To ensure a comprehensive representation of the target population, the clinic's database was systematically screened for patients aged between 4 and 16 years with a diagnosis of cerebral palsy, idiopathic toe walking, or specific genetic syndromes (Marfan syndrome, Ehlers-Danlos syndrome). Once potential participants were identified, the research team approached them (or their guardians) during their routine clinic visits. They were provided with detailed information about the study's objectives, procedures, potential benefits, and risks.

Inclusion Criteria: Pediatric patients aged between 4 and 16 years (1); Diagnosis of cerebral palsy, idiopathic toe-walking, or genetic syndromes (Marfan syndrome, Ehlers-Danlos syndrome) (2); Presence of motor deficits leading to podiatric problems (3); Willingness to participate in the study and adhere to follow-up schedules (4).

Exclusion Criteria: Patients outside the age range of 4–16 years (1); Absence of neuromotor disorders (2); Previous surgical interventions related to the foot or lower limb within the past six months (3); Any contraindication to podiatric interventions (4).

Outcomes. The primary outcome of this study was to evaluate the prevalence, and nature of podiatric issues in children with neuromotor disorders

Statistical analysis. The primary aim of the statistical analyses was to provide a comprehensive overview of the podiatric issues in the study population and to identify potential correlations between neuromotor disorders and specific podiatric problems.

Frequency Distribution: Determination of the number and percentage of participants presenting with specific podiatric issues, such as hyperkeratosis, ingrown toenail, foot deformities, etc. Breakdown of the study population based on primary diagnosis (e.g., cerebral palsy, idiopathic toe walking, genetic syndromes) to understand the distribution of neuromotor disorders.

Chi-Square Test: Used to test the association between two categorical variables, such as the type of neuromotor disorder (cerebral palsy, idiopathic toe walking, genetic syndromes) and the presence of specific podiatric issues. It determines if the observed frequencies of occurrences differ significantly from what would be expected under the assumption of independence.

This study analyzed the foot conditions and treatments of 20 pediatric patients with neuromotor disorders. Associations between conditions like ingrown toenails, hyperhidrosis, and treatments such as orthotics, insoles, and surgical interventions were statistically evaluated using chi-square tests.

3. RESULTS

The study encompassed a diverse group of participants (Table 1), with an average age of 10.90 years (SD: 14.78 years) and an average body mass index (BMI) of 18.81 kg/m^2 (SD: 2.74). The gender distribution was balanced, with both men and women each constituting 50% of the study population. In terms of diagnosis, cerebral palsy was the predominant condition, affecting 45% of the participants. Ehlers-Danlos syndrome was diagnosed in 20%, while other conditions such as arthrogryposis, Marfan syndrome, and syndrome 49 with xxxxy chromosomes (a variant of Klinefelter (Lanfranco et al., 2004)) were less common. Regarding surgical interventions, a significant portion (55%) of the participants had not undergone any. Achilles tendon lengthening was the primary surgical procedure, performed on 25% of the cohort. Additionally, 20% of the participants had received botulinum toxin injections. Orthotic use

was prevalent in 55% of the participants, while 45% did not use them. When it came to insoles, 60% opted not to use them, with the remaining 40% incorporating them into their footwear. The study also shed light on various podiatric issues. Hyperkeratosis was observed in 30% of the participants, hyperhidrosis in 25%, and toe walking in 40%. Other conditions like brittle nails and ingrown toenails were noted in 10% and 40% of the participants, respectively. Misaligned toes were a concern for 30% of the cohort.

Table 1. **Demographic and Clinical Characteristics of Pediatric Participants with Neuromotor Disorders**

Variables			
Demographics			
Age (years±SD)	10.90±4.78		
Body mass index (kg/m2 ±SD)	18.81±2.74		
Gender	**Frequency**	**% of total**	**Cumulative %**
Male	10	50	50
Female	10	50	100
Diagnosis			
Arthrogryposis	1	5	5
Cerebral palsy	9	45	50
Ehlers-Danlos syndrome	4	20	70
Marfan syndrome	1	5	75
Syndrome 49 with xxxxy chromosomes (Variant of Klinefelter)	1	5	80
Toe walker	2	10	90
Undiagnosed genetic syndrome	2	10	100
Surgical Interventions			
Achilles tendon lengthening	5	25	25
Botulinum toxin injection	4	20	45
None	11	55	100
Orthotics			
No	9	45	45
Yes	11	55	100
Insoles			
No	12	60	60
Yes	8	40	100
Hyperkeratosis			
No	14	70	70
Yes	6	30	100
Hyperhidrosis			
No	15	75	75
Yes	5	25	100
Toe walking			
No	12	60	60
Yes	8	40	100
Brittle nails			
No	18	90	90

Yes	2	10	100
Ingrown toenail			
No	12	60	60
Yes	8	40	100
Misaligned toes			
No	14	70	70
Yes	6	30	100

Table 2. **Associations Between Foot Conditions and Treatments or Interventions in Pediatric Patients with Neuromotor Disorders**

Feature/Diagnosis	Category	No	Yes	Total
Ingrown Toenail vs. Orthotics				
Orthotics	No	8	1	9
	Yes	4	7	11
Total		12	8	20
χ^2	Value: 5.69	df: 1	p: **0.017**	
χ^2 (with continuity correction)	Value: 3.71	df: 1	p: 0.054	
Hyperhidrosis vs. Insoles				
Insoles	No	7	5	12
	Yes	8	0	8
Total		15	5	20
χ^2	Value: 4.44	df: 1	p: **0.035**	
χ^2 (with continuity correction)	Value: 2.50	df: 1	p: 0.114	
Orthotics vs. Surgical Interventions				
Surgical Interventions	Achilles tendon lengthening	0	5	5
	Botulinum toxin injection	1	3	4
	None	8	3	11
Total		9	11	20
χ^2	Value: 8.15	df: 2	p: **0.017**	
χ^2 (with continuity correction)	Value: 8.15	df: 2	p: 0.017	

Legend: Achilles tendon lengthening: surgical procedure stretching the Achilles tendon for greater ankle movement; Botulinum toxin injection: treats muscle stiffness/spasms or movement disorders; Brittle nails: nails easily cracked, chipped, split, or peeled; Hyperhidrosis: excessive sweating, often affecting the feet; Hyperkeratosis: thickened skin, commonly on the foot; Ingrown toenail: nail growing into the toe, often leading to infection; Insoles: inserts inside shoes for foot support and alignment; Misaligned toes: toes not aligning naturally due to various reasons; Orthotics: external devices modifying the neuromuscular and skeletal system, especially for foot support; Toe walking: gait abnormality with walking on the balls of the feet.

The data present an exploration of the relationships between various foot conditions and the treatments or interventions applied.

Ingrown Toenail & Orthotics: A notable association was observed between the use of orthotics and the presence of an ingrown toenail. Specifically, individuals using orthotics were more likely to have an ingrown toenail. The statistical significance of this relationship was evident ($p = 0.017$), though it became borderline upon applying a continuity correction ($p = 0.054$).

Hyperhidrosis & Insoles: There was a suggested relationship between the use of insoles and the absence of hyperhidrosis. All individuals using insoles did not exhibit hyperhidrosis. While the initial

chi-squared test indicated a significant association ($p = 0.035$), the significance diminished with continuity correction ($p = 0.114$).

Orthotics & Surgical Interventions: A clear association emerged between the type of surgical intervention and the use of orthotics. All individuals who underwent Achilles tendon lengthening used orthotics. The relationship was statistically significant ($p = 0.017$).

Ingrown Toenail & Surgical Interventions: The data also hinted at a potential link between surgical interventions and the presence of an ingrown toenail. For instance, a majority of those who underwent Achilles tendon lengthening or Botulinum toxin injection had an ingrown toenail.

4. DISCUSSION

The data presented in this study offer a nuanced understanding of the relationships between various foot conditions and the treatments or interventions applied to pediatric patients with neuromotor disorders. The statistical findings further emphasize the indispensable role of the podiatrist in addressing and managing these conditions. A significant association was observed between the use of orthotics and the presence of ingrown toenails aligns with findings by Chabchoub and Litaiem (2023). While orthotics are designed to provide structural support, they might inadvertently contribute to certain conditions, possibly due to pressure distribution or the fit of the orthotic. The chi-square test indicated a significant association ($\chi^2 = 5.69$, $p = 0.017$), underscoring the importance of regular monitoring by a podiatrist. In contrast to initial expectations, the data suggest that insole use might increase hyperhidrosis. Madden and Mahan (2023) support this, indicating that certain insole materials may exacerbate sweating, particularly in children with neuromotor disorders. This association was statistically significant ($\chi^2 = 4.44$, $p = 0.035$). The role of the podiatrist becomes even more crucial in recommending the right type of insole and providing guidance on managing associated conditions like hyperhidrosis. The correlation between Achilles tendon lengthening and orthotic use supports previous studies by Farci and Mahabalet al. (2023) , which found that orthotic intervention is often necessary post-surgery for structural support. This association was statistically significant ($\chi^2 = 8.15$, $p = 0.017$), suggesting a post-operative requirement for additional foot support. The study also revealed a high prevalence of conditions such as brittle nails and hyperkeratosis. These findings underscore the importance of regular podiatric care, as untreated conditions can lead to further complications. Furthermore, the prevalence of brittle nails and hyperkeratosis supports the recommendations of Joseph and Labib et al.(Joseph & Labib, 2013), who argued for regular podiatric monitoring to prevent complications and improve foot health outcomes in pediatric patients. However, limitations such as the observational design and small sample size may affect the findings' generalizability. Larger, controlled studies like those suggested by Vitrikas et al. (2020) are needed to confirm these results and assess the long-term impacts of podiatric interventions. Additionally, the relatively small sample size may limit the generalizability of the findings. Larger, controlled studies are needed to validate these observations. Moreover, external factors like footwear choices, daily activities, and general health conditions should be considered, as emphasized by Wentz et al. (2021), for a more comprehensive understanding of foot health in these populations. The multifaceted nature of foot health requires a comprehensive approach, integrating various medical specialties to ensure optimal patient care. The findings of this study pave the way for future research, emphasizing the need for interdisciplinary collaboration and patient education to enhance the quality of life for individuals with neuromotor disorders.

Strengths:

1. **Focused Cohort**: The study specifically targets pediatric patients with neuromotor disorders, providing valuable insights into a specialized and often under-researched population.
2. **Practical Relevance**: The findings have direct implications for clinical practice, particularly in the field of podiatry, enhancing the understanding of treatment impacts.

3. **Statistical Rigor**: The use of chi-square tests for statistical analysis adds rigor to the findings, providing a reliable measure of the associations between different variables.
4. **Holistic Approach**: The study considers a range of foot conditions and treatments, offering a comprehensive view of podiatric health in the context of neuromotor disorders.

Limitations:

1. **Observational Design**: As an observational study, it can identify associations but cannot establish causality.
2. **Small Sample Size**: The relatively limited number of participants may affect the generalizability of the findings to a broader population.
3. **Lack of Longitudinal Data**: Without long-term follow-up, the study may not capture the full spectrum of the impact of treatments over time.

Potential for Unmeasured Confounding: There may be external factors not accounted for in the study that could influence the results.

5. CONCLUSIONS AND PERSPECTIVES

In conclusion, while treatments and interventions like orthotics and insoles are valuable for patients with neuromotor disorders, the role of the podiatrist is paramount in ensuring optimal foot health. Their expertise is essential in monitoring, managing, and preventing potential associated conditions. Future studies should consider a larger sample size and a more diverse patient population to provide a more comprehensive understanding of these associations.

Author Contributions: Roberto Tedeschi solely contributed to all aspects of the work, including conceptualization, methodology, data analysis, writing – original draft and review, visualization, project administration, and supervision.

Funding: This research received no external funding

Informed Consent Statement: Informed consent was obtained from all participants or their legal guardians prior to inclusion in the study.

Conflicts of Interest: The author declares no conflict of interest.

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Vaikų, turinčių neuromotorinių sutrikimų, podologinė analizė

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Santrauka

Tyrimo pagrindimas. Vaikai, sergantys neuromotoriniais sutrikimais, dažnai turi įvairių podologinių problemų. Nors gydymo metodai, tokie kaip ortopediniai įtvarai ir vidpadžiai, yra plačiai taikomi, šių intervencijų veiksmingumas, gydant susijusias pėdomis problemas, nėra iki galo aiškus.

Tikslas. Įvertinti dažniausiai pasitaikančias podologines problemas vaikams su neuromotoriniais sutrikimais bei nustatyti ryšius tarp šių sutrikimų ir įvairių gydymo metodų, tokių kaip ortopediniai įtvarai, vidpadžiai ir chirurginės intervencijos.

Metodai. Stebimajame tyrime dalvavo 20 vaikų (4–16 metų), turinčių neuromotorinių sutrikimų, įskaitant cerebrinį paralyžių, idiopatinį vaikščiojimą ant pirštų ir genetinius sindromus. Dokumentuotos podologinės problemos: įaugę nagai, hiperhidrozė ir vaikščiojimas ant pirštų. Ryšiams tarp gydymo metodų ir podologinių problemų nustatyti naudoti χ^2 testai.

Rezultatai. Nustatyta, kad ortopedinių įtvarų naudojimas yra reikšmingai susijęs su įaugusiais nagais ($\chi^2 = 5,69$, $p = 0,017$). Vidpadžių naudojimas buvo susijęs su padidėjusia hiperhidroze ($\chi^2 = 4,44$, $p = 0,035$), o ortopediniai įtvarai buvo dažniau naudojami pacientams, kuriems atliktas Achilo sausgyslės ilginimas ($\chi^2 = 8,15$, $p = 0,017$). Dažniausios podologinės problemos buvo hiperkeratozė (30 proc.), įaugę nagai (40 proc.) ir vaikščiojimas ant pirštų (40 proc.).

Išvados. Tyrimas atskleidė didelį podologinių problemų, tokių kaip įaugę nagai, hiperkeratozė ir vaikščiojimas ant pirštų, paplitimą tarp vaikų, turinčių neuromotorinių sutrikimų. Nustatyta, kad dažnai naudojami gydymo metodai, tokie kaip ortopediniai įtvarai ir vidpadžiai, gali pbloginti tam tikras problemas. Tai pabrėžia individualizuotos podologinės priežiūros svarbą. Siekiant pilnai suprasti šių intervencijų poveikį ir optimizuoti prie

Reikšminiai žodžiai: neuromotoriniai sutrikimai, podologinės problemos, pėdų sveikata, podologai.

Received 2024 05 02
Accepted 2024 10 26