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Research Article

The Influence of Movement Imitation Therapy on Neurological Outcomes in Children Who Have Experienced Adverse Perinatal Conditions

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Abstract

This study aimed to evaluate the effectiveness of early intervention (EI) for infants at high risk for cerebral palsy (CP), particularly in the context of their neurological development. The study was conducted at the Regional Perinatal Center in Aktobe, Kazakhstan, and included 69 preterm infants with adverse neonatal periods. The infants were divided into two groups: the first group (n=50) began EI at 42 weeks postmenstrual age, while the second group (n=19) started at 52 weeks. Both groups underwent general movements assessment (GMA) and motor activity monitoring using general movement optimality score (GMOS). Results showed that infants receiving EI earlier demonstrated significant improvements in movement quality and a reduced risk of adverse neurological outcomes compared to the control group. The findings highlight the importance of early detection and intervention, as well as the need for implementing early diagnostic programs for infants at risk.

Keywords: early intervention, cerebral palsy, general movements, neurological development, preterm infants

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1. Introduction

During the prenatal development period and the first 2 years after birth, the brain exhibits strong developmental activity. The peak of this developmental activity occurs in the first three months after birth and continues throughout the first year. This indicates high neuroplasticity during this time, which opens up significant opportunities for early intervention. Infants born very preterm (gestational age <32 weeks) are at increased risk of adverse neurological developmental outcomes due to prenatal or perinatal brain injury [1, 2]. Although the incidence of severe cerebral palsy (CP) in infants has decreased in recent years [3], very early preterm birth remains a risk factor for this diagnostic outcome [4, 5].

The Prechtl general movements assessment (GMA) [6-8] allows us to reliably, sensitively, and nonintrusively assess the young nervous system during the preterm period up to approximately 5 months post-term. Abnormal general movements (GMs) are predictive of adverse neurological outcomes, particularly cerebral palsy [8-12]. Mainly, the pattern of cramped-synchronized (CS) GMs predicts spastic cerebral palsy (with a positive likelihood ratio of 45) if consistently present for several weeks [8-15].

Early identification of high risk for cerebral palsy, followed by specific early intervention, is recommended as the standard of care to optimize infant neuroplasticity, prevent complications, and improve parental well-being. It is essential to ensure that children diagnosed with cerebral palsy or those at high risk of receiving such a diagnosis have immediate access to targeted intervention measures tailored to their age and specific needs related to cerebral palsy.

One of the strong recommendations for early intervention (EI) is the application of movement imitation therapy, starting with the onset of pathological movements [8-18]. Therefore, the aim of this study considering the high risk of developing cerebral palsy in children who have experienced adverse conditions, assess the impact of the GMs assessment and movement imitation aimed at overlaying smooth and variable sequences of GMs (i.e., mediated by a therapist) on neurological development outcomes.

2. Materials and Methods

2.1. Participants

This open clinical controlled study was conducted at the Regional Perinatal Center in Aktobe, Kazakhstan (Figure **1**). According to the inclusion criteria, the sample consisted of preterm infants with an adverse neonatal period who had previously undergone a GMA.

Two groups of children were identified: the first group included 50 children classified as high risk for cerebral palsy (children with pathological movements and suboptimal scores on the GMOS <25). Rehabilitation intervention was initiated at 42 weeks and continued until 60 weeks postmenstrual age.

The second group included 19 children who did not exhibit fidgety movements and were also categorized as high risk for cerebral palsy. This group began rehabilitation intervention and continued to receive it until 60 weeks postmenstrual age.

Inclusion criteria:

-The study included children who scored less than 25 points on the general movement optimality score (GMOS) assessment, as well as children who did not exhibit fidgety movements.

Exclusion criteria:

-Hereditary diseases

-Major congenital anomalies

-Mortality

The study received approval from the Bioethics Committee of the West Kazakhstan Medical University (No. 10 dated 11.12.2020).

2.2. General movements assessment

Originally described by Heinz Prechtl, it is an integral part of spontaneous motor activity observed from the early fetal stage to the fifth month of an infant's life [8-20]. These movements encompass complex motor actions of the entire body, varying in amplitude and speed, and include successive movements of the arms, legs, neck, and torso. They demonstrate a gradual intensification and fading. After reaching term, two main types of GMs are observed: writhing and fidgety movements.

Writhing movements are characteristic from birth until approximately the ninth week and can be classified as normal or having three variants of deviation: poor repertoire (PR), cramped-synchronized (CS), or chaotic (Ch) GMs. Fidgety movements, on the other hand, emerge around 7–8 weeks and continue up to 20 weeks, when purposeful voluntary movements begin. Disorders or damage to the integrity of the nervous system leads to a loss of complexity and variability in GMs, rendering them monotonous and weak [18, 21]. During the period of fidgety movements, normal movements are characterized by fine amplitude circular motions of varying acceleration of the neck, torso, and limbs at a medium speed. Meanwhile, abnormal GMs are classified as the absence of fidgety movements (observed during the period from 6 to 20 weeks post-term) and movements with amplitude and speed exceeding normal fidgety movements [22]. We conducted assessments of GMs by analyzing three-minute video recordings made during the periods of writhing and fidgety movements.

The GMA assessments were conducted by qualified specialists: three pediatric neurologists who had completed both basic and advanced GMA courses. The assessors' decisions were meticulously documented.

These assessors, certified and experienced in evaluating GMs, were not informed about the medical histories of the newborns to ensure that their assessments were objective and not influenced by prior

knowledge of the children's conditions. The level of agreement was 0.80, indicating a good degree of consistency.

2.3. General movement optimality score

A detailed assessment of the GMOS was conducted during the writhing movements phase at 2–3 weeks of life. The first part of the assessment sheet relates to general categories of movement:

1. -Writhing – normal movement – refers to diverse sequences of movements, amplitude, speed, and intensity.

2. -PR– characterizes monotonous movement components with limited variability in amplitude, speed, and intensity.

3. -CS – where GMs lack smoothness and appear rigid, with contraction and relaxation of limb and trunk muscles occurring almost simultaneously.

4. -Ch – includes movements with large amplitude and fast speed, characterized by constant abrupt movements.

The term "hypokinetic" is used when GMs are not observed throughout the assessment, but isolated movements, typically in the upper limbs, are present. In such cases, a detailed assessment is not possible. The sequence of movements is associated with specific global categories of GMs, labeled as "variable" for normal GMs, "monotonous and/or interrupted" for PR, "synchronized" for CS, and "disorganized" for chaotic GMs.

The detailed scoring assessment focuses on individual aspects such as the neck and torso, and the upper and lower limbs. Each element is described, with optimal performance receiving a score of "2" (e.g., absence of cramped-synchronized components), less optimal performance receiving a score of "1" (e.g., periodic presence of cramped-synchronized components), and nonoptimal performance receiving a score of "0" (e.g., predominance of cramped components). However, five elements are assessed exclusively as "2" or "1": (1) assessment of GMs; (2) involvement of the neck – a distinction is made only if the neck is involved or almost/not involved in the sequence; (3) amplitude of movements in the upper and lower limbs; (4) speed of movements in the upper and lower limbs; and (5) sequence of observed movements.

To determine the optimal score for GMs, the scores of each element in the categories "neck and torso," "upper limb," and "lower limb," as well as the score for "sequence," are summed, leading to a maximum value of 42, representing optimal performance. The worst possible score, indicating the poorest performance, is 5. Suboptimal values, which serve as borderline indicators for identifying high risk of cerebral palsy, are up to 25 points [23].

2.4. Motor optimality score

The next method for quantitative analysis of GMs at 49–60 weeks postmenstrual age is the MOS.

The MOS consists of five components:

1. Temporal organization and quality of fidgety movements (normal 12 points, pathological enhanced 4 points, absent 1 point);

2. Quality of motor patterns (normal (N) more than atypical (A) 4 points, N=A 2 points, N<A 1 point);

3. Age-appropriate motor repertoire (present 4 points, reduced 2 points, absent 1 point);

4. Postural patterns (normal more than atypical 4 points, N=A 2 points, N<A 1 point);

5. Nature of movements (smooth and fluid 4 points, pathological but not CS 2 points, CS 1 point).

The MOS was considered optimal when it was in the range of 25 to 28 (minimum score 5, maximum score 28), while a score <25 was regarded as less optimal or reduced. The child's MOS was categorized as follows: optimal score ≥25; slightly reduced: 20–24; moderately reduced: 9–19; and severely reduced ≤8.

Starting from 5 months of age, children begin to exhibit purposeful voluntary antigravity movements, at which point the sensitivity of the GMs assessment method significantly decreases.

2.5. Assessment of cerebral palsy

We employed a comprehensive approach to diagnosing cerebral palsy in children. The initial assessment began with a thorough collection of medical history and a physical examination, which included evaluating motor functions and monitoring developmental milestones. Identifying typical signs of cerebral palsy, such as coordination disorders, abnormalities in muscle tone, and postural issues, was a critical aspect of the evaluation. It is important to note that, despite the high diagnostic value of magnetic resonance imaging (MRI) in detecting structural changes in the brain associated with cerebral palsy, we encountered limitations in our study that prevented the use of MRI for all participants.

2.6. Assessment of the severity of cerebral palsy

The GMFCS-E&R is a system that classifies and assesses the movement abilities of children with cerebral palsy across five levels and five age ranges. It documents a child's functional abilities and performance in various contexts, particularly while sitting, walking, and using mobility devices. Lower levels indicate greater independence in gross motor skills.

According to international standards and clinical protocols for cerebral palsy, the severity of motor impairment in children with CP was assessed using the expanded revised gross motor function classification system (GMFCS). The age at the time of assessment was 18 months.

Level I: At this level, infants demonstrate the ability to transition in and out of sitting positions and can sit comfortably on the floor, using both hands to interact with objects. They can also crawl on hands

and knees, pull to a standing position, and take steps while holding onto furniture. Typically, they begin walking independently between 18 months and 2 years without relying on any assistive devices.

Level II: Infants at this stage can maintain a sitting position on the floor but may need hand support to keep their balance. They can move by crawling on their stomach or using their hands and knees. Additionally, they can pull themselves into a standing position and take a few steps while holding onto furniture.

Level III: Infants in this category can maintain a sitting position when their lower back is supported. They are capable of rolling and moving forward while lying on their stomach.

Level IV: Infants with head control who require trunk support can achieve a sitting position on the floor. They can roll from lying on their back to lying on their stomach and vice versa.

Level V: Infants with physical impairments experience limitations in voluntarily controlling movement. They struggle to maintain antigravity positions of the head and trunk while lying on their stomach or sitting. Rolling requires assistance from adults.

2.7. Movement imitation therapy procedure: Optimizing the pattern of general movements

GMs are initiated by a central pattern generator (CPG), which is likely located in the brainstem. To ensure variability in motor output, the activity of the CPG is modulated by supraspinal projections and sensory feedback (Einspieler et al. 2004, 2016). In cases of brain injury, the modulation of CPG activity by supraspinal projections may be limited. Therefore, it is suggested that one method of modulating CPG activity is through the use of variable limb movements in infants to enhance the variability of sensory feedback.

A few days after diagnosing the infant with cramping synchronized movements (CS), the MIT-PB movement imitation therapy for preterm babies (MIT-PB) procedure was initiated. MIT-PB was initiated by the first author, a neonatologist, in collaboration with a developmental physiotherapist (hereafter referred to as “therapists”). The procedure was carried out as follows: when the infant exhibited CS movements, the therapists (or a therapist and a parent) intervened by gently guiding the infant’s limbs to smooth their movements and imitate normal GM sequences as closely as possible. The therapists transformed simultaneous extensions and relaxations of the limbs into smooth and coordinated movements by overlaying variable sequences that mimic normal GMs, such as increasing rotational components and altering movement amplitude to enhance variability. It was crucial to avoid stressful movements to keep the infants’ calm. Each intervention lasted at least 10 minutes. Similar to normal GMs, the mimicked movements were paused, and the intervention resumed when the infant initiated a new cramping synchronized movement. If the infant began to cry, the intervention was paused; the infant was comforted through increased physical contact and cuddling. The intervention was repeated at least five times a day, and

parents were trained from the outset to continue these interventions after hospital discharge. Thus, MIT-PB was maintained until five weeks post-term. After discharge (at 38- or 39-weeks postmenstrual age), parents continued to implement MIT-PB as described above; the infants were also seen by therapists weekly for monitoring and adjusting parental maneuvers.

Additionally, parents were trained in proper handling and positioning of their infant, which is a standard practice for all preterm infants born at Regional Perinatal Center.

2.8. Statistical analysis

All statistical tests were considered significant at a p-value of less than 0.05. Data analysis was performed using IBM SPSS Statistics 22 software (SPSS Inc., Chicago, Illinois, USA), while results visualization was conducted using GraphPad software (version 9.5.1, San Diego, California, USA) and RStudio (version 2023.09.0+463, PBC, Boston, Massachusetts).

3. Results

EI refers to the implementation of imitation movements during the child's display of a repertoire of pathological movements. This type of EI is considered effective when conducted before 60 weeks of postmenstrual age (PMA).

Earlier, 50 children from a high-risk group for cerebral palsy (CP) — those with pathological movements and suboptimal scores on the GMOS < 25 — began EI at 42 weeks PMA and continued until 60 weeks PMA. At 52 weeks, 19 children who had not exhibited fidgety movements were also classified into the high-risk group for CP. This group began EI and continued to receive it until 60 weeks PMA.

To evaluate the impact of EI on neurological outcomes and the severity of the condition, a specific study design was developed. The sample consisted of groups that received EI starting from 42 weeks (main group, n=36) and from 52 weeks (control group, n=18). The criteria for sample selection were based on quantitative movement analysis using the MOS at 52 weeks, where children scoring in the range of 9–19 points (indicating moderate severity of suboptimality) were grouped. After the completion of the EI period at 60 weeks PMA, MOS scores were re-evaluated for comparison.

The mean MOS in the main group was 14.19±0.83 at 52 weeks, increasing to 17.28±0.13 at 60 weeks. In contrast, the control group recorded values of 16.61±0.145 and 16.83±0.143 at 52- and 60-weeks PMA, respectively (Figure **1**).

As seen in Figure **2**, statistical analysis indicated that the differences between the groups were significant at the level of 0.005, while in the main group, the differences reached a level of 0.001, indicating a high degree of reliability for the observed differences. This means that the children in the

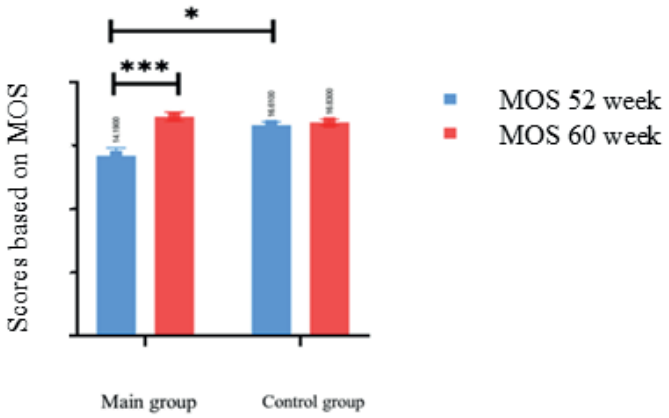

Figure 1: Dynamics of MOS data in both groups of children with cerebral palsy (n=54).

main group who received EI from 42 to 60 weeks showed results trending towards improvement in their MOS scores, reflecting their motor capabilities.

To assess the role of EI on neurological outcomes, particularly regarding the confirmed diagnosis of cerebral palsy (CP), a comparative analysis was conducted among children in both groups. This analysis revealed that 35 out of 36 (97.2%) children in the main group were diagnosed with CP, whereas all 18 (100%) children in the control (Figure **2**).

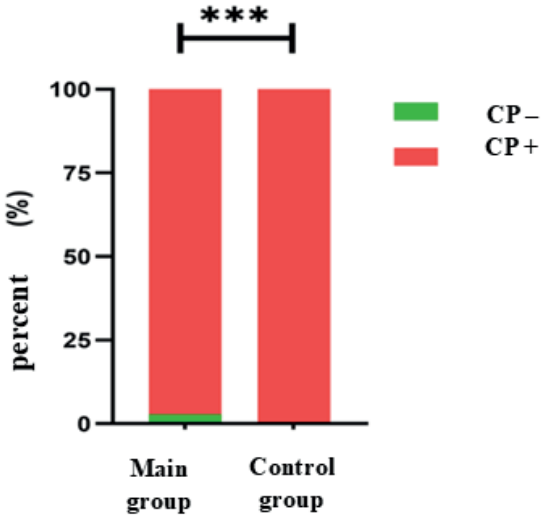

Figure 2: Frequency of cerebral palsy realization in both groups (n=54).

The analysis of Figure **2** indicates that the risk of developing cerebral palsy (CP) primarily depends on the initial conditions of the children, while EI had a negligible impact. Statistical analysis revealed significance at $p < 0.01$.

To evaluate the role of EI on the severity of CP at 18 months, the severity of the children's conditions was assessed using the GMFCS classification. The analysis of the obtained data showed that in the main group, the distribution across GMFCS levels was as follows: Level I - 11 (30.5%) children; Level II - 10 (27.7%)

children; Level III - 5 (13.8%) children; Level IV - 6 (16.6%) children; Level V - 3 (8.3%) children. In the control group, the distribution was: Level I - none; Level II - 1 (5.5%) child; Level III - 5 (27.7%) children; Level IV - 12 (66.8%) children; Level V - none (Figure **3**).

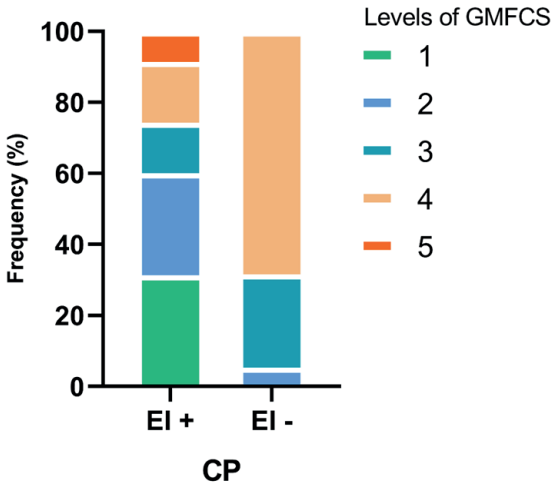

Figure 3: Outcome measures in the severity level of cerebral palsy (GMFCS) in children from both groups ($p < 0.05$).

The analysis shows that children in the control group predominantly exhibited Levels III to V on the GMFCS, indicating a severe degree of impairment without independent walking. In contrast, the main group demonstrated Levels I to II on the GMFCS. Thus, despite the diagnosis of cerebral palsy, the severity was less pronounced in the children of the main group.

4. Discussion

For about 25 years, the assessment of GMs according to Prechtl has reliably identified infants at high risk for later neurological disorders at a very early stage, especially when combined with MRI at term [9, 24]. Based on this data, movement imitation therapy has been proposed by many authors as an effective EI method that does not require special equipment.

A recent study conducted EI for four children with an adverse neonatal period [24]. The results showed that systematic work with these infants improved their development and reduced the risk of negative neurodevelopmental outcomes. This aligns with our observations, which also highlight the importance of EI for high-risk children.

Data from our study indicate that infants exhibiting cramped synchronized movements in the first weeks of life can benefit from targeted rehabilitation. In particular, we note that children participating in the EI program showed improvements in movement quality within the first-month post-term, emphasizing the importance of early detection and intervention [12, 24].

Several EI programs have been developed and recommended for high-risk infants, including goals activity motor enrichment (GAME), the Small Steps Program, and COPing with and caring for infants with

special needs (COPCA) [12, 17, 25]. For infants at high risk of unilateral cerebral palsy, methods such as constraint-induced movement therapy (baby-CIMT), movement imitation therapy, and hand-arm bimanual intensive therapy are recommended. In particular, movement imitation therapy has been proposed by many authors as an effective EI method that does not require special equipment.

Therefore, the results of both our study and the aforementioned research confirm that EI can significantly impact neurodevelopmental outcomes in infants with an adverse neonatal period. This underscores the necessity of implementing early diagnosis and intervention programs, especially for those at high risk.

5. Conclusion

Early intervention, initiated from birth, influenced the outcome by reducing the risk of severe cases by half, through changes in the variability of pathological movements at early stages.

Early identification of high risk for cerebral palsy, followed by specific early intervention, is essential for optimizing infant neuroplasticity, preventing complications, and enhancing the well-being of parents and caregivers. Currently, there are no early detection and intervention programs in Kazakhstan, making it crucial to recognize early markers of neurological disorders and refer infants in need of neurological support.

This study shows that early diagnosis of neurological issues, combined with rehabilitation approaches such as movement imitation therapy, can significantly improve an infant's development, enhance quality of life, and reduce disease severity. The assessment of general movements in infants may serve as a noninvasive and cost-effective tool in this process.

References

[1] Patel RM. Short- and long-term outcomes for extremely preterm infants. Am J Perinatol. 2016;33(3):318-28, https://doi.org/10.1055/s-0035-1571202

[2] Valdez Sandoval P, Hernández Rosales P, Quiñones Hernández DG, Chavana Naranjo EA, García Navarro V. Intraventricular hemorrhage and posthemorrhagic hydrocephalus in preterm infants: diagnosis, classification, and treatment options. Childs Nerv Syst. 2019;35(6):917-927, https://doi.org/10.1007/s00381-019-04127-x

[3] McGowan EC, Vohr BR. Neurodevelopmental follow-up of preterm infants: what is new? Pediatric Clinics. 2019;66(2):509-523,

[4] Burnett AC, Cheong JLY, Doyle LW. Biological and social influences on the neurodevelopmental outcomes of preterm infants. Clin Perinatol. 2018;45(3):485-500, https://doi.org/10.1016/j.clp.2018.05.005

[5] Spittle AJ, Morgan C, Olsen JE, Novak I, Cheong JLY. Early diagnosis and treatment of cerebral palsy in children with a history of preterm birth. Clin Perinatol. 2018;45(3):409-420, https://doi.org/10.1016/j.clp.2018.05.011

[6] Palmer FB. Strategies for the early diagnosis of cerebral palsy. Journal of Pediatrics. 2004;145(2 SUPPL.):S8-S11, https://doi.org/10.1016/j.jpeds.2004.05.016

[7] Stanojevic M, Perlman JM, Andonotopo W, Kurjak A. From fetal to neonatal behavioral status. Ultrasound Review of Obstetrics and Gynecology. 2004;4(1):59-71, https://doi.org/10.1080/14722240410001713939

[8] Einspieler C, Prechtl HFR. Prechtl's assessment of general movements: A diagnostic tool for the functional assessment of the young nervous system. Mental Retardation and Developmental Disabilities Research Reviews. 2005;11(1):61-67, https://doi.org/10.1002/mrdd.20051

[9] Bosanquet M, Copeland L, Ware R, Boyd R. A systematic review of tests to predict cerebral palsy in young children. Developmental Medicine and Child Neurology. 2013;55(5):418-426, https://doi.org/10.1111/dmcn.12140

[10] Einspieler C, Marschik PB, Bos AF, Ferrari F, Cioni G. Heinz F. R. Prechtl, 1927-2014 crossing the borders. Developmental Psychobiology. 2014;56(7):1609-1611, https://doi.org/10.1002/dev.21255

[11] Einspieler C, Sigafoos J, Bartl-Pokorny KD, Landa R, Marschik PB, Bölte S. Highlighting the first 5 months of life: General movements in infants later diagnosed with autism spectrum disorder or Rett syndrome. Research in Autism Spectrum Disorders. 2014;8(3):286-291, https://doi.org/10.1016/j.rasd.2013.12.013

[12] Novak I, Morgan C, Adde L, Blackman J, Boyd RN, Brunstrom-Hernandez J, et al. Early, accurate diagnosis and early intervention in cerebral palsy: Advances in diagnosis and treatment. JAMA Pediatrics. 2017;171(9):897-907, https://doi.org/10.1001/jamapediatrics.2017.1689

[13] Ferrari F, Cioni G, Prechtl H. Qualitative changes of general movements in preterm infants with brain lesions. Early human development. 1990;23(3):193-231,

[14] Hadders-Algra M. Early diagnostics and early intervention in neurodevelopmental disorders—age-dependent challenges and opportunities. Journal of Clinical Medicine. 2021;10(4):1-24, https://doi.org/10.3390/jcm10040861

[15] Kniaziew-Gomoluch K, Szopa A, Łosień T, Siwiec J, Kidoń Z, Domagalska-Szopa M. Reliability and Repeatability of a Postural Control Test for Preterm Infants. International Journal of Environmental Research and Public Health. 2023;20(3), https://doi.org/10.3390/ijerph20031868

[16] El-Dib M, Massaro AN, Glass P, Aly H. Neurodevelopmental assessment of the newborn: An opportunity for prediction of outcome. Brain and Development. 2011;33(2):95-105, https://doi.org/10.1016/j.braindev.2010.04.004

[17] Morgan C, Novak I, Dale RC, Guzzetta A, Badawi N. GAME (Goals - Activity - Motor Enrichment): Protocol of a single blind randomised controlled trial of motor training, parent education and environmental enrichment for infants at high risk of cerebral palsy. BMC Neurology. 2014;14(1), https://doi.org/10.1186/s12883-014-0203-2

[18] Crowle C, Jackman M, Morgan C. The general movements motor optimality score in high-risk infants: A systematic scoping review. Pediatric Physical Therapy. 2023;35(1):2-26, https://doi.org/10.1097/PEP.0000000000000969

[19] Prechtl HFR. Spontaneous motor activity as a diagnostic tool: Functional assessment of the young nervous system. A Scientific Illustration of Prechtl's Method: GM Trust; 1997.

[20] Prechtl HFR. General movement assessment as a method of developmental neurology: New paradigms and their consequences: The 1999 Ronnie MacKeith Lecture. Developmental Medicine and Child Neurology. 2001;43(12):836-842, https://doi.org/10.1111/j.1469-8749.2001.tb00173.x

[21] Einspieler C, Marschik PB, Pansy J, Scheuchenegger A, Krieber M, Yang H, et al. The general movement optimality score: A detailed assessment of general movements during preterm and term age. Developmental Medicine and Child Neurology. 2016;58(4):361-368, https://doi.org/10.1111/dmcn.12923

[22] Einspieler C, Peharz R, Marschik PB. Fidgety movements–tiny in appearance, but huge in impact. Jornal de Pediatria. 2016;92:64-70,

[23] Einspieler C, Bos AF, Spittle AJ, Bertoncelli N, Burger M, Peyton C, et al. The general movement optimality score-revised (GMOS-R) with socioeconomically stratified percentile ranks. Journal of Clinical Medicine. 2024;13(8):2260,

[24] Soloveichick M, Marschik PB, Gover A, Molad M, Kessel I, Einspieler C. Movement imitation therapy for preterm babies (MIT-PB): A novel approach to improve the neurodevelopmental outcome of infants at high-risk for cerebral palsy. J Dev Phys Disabil. 2020;32(4):587-598, https://doi.org/10.1007/s10882-019-09707-y

[25] Marschik PB, Kwong AKL, Silva N, Olsen JE, Schulte-Rüther M, Bölte S, et al. Mobile solutions for clinical surveillance and evaluation in infancy—general movement apps. Journal of Clinical Medicine. 2023;12(10), https://doi.org/10.3390/jcm12103576