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Healthy Beginnings, Hopeful Futures:
From Evidence to Clinical Practice

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Journal of
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*Journal of Pediatric and Neonatal Clinical Practice (JPNCP)* is an international, peer-reviewed, open-access scientific journal dedicated to advancing research, knowledge, and clinical practice in pediatric and neonatal healthcare. The journal publishes high-quality contributions that support the prevention, diagnosis, treatment, and long-term management of conditions affecting infants, children, and adolescents.

JPNCP promotes the development, integration, and exchange of evidence that informs clinical practice, education, and health policy, and supports the dissemination of evidence-based, patient- and family-centered care.

The journal welcomes interdisciplinary research from pediatrics, neonatology, nursing, developmental medicine, psychology, rehabilitation sciences, public health, and related fields. Particular emphasis is placed on studies that address complex healthcare challenges, evaluate innovative interventions, and contribute to improving outcomes for pediatric and neonatal populations.

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## Editorial

# Healthy Beginnings, Hopeful Futures: From Evidence to Clinical Practice

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Launching the first editorial of the Journal of Neonatal and Pediatric Clinical Practice is both an honor and a responsibility. It represents the beginning of a shared scientific journey, but above all, an opportunity to reaffirm a fundamental principle: the health of tomorrow's adults begins even before pregnancy and continues to be shaped during the earliest years of life.

This vision strongly aligns with the World Health Organization's current global focus, "Healthy beginnings, hopeful futures," which highlights maternal and newborn health as a priority for improving lifelong outcomes. The WHO campaign calls for reducing preventable maternal and newborn deaths, supporting parents and healthcare professionals, and strengthening long-term health outcomes for women, newborns, and families worldwide. This is not simply a public health slogan. It is a scientific and ethical imperative.

Health trajectories are built early. Prevention, education, access to care, and the promotion of healthy behaviors during pregnancy, infancy, childhood, and adolescence profoundly shape future well-being. For this reason, improving awareness of and access to appropriate health choices for children is not only a pediatric priority, but a strategic investment in the health of future generations.

Today, more than ever, scientific research has provided healthcare professionals with a solid body of evidence. Multidisciplinary and interprofessional teams have access to increasingly robust knowledge, capable of guiding safer and more effective care pathways. Yet, as professionals, we must also recognize a critical truth: often, the problem is no longer the absence of evidence. The real challenge lies in implementation.

There are several clear examples in child health and development. Strong evidence shows that prevention is a key element in supporting harmonious psychological, physical, and cognitive development in children. Prevention must begin with the foundations of child development, addressing primary needs and essential functions such as nutrition, sleep, affective care, and social interaction. Breastfeeding is one of the clearest examples: its benefits are widely recognized, yet in many contexts breastfeeding still does not reach acceptable levels of support and continuity, and current practices often remain below WHO infant feeding recommendations (Zong et al., 2021; Klicker et al., 2026; Tang et al., 2026). In some settings, formula feeding is too readily presented as an equivalent alternative, rather than as an option to be used when breastfeeding is not possible or not chosen after informed counselling.

Another example concerns complementary feeding. Despite available recommendations, the introduction of solid foods is often accompanied by feeding practices that do not always reflect

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the child's actual nutritional needs. Excessive caloric intake, unbalanced food choices, and early exposure to highly palatable foods may contribute to the development of unhealthy eating patterns (Marinho et al., 2026). Over time, these patterns can increase the risk of overweight and obesity, with potential consequences extending throughout childhood and adolescence.

The same applies to early exposure to digital devices. Scientific evidence increasingly highlights the potential impact of excessive or premature screen exposure on language development, sleep quality, cognitive abilities, attention, and emotional well-being. Nevertheless, the data remain alarming: a significant proportion of children have access to smartphones and digital devices before the recommended age, often without adequate guidance, limits, or parental awareness (Sutton and Thompson, 2026).

Mental health in childhood and adolescence is another area where the gap between evidence and practice is particularly concerning. Behaviours such as early and uncontrolled access to smartphones and digital platforms have been associated with negative effects on sleep, cognitive functioning, anxiety, depressive symptoms, and social development (Weingarten et al., 2026). Yet, despite recommendations and warnings, these behaviours are becoming increasingly normalized in everyday family life.

However, health promotion cannot exist without trust. Families need reliable relationships with healthcare professionals who accompany them across different care settings, whether in hospitals, outpatient clinics, primary care services, schools, or community contexts. Prevention, treatment, rehabilitation, and long-term support all require strong therapeutic alliances based on competence, continuity, and communication.

These examples show that having evidence is not enough. Evidence must be translated into practice, into education, into family support, and into coherent public health strategies. The responsibility of healthcare professionals is therefore not only to know the evidence, but also to promote its implementation, helping families to make informed, sustainable, and developmentally appropriate choices for their children.

We know what should be done, but translating evidence into daily clinical practice remains one of the greatest barriers in healthcare. Changing behaviours, redesigning systems, supporting professionals, and ensuring that best practices are consistently applied are complex processes that require leadership, culture, and accountability. Implementation science is not an accessory to research, it is the bridge between knowledge and real impact.

It is precisely within this space that the Journal of Neonatal and Pediatric Clinical Practice finds its purpose.

It aims to give voice not only to scientific production, but especially to translational research, implementation studies, and clinical innovation capable of improving everyday care. We want to promote evidence that can be applied, measured, and transformed into better outcomes for neonates, children, adolescents, and, inevitably, their families.

Clinical practice must remain the final destination of research.

Our ambition is to create an international scientific space where neonatal and pediatric professionals can share not only discoveries, but solutions; not only evidence, but implementation; not only theory, but meaningful change.

Because every healthy beginning deserves a hopeful future.

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Research

# Critical Care Pathways for Pediatric Hematology-Oncology Patients in Italy: A National Survey of Organizational Models and Escalation of Care

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## Abstract

**Introduction.** The management of critically ill pediatric hematology-oncology patients represents a major organizational and clinical challenge due to the high risk of rapid clinical deterioration related to both disease and treatment. Early recognition of deterioration and timely transfer to intensive care units (ICUs) are essential to improve outcomes. However, organizational models and emergency management pathways may vary significantly among centers. The aim of this study is to describe organizational models for the management and transfer of critically ill pediatric oncohematology patients across Italian centers, with particular focus on access to

pediatric intensive care, escalation of care processes, use of clinical deterioration scores, multidisciplinary collaboration, and transfer procedures.

**Methods.** A multicenter cross-sectional descriptive survey was conducted among the 47 pediatric hematology-oncology centers belonging to the Italian Association of Pediatric Hematology and Oncology (AIEOP) network. Data were collected between May and September 2024 through an ad hoc questionnaire developed by the Nursing Working Group after literature review and expert content validation. The questionnaire explored intensive care availability, transfer logistics, emergency response organization, clinical deterioration assessment systems, transfer documentation, and communication practices.

**Results.** Thirty-one centers participated (response rate 66%). Most centers were exclusively pediatric (80.6%), while 61.3% had an on-site pediatric intensive care unit (PICU). Among centers without a PICU, patients were transferred either to adult ICUs within the same hospital or to external pediatric ICUs. Transport modalities included stretcher transfer (51.6%), ambulance (25.8%), and helicopter emergency services. Clinical deterioration scores were used in 52% of centers, with Pediatric Early Warning Score (PEWS) being the most frequently adopted tool (69%). Critically ill patients were mainly managed within pediatric hematology-oncology wards or dedicated high-dependency areas (65%). ICU transfer decisions were multidisciplinary in 71% of centers. Most centers (84%) did not have a dedicated Medical Emergency Team or Transfer Rapid Response Team. Standardized nursing handover tools were used in only 32% of centers. Dedicated ICU rooms for pediatric hematology-oncology patients were available in 52% of centers.

**Discussion.** Despite organizational heterogeneity among Italian pediatric hematology-oncology centers, timely access to intensivecareandmultidisciplinarymanagementaregenerally ensured. However, variability persists regarding emergency response structures, use of clinical deterioration scores, and standardized handover procedures. Strengthening shared organizational models, promoting structured communication tools, and implementing multidisciplinary training programs may further improve the management and safety of critically ill pediatric hematology-oncology patients.

**Keyword:** Pediatric Hematology-Oncology, Clinical Deterioration, Escalation of Care, Pediatric Intensive Care Unit, Nursing

## Introduction

The management of emergencies in pediatric hematology-oncology patients represents a complex clinical challenge. The vulnerability of these patients, resulting both from the

underlying oncological disease and from intensive treatments, exposes them to severe complications such as sepsis, respiratory failure, and hemorrhagic shock (Jagt, 2013). Appropriate and timely intervention is essential; indeed, the literature highlights how a rapid and high-quality response can significantly reduce mortality and improve prognosis (Jones et al., 2015, Hayes et al., 2012).

In Italy, the Italian Association of Pediatric Hematology and Oncology (AIEOP) coordinates a network of specialized centers aimed at providing advanced care and support to children and adolescents affected by oncohematological diseases.

Organizational and logistical differences exist among centers, including the proximity to intensive care services. The aim of this study was to evaluate the availability and distance of intensive care units from AIEOP centers through a cross-sectional observational survey, in order to identify organizational models across different care settings.

## Materials and Methods

### *Study Design, Sample, and Setting*

A multicenter cross-sectional descriptive study was conducted involving the 47 pediatric hematology-oncology centers affiliated with AIEOP. The study was carried out by the AIEOP Nursing Working Group. A formal email invitation was sent to the nursing coordinators of each center, requesting that they complete the questionnaire once during the period from May 2024 to September 2024. Completion of the questionnaire was considered implied informed consent for the anonymous processing and dissemination of data for study purposes.

### *Instrument*

A comprehensive literature review was conducted to identify a validated questionnaire investigating organizational models in the management of emergencies in pediatric hematology-oncology. As no suitable validated instrument was identified, an ad hoc questionnaire was developed. Once created, the questionnaire was assessed for clarity and content validity by four members of the AIEOP Nursing Working Group.

The questionnaire consisted of five sections, for a total of 24 questions:

1. Respondent demographics and affiliated center
2. Type of center (pediatric or mixed) and availability of a pediatric intensive care unit (PICU)
3. Distance, transfer time, and mode of transportation
4. Team responsible for identifying clinical deterioration, use of clinical assessment scales, transfer team, and handover procedures
5. Location of dedicated rooms within intensive and sub-intensive care units and isolation measures for pediatric hematology-oncology patients

### *Ethical Considerations*

Ethical committee approval was not required for this study, as it involved an anonymous survey of healthcare professionals and did not collect sensitive personal data. Participation was voluntary, and completion of the questionnaire implied informed consent. Confidentiality and anonymity were ensured throughout the study in accordance with the principles of the Declaration of Helsinki.

## Results

This study provides an overview of the characteristics of AIEOP centers regarding the management of emergencies in pediatric hematology-oncology.

All 47 centers belonging to the AIEOP network were contacted; the response rate was 66% (31 centers). Among respondents, 20 were Hub centers, 6 were Spoke centers, while the status of the remaining centers was unknown.

Twenty-five centers (80.6%) were exclusively pediatric, whereas six (19.4%) were mixed pediatric-adult centers.

Detailed analysis of the collected data showed that 19 centers (61.3%) had an in-house pediatric intensive care unit, while 12 centers (38.7%) relied on external intensive care services.

Specifically, among centers with a pediatric intensive care unit, the survey evaluated whether

the PICU was located within the same building or in a different hospital building. In 11 centers (58%), the PICU was located within the same building, whereas in eight centers (42%) it was situated in a different building. In the latter case, transfer times ranged from 5 to 20 minutes.

Regarding the management of oncohematological emergencies in the 13 centers without an on-site PICU, 43% reported transferring patients to general or specialized adult intensive care units within the same hospital, whereas 57% transferred patients to an external pediatric intensive care unit, with transport times ranging from 10–15 minutes to longer durations.

Concerning transport modalities, in 51.6% of cases patients were transferred by stretcher, followed by 25.8% by ambulance, and 9.7% by helicopter emergency medical service or by a combination of these modalities (see Figure 1).

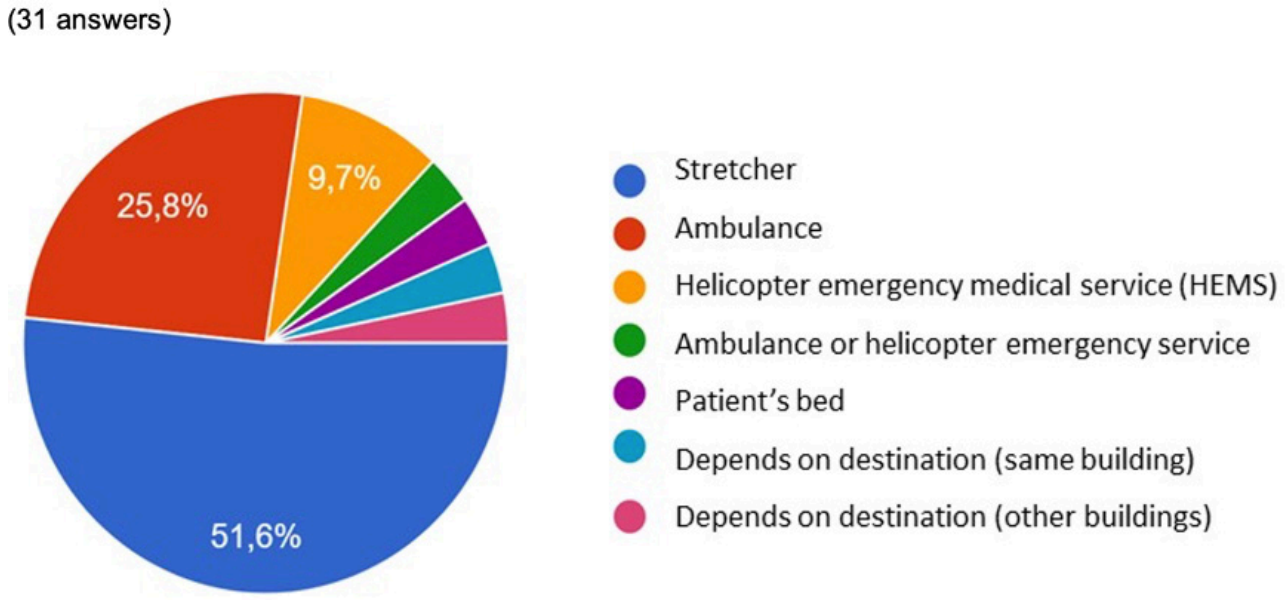


Figure 1. Distribution of transport modalities for critically ill pediatric oncohematology patients transferred to intensive care settings.

The collected results regarding the use of a clinical score for the assessment of deterioration in critically ill pediatric hematology-oncology patients showed that 16 centers (52%) adopted such a tool, whereas the remaining 15 centers (48%) did not use any scoring system (see Figure 2).

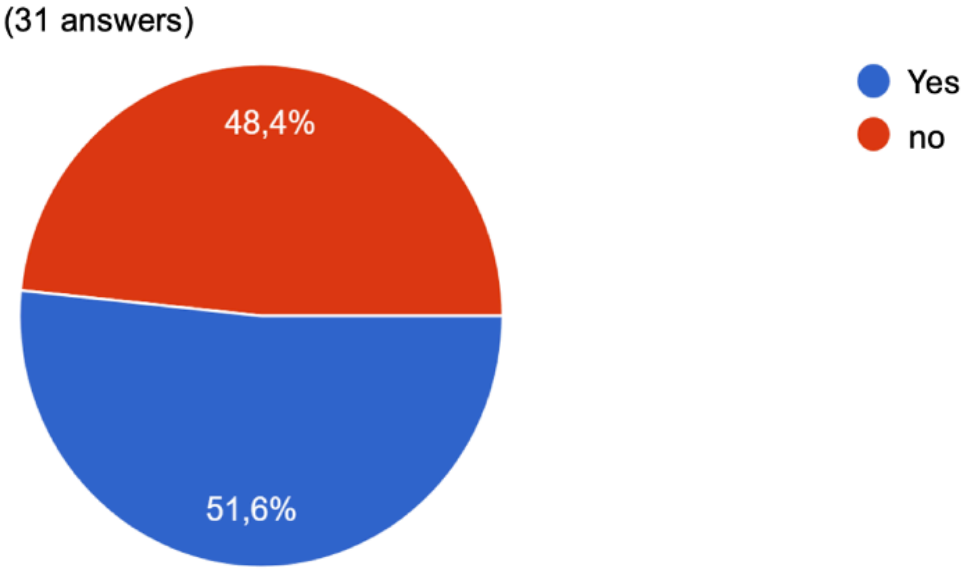


Figure 2. Use of pediatric early warning and clinical deterioration scoring systems across participating centers.

Sixty-nine percent of centers reported using the PEWS score, while the remaining centers used PALARM, PRIMAP, or MEWS scoring systems.

In 22% of cases, critically ill patients were transferred directly to an intensive care unit or a high-dependency care unit.

In 65% of cases, patients were managed within the standard pediatric hematology-oncology ward or in a dedicated high-dependency care area belonging to the same hematology-oncology department (see Figure 3).

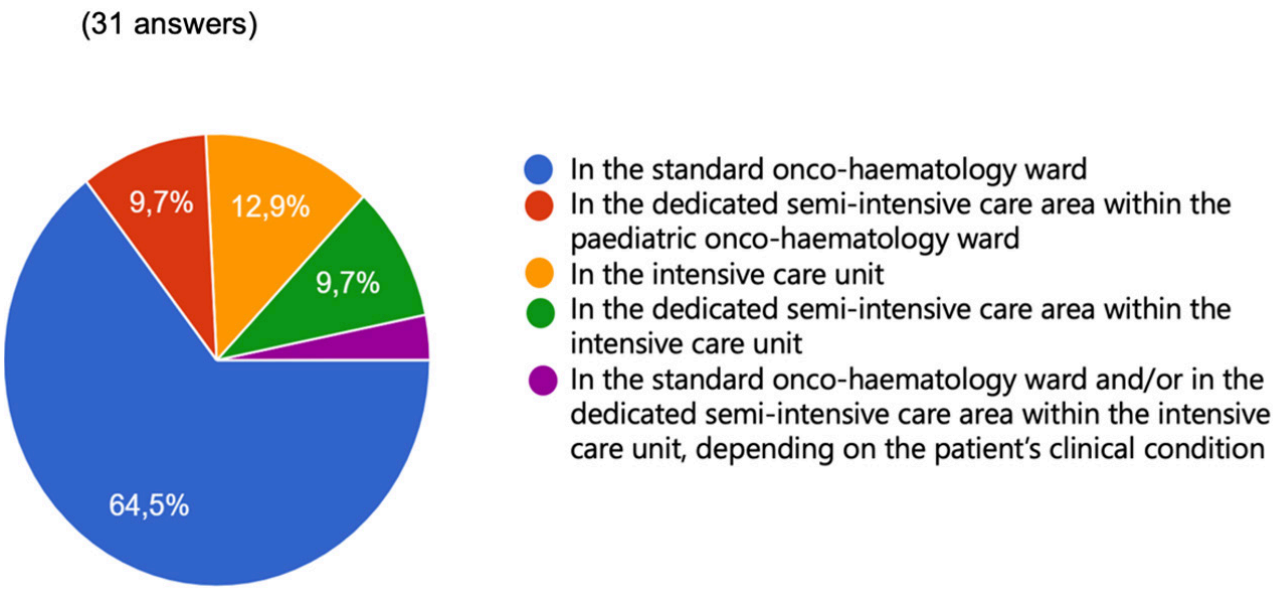


Figure 3. Clinical management of pediatric oncohematology patients requiring semi-intensive care.

When the patient is transferred to the intensive care unit, the decision is made by a multidisciplinary medical and nursing ward team in collaboration with the intensive care team in 71% of cases (see Figure 4).

With regard to patient transfer management, in 26 centers, corresponding to 84% of those surveyed, there was no dedicated team available, such as a TRR or MET (Medical Emergency Team). In the remaining five centers (16%), a

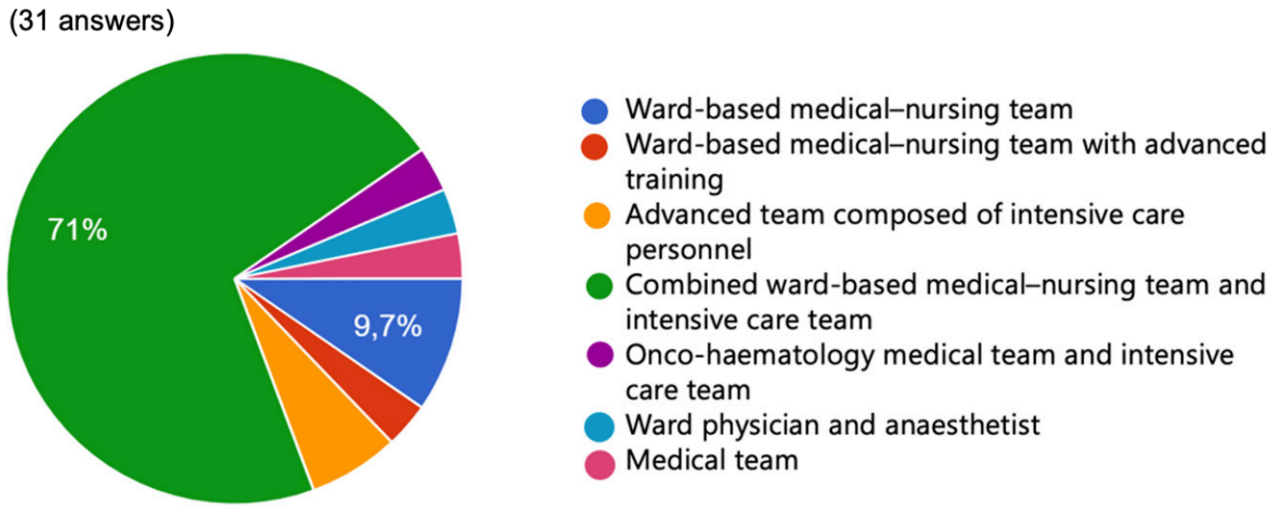


Figure 4. Collaborative decision-making for transfer of critically ill pediatric oncohematology patients to intensive careing centers.

well-structured team was available, composed of various healthcare professionals including an anesthesiologist, an intensive care nurse, and, in some cases, a pediatric hematology-oncology nurse.

In centers where no dedicated structured team was available, additional healthcare professionals were involved alongside those previously mentioned, such as ward pediatricians or healthcare assistants, depending on the patient's level of clinical severity (see Figure 5).

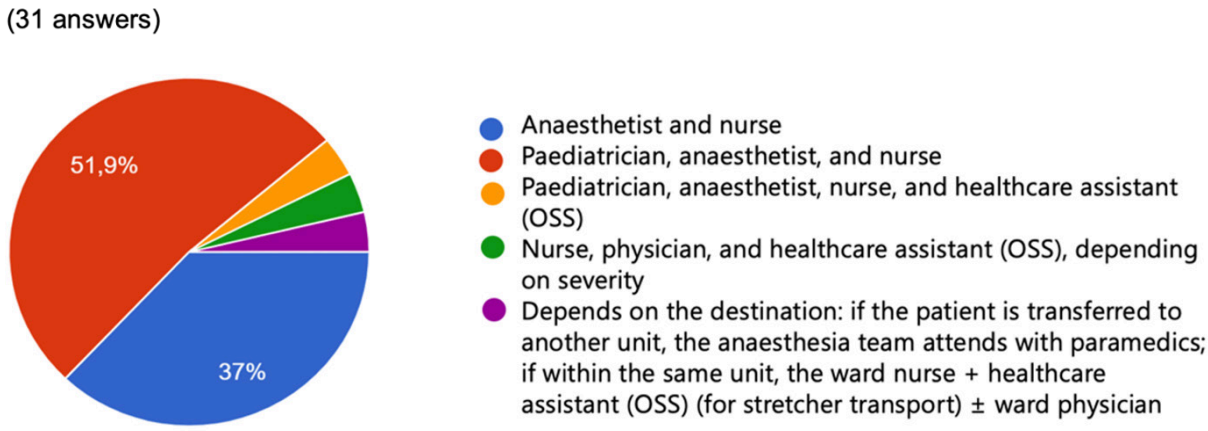


Figure 5. Presence of structured Medical Emergency Teams across participating centers.

Thirty-two percent of centers used a nursing transfer form to facilitate handover communication for critically ill patients (e.g., SBAR, structured handover tools, or integrated electronic medical records), whereas 68% did not use any standardized transfer documentation.

Twelve centers (39%) documented the patient's clinical condition during transfer.

Furthermore, the study investigated whether, following transfer, a dedicated room for critically ill pediatric hematology-oncology patients was available within the intensive care unit, considering the particular vulnerability of these patients.

A dedicated room was available in 16 centers (52%), whereas 10 centers (32%) did not provide a dedicated room; in the remaining cases, availability depended on bed capacity and the patient's infectious status (see Figure 6).

Twenty-five centers included in the study (81%) did not use objective assessment criteria to define the clinical situations in which patients should be transferred to the intensive care unit.

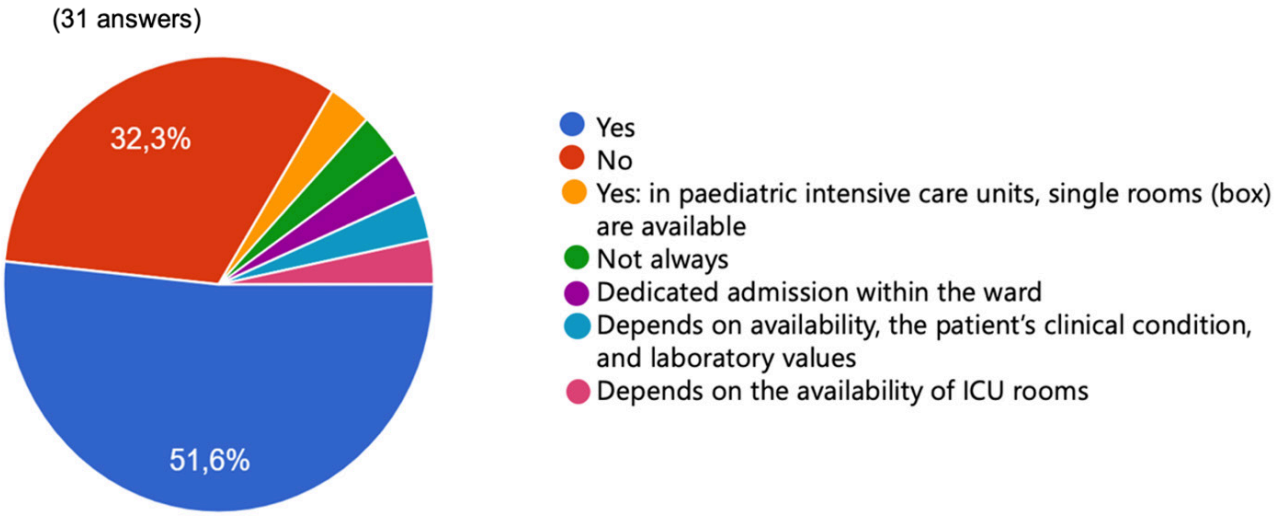


Figure 6. Availability of dedicated ICU rooms for critically ill pediatric oncohematology patients.

## Discussion

The logistical and organizational heterogeneity among AIEOP centers allows, in all cases, timely transfer to intensive care units, supported by specialized multidisciplinary teams managing critically ill patients.

The literature highlights that early access to the PICU is significantly associated with improved outcomes during critical illness. In a study conducted at St. Jude Children's Research Hospital, mortality among pediatric oncology patients admitted to intensive care was 17%, with a 6-month survival rate of 69% among patients who had not undergone bone marrow transplantation (Fiser et al., 2005). These findings emphasize how adequate intensive care support may allow approximately two-thirds of patients to survive severe events such as sepsis. Broadening the perspective, a meta-analysis including approximately 17,000 PICU admissions of pediatric oncology patients estimated an average mortality rate of 27.8% (Wösten-van Asperen et al., 2019). Despite slight improvements in recent years, mortality rate remains significantly higher than that observed in the general pediatric population, highlighting the fragility of patients undergoing oncological treatment.

A crucial issue concerns delays in PICU admission: a French multicenter study involving 224 children with cancer demonstrated that non-survivors had waited an average of 24 hours for PICU admission, compared with 12 hours among survivors (Wösten-van Asperen et al., 2019). One-month mortality was influenced by disease severity at admission, with an increased risk (odds ratio 2.3) among patients presenting grade 4 toxicity prior to admission (Fausser et al., 2019). These findings strongly suggest that early recognition of clinical deterioration followed by timely access to intensive care improves survival.

Additional data from a pediatric oncology center in Mexico reported a mortality rate of 9.1% for unplanned PICU admissions, consistent with rates reported in high-income countries (ranging from 6.8% to 17.5%) (Cardenas-Aguirre et al., 2022). This result demonstrates that, even in resource-limited settings, effective organization including critical response teams, Early Warning Scores, and protocols such as the "Golden Hour" can achieve comparable outcomes.

Finally, a large European study highlighted that nighttime or weekend admissions were not associated with increased PICU mortality (Wösten-van Asperen et al., 2019), suggesting that the timing of admission itself is not a determining factor.

The familiarity of intensive care teams with the complexity of pediatric oncology patients, together with the availability of early recognition systems for clinical deterioration such as Pediatric Early Warning Scores (PEWS), is crucial to ensure timely escalation of care. The BedsidePEWS, for example, has been associated with a significant reduction in critical events and has proven to be a useful tool in guiding the intensification of care proportionally to clinical risk (Gawronski et al., 2022). However, as highlighted by a qualitative study conducted in the same setting, the effectiveness of these systems is closely linked to staff training, interprofessional communication, and the organizational context in which care is delivered (Gawronski et al., 2018).

Furthermore, the concept of "critical deterioration", defined as transfer to intensive care followed by the need for ventilation, intubation, or vasopressor support within 12 hours, has been proposed as a pragmatic and early metric to evaluate the effectiveness of rapid response systems in pediatric settings. This indicator was found to occur eight times more frequently than cardiac arrest and was strongly associated with in-hospital mortality, making it a valuable measure for monitoring and optimizing clinical response in high-risk patients (Bonafide et al., 2012). International literature confirms that the effective implementation of rapid response systems, well integrated with early assessment tools and supported by organizational structures capable of sustaining timely decision-making, can significantly improve outcomes even in emergency settings, as demonstrated in Australian pediatric emergency departments (Considine et al., 2018).

The organizational structure of AIEOP centers allows compliance with the fundamental principles recommended by the literature, namely management by specialized personnel and rapid transfer to intensive care units.

The analysis showed that centers without a dedicated emergency team structure (MET or TRR) still consistently involve pediatricians, anesthesiologists, nurses, and healthcare assistants in the management of pediatric oncohematological emergencies.

The development of a multidisciplinary training program promoted by AIEOP, based on high-fidelity simulation for the management of pediatric oncohematological emergencies, could become a cornerstone in fostering staff specialization throughout Italy.

Most centers reported the use of a specific clinical deterioration score for early recognition of patient worsening, a key element in ensuring timely intervention and avoiding delays in ICU transfer.

The literature recommends the adoption and implementation of a generic early warning system such as the Pediatric Early Warning Score (PEWS) (Lambert et al., 2017). Compared with a disease-specific tool such as the Oncology Pediatric Early Warning Score (OPEWS), PEWS reflects a balance between clinical effectiveness, operational simplicity, and interdepartmental standardization. PEWS has become a validated and widely used pediatric tool for clinical monitoring and early identification of deterioration due to its simple structure, rapid applicability, and adaptability across different healthcare settings.

Its broad use promotes a common language among professionals working in heterogeneous environments, facilitating clinical communication and coordination between departments. However, this universality also represents a limitation in highly complex settings such as pediatric hematology-oncology, where patients present specific pathophysiological characteristics that may reduce the sensitivity and specificity of PEWS in identifying early clinical deterioration.

OPEWS was developed to address this need by proposing an assessment system specifically designed for pediatric hematology-oncology patients, including targeted parameters such as heart rate, respiratory rate, and hourly urine output, while reducing subjectivity in clinical domains where PEWS may be less effective (Maccarana et al., 2024). Nevertheless, widespread adoption of a specialist score presents operational barriers, including the need for dedicated staff training, updating internal protocols, and the risk of fragmentation of assessment criteria among different units, all of which may hinder systemic implementation.

Furthermore, the limited availability of multicenter evidence and the lack of large-scale external validation raise concerns regarding the reliability and reproducibility of the score in settings different from those in which it was originally developed. In this context, PEWS continues to represent the preferred option in many institutions because of its well-established operational effectiveness, despite the limitations observed in specific clinical subgroups.

This study demonstrates that most AIEOP centers use clinical deterioration scores in accordance with the gold standard promoted by the scientific literature.

Future perspectives require intelligent integration between generic and specialist tools, moving toward risk-stratification models and personalized medicine approaches implemented across all centers. The adoption of a hybrid system, in which OPEWS is reserved for patients with known oncohematological conditions while PEWS remains the reference tool for the general pediatric population, could represent an effective strategy.

The literature also highlights the importance of an adequate handover system for patient-related information, with communication perceived as an integral component of interfacility transfers (Rosenthal et al., 2016).

Structured and validated handover tools specifically developed for interfacility communication are recommended (Thirnbeck et al., 2024). The use of SBAR forms, for example, has proven to be an effective methodology for improving communication and the quality of information exchange (Shahid et al., 2022).

The use of nursing transfer forms is partially widespread among AIEOP centers; therefore, it is essential that communication strategies be designed and shared in order to streamline the process, improve the quality of information transfer and bidirectional communication, and facilitate positive relationships among healthcare professionals from different institutions.

Despite the large body of scientific literature dedicated to the analysis of treatments in pediatric oncology patients admitted to intensive care units, there are currently no studies directly comparing mortality — the most frequently analyzed outcome — between these patients and clinically comparable patients managed in standard pediatric wards, whether oncological or non-oncological. This gap may be explained by the marked clinical differences between patients admitted to PICU and those remaining in standard wards, as PICU admission is generally

reserved for critically ill patients and therefore does not represent a treatment arm comparable to standard hospitalization. Additionally, most retrospective studies adopt a predominantly descriptive approach.

Although of significant clinical interest, data regarding mortality in standard pediatric oncology wards remain limited. The high heterogeneity of patients and the substantial differences among malignancies make aggregation and comparative analysis of outcomes particularly difficult. Furthermore, many deaths occurring in these settings happen during advanced stages of disease and are not systematically investigated, unlike deaths occurring in intensive care settings.

Among patients admitted to PICU, mortality ranges between 18% and 45%, with peaks exceeding 60% in the most complex cases or in settings with limited resources and less developed healthcare systems (Bhosale et al., 2021, Pechlaner et al., 2022).

It should also be emphasized that differences in PICU admission criteria for pediatric hematology-oncology patients, likely heterogeneous among centers, may significantly contribute to the variability in survival rates reported in the literature.

The higher mortality observed among pediatric oncology patients admitted to PICU, compared with those managed in standard wards, mainly reflects the severity of illness among patients selected for intensive care admission. The principal determinants of poor outcome are therefore not attributable to the care setting itself, but rather to the burden of organ dysfunction present at admission (Dalton et al., 2003, Turner et al., 2016).

The literature focuses particularly on several recurring themes, including the identification of mortality predictors among pediatric oncology patients admitted to PICU, such as the need for mechanical ventilation, inotropic support, or high-intensity treatments, all associated with significantly worse outcomes, especially in patients with hematological malignancies. Several studies have compared mortality between oncological and non-oncological patients treated within the same intensive care unit, generally demonstrating an increased risk for oncology patients even after adjustment for age, severity, and treatment.

Another key area concerns the impact of early intensive care admission, which has been associated with a significant reduction in mortality (Hourmant et al., 2021, El Halal et al., 2012). Finally, some evidence suggests that the care environment itself, particularly the difference between pediatric and adult intensive care units, may influence outcomes in favor of specialized pediatric units (Flerlage et al., 2023, Peltoniemi et al., 2016).

## Conclusions

In light of the results obtained through this observational study, it emerges that, despite the organizational heterogeneity across centers within the AIEOP network, the criteria for optimal management of critically ill pediatric hematology-oncology patients are generally respected.

In all participating centers, patients can be transferred to intensive care units within appropriate timeframes, and the management of critically ill patients is entrusted to specialized multidisciplinary teams, either through dedicated Emergency Medical Teams or collaboration between ward-based hematology-oncology staff and anesthesia and intensive care specialists.

The scientific literature suggests the need for continuous organizational reassessment in order to guarantee access to intensive care as rapidly as possible.

The use of clinical deterioration assessment scales is recommended and, in the future, it would be desirable for all centers to adopt them uniformly.

Effective communication and information transfer represent key elements in patient transfer management. One of the future developments of this study will be the creation of a structured and validated nursing transfer form.

The literature does not clearly indicate which setting — standard ward versus intensive care unit — is most appropriate for managing pediatric hematology-oncology patients requiring high-dependency care. Most centers currently manage these patients within hematology-oncology wards. Further studies are needed to define the most appropriate care setting.

This study presents several limitations typical of survey-based and bibliographic research. The

survey design entails potential heterogeneity in the quality and completeness of collected information, with possible bias related to voluntary participation and data availability. Furthermore, the information gathered from

AIEOP centers reflects diverse organizational and operational realities, whereas data from the international literature derive from individual hospitals belonging to healthcare systems structured differently from the Italian system.

Terminology, procedures, and team roles may vary across contexts, making it difficult to consistently attribute a uniform meaning to specific practices. Nevertheless, the results provide valuable insight into pediatric intensive care practices, allowing comparison of organizational approaches and identification of potential areas for improvement and harmonization of clinical practice.

In particular, the findings emphasize the importance of early recognition of critically ill pediatric hematology-oncology patients and their timely transfer to intensive care units, factors that may significantly influence clinical outcomes and guide optimization of care pathways across different clinical settings.

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Research

# Procedural Analgesia in a Pediatric Emergency Department: Nurses' Perceptions, Decision-Making Processes, and Organizational Barriers

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## Abstract

**Introduction**. Procedural pain is a common reason for pediatric emergency department visits and remains frequently undertreated despite the availability of evidence-based recommendations. Nurses play a key role in pain assessment and management; however, limited evidence is available regarding the factors influencing their clinical decision-making in everyday practice. This study aimed to describe nurses' perceptions, self-reported practices, decision-making criteria, and perceived barriers related to procedural analgesia in a tertiary pediatric emergency department.

**Methods.** A cross-sectional observational study was conducted in February 2026 in the emergency department of a tertiary pediatric hospital in Italy. An anonymous online questionnaire was administered to nurses working in the department. The survey explored procedural pain perception, analgesia and sedation decision-making, pain assessment practices, organizational barriers, and self-perceived competence. Descriptive statistics were performed, while exploratory analyses included Fisher's exact test, Mann–Whitney U test, and Spearman's correlation coefficient.

**Results.** Twenty-five nurses completed the survey (response rate 75.8%). Most participants had received specific training on procedural pain management within the previous 24 months

(68%) and reported the availability of local protocols (88%). Procedural pain management was considered a high priority by 68% of respondents, although 48% believed procedural pain was frequently underestimated in their workplace. Clinical judgment combined with team consultation represented the most common decision-making approach (80%). Procedural invasiveness was the main criterion guiding analgesic escalation (44%). Workload and crowding were identified as the principal barriers to effective analgesia (72%). Emergency department experience was positively associated with perceived competence (rho=0.428; p=0.037) and negatively associated with the perceived impact of crowding on clinical decisions (rho=-0.417; p=0.043).

**Discussion.** Organizational constraints and reliance on subjective clinical judgment continue to influence procedural analgesia practices. Decision-support tools, targeted training, and strategies to strengthen nursing autonomy may improve the consistency of pediatric procedural pain management.

**Keyword:** Pediatric Emergency Service, Procedural Pain, Pain Management, Nurses, Decision Making

## Introduction

Pain is a complex and subjective phenomenon, influenced by psychosocial, physical, emotional and cognitive factors (Eull et al., 2023).

Pain management in the paediatric population represents a clinical and ethical challenge of primary importance, particularly within the emergency medicine setting where pain constitutes one of the main reasons for admission (Sabetsarvestani et al., 2024).

Despite the availability of validated assessment scales and international evidence-based recommendations, the literature documents a persistent inconsistency in the management of procedural pain (Mahon et al., 2023). Indeed, a significant gap remains between professionals' theoretical awareness and the systematic application of analgesic protocols in daily practice (Mahon et al., 2023).

This gap is driven by multifactorial barriers: structural and organisational constraints, such as high workloads, inadequate spaces for sedation, and time shortages (Mahon et al., 2023, Czarnecki et al., 2014, Langeli et al., 2025); specific educational deficits, especially regarding the use of non-pharmacological techniques (Hasanah et al., 2024, Skog et al., 2021); and intrinsic complexities in communicating with the paediatric patient and their family (Czarnecki et al., 2014, Yuan, 2024). The consequences of a sub-optimal approach to procedural pain are severe and well-documented both in the short term, in the form of anxiety, stress, and resistance to procedures (de Souza et al., 2025), and in the long term, promoting the development of specific phobias (needle phobia), hyperalgesia, and early avoidance of future healthcare (Mahon et al., 2023, de Souza et al., 2024, Guillari et al., 2024). Furthermore, in neonates, repeated exposure to painful stimuli can negatively interfere with brain development (Yan et al., 2024).

Promptly identifying and managing procedures perceived as most painful (such as airway suctioning, urinary catheterisation, nasogastric tube insertion, intravenous access, and suturing) therefore represents an absolute care priority (de Souza et al., 2025, Lorente et al. 2023). Although optimal management requires a multimodal and family-centred model capable of integrating pharmacological strategies (Moll-Berto et al., 2024, Stavleu et al., 2025) and non-pharmacological interventions (distraction, virtual reality, music therapy, sucrose administration) within nursing autonomy (Hasanah et al., 2024, Guillari et al., 2024, Moll-Berto et al., 2024), the effective translation of these principles into clinical routine remains imperfect. The nurse plays a central role in this

process (de Souza et al., 2024, Seipajaervi et al., 2025); however, there remains a compelling need to fully understand how professionals perceive procedural pain and what factors guide their choices.

This study therefore aims to explore the perceptions, clinical practices, and decision-making determinants of nursing staff in the management of procedural analgesia within a paediatric Emergency Department.

However, data remain limited regarding how paediatric Emergency Department nurses integrate protocols, clinical judgement, available resources, and organisational conditions when choosing procedural analgesic strategies.

The objective of this study was to describe the perceptions, self-reported practices, decision-making criteria, and organisational barriers reported by nurses in the management of paediatric procedural analgesia within a tertiary-level Emergency Department.

## Methods

In February 2026, a cross-sectional observational study was conducted based on the administration of an anonymous online questionnaire via the Google Forms® platform.

The survey took place in the Emergency Department (ED) of a tertiary-level paediatric hospital in Italy. A convenience sampling method was adopted, which included nurses on duty within the Emergency and Admission Department (DEA). Out of a total of 33 eligible professionals, 25 completed the questionnaire, yielding a response rate of 75.8%.

The data collection tool was developed by the authors based on the available literature on paediatric procedural pain management, analgesia and sedation in the Emergency Department, and the main barriers perceived by nurses in clinical practice.

A first version of the questionnaire was subsequently reviewed by a group of professionals with experience in paediatric emergencies, procedural pain management, and nursing research. The review aimed to assess the clarity of the questions, the relevance of the contents to the study objectives, and the completeness of the areas investigated. Following this discussion, some items were modified in their phrasing and response options to improve understanding and uniformity of interpretation.

Prior to final dissemination, the questionnaire was piloted on a small group of professionals with characteristics similar to those of the study population but not included in the final analysis. This preliminary phase allowed for verification of the comprehensibility of the questions, the functionality of the online completion process, and the time required to complete the questionnaire. The feedback collected led to some minor modifications in the structure and formulation of the items, without altering the content of the planned thematic areas.

The final version comprised 25 questions, including 23 closed-ended and 2 open-ended questions, organised into five sections: professional and organisational characteristics, perception of procedural pain, decision-making criteria for analgesia and sedation, pain assessment and reassessment, and organisational and educational barriers.

The closed-ended questions included dichotomous questions, single-choice questions, multiple-choice questions, and ordinal Likert-type scales. The latter were used to explore aspects such as the priority attributed to procedural pain management, the perceived frequency of certain phenomena, the level of perceived competence, and the degree of support towards potential decision-making tools.

For multiple-choice questions, each option was analysed as an independent variable and coded as the presence or absence of the response. Consequently, the percentages reported for these items were not mutually exclusive and could overall exceed 100%.

For exploratory analyses using Fisher's exact test, some variables were recoded into a dichotomous format. Specifically, specific training received within the last 24 months was classified as present or absent; the perception of pain underestimation was divided into frequent versus non-frequent perception; perceived competence in selecting patients eligible for advanced analgesia or sedation was classified as high versus non-high. Similarly, support towards the introduction of a nursing decision-support algorithm was converted into in favour versus not in favour. This procedure was adopted to limit the fragmentation of categories and to make the statistical analysis more stable, given the small sample size. Quantitative variables analysed overall and specific professional experience

in the Emergency Department; categorical variables investigated training in the last 24 months, the presence of dedicated protocols, the perception of symptom underestimation, perceived competence, and the impact of crowding on clinical choices.

Statistical analysis was performed using R software (version 4.3.2). Given the sample size (n=25), the analysis was predominantly descriptive and exploratory. Continuous variables were summarised using mean, standard deviation, median, and interquartile range (IQR). Categorical variables were described as absolute frequencies and percentages. Associations between categorical variables were assessed using Fisher's exact test, applying the Haldane–Anscombe correction for cells with a frequency equal to zero. Group comparisons for non-parametric quantitative variables were performed using the Mann–Whitney U test, while correlations between ordinal variables and years of experience were calculated using Spearman's correlation coefficient (rho). Tests were two-tailed, assuming a p-value < 0.05 as the threshold for statistical significance.

Given the small sample size, inferential analyses were considered exclusively exploratory and aimed at identifying potential associative patterns to be further investigated in future studies. The results were not interpreted in terms of causality.

*Ethical Considerations*

The study was conducted in accordance with the Declaration of Helsinki and EU Regulation 2016/679 (GDPR). Participation was voluntary and anonymous, following implicit informed consent expressed upon submitting the questionnaire. The study was authorised according to the internal procedures of the operational unit and health management. No identifying data of the participants nor information traceable to patients were collected.

## Results

*Sample characteristics*

A total of 25 nurses working in the Emergency Department participated in the study. The most represented primary work area was triage (36%; n=9), followed by the short-stay observation unit (OBI) (16%; n=4), the resuscitation/red room (12%; n=3), and rotation/multi-area assignment (8%; n=2), while the remaining areas showed lower frequencies.

The mean overall professional experience was 13.87 ± 8.47 years, whereas the specific experience within the Emergency Department was 7.23 ± 7.62 years (Table 1 and Table 2).

Table 1. Sample characteristics.

| Variable | n | Mean (DS) | Median (IQR) | Min–Max |
|---|---|---|---|---|
| Years of overall nursing experience | 23 | 13.87 (8.47) | 13 (10-18) | 2-36 |
| Years of ED experience | 24 | 7.23 (7.62) | 4 (2-8) | 0-25 |

Table 2. Sample characteristics.

| Area | n | % |
|---|---|---|
| Triage | 9 | 36.0 |
| Other | 6 | 24.0 |
| Short-stay observation room | 4 | 16.0 |
| Resuscitation room | 3 | 12.0 |
| Rotating | 2 | 8.0 |
| Low-acuity area | 1 | 4.0 |

The majority of the sample (68%; n=17) reported having received specific training on pain management or procedural analgesia within the last 24 months, while 88% (n=22) stated that a procedural analgesia or sedation protocol was available in their Emergency Department.

Regarding available resources, 72% (n=18) reported the immediate availability of analgesic or sedative medications, 68% (n=17) the presence of written and updated protocols, and 56% (n=14) local or topical anaesthetics. Dedicated spaces and nitrous oxide were reported less frequently (28% each), as were distraction or comfort tools (16%).

*Procedural pain perception and self-perceived competence*

Procedural pain management was considered a care priority by nearly all participants: 68% (n=17) defined it as a high priority and 28% (n=7) as a priority. Despite this, nearly half of the sample (48%; n=12) reported that procedural pain is often underestimated within their work environment (Figure 1).

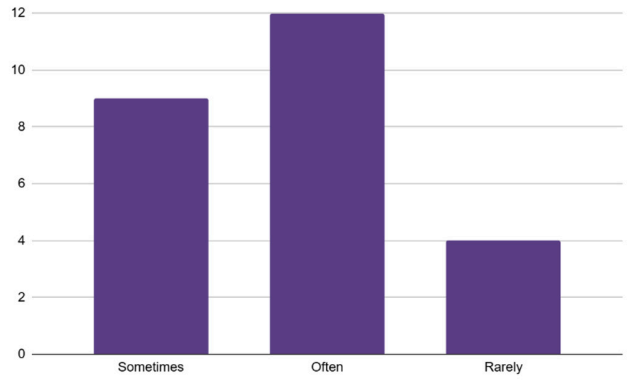


Figure 1. How frequently do you believe procedural pain is underestimated in your workplace?

In the exploratory analysis, no statistically significant association was found between years of Emergency Department experience and the frequent perception of pain underestimation (median 3.0 vs 5.0 years; Mann–Whitney U=64.0; p=0.663). However, a non-significant trend towards a lower perception of underestimation was observed among professionals who had received specific training within the last 24 months (OR=0.22; 95%CI 0.04-1.25; p=0.097) (Table 2).

The primary objective associated with procedural pain management was the reduction of pain intensity reported by the patient (48%; n=12), followed by the reduction of anxiety and distress (28%; n=7). The indicators deemed most useful for evaluating the effectiveness of the intervention were patient or caregiver satisfaction (76%; n=19) and improvement in pain scale scores (60%; n=15).

Forty-eight per cent (48%; n=12) of the participants reported feeling moderately competent in selecting cases eligible for advanced analgesia or sedation, while 24% (n=6) defined themselves as highly competent. Emergency Department experience showed a significant positive correlation with perceived competence (p=0.428; p=0.037), whereas no significant association emerged between recent training and perceived competence (OR=1.59; 95%CI 0.25-10.32; p=1.000) (Table 3).

*Decisional criteria and organizational impact*

The primary factor guiding the intensification of pain management was the type of procedure and its degree of invasiveness (44%; n=11), followed by patient characteristics (28%; n=7).

The criteria most frequently used to select cases eligible for procedural sedation were the high invasiveness of the procedure (68%; n=17) and expected severe pain (48%; n=12). Furthermore, 80% (n=20) of the participants stated that they base their decision-making approach predominantly on individual clinical assessment and consultation with the team (Figure 2).

Table 3. Inferential analyses.

| Association | Test | Result |
|---|---|---|
| Training (yes/no) vs frequent underestimation (often yes/no) | Fisher exact + OR (95% CI) | OR=0.22 (IC95% 0.04-1.25); p=0.097 |
| Training (yes/no) vs high competence | Fisher exact + OR (95% CI) | OR=1.59 (IC95% 0.25-10.32); p=1.000 |
| Years of ED experience vs frequent underestimation | Mann–Whitney U | Median years in ED: frequent=3.0 vs non- frequent=5.0; U=64.0; p=0.663 |
| Years of ED experience vs competence (ordinal) | Spearman's rho | rho=0.428; p=0.037 |
| Years of ED experience vs crowding impact (ordinal) | Spearman's rho | rho=-0.417; p=0.043 |

**Note.** The inferential results must be interpreted strictly from an exploratory perspective, given the small sample size and the non-probability sampling method.

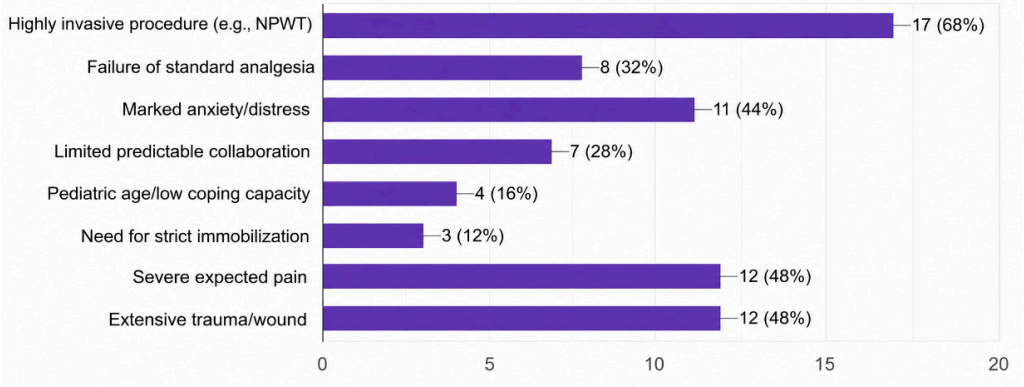


Figure 2. Which criteria do you use most frequently to select cases eligible for procedural sedation or advanced analgesia? (multiple choices allowed)

Regarding the impact of Emergency Department crowding, 28% (n=7) reported that it significantly affects analgesic choices, while 8% (n=2) stated that it directly determines the choice. Furthermore, a significant negative correlation was observed between years of Emergency Department experience and the perceived impact of crowding (p=-0.417; p=0.043) (Table 2).

When the procedure was perceived as painful but brief, the most frequently reported approach was a combined pharmacological and non-pharmacological one (36%; n=9). Lower percentages were observed for exclusively non-pharmacological techniques, baseline analgesia, and rapid analgesia (16% each).

The fear of adverse events was found to influence clinical choices with variable frequency, showing a substantially homogeneous distribution across the categories "often", "sometimes", and "rarely" (32% each).

*Pain assessment, revaluation and organizational barriers*

Fifty-two per cent (52%; n=13) of the participants reported always assessing pain before the procedure, while 72% (n=18) stated that they always or almost always reassess it within 30 minutes. The tools most frequently used were the NRS scale (60%; n=15) and the VAS (44%; n=11) (Table 4).

Table 4. Main descriptive outcomes (n = 25).

| Variable | n (%) |
|---|---|
| Specific training within the last 24 months (yes) | 17 (68%) |
| Analgesia/sedation protocol present (yes) | 22 (88%) |
| Procedural pain management priority: "high priority" | 17 (68%) |
| Perceived procedural pain underestimated "often" | 12 (48%) |
| Pain assessment "Always before the procedure" | 13 (52%) |
| Reassessment within 30 min: "Always/ Almost always" | 18 (72%) |
| In favour of an algorithm (Very/ Completely) | 19 (76%) |

The main causes of failure to reassess pain were reported to be workload or crowding (92%; n=23) and competing clinical priorities (52%; n=13).

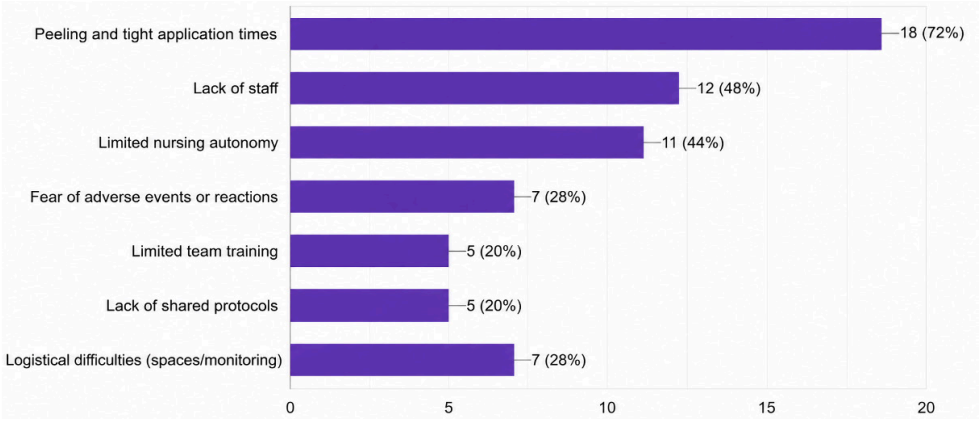


Figure 3. – What are the main barriers to an effective procedural analgesia in your ED? (multiple choices allowed)

Among the organisational barriers to effective procedural analgesia, nurses primarily indicated crowding and tight time constraints (72%; n=18), staffing shortages (48%; n=12), and limited nursing autonomy (44%; n=11) (Figure 3).

Seventy-six per cent (76%; n=19) of the sample reported being highly or completely in favour of introducing a nursing decision-support algorithm for procedural analgesia (Figure 4; Table 4).

Emergency Department experience showed a positive correlation with perceived competence and a negative correlation with the perceived

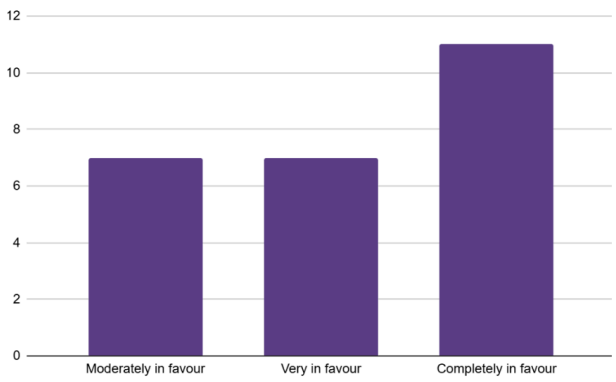


Figure 4. How much would you be in favour of a nursing decision-support algorithm for procedural analgesia?(multiple choices allowed)

impact of crowding. These findings must be interpreted with caution due to the small sample size.

## Discussion

The findings describe a scenario characterised by high nursing sensitivity towards procedural analgesia, which is nonetheless counterbalanced by organisational resistance and decision-making dynamics that limit its effectiveness in the field (Mahon et al., 2023, Skog et al., 2021).

The primary evidence emerging from the statistical analysis maps a clear line of demarcation based on professional experience: the positive correlation between years of experience in the Emergency Department and perceived competence ($p < 0.05$) is associated with a lower subjective impact of crowding on clinical choices. In line with international literature using validated tools such as the PNKAS20, these results suggest that greater professional experience may be associated with increased decision-making confidence and a lower perceived influence of crowding on clinical choices. Professionals with more experience reported higher levels of perceived competence and a lower perceived influence of crowding (Mahon et al., 2023, de Souza et al., 2024). Conversely, staff with less seniority are more affected by the pressure of overcrowding, translating it into a potential clinical barrier. Furthermore, the lack of suitable spaces and structured monitoring remains a critical logistical barrier for complex procedures such as procedural sedation (Sahyoun et al., 2021).

Alongside experience, a further critical issue emerges regarding operational tools. The study highlights a substantial paradox: despite a high formal availability of institutional protocols (88%), 80% of nurses report relying predominantly on their "clinical eye" (subjective assessment) for pain management. This lack of operational integration of protocols into clinical routine reflects a scepticism towards assessment scales and the urgency imposed by tight work schedules (Skog et al., 2021, (Yuan, 2024). This tendency towards subjectivity increases care variability and directly fuels the phenomenon of paediatric pain underestimation, which is deemed frequent by 48% of respondents (Sabetsarvestani et al., 2024, Neshat & Ghorbani, 2023). The bureaucratic presence of guidelines is therefore insufficient if not supported by actual assimilation into triage pathways and by prescriptive autonomy (nurse-initiated analgesia), which nearly half of the sample still identifies as a stringent regulatory constraint (Czarnecki et al., 2014, de Souza et al., 2024).

The educational data also require a structural review. Although 68% of professionals reported recent training, the absence of statistically significant associations does not allow for conclusions to be drawn regarding the effectiveness of training, but highlights the need to further investigate the role and characteristics of educational interventions. Training cannot be limited to theoretical aspects but must evolve towards continuous strategies focused on non-pharmacological techniques—interventions that, despite being within full nursing autonomy, remain heavily underutilized (Guillari et al., 2024, Celik & Duzkaya, 2024, Shamsi, 2025).

The present results must be interpreted considering intrinsic methodological limitations. The cross-sectional design precludes the definition of causal links, and the monocentric nature of the study, conducted using convenience sampling in a single tertiary-level Emergency Department, limits the generalisability of the data. The small sample size (n=25) assigns an exclusively exploratory value to the inferential analyses. The observed associations must therefore be interpreted with caution and considered as hypothesis-generating for future studies rather than definitive evidence. Furthermore, the use of a self-reported tool that has not been psychometrically validated exposes the results to recall bias regarding training and social desirability bias in the responses. Nonetheless, this research provides a clear snapshot of care criticalities and the vulnerability of nursing decision-making processes under the effect of crowding. Finally, the study relies on self-reported practices and perceptions, which may not fully reflect the clinical behaviours actually adopted during procedures.

## Conclusions

The study suggests that optimising paediatric procedural analgesia requires not only educational interventions but also organisational and decision-making tools capable of reducing clinical practice variability. Therefore, implementing rapid decision-support

algorithms, enhancing nursing autonomy at triage, and structuring practical training programmes emerge as key priorities.

Only by eliminating the variability linked to subjective judgment and managing the impact of crowding will it be possible to transform scientific recommendations into a systematic care reality for the paediatric patient. Future multicentre studies will be essential to validate the effectiveness of such interventions on larger samples and within an evidence-based framework.

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Research

# Beyond Blood Ties: Redefining Family in Pediatric Hospital Care Through a Thematic Analysis of Multistakeholder Perspectives

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**Abstract**

**Introduction.** The concept of family in pediatric care is central to the implementation of Family-Centred Care (FCC), yet it remains ambiguously defined in clinical practice. Existing definitions are often limited to traditional structures and rarely reflect the perspectives of children, caregivers, and healthcare professionals.

**Methods.** A qualitative study using thematic analysis was conducted in a pediatric hospital setting. Semi-structured interviews were carried out with 22 healthcare professionals, 29 caregivers, and 8 adolescents. Data were analysed following an inductive approach. The study was reported according to COREQ guidelines.

**Results.** Five main dimensions of family emerged: structure, relationship, care and support, context, and choice. The findings highlight a shift from traditional structural definitions toward more relational and subjective understandings. Differences across participant groups were observed: caregivers emphasised structural aspects, while adolescents and healthcare professionals highlighted relational and functional dimensions.

**Discussion.** The findings support a reconceptualisation of family as a dynamic, multidimensional construct shaped by context and individual perspectives. This has significant implications for the implementation of FCC and the application of the Fundamentals of Care framework in pediatric settings.

**Keyword:** Family Nursing, Pediatric Nursing, Family, Qualitative Research, Adolescent, Child

## Introduction

In recent decades, the concept of family has undergone profound transformations driven by social, cultural, and demographic changes. Traditional definitions, primarily based on biological ties and co-residence, are increasingly insufficient to capture the complexity of contemporary family configurations (Bengtson, 2000; Widmer, 2010). The emergence of single-parent, blended, and same-sex families has contributed to a more dynamic and context-sensitive understanding of family.

In healthcare, particularly in pediatric settings, families are a central component of the care process. The Family-Centred Care (FCC) approach recognises the family as an active partner in the child's care (Kuo et al., 2012; Smith et al., 2017). However, despite its widespread adoption, the literature highlights considerable variability in how "family" is operationally defined, often implicitly restricted to parents or primary caregivers (Coyne et al., 2018).

This conceptual ambiguity has important clinical implications. A restrictive definition may exclude significant individuals in the child's life, potentially compromising the effectiveness of care and limiting the meaningful implementation of FCC (Foster et al., 2019). Furthermore, terms such as "caregiver" do not adequately reflect the complexity of relational networks that contribute to pediatric well-being.

At the same time, the Fundamentals of Care (FoC) framework emphasises that care quality is deeply influenced by interpersonal relationships and by professionals' ability to understand the patient's individual context (Kitson et al., 2014; Feo et al., 2018). Within this perspective, a broader, more nuanced definition of family is essential to ensure genuinely family-centred care.

Despite extensive research on family roles and FCC, a significant gap persists: the lack of a definition of family grounded in the lived experiences of children, adolescents, caregivers, and healthcare professionals in clinical settings (Coyne et al., 2018).

Therefore, this study aims to explore the meaning attributed to the concept of family in a pediatric hospital context through a qualitative analysis of perspectives from adolescents, caregivers, and healthcare professionals. The goal is to contribute to a conceptual redefinition of family as a dynamic, relational, and context-dependent construct capable of supporting clinical practice and the implementation of Family-Centred Care and Fundamentals of Care.

## Methods

### *Study Design*

A qualitative study using thematic analysis was conducted to explore in depth the perceptions and meanings attributed to the concept of family in pediatric care. The study was designed and reported in accordance with the COREQ checklist for qualitative research.

### *Setting*

The study was carried out at a major tertiary pediatric hospital in Italy, a national referral centre for pediatric care. Multiple units were involved, including Emergency Medicine, Pediatric Hospice, Cardiovascular Surgery, Oncology Day Hospital, Neonatology, Week Surgery, and Pediatric Endocrinology.

### *Participants*

The sample consisted of three groups: healthcare professionals, caregivers, and adolescents, recruited through convenience sampling.

The healthcare professionals included a multidisciplinary team with experience in pediatric care, including pediatric nurses, physicians, and allied health professionals. Their clinical roles spanned various areas of pediatric practice, providing a broad representation of perspectives within the hospital setting.

Caregivers were primarily parents or primary figures responsible for the child's care during hospitalisation. They represented a heterogeneous group in terms of educational background, caregiving experience, and

familiarity with the healthcare system.

Adolescents were individuals receiving care within the pediatric setting, representing a developmental stage characterised by increasing autonomy and the ability to reflect on personal relationships and social contexts.

Inclusion criteria were the ability to understand Italian and the provision of informed consent. Adolescents were required to fall within a predefined age range (10-19 years) consistent with pediatric care settings.

*Data Collection*

Data were collected through semi-structured interviews based on two open-ended questions developed from the literature and validated by an expert panel.

The questions were: "Who do you consider part of your family?" and "Who should be considered family during hospitalisation?"

Interviews were conducted in a private setting, audio-recorded with consent, and supplemented by field notes.

Data Analysis

Interviews were transcribed verbatim and analysed using thematic analysis.

Two researchers independently coded the data, identifying codes, categories, and themes. Discrepancies were resolved through discussion with a third researcher.

Analysis was iterative, involving repeated reading and constant comparison. No software was used. Data saturation was reached during data collection and analysis.

*Rigor*

Methodological rigour was ensured by adhering to Lincoln and Guba's criteria of credibility, transferability, dependability, and confirmability.

Credibility was strengthened by including multiple participant groups (healthcare professionals, caregivers, and adolescents), enabling data triangulation across perspectives. In addition, independent coding by two researchers and subsequent consensus discussions contributed to the robustness of the analytical process.

Dependability was supported by maintaining a clear, systematic analytic process, including iterative coding, documentation of decisions, and regular research team meetings to discuss emerging themes and resolve discrepancies.

Confirmability was addressed by minimising researcher bias through reflexive discussions within the team and by grounding interpretations in participants' narratives. Field notes were used to support contextual understanding and to enhance transparency in data interpretation.

Transferability was facilitated by providing detailed descriptions of the study setting, participant characteristics, and data collection procedures, enabling readers to assess the applicability of the findings to other contexts.

*Ethical Considerations*

Ethical approval was obtained from the Internal Review Board of IRCCS Istituto Giannina Gaslini prior to the initiation of the study.

All participants received detailed information about the study aims, procedures, and their rights as participants. Written informed consent was obtained from all adult participants. For adolescents, consent was obtained in addition to that of their parents or guardians, in accordance with ethical standards for research involving minors.

Participation was voluntary, and participants were informed of their right to withdraw from the study at any time without any consequences for their care.

Confidentiality and anonymity were strictly maintained throughout the study. Audio recordings and transcripts were securely stored and accessible only to the research team. Any identifying information was removed during transcription to ensure participant anonymity.

Particular attention was paid to the vulnerability of pediatric participants, ensuring that interviews were conducted in a sensitive and age-appropriate manner, minimising any potential discomfort or distress.

*Results*

*Participant Characteristics*

The sample included 22 healthcare

professionals, 29 caregivers, and 8 adolescents, providing a broad range of perspectives on the concept of family within pediatric care.

Healthcare professionals were predominantly pediatric nurses (n=18), alongside one physician, one physiotherapist, one radiology technician, and one midwife. The group was mainly female, with a mean age of approximately 45 years. Their clinical experience across multiple pediatric units contributed to a predominantly functional, care-oriented understanding of families.

Caregivers (n=29) were primarily parents, most frequently mothers, with a mean age of approximately 44.5 years. They represented a heterogeneous group in terms of educational background and caregiving experience. Their perspectives were strongly influenced by lived experience and emotional involvement, often reflecting a more structure-oriented yet affectively rich conceptualization of family.

Adolescents (n=8) had a mean age of approximately 14 years and included both males and females. Their accounts emphasised relational and subjective dimensions of family, highlighting autonomy, emotional reciprocity, and the importance of personally meaningful relationships, often extending beyond traditional family boundaries.

Overall, the diversity of participants allowed for a comprehensive exploration of the concept of family, revealing both shared elements and differences across groups.

*Thematic Analysis Findings*

Five main themes emerged, describing family as a dynamic and multidimensional construct.

*Family as Structure*

Family was initially described in structural terms, particularly by caregivers, who often referred to the traditional nuclear family, comprising parents and children. This perspective was often grounded in lived experience and caregiving responsibility:

"Since I became a mother, family means my children and my partner."

Caregivers frequently emphasised cohabitation, biological ties, and parental roles as defining elements. However, this structural view was not exclusive.

Healthcare professionals and adolescents expanded this definition by including non-biological and non-cohabiting relationships:

"A group of people connected by marriage, adoption, or affinity." (Healthcare professional)

"My friends, my teammates… they are my family too." (Adolescent)

This variation suggests that while structural definitions remain relevant, they are increasingly permeable and open to broader interpretations depending on perspective.

*Family as Relationship*

Across all participant groups, family was consistently described as a network of meaningful relationships characterised by affection, trust, and reciprocity.

Adolescents particularly emphasised emotional mutuality:

"Anyone who cares about me and that I care about."

Caregivers highlighted emotional bonds and shared values:

"People who love each other, support each other, and stay together."

Healthcare professionals framed relationships in a slightly more formalised way, emphasising emotional connection as a defining criterion:

"People linked by a bond of affection and emotional closeness."

This theme emerged as a central and shared dimension, suggesting that relational quality often outweighs structural characteristics in defining family.

*Family as Care and Support*

Family was frequently conceptualised as a system of care and support, particularly by caregivers and healthcare professionals.

Caregivers also described family as those who provide continuous and multidimensional care:

"Those who take care of the child physically, emotionally, and spiritually."

Healthcare professionals extended this definition to include the care team within the hospital context:

"Nurses, doctors, staff… everyone who takes care of the child becomes part of that family in

that moment."

Adolescents emphasised presence and emotional support rather than responsibility:

“People who stay with you and help you when you need it."

This theme highlights how the concept of family in pediatric care may temporarily expand to include healthcare providers, particularly in contexts of vulnerability and hospitalisation.

*Family as Context*

A less expected but significant dimension was the conceptualisation of family as context, including environmental, symbolic, and experiential elements.

Caregivers and healthcare professionals often referred to routines and familiarity:

"Home, habits, daily life... that's what family is."

Within the hospital setting, this concept extended to recreating a sense of normality:

"Everything that makes the hospital feel a bit like home." (Healthcare professional)

Adolescents were particularly sensitive to this dimension, emphasising continuity between home and hospital:

"When I have my things and feel like myself, that feels like family."

This theme underscores the importance of environmental and contextual factors in shaping the experience of family, especially during hospitalisation.

*Family as Choice*

The final theme reflects the idea of family as a subjective and individual choice, strongly emphasised by adolescents and supported by healthcare professionals.

Adolescents articulated this clearly:

"Family should be whomever you want next to you."

Healthcare professionals reinforced this patient-centred perspective:

"Family is who the patient identifies as family."

Caregivers showed limited reference to this dimension, tending instead to maintain a more traditional understanding of family grounded in structural and caregiving roles.

This theme aligns with the concept of "family of choice" and highlights the importance of recognizing the patient's perspective in defining family, particularly in pediatric care.

*Conceptual Synthesis*

The analysis of the interviews highlights that the concept of family in pediatric care is not confined to a single definition but unfolds across five interconnected dimensions: structure, relationship, care and support, context, and choice.

These dimensions emerged consistently across participant groups, although with different emphases depending on the perspective. Caregivers more frequently referred to structural elements, grounding the concept of family in biological ties and caregiving roles. In contrast, adolescents emphasised relational and subjective aspects, while healthcare professionals tended to integrate functional and care-related components into their definitions.

The structural dimension represents the most immediate and socially recognised understanding of family, often serving as an initial reference point. However, it is increasingly complemented by relational elements that shift the focus to emotional bonds, reciprocity, and perceived closeness between individuals.

The dimension of care and support further expands this understanding by framing family as an active system of assistance, particularly relevant in the context of illness. In the hospital setting, this dimension may extend beyond traditional boundaries to include healthcare professionals, reflecting the dynamic nature of caregiving relationships.

The contextual dimension introduces the roles of environment, routines, and familiarity in shaping the family experience. This aspect becomes especially salient during hospitalisation, where maintaining continuity with the child's usual environment contributes to a sense of security and belonging.

Finally, the dimension of choice reflects the subjective nature of family, highlighting the importance of individual perception. This dimension was particularly evident in adolescents' narratives, in which family was defined by personal meaning rather than predefined categories.

Taken together, these findings suggest that family in pediatric care is best understood as a composite construct, in which different dimensions coexist and interact. This conceptualisation provides a framework for interpreting the variability observed across participants and supports the representation of family as a multidimensional system centred on the child, as illustrated in Figure 1.

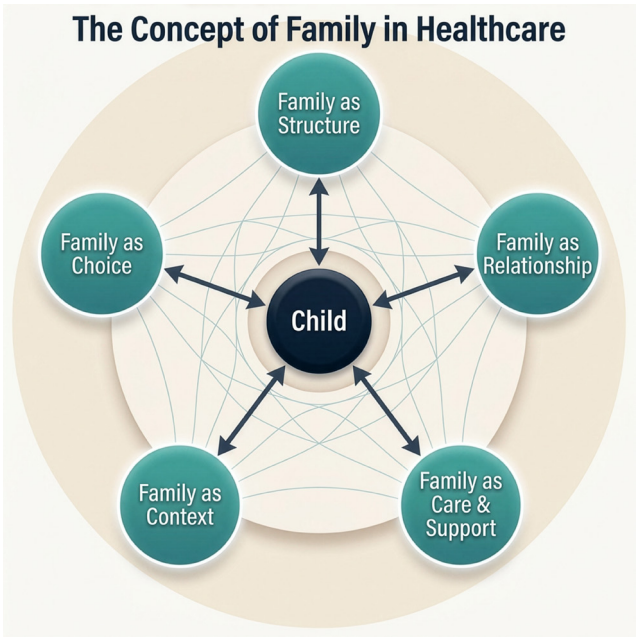


Figure 1. Conceptual model of family in pediatric care showing five interrelated dimensions: structure, relationship, care and support, context, and choice.

## Discussion

The findings of this study indicate that the concept of family in pediatric care cannot be reduced to a single, stable definition; rather, it should be understood as a dynamic, multidimensional construct shaped by relational, contextual, and subjective elements. The five dimensions identified—structure, relationship, care and support, context, and choice—provide an empirically grounded framework that reflects how family is experienced within pediatric clinical settings.

A central finding concerns the shift from structural to relational and functional understandings of family. While caregivers more frequently referred to traditional, structure-based definitions rooted in biological ties and parental roles, adolescents and healthcare professionals articulated broader and more inclusive perspectives. This divergence highlights how the meaning of family is not fixed but varies according to experiential position and role within the care process. Similar tensions between structural and relational conceptualisations have been described in the literature, in which family is increasingly recognised as a flexible, socially constructed entity rather than a purely biological unit (Widmer, 2010; Grandclerc et al., 2020).

These findings align with and extend the Family-Centred Care (FCC) framework, which positions the family as a central partner in pediatric care (Kuo et al., 2011). Although the FCC emphasises collaboration and respect for family preferences, it often lacks a clear operational definition of who constitutes "family" in practice (Coyne et al., 2018). The present study contributes to this gap by demonstrating that family should be understood not only in structural terms but also through relational and functional dimensions that reflect the lived experiences of children, caregivers, and healthcare professionals. Recent studies have similarly called for a more flexible and context-sensitive application of FCC, particularly in complex care environments (Foster et al., 2019; Uniacke et al, 2018).

The relational dimension emerged as a core component across all participant groups, suggesting that emotional bonds, reciprocity, and perceived closeness are central to defining family. This supports a shift from asking "who is family" to "what makes someone family," emphasizing the primacy of relationships over formal or biological criteria. Such findings are consistent with previous qualitative research highlighting the importance of emotional connectedness and relational meaning in family definitions (Coyne et al., 2018; Grandclerc et al., 2020).

The care and support dimension further reinforces this perspective by framing the family as an active system of assistance. In the pediatric hospital context, this role may extend beyond traditional family members to include healthcare professionals, particularly during periods of vulnerability. This finding resonates with the Fundamentals of Care (FoC) framework, which emphasises that high-quality care is grounded in relationships and the integration of physical, psychosocial, and relational needs (Kitson et al., 2014; Feo et al., 2018). Recognising who provides meaningful care to the child is essential to delivering holistic, person-centred care.

The contextual dimension highlights the importance of the environment, routines, and familiarity in shaping family experience. Particularly during hospitalisation, the presence of familiar objects, habits, and relational cues can contribute to a sense of continuity and emotional security. This finding underscores the need for healthcare environments to support not only clinical care but also the preservation of the child's everyday life context.

Finally, the dimension of choice underscores the subjective and patient-defined nature of family. Adolescents, in particular, emphasised autonomy in identifying whom they consider family, aligning with the concept of "family of choice" described in sociological literature. This has important implications for clinical practice, as it challenges professionals to move beyond predefined categories and actively engage with the patient's own definition of family.

From a clinical perspective, these findings suggest that pediatric nurses and healthcare teams should adopt a flexible and individualised approach when identifying and involving family members in care. In line with FCC principles, professionals should explicitly ask patients and caregivers whom they consider family and ensure that these individuals are included in communication and decision-making processes. This approach may enhance trust, improve patient experience, and support more effective care delivery.

At an organisational level, the results highlight the need to reconsider policies related to visiting, family presence, and participation in care. Restrictive or standardised definitions of family may inadvertently exclude significant individuals, limiting the effectiveness of family-centred approaches. Adapting institutional policies to accommodate diverse and patient-defined family structures may therefore represent an important step toward more inclusive and responsive care systems.

This study has several strengths, including the inclusion of multiple perspectives and the use of a qualitative approach that captures the complexity of the concept of family. However, some limitations should be acknowledged. The monocentric design may limit the transferability of findings to other settings, and the use of convenience sampling may have introduced selection bias. Future research should explore these findings in multicenter and cross-cultural contexts and examine how different conceptualisations of family influence clinical outcomes and care experiences.

## Conclusions

This study highlights that family in pediatric care should be understood as a dynamic, multidimensional, and patient-defined construct rather than a fixed, purely structural entity. The integration of structural, relational, functional, contextual, and subjective dimensions provides a more comprehensive understanding of family as experienced in clinical settings.

Recognising this complexity has direct implications for practice. Adopting a flexible and inclusive approach to defining family may enhance the implementation of Family-Centred Care and support the delivery of care that is truly responsive to the needs of children and their families. In particular, actively involving individuals identified by the patient as significant can strengthen therapeutic relationships and improve care experiences.

From a broader perspective, these findings support the need for healthcare systems to move toward more personalised and context-sensitive models of care. Embedding this conceptualisation of family into clinical practice and organisational policies may represent a key step in advancing pediatric care.

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## Case Series

# Long-Term Podiatric Functional Outcomes After Evans-Mosca Correction in Adolescents With Idiopathic Flexible Flatfoot: A Case Series

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### Abstract

**Introduction.** Severe symptomatic idiopathic flexible flatfoot in adolescence may require surgical correction when conservative treatment fails. The Evans-Mosca procedure has been reported to provide satisfactory clinical and radiographic correction, but podiatric functional findings after surgery are less frequently described.

**Case Presentation.** This case series reports long-term podiatric findings in 14 adolescents, corresponding to 26 surgically treated feet, who had previously undergone treatment for idiopathic flexible flatfoot. The same cohort was previously described from orthopedic, clinical, and radiographic perspective.

**Intervention.** All patients underwent lateral column calcaneal lengthening according to the Evans-Mosca technique, associated with medial soft-tissue correction and Achilles tendon lengthening where indicated.

**Outcome.** At a mean follow-up of 7 years and 7 months, podiatric assessment showed no lower-limb length discrepancy, preserved ankle dorsiflexion, satisfactory subtalar mobility, physiological first-ray motion, positive Jack's and tip-toe tests, and plantigrade support on podoscopic examination. Static baropodometry showed balanced load distribution between left and right feet and physiological

rearfoot-forefoot distribution. Dynamic baropodometry showed similar plantar contact surfaces between feet and generally physiological gait-line progression. One case of functional hallux limitus was detected.

**Conclusion.** Evans-Mosca correction achieved satisfactory long-term functional outcomes in this series of 26 feet. Beyond the clinical and radiographic improvements already reported for this cohort, podiatric evaluation revealed preserved joint mobility, plantigrade support, balanced weight distribution, and physiological gait patterns in most patients. One case of functional hallux limitus was identified during dynamic testing.

**Keyword:** Flexible Flatfoot, Adolescent, Evans-Mosca Procedure, Podiatric Assessment, Baropodometry, Gait Line

## Introduction

Idiopathic flexible flatfoot is common during skeletal growth and is usually asymptomatic. Most pediatric flexible flatfeet are managed through observation, education, footwear advice, exercises, orthoses, or rehabilitation, especially when symptoms are absent or mild. Conservative management remains the first-line treatment for symptomatic pediatric flexible flatfoot. Exercises and orthoses can improve pain, function, and arch development (Molina-García et al., 2024). Surgery is typically reserved for cases with persistent symptoms despite adequate conservative care (Sha et al., 2026).

When adolescent flexible flatfoot becomes painful and functionally limiting, surgical treatment may be considered. Available surgical options include subtalar arthroereisis, calcaneal osteotomy, and combined procedures, with the choice depending on age, flexibility, severity, symptoms, surgeon expertise, and anatomical presentation. Recent comparative literature confirms that there is still no single universally accepted operative approach for pediatric flexible flatfoot, and that different procedures may provide comparable long-term correction while differing in invasiveness, operative time, and recovery profile (Hu et al., 2025).

Lateral column calcaneal lengthening, originally described by Evans and later modified by Mosca, remains one of the joint-preserving procedures used for severe symptomatic flexible flatfoot. The procedure aims to correct hindfoot valgus, forefoot abduction, and collapse of the medial longitudinal arch while preserving motion of the subtalar and midtarsal joints. Recent open-access evidence still reports significant clinical and radiographic improvement after Evans osteotomy in young patients with flexible flatfoot, including improvements in quality-of-life measures and radiographic parameters (Yasin et al., 2025).

The orthopedic outcomes of the cohort described in this manuscript were previously reported by De Luna et al. (2021). That study included 14 adolescent patients and 26 surgically treated feet, with a mean follow-up of 7 years and 7 months. It documented statistically significant clinical and radiographic improvement after Evans-Mosca correction, including improvement in AOFAS, FADI, Meary's angle, and Costa-Bertani's angle, without significant midtarsal osteoarthritic changes. Those findings are treated in the present manuscript as previously published orthopedic context, not as new results.

The present case series has a narrower aim: to describe long-term podiatric functional findings after surgical correction. This focus is clinically relevant because gait analysis studies continue to show that pediatric flexible flatfoot can be associated with measurable dynamic alterations, and that clinical/radiographic assessment alone may not fully describe functional behavior during walking (Böhm et al., 2024). The present manuscript therefore reports podiatric, podoscopic, static baropodometric, and dynamic baropodometric findings collected after Evans-Mosca correction in adolescents with severe symptomatic idiopathic flexible flatfoot.

## Case Presentation

This case series included 14 adolescent patients affected by severe symptomatic idiopathic flexible flatfoot. Eight patients were male and six were female. Mean age at surgery was 12.8 years, with a range from 11 to 14.6 years. Twelve patients underwent bilateral surgery and two underwent unilateral surgery, for a total of 26 treated feet. In all patients, surgery had been indicated because of persistent symptoms despite conservative treatment. The same cohort had already been described in a long-term orthopedic follow-up study by De Luna et al. (2021). The previous article reported the surgical technique, clinical scores, radiographic measurements, complications, and statistical analysis of the orthopedic outcomes. In the present manuscript, those data are cited only as previously published contextual information. The original contribution of this case series is the podiatric functional follow-up. Mean follow-up was 7 years and 7 months. (Table 1)

Table 1. Cohort and Previously Published Orthopedic Context.

| Variable | Finding |
|---|---|
| Study design | Case series based on a secondary podiatric functional follow-up of a previously published cohort |
| Patients | 14 adolescents |
| Treated feet | 26 feet |
| Sex | 8 male, 6 female |
| Mean age at surgery | 12.8 years, range 11–14.6 years |
| Condition | Severe symptomatic idiopathic flexible flatfoot unresponsive to conservative treatment |
| Surgery | Evans-Mosca lateral column calcaneal lengthening |
| Associated procedures | Medial soft-tissue correction; Achilles tendon lengthening when indicated |
| Mean follow-up | 7 years and 7 months |
| Previously published orthopedic outcomes | AOFAS Ankle-Hindfoot Scale, FADI, Yoo criteria, Meary's angle, Costa-Bertani's angle, complications |
| Previously reported statistical results | Significant improvement in clinical and radiographic outcomes, with $p < .01$ for the reported preoperative-to-follow-up comparisons |
| Present manuscript contribution | Long-term podiatric functional assessment, including clinical podiatric testing, podoscopy, static baropodometry, dynamic baropodometry, plantar support, load distribution, gait-line progression, and hallux function |

## Intervention

All patients underwent lateral column calcaneal lengthening according to the Evans-Mosca technique. The procedure included calcaneal lengthening with insertion of a tricortical iliac crest graft and fixation with wires. A medial soft-tissue procedure involving the tibialis posterior tendon and talonavicular capsule was associated. Achilles tendon lengthening was performed when indicated. The previously published orthopedic analysis reported statistically significant improvement in clinical and radiographic outcomes. AOFAS Ankle-Hindfoot Scale improved from 60.03 to 95.26, FADI improved from 71.41 to 97.44, Meary's angle improved from 25° to 1.38°, and Costa-Bertani's angle improved from 154.2° to 130.9°, with $p < .01$ for the reported preoperative-to-follow-up comparisons (De Luna et al., 2021). These results are not treated as new findings in the present manuscript.

## Podiatric Assessment

The podiatric evaluation included morphometric tests, clinical functional tests, podoscopic examination, and static and dynamic baropodometric assessment. Morphometric and clinical testing assessed lower-limb length discrepancy, hip screening through FABER and FADIR tests, passive ankle dorsiflexion through the Silfverskiöld test, subtalar joint mobility, first-ray flexion-extension, medial arch behavior, hindfoot correction, and signs of residual forefoot abduction. Under weight-bearing conditions, Jack's test was used to assess reinforcement of the medial longitudinal arch. The tip-toe test was used to evaluate medial arch activation and correction of hindfoot valgus. The too-many-toes

test was used as a clinical indicator of residual forefoot abduction. Podoscopic examination evaluated plantar footprint morphology and the quality of plantigrade support. Static baropodometry assessed load distribution between left and right feet and rearfoot-forefoot load distribution. Dynamic baropodometry assessed plantar contact surface, angle relative to the walking axis, mean gait line, maximum-pressure gait line, and symmetry across the main stance phases. Because podiatric data were collected as follow-up functional findings and were available mainly as aggregate values, the present case series reports descriptive statistics only. Continuous variables are expressed as means and ranges when available. Categorical findings are reported as frequencies (Table 2).

Table 2. Clinical and Morphometric Podiatric Findings at Follow-Up.

| Domain | Test or Parameter | Finding |
|---|---|---|
| Limb alignment | Lower-limb length discrepancy | Not detected in any patient |
| Hip screening | FABER test | Negative for pain |
| Hip screening | FADIR test | Negative for pain |
| Ankle dorsiflexion | Silfverskiöld test | Passive ankle dorsiflexion of at least 10° with the knee both extended and flexed |
| Subtalar mobility | Range of motion | Preserved in all surgically treated feet; mean 26°, range 21°–32° |
| First ray function | Flexion-extension | Physiological in all patients |
| First metatarsal position | Clinical observation | First metatarsal head positioned more dorsally than the lesser metatarsal heads, consistent with physiological morphology |
| Medial longitudinal arch | Jack's test | Positive functional response, with reinforcement of the medial longitudinal arch |
| Hindfoot correction | Tip-toe test | Positive, with reinforcement of the medial longitudinal arch and correction of hindfoot valgus |
| Forefoot abduction | Too-many-toes test | Overall satisfactory; mild residual visibility of fourth and fifth toes in selected patients |
| Plantar footprint | Podoscopic examination | Plantigrade foot and correct plantar support in all patients |
| Isthmus of plantar footprint | Podoscopic examination | Approximately one third of the anterior heel width, consistent with correct plantar support |

## Outcome

Clinical podiatric findings were favorable. Ankle dorsiflexion exceeded 10° in all cases, regardless of knee position. Subtalar joint mobility was preserved in all surgically treated feet, with a mean range of motion of 26° and a range from 21° to 32°. First-ray flexion-extension was physiological in all patients. Weight-bearing tests were also satisfactory. Jack's test showed reinforcement of the medial longitudinal arch. The tip-toe test showed both increased medial arch formation and correction of hindfoot valgus. The too-many-toes test showed overall good findings, although some patients showed mild residual visibility of the fourth and fifth toes. Podoscopic examination showed a plantigrade foot and correct plantar support in all patients, with the central isthmus of the footprint approximately one third of the anterior heel width. Static baropodometric assessment showed physiological load distribution between feet. Mean total load was 52% on the left foot and 48% on the right foot. Mean rearfoot-forefoot distribution was 53.25% for the rearfoot and 46.75% for the forefoot. Two patients showed mild rearfoot-forefoot imbalance without clinical relevance. In one patient, the left foot showed increased forefoot loading, with 53% forefoot and 47% rearfoot. In another patient, the right foot showed mild rearfoot overload, with 42% forefoot and 58% rearfoot. Dynamic baropodometric assessment showed similar plantar contact surfaces between the left and right feet. Mean contact surface was 124.5 $cm^2$ among left feet, with a range from 115 to 134 $cm^2$. Mean contact surface was 123.5 $cm^2$ among right feet, with a range from 107 to 140 $cm^2$. The mean angle relative to the walking axis was similar between feet, with an average variation of approximately 2°. The mean gait line began from the latero-central portion of the heel, progressed laterally, and ended at the first toe. The maximum-pressure gait line in the left feet

generally began from the latero-central heel, progressed laterally toward the forefoot, and transferred to the first metatarsal and first toe. Functional hallux limitus was detected in 1/26 feet, corresponding to 3.8%, during dynamic assessment, with incomplete load transmission to the first toe. In the right feet, the maximum-pressure gait line generally began centrally at the heel, progressed through the forefoot, and ended at the first toe. In two cases, the maximum-pressure gait line changed direction toward the third and fourth metatarsals before ending at the first toe; however, first metatarsal loading was preserved, and load transfer to the first toe was considered adequate. During kinematic assessment of plantar support, patients generally showed symmetry between feet across the main stance phases. The most evident differences concerned mean speed during stance-phase progression. Mean speed values were 222 mm/s in left feet and 335 mm/s in right feet during initial contact, 219 mm/s and 132 mm/s during loading response, 507 mm/s and 413 mm/s during midstance, and 263.8 mm/s and 285.2 mm/s during final contact, respectively (Table 3).

Table 3. Static, Dynamic, and Kinematic Baropodometric Findings at Follow-Up.

| Domain | Parameter | Finding |
|---|---|---|
| Static baropodometry | Left-right load distribution | 52% left foot / 48% right foot |
| Static baropodometry | Rearfoot-forefoot distribution | 53.25% rearfoot / 46.75% forefoot |
| Static baropodometry | Mild imbalance cases | 2 patients, without clinical relevance |
| Static baropodometry | Left forefoot overload example | 53% forefoot / 47% rearfoot |
| Static baropodometry | Right rearfoot overload example | 42% forefoot / 58% rearfoot |
| Dynamic baropodometry | Left plantar contact surface | Mean 124.5 $cm^2$, range 115–134 $cm^2$ |
| Dynamic baropodometry | Right plantar contact surface | Mean 123.5 $cm^2$, range 107–140 $cm^2$ |
| Dynamic baropodometry | Walking-axis angle | Similar between feet, with average variation of approximately 2° |
| Gait-line assessment | Mean gait line | Latero-central heel to first toe |
| Gait-line assessment | Maximum-pressure gait line | Generally transferred toward first metatarsal and first toe |
| Gait-line assessment | Functional hallux limitus | 1 patient |
| Gait-line assessment | Directional changes in maximum-pressure gait line | 2 cases, with preserved first metatarsal loading |
| Kinematic assessment | Initial contact mean speed | 222 mm/s left feet / 335 mm/s right feet |
| Kinematic assessment | Loading response mean speed | 219 mm/s left feet / 132 mm/s right feet |
| Kinematic assessment | Midstance mean speed | 507 mm/s left feet / 413 mm/s right feet |
| Kinematic assessment | Final contact mean speed | 263.8 mm/s left feet / 285.2 mm/s right feet |
| Overall interpretation | Static and dynamic plantar function | Generally physiological, with isolated functional alterations |

## Discussion

Functional outcomes were reassuring in this series. Joint mobility remained preserved, weight distribution was balanced, and most patients showed physiological gait patterns. These findings suggest that Evans-Mosca correction can maintain adequate foot function over time. To date, few studies have reported detailed podiatric functional data after Evans-Mosca correction. The previous orthopedic publication documented clinical and radiographic improvement in the same cohort. The present manuscript adds postoperative podiatric information on how the corrected foot behaved under static and dynamic loading. This distinction is clinically relevant, as pediatric flexible flatfoot is increasingly discussed as a functional condition, not only as a static morphological deformity. Recent gait-analysis literature highlights that dynamic assessment can provide clinically relevant information on walking mechanics, intervention planning, and follow-up in pediatric flatfoot (Böhm et al., 2024). Static baropodometry was reassuring in this series. Mean left-right load distribution remained close to physiological distribution, and mean rearfoot-forefoot distribution did not show a clinically relevant overload pattern. The two mild imbalances observed were minor and were not considered clinically significant. Dynamic findings were also favorable. Plantar contact surfaces were similar between left and

right feet, and the mean gait line progressed from the heel toward the first toe. The isolated case of functional hallux limitus remains clinically relevant. It shows that podiatric follow-up can identify specific dynamic dysfunctions that may remain hidden behind satisfactory clinical scores or radiographic correction. The two cases with directional changes of the maximum-pressure gait line also suggest that subtle compensatory strategies may persist after correction. These findings may inform podiatric surveillance, footwear advice, orthotic decision-making, rehabilitation, and sport-specific monitoring. The present findings fit within recent surgical literature showing that operative treatment can improve clinical and radiographic parameters in selected symptomatic pediatric or adolescent patients. A recent retrospective study on Evans osteotomy in young patients reported postoperative improvement in foot health and radiographic alignment, supporting the role of calcaneal lengthening when surgery is clinically indicated (Yasin et al., 2025). A recent comparative cohort study also confirmed that different surgical approaches for pediatric flexible flatfoot can provide meaningful correction, while treatment selection remains complex and procedure-dependent (Hu et al., 2025). This case series has limitations. The sample is small, with 14 patients and 26 treated feet. The same cohort had already been published from an orthopedic perspective; therefore, the present manuscript should be interpreted as a secondary podiatric functional follow-up, not as an independent surgical outcome study. The podiatric analysis is mainly descriptive because complete patient-level baropodometric data were not available for inferential statistical testing. There was no untreated control group and no comparison with alternative surgical procedures. Preoperative podiatric data were limited, so the present report mainly describes long-term follow-up status rather than quantified preoperative-to-postoperative podiatric change. Despite these limitations, the findings support the inclusion of podiatric functional assessment in long-term follow-up after adolescent flatfoot correction. Future prospective studies should collect standardized preoperative and postoperative podiatric variables, including plantar pressure parameters, center-of-pressure progression, first-ray function, hallux function, propulsion indices, sport participation, and patient-reported activity outcomes.

## Conclusion

Evans-Mosca correction was associated with satisfactory podiatric functional outcomes at a mean follow-up of 7 years and 7 months in this adolescent case series. In addition to the previously reported clinical and radiographic improvements, podiatric evaluation showed preserved mobility, plantigrade support, balanced load distribution, and generally physiological gait-line progression. These findings support the functional validity of the procedure over time, while larger prospective studies with preoperative podiatric data are needed to confirm these results.

*Patient Consent*

No identifiable patient information, clinical photographs, radiographs, podoscopic images, or individual baropodometric images are included in this manuscript. The case series reports only anonymized and aggregated follow-up data. The availability and applicability of written informed consent for publication are being verified with the corresponding author of the previously published cohort before submission.

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## Case Series

# Effects of a Robot-Assisted Equine-Movement Intervention on Postural Control and Standing Kinematics in Children With Cerebral Palsy: A Preliminary Observational Case Series

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### Abstract

**Introduction.** Hippotherapy and horse-riding simulators have been proposed as complementary approaches to improve postural control and motor function in children with cerebral palsy, but evidence remains heterogeneous and advanced robotic equine-movement systems require further clinical investigation. To describe the short-term clinical and standing kinematic changes associated with a HIROB-based rehabilitation intervention in children with cerebral palsy characterized by impaired axial control and immature standing posture.

**Methods.** This preliminary observational case series included four children with cerebral palsy. Participants underwent a three-week HIROB-based intervention delivered 5 sessions per week, 45 minutes per session. Assessments were performed at baseline and after treatment using the Gross Motor Function Measure-88 (GMFM-88), the first-generation Paediatric Balance Scale (PBS), passive range of motion assessed with a goniometer, and instrumented standing analysis using the BTS Smart-DX-1000 system with the Davis protocol.

**Results.** All participants showed improvements in GMFM-88 total scores and PBS scores after treatment. Joint range of motion improved across the assessed parameters, with the most consistent changes observed in hip abduction and unilateral popliteal angle. Standing kinematic analysis showed a trend toward improved postural alignment, particularly in pelvic and hip parameters, with reduced asymmetry and

closer approximation to normative values.
**Discussion.** These preliminary findings suggest that HIROB-based rehabilitation may be feasible and may contribute to short-term improvements in standing alignment, joint mobility, and balance-related outcomes in selected children with cerebral palsy. Given the small sample size, absence of a control group, and concomitant rehabilitation context, the results should be interpreted as exploratory and hypothesis-generating.

**Keywords**: Cerebral Palsy, Hippotherapy, Robot-Assisted Rehabilitation, Equine Movement Simulation, Postural Control, Standing Kinematics, Pediatric Neurorehabilitation, Gross Motor Function, Balance, Range of Motion

## Introduction

Cerebral palsy (CP) comprises a group of permanent disorders of movement and posture caused by a non-progressive lesion of the developing brain and is commonly associated with activity limitations that affect functional independence throughout childhood (Plotas et al., 2024, Obrero-Gaitán et al., 2022). In addition to the primary motor disorder, children with CP frequently present impaired postural control, balance deficits, abnormal muscle tone, reduced selective motor control, and gait abnormalities, all of which negatively influence daily activities, participation, and quality of life (Plotas et al., 2024, Obrero-Gaitán et al., 2022).

In recent decades, hippotherapy has gained increasing attention as a complementary rehabilitation approach in paediatric neurorehabilitation (Plotas et al., 2024, Corral Granados & Fernández Agís, 2011). Its neurophysiological rationale is based on the rhythmic, repetitive, and three-dimensional movement generated by the horse during walking, which provides continuous multisensory input and elicits ongoing postural adjustments by the rider (Corral Granados & Fernández Agís, 2011). This movement has been described as biomechanically comparable, at least in part, to pelvic and trunk displacement during human gait, thereby creating a task-specific environment in which trunk control, pelvic mobility, balance reactions, and postural alignment can be trained in a functional and motivating context (Corral Granados & Fernández Agís, 2011, Shurtleff et al., 2009, Kwon et al., 2011).

The available literature suggests that hippotherapy may positively influence several motor domains in children with CP. Previous studies have reported improvements in dynamic trunk and head stability, upper-limb reaching efficiency, gross motor performance, gait speed, stride length, pelvic kinematics, and functional balance following hippotherapy-based interventions (Shurtleff et al., 2009, Kwon et al., 2011). Additional evidence indicates favourable effects on muscle activation patterns and adductor symmetry, as well as on the reduction of hypertonicity in selected muscle groups, supporting the hypothesis that equine-assisted movement may contribute to more effective postural organization and motor control (McGibbon et al., 2009, Ribeiro et al., 2019). Recent reviews have generally supported the potential of hippotherapy to improve gross motor function, balance, coordination, gait-related outcomes, and postural performance, although they also highlight heterogeneity in treatment protocols, outcome measures, sample characteristics, and study design (Plotas et al., 2024, Martín-Valero et al., 2018).

Despite these promising findings, the use of real horse hippotherapy in clinical practice is often limited by logistical, environmental, and organizational constraints, including restricted accessibility, high costs, weather dependence, and difficulties in standardizing treatment intensity and movement characteristics (Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020).

To address these limitations, horse-riding simulators and robotic equine-movement systems have been developed to reproduce, in a controlled and safer environment, the multidirectional and rhythmic characteristics of horseback motion

(Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025). Systematic reviews and meta-analytic data suggest that simulator-based interventions may improve gross motor function, sitting ability, functional balance, and hip range of motion, particularly when combined with conventional physiotherapy (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025). More recent studies have also suggested positive effects on muscle tone, trunk postural control, gait-related parameters, and functional independence, reinforcing the potential value of simulator-assisted equine-movement training in paediatric rehabilitation (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025, Günay Yazıcı et al., 2025).

However, although hippotherapy and horse-riding simulators have shown promising effects on motor outcomes in children with CP, the available evidence remains heterogeneous, and clinically relevant questions are still open (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020, Ortega-Cruz et al., 2025). In particular, treatment protocols are often not standardized, the duration and intensity of interventions vary considerably, samples are frequently small and clinically heterogeneous, and the relationship between changes in postural control and broader functional outcomes is not yet fully clarified (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020, Ortega-Cruz et al., 2025). These limitations are especially relevant when considering advanced robotic systems, whose main advantage lies in the possibility of delivering a reproducible, adaptable, and measurable equine-like movement stimulus tailored to the child's clinical presentation.

Within this framework, HIROB is a robotic system designed to reproduce horse-like movement while allowing precise modulation of speed, intensity, and therapeutic task demands according to the patient's clinical characteristics. This feature makes it potentially suitable for targeting axial control, trunk-pelvis dissociation, postural alignment, balance reactions, and sensorimotor integration in children with CP within a highly standardized rehabilitation setting. From a clinical perspective, such a system may represent a useful complement to conventional therapy when the rehabilitation goal is to promote adaptive postural strategies, improve trunk organization, and facilitate motor control in a repetitive but customizable environment.

Therefore, the present preliminary observational case series aimed to describe the clinical effects of HIROB-based intervention in four children with cerebral palsy characterized by impaired trunk control and immaturity of standing posture. In particular, the study focused on changes in postural control, balance, gross motor function, joint mobility, and gait-related organization, to provide preliminary clinical data for the future development of structured rehabilitation protocols based on robot-assisted equine-movement systems.

## Materials and Methods

### *Study design*

This study reports preliminary observational data from a case series on the use of a HIROB-based rehabilitation program in four children with CP undergoing inpatient paediatric neurorehabilitation. Clinical and functional assessments were performed at baseline and repeated after the intervention period to explore pre-post changes associated with treatment.

Given the exploratory nature of the study and the limited sample size, no control group was included, and no between-group comparison was planned. The study was intended as a preliminary observational case series aimed at describing feasibility and potential short-term clinical changes associated with a structured HIROB-based intervention in children with CP characterized by impaired axial control and immaturity of standing posture. The study was conducted in accordance with the principles of the Declaration of Helsinki. The study included four children with cerebral palsy presenting a comparable clinical-functional profile characterized by impaired trunk control and immaturity of standing posture. All recruited participants presented a motor profile compatible with the use of the HIROB system and with the rehabilitative targets of the study, specifically postural control, trunk organization, balance, and motor function.

### *Eligibility criteria*

#### *Inclusion criteria*

Children were eligible for inclusion if they met

all the following criteria:

- diagnosis of CP with spastic diplegic or quadriplegic clinical presentation and Gross Motor Function Classification System (GMFCS) level III or IV.
- cognitive level within the normal range or consistent with mild intellectual disability.
- hip abduction range of at least 25 degrees.
- preserved receptive communication sufficient to understand simple verbal commands.
- age between 3 and 10 years.

*Exclusion criteria*

Children were excluded in the presence of any of the following:

- orthopaedic, bone, muscular, or neurosurgical procedures performed within 12 months before enrolment.
- botulinum toxin injections administered within 6 months before enrolment.
- visual field deficits or clinically relevant impairment of the vestibular-oculomotor system likely to interfere with treatment or assessment.
- moderate or severe intellectual disability.
- physical impairments considered incompatible with safe use of the HIROB system.

*Outcome measures*

All participants underwent a structured pre-post clinical assessment at the beginning and at the end of the intervention period. The same evaluator performed the assessments at both time points. The assessment protocol was designed to investigate the main domains potentially influenced by HIROB-based rehabilitation, namely visual-vestibular function, musculoskeletal mobility, postural control, balance, gross motor function, and gait-related performance. A functional vestibular-oculomotor assessment was performed to identify possible impairments capable of influencing postural organization, head control, balance responses, and motor performance during treatment.

Musculoskeletal assessment included the evaluation of passive joint range of motion (ROM) using a goniometer according to a standardized positioning protocol, with particular attention to the lower limbs and hip mobility. ROM assessment was used to verify clinical compatibility with device positioning and to document possible pre-post changes after treatment.

Postural control and balance were assessed using the first-generation Paediatric Balance Scale (PBS), to investigate functional balance performance in paediatric patients. Gross motor performance was assessed using the Gross Motor Function Measure-88 (GMFM-88). The total GMFM-88 score was calculated from the sum of the five domains and used to document possible changes in global motor function after the intervention.

Instrumented gait and static postural assessment were performed using the BTS Smart-DX-1000 system (BTS Bioengineering, Italy). The Davis protocol was used for marker placement and data acquisition. For each participant, three standing trials were acquired at baseline (T0) and after treatment (T1). Static standing analysis and gait analysis, where feasible according to the child's functional abilities, were used to explore changes in postural alignment and locomotor organization after treatment.

*Intervention*

All participants underwent a three-week individualized HIROB-based rehabilitation program integrated into the routine inpatient neurorehabilitation schedule. HIROB is a robotic system designed to support intensive, task-oriented, and highly reproducible rehabilitation interventions. Through controlled and assisted movement patterns, it facilitates active patient participation while ensuring safe and progressive motor training. HIROB promotes motor relearning by integrating repetitive practice, sensory feedback, and individualized exercise modulation. By combining treatment standardization with patient-specific adaptability, HIROB represents a valuable tool to enhance clinical rehabilitation pathways. The HIROB intervention was delivered 5 sessions per week, 45 minutes per session, for a total duration of 3 weeks. The intervention was specifically designed for children with reduced axial control and immature standing organization, with the aim of promoting postural adaptation, trunk-

pelvis coordination, balance responses, and functional motor organization.

The therapeutic program was structured around three main macro-objectives:

1. exercises for functional head control.
2. exercises for functional trunk control.
3. exercises for functional standing organization.

Within these macro-areas, the activities were individualized according to each child's clinical profile, postural abilities, and adaptive responses. For each activity, the following elements were defined: specific goal, materials used, therapeutic request, execution modality, and clinical indicators of progression.

The HIROB system was used to provide rhythmic, multidirectional, and adjustable perturbations reproducing horse-like movement. Speed and intensity were modulated according to the child's trunk control, motor competence, and tolerance to the task. During treatment, the therapist adjusted the level of facilitation, the complexity of the task, and the sensory-motor demands according to the child's performance.

A representative example of the therapeutic logic was a head-control exercise based on visual tracking. In this task, the child, positioned in sitting, was asked to fix and maintain attention on a moving visual target while postural perturbations were generated by the HIROB device. The target was gradually moved in frontal, transverse, and oblique trajectories, and task duration, speed, and directional complexity were adapted according to the child's responses and level of competence.

*Data analysis*

Given the very small sample size and the exploratory observational design, data were analysed descriptively. Individual pre-post changes were examined for each participant, and outcome variation was interpreted in relation to each child's baseline clinical profile. No inferential statistical testing was performed. The aim of the analysis was not to establish treatment efficacy at a confirmatory level, but to provide preliminary clinical observations on the use of HIROB in children with CP presenting reduced trunk control and immature standing posture.

*Ethical Considerations*

The study was conducted in accordance with the Declaration of Helsinki. The reported data were obtained from routine clinical rehabilitation pathways performed during intensive inpatient rehabilitation. No additional intervention beyond standard clinical care was performed for research purposes. All data are presented in anonymized form, with no identifiable personal information.

## Results

*Participant characteristics*

Four children with CP were included in this preliminary observational case series. The median age was 6.5 years, with an age range from 5 to 9 years. Three participants were female and one was male. Three children had spastic diplegia and one child had quadriplegia. According to the Gross Motor Function Classification System (GMFCS), three participants were classified as level III and one as level IV. Cognitive functioning was within the normal range in two children, borderline in one child, and characterized by mild delay in one child. At the oculo-vestibular assessment, two participants showed no relevant abnormalities, while two presented exophoria, bilateral in one case and right-sided in one case (Table 1).

Table 1. Baseline demographic and clinical characteristics of the participants. All participants presented impaired axial control and immaturity of standing posture, with a clinical profile compatible with HIROB-based rehabilitation.

| Patient | Age, years | Sex | Diagnosis | GMFCS | Cognitive level | Oculo-vestibular findings |
|---|---|---|---|---|---|---|
| P1 | 7 | M | Spastic diplegia | III | Borderline | Normal |
| P2 | 6 | F | Spastic diplegia | III | Normal | Bilateral exophoria |
| P3 | 9 | F | quadriplegia | IV | Mild cognitive delay | Normal |
| P4 | 5 | F | Spastic diplegia | III | Normal | Right-sided exophoria |

*Functional outcomes*

Gross motor function and balance outcomes are reported in Table 2 and depicted in Figure 1. All participants demonstrated improvements in GMFM-88 total scores following the intervention, with individual changes ranging from +2 to +6 points. PBS scores also increased in all subjects, with changes ranging from +3 to +6 points. Compared to GMFM-88, PBS improvements appeared more consistent across participants, showing a more homogeneous pattern of change.

Changes in joint range of motion are reported in Table 3. Overall, all participants showed improvements across the assessed joint parameters following the intervention.

The most consistent and marked increases were observed in hip abduction, with bilateral improvements ranging from +10 to +14 degrees across participants. Similarly, unilateral popliteal angle showed the greatest gains, with increases exceeding +12 degrees in all subjects

Table 2. Individual GMFM-88 total and PBS scores at baseline (T0) and after treatment (T1), with pre–post changes expressed as Δ.

| Patient | GMFM T0 | GMFM T1 | Δ GMFM | PBS T0 | PBS T1 | Δ PBS |
|---|---|---|---|---|---|---|
| P1 | 72 | 74 | 2 | 20 | 26 | 6 |
| P2 | 68 | 74 | 6 | 18 | 22 | 4 |
| P3 | 60 | 64 | 4 | 15 | 19 | 4 |
| P4 | 70 | 73 | 3 | 19 | 22 | 3 |

Table 3. Joint angles are expressed in degrees as pre–post values (T0→T1), with corresponding changes (Δ) in parentheses.

| Patient | Hip Abd R | Hip Abd L | Hip Add R | Hip Add L | Popliteal Angle Unilateral R | Popliteal Angle Unilateral L | Popliteal Angle Bilateral R | Popliteal Angle Bilateral L | Plantarflexion R | Plantarflexion L |
|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 34→46 (+12) | 36→48 (+12) | 26→30 (+4) | 28→34 (+6) | 136→150 (+14) | 138→150 (+12) | 142→150 (+8) | 142→152 (+10) | 142→144 (+2) | 140→144 (+4) |
| P2 | 32→44 (+12) | 34→48 (+14) | 24→30 (+6) | 26→30 (+4) | 134→150 (+16) | 136→150 (+14) | 140→148 (+8) | 140→150 (+10) | 136→142 (+6) | 138→146 (+8) |
| P3 | 30→40 (+10) | 32→44 (+12) | 22→28 (+6) | 24→28 (+4) | 132→146 (+14) | 134→146 (+12) | 138→146 (+8) | 138→148 (+10) | 136→140 (+4) | 136→142 (+6) |
| P4 | 34→48 (+14) | 36→48 (+12) | 26→32 (+6) | 28→32 (+4) | 136→150 (+14) | 138→152 (+14) | 142→150 (+8) | 142→152 (+10) | 140→146 (+6) | 140→146 (+6) |

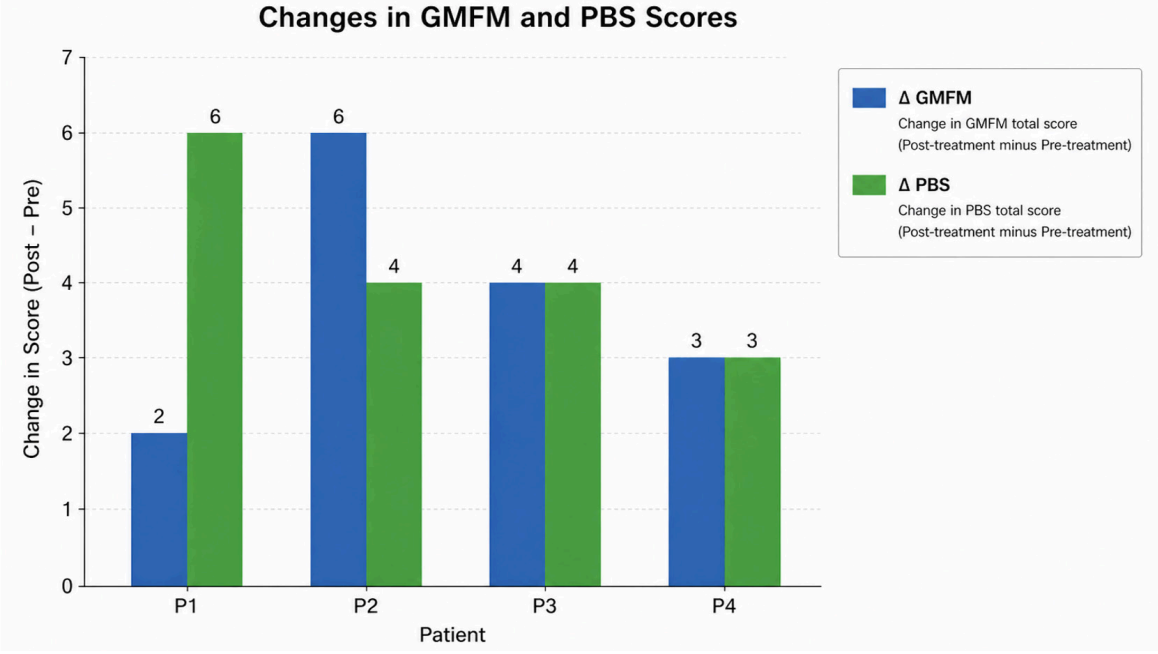


Figure 1. Individual changes in GMFM and PBS scores following the HIROB intervention. Bars represent pre–post differences (Δ) for each participant.

**Legend**. GMFM: Gross Motor Function Measure; PBS: Pediatric Balance Scale; Δ: change (Post – Pre).

and reaching up to +16 degrees in some cases.

Improvements in hip adduction were present but of smaller magnitude, generally ranging between +4 and +6 degrees. Changes in bilateral popliteal angle were more moderate, with increases between +8 and +10 degrees. Ankle plantarflexion showed variable and generally smaller changes across participants, with increases ranging from +2 to +8 degrees, without a consistent pattern.

*Standing kinematic analysis*

Standing kinematic parameters are illustrated in Figure 2. Overall, all participants showed a consistent trend toward normalization of joint alignment following the intervention, with reductions in pathological deviations and improved symmetry between sides. At baseline, all participants presented increased pelvic tilt and marked asymmetries in pelvic rotation. After the intervention, pelvic tilt values decreased bilaterally in all subjects, approaching the normative range. Similarly, pelvic rotation showed a substantial reduction in asymmetry, with right and left values becoming more balanced and closer to zero.

Hip kinematics showed positive pre-post changes across both planes. In the frontal plane, hip abduction/adduction values shifted toward normative values, with reduced excessive abduction and improved side symmetry.

In the sagittal plane, hip flexion angles decreased in all participants, indicating a reduction of the flexed posture observed at baseline. Knee kinematics showed a more variable pattern. In the sagittal plane, knee flexion decreased across participants, particularly on the left side, indicating a tendency toward a more extended and extended posture. In the transverse plane, knee rotation values moved toward normative ranges, with a reduction in excessive external rotation on the right side and greater bilateral symmetry.

**Standing Kinematic Parameters Before and After HIROB Intervention**

| JOINT / PLANE | PRE (T0) | | | | | | | | POST (T1) | | | | | | | | NORMATIVE VALUES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | | P2 | | P3 | | P4 | | P1 | | P2 | | P3 | | P4 | | |
| | R | L | R | L | R | L | R | L | R | L | R | L | R | L | R | L | Mean ± SD |
| **PELVIS** (Sagittal) Pelvic tilt (°) + = anterior tilt | 17.3 | 17.3 | 16.2 | 18.0 | 18.5 | 16.8 | 15.8 | 17.6 | 7.9 | 7.9 | 8.8 | 8.3 | 9.4 | 8.7 | 7.6 | 8.1 | 10±4 |
| **PELVIS** (Transverse) Pelvic rotation (°) + = right rotation | -14.3 | 14.3 | -12.6 | 13.8 | -15.1 | 12.9 | -13.7 | 15.0 | 4.4 | -4.4 | 3.9 | -3.7 | 5.1 | -3.9 | 4.7 | -4.9 | 0±5 |
| **HIP** (Frontal) Hip abd/add (°) + = abduction | 4.5 | 5.9 | 5.2 | 6.4 | 4.8 | 6.1 | 5.6 | 5.4 | 0.8 | 4.1 | 1.4 | 3.6 | 1.2 | 3.8 | 1.1 | 3.2 | 0±3 |
| **HIP** (Sagittal) Hip flex/ext (°) + = flexion | 35.9 | 29.0 | 33.4 | 30.6 | 37.2 | 31.5 | 34.8 | 28.4 | 21.9 | 13.3 | 20.8 | 15.2 | 23.4 | 16.0 | 22.1 | 14.1 | 10±4 |
| **KNEE** (Sagittal) Knee flex/ext (°) + = flexion | 26.1 | 18.6 | 24.8 | 19.9 | 27.4 | 20.1 | 25.5 | 17.9 | 24.6 | 10.7 | 22.5 | 12.4 | 25.2 | 12.0 | 23.1 | 11.4 | 5±5 |
| **KNEE** (Transverse) Knee rotation (°) + = external rotation | 19.8 | 3.9 | 17.5 | 5.1 | 20.6 | 4.6 | 18.7 | 4.2 | 6.6 | 9.1 | 7.2 | 8.3 | 8.0 | 8.8 | 7.0 | 8.5 | -10±5 |

R = right side
L = left side

**Standing – Quiet Standing**
Values are expressed as mean joint angles (degrees).
T0 = pre-intervention; T1 = post-intervention; SD = standard deviation.

Normative values are reported as mean ± SD.
Mini-bars show the normative band; dashed line indicates the mean.
Positive values follow the biomechanical convention listed per row.

Figure 2. Mean joint angles (degrees) are reported for each participant (P1–P4) in quiet standing, for right (R, green) and left (L, red) sides, at baseline (T0) and after the intervention (T1). Normative values (general population) are shown as mean ± standard deviation (SD), with the shaded bar representing the normal range (±2 SD) and the dashed line indicating the mean. Positive values are defined according to the biomechanical conventions reported for each variable.

## Discussion

This preliminary observational case series explored short-term clinical and standing kinematic changes after a three-week HIROB-based intervention in four children with CP characterized by impaired trunk control and

immaturity of standing posture. The main finding was a consistent descriptive trend toward more favourable postural organization in standing, with smaller deviations from normative kinematic values, particularly at the level of the pelvis and hip. These findings are consistent with the theoretical rationale of hippotherapy, according to which rhythmic, repetitive, and three-dimensional movement provides multisensory inputs capable of eliciting adaptive postural responses and facilitating neuromotor reorganization (Corral Granados & Fernández Agís, 2011, Shurtleff et al., 2009, Martín-Valero et al., 2018, Whalen & Case-Smith, 2012, Tseng et al., 2013). In this context, HIROB may reproduce some of the key therapeutic principles of horseback movement within a controlled and reproducible robotic environment.

The most relevant changes emerged from the standing kinematic analysis. After the intervention, pelvic tilt decreased bilaterally in all participants, approaching normative values, while pelvic rotation showed reduced asymmetry. This is clinically relevant because pelvic alignment plays a central role in both static postural organization and gait mechanics in children with CP (Kwon et al., 2011, Günay Yazıcı et al., 2025, Sterba et al., 2002). At the hip level, changes were observed in both frontal and sagittal planes. Hip abduction/adduction values shifted toward normative ranges, and excessive hip flexion decreased across participants. These results suggest an improvement in proximal alignment and trunk-pelvis organization. Similar changes have been reported after hippotherapy and horse-riding simulator interventions, which appear to promote trunk-pelvis coordination and more physiological lower-limb alignment through repetitive sensorimotor stimulation (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025, Park et al., 2014, Kwon et al., 2015). Knee kinematics showed a more variable pattern. Nevertheless, a general trend toward reduced flexion and more favourable rotational alignment was observed. These distal changes may reflect, at least in part, a secondary effect of improved proximal stability. The relationship between trunk-pelvis control and lower-limb biomechanics is particularly relevant in children with cerebral palsy, in whom compensatory postural strategies often influence hip, knee, and ankle alignment (Benda et al., 2003, Casady et al., 2004, Zadnikar & Kastrin, 2011).

A relevant aspect of the present findings concerns joint mobility. The most consistent descriptive increases were observed in bilateral hip abduction and unilateral popliteal angle. These changes may suggest a favourable effect on muscle extensibility and tone regulation, particularly in muscle groups commonly involved in spastic patterns, such as hip adductors, iliopsoas, hamstrings, and triceps surae.

Although muscle activity and tone were not directly measured in this study, previous works have shown that hippotherapy may promote more symmetrical muscle activation and reduce spasticity, especially in the lower limbs (McGibbon et al., 2009, Ribeiro et al., 2019, Hamill et al., 2007, Lucena-Antón et al., 2018, Hemachithra et al., 2020). Benda et al. reported improved muscle symmetry after equine-assisted therapy, while McGibbon et al. described changes in adductor activity and functional ability in children with spastic cerebral palsy (McGibbon et al., 2009, Benda et al., 2003). In line with these findings, the present ROM results may be interpreted as indirect clinical indicators of more favourable muscle balance and reduced hypertonic constraints, although this interpretation remains speculative.

The increase in unilateral popliteal angle is especially relevant because hamstring shortening and increased posterior-chain tone can influence pelvic position, knee flexion, and standing alignment. Similarly, increased hip abduction may reflect a reduction in adductor restriction, potentially supporting more favourable pelvic positioning and lower-limb alignment during standing.

Functional outcomes, assessed by GMFM-88 and PBS, showed positive pre-post changes in all participants. However, the magnitude of change was limited. This should be interpreted cautiously, considering both the small sample size and the ordinal nature of these clinical scales. GMFM-88 and PBS are useful tools for describing gross motor function and balance, but they may be less sensitive to subtle short-term biomechanical and postural changes in small case series.

Despite the modest numerical changes, the consistent direction of change across participants suggests a positive qualitative trend. This is also supported by the kinematic findings, which captured changes in postural alignment that may not be fully reflected by global functional scales.

Similar discrepancies between clinical scores and instrumented biomechanical measures have been described in previous rehabilitation studies, where gait or postural analysis detected changes not clear on ordinal clinical scales (Sterba et al., 2002, Herrero et al., 2012, Temcharoensuk et al., 2015, Champagne et al., 2017).

*Clinical implications*

The present findings suggest that HIROB may represent a promising adjunctive tool for children with CP characterized by impaired axial control and immature standing organization. By providing rhythmic, multidirectional, and adjustable perturbations, HIROB may support postural adaptation, trunk-pelvis coordination, balance reactions, and lower-limb alignment within a controlled rehabilitation setting. Its potential advantages over traditional hippotherapy include greater standardization, reproducibility, and easier integration into hospital-based pediatric neurorehabilitation programs (Obrero-Gaitán et al., 2022, Dominguez-Romero et al., 2020, Chang et al., 2021). These preliminary results are consistent with previous studies reporting positive effects of hippotherapy and horse-riding simulators on motor function, postural control, balance, gait-related outcomes, and quality of life in children with CP (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Ortega-Cruz et al., 2025, Herrero et al., 2010, De Guindos-Sanchez et al., 2020, Dominguez-Romero et al., 2020, Deutz et al., 2018, Mutoh et al., 2019).

*Limitations and future perspectives*

This study has several limitations. First, the sample size was small, as expected in a preliminary case series. Second, the absence of a control group, randomization, and blinded assessment prevents causal inference regarding the effectiveness of the intervention. Third, the specific contribution of HIROB cannot be separated from the effects of concomitant rehabilitation, clinical variability, or short-term learning effects. Fourth, muscle tone and muscle activation were not directly assessed through objective measures such as electromyography or dynamometry. Finally, the short intervention period and lack of follow-up do not allow conclusions on the persistence of the observed changes over time.

Future studies should include larger samples and a control group receiving an alternative intervention with similar therapeutic objectives and comparable treatment intensity. Further research should also incorporate objective neuromuscular measures, such as surface electromyography, to better investigate the effects of HIROB on muscle activation, symmetry, and hypertonicity. Long-term follow-up would also be useful to determine whether postural and kinematic changes are maintained and whether they translate into meaningful improvements in gait, daily activities, and participation.

## Conclusion

This preliminary case series suggests that HIROB-based rehabilitation is feasible and may be associated with short-term positive changes in standing alignment, joint mobility, and balance-related outcomes in selected children with CP. The observed changes support the potential role of HIROB in promoting postural reorganization, although the underlying neuromuscular mechanisms were not directly assessed. Given the small sample size, lack of control group, absence of blinded assessment, and concomitant rehabilitation context, these findings should be interpreted as preliminary and hypothesis-generating. Larger controlled studies with follow-up assessments are needed to clarify the efficacy of HIROB-based rehabilitation in pediatric CP.

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