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Efficacy of Neurodevelopmental therapy (NDT) intervention with incorporation of interactive toys in high risk infants: a randomized control trial.

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ABSTRACT

INTRODUCTION: Cerebral palsy (CP) is the most common cause of physical disability in childhood, characterized by a group of permanent disorders affecting movement and posture due to non-progressive disturbances in the developing fetal or infant brain. Current research on neuroplasticity indicates that early, at the crucial stage of brain development, intensive, task-specific intervention should have started. Despite significant advancements in perinatal and neonatal intensive care, preterm infants, especially those requiring NICU admission, remain vulnerable to a host of neurodevelopmental impairments. Timely identification of infants at high risk of CP is critical to enabling early intervention. Several early intervention programs have been developed and tested in recent years. The risk factors necessitate the implementation of structured and culturally sensitive early intervention strategies that begin within the hospital setting and extend into the home environment.

METHODOLOGY: Fifty cases of infants born in Krishna hospital from January 2023 to January 2025 and diagnosed with high risk of cerebral palsy were included in the experimental group and control group. Intervention was performed on the observation group after diagnosis (within seven days of birth), using neurodevelopmental therapy in combination with interventional toys (NDT). Children in the control group underwent intervention after diagnosis using exclusively the neurodevelopmental therapy (NDT). Changes in outcome measure of TIMP and GMOS-R were compared among the experimental group and control group.

RESULTS: At baseline, the Test of Infant Motor Profile (TIMP) and General Motor Optimality Score (GMOS-R) were significantly lower in the experimental and control. At twelve weeks, the TIMP and GMOS-R score showed significant difference between experimental and control ($p < 0.05$). At birth the ratio of normal: poor repertoire: cramped synchronous for the experimental group was 3:18:4 and for the control group 3:20:2. At 12–15 weeks CA the ratio of normal: abnormal fidgety: absent fidgety for the experimental group was 23:1:1 and for the control group 19:5:1. Significant between group differences favored NDT with interventional toys participants at 12 months on TIMP and GMOS-R score.

CONCLUSION: Early diagnosis and NDT with inclusion of toys intervention can significantly accelerate the motor development of infants at high risk of cerebral palsy. Early intervention in neonates promotes better outcome. NDT in combination with interventional toys intervention resulted in advanced motor outcomes when compared with NDT intervention.

KEYWORDS: General Movements; Cramped–Synchronized; Fidgety; Early Intervention, High-Risk Of Cerebral Palsy.

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INTRODUCTION

Cerebral palsy (CP) represents the most prevalent cause of physical disability in childhood and encompasses a group of permanent disorders of movement and posture attributed to non-progressive disturbances in the developing fetal or infant brain[1]. Globally, CP affects approximately 1.6 per 1,000 live births, with a notably higher prevalence among preterm infants[2]. Preterm birth, defined as birth before 37 weeks of gestation, remains a significant global health concern with an estimated incidence of 10.6%, corresponding to around 15 million live births annually[3]. The risk of CP increases inversely with gestational age and birth weight, with extremely preterm infants (<28 weeks) showing CP rates as high as 34.1 per 1,000 live births compared to full-term infants[4]. Despite notable advances in perinatal and neonatal intensive care, preterm infants particularly those requiring admission to neonatal intensive care units (NICUs) remain at heightened risk for a range of neurodevelopmental impairments[5]. These impairments encompass not only cerebral palsy but also deficits in cognition, behavior, and language, collectively imposing a significant burden of lifelong disability[5,6]. The underlying etiology is multifactorial, involving a complex interplay of prenatal, perinatal, and postnatal risk factors, including intraventricular hemorrhage, hypoxic-ischemic encephalopathy, infection, inflammation, and nutritional deficiencies[7]. Among these, white matter injury of the developing brain particularly in the periventricular region is a hallmark feature strongly associated with the later development of CP[4,8].

Preterm infants admitted to NICUs are particularly susceptible to neurodevelopmental disturbances due to the immaturity of their organ systems and the extrauterine environment of care.[6] White matter injury, periventricular leukomalacia, and disturbances in neural connectivity are frequently observed in neuroimaging studies of these infants[7]. The brain during this period is undergoing rapid synaptogenesis, axonal growth, and myelination processes that are vulnerable to systemic instability and environmental insults[9]. Even with survival rates improving globally, especially in high-income countries, the accompanying increase in neurodevelopmental disabilities poses new challenges for healthcare systems and families[4].

Early intervention refers to services and supports provided to infants and toddlers with developmental delays and their families[10]. This approach is predicated on the understanding that the brain exhibits heightened plasticity during the first two years of life, presenting a critical window during which targeted interventions can effectively alter developmental trajectories[11]. Interventions may include physiotherapy, occupational therapy, speech and language support, and family education, often provided through transdisciplinary models of care[12].

In view of the persistent burden of CP among premature infants and the increasing survival of high-risk neonates, early intervention must be positioned as a core component of neonatal and developmental care[12–16]. From the NICU to the home environment, continuity of care through structured programs can address the multifaceted needs of these infants and their families. Interventions that leverage early brain plasticity, prioritize family empowerment, and use evidence-based frameworks can potentially alter developmental trajectories and reduce the lifelong impact of CP.

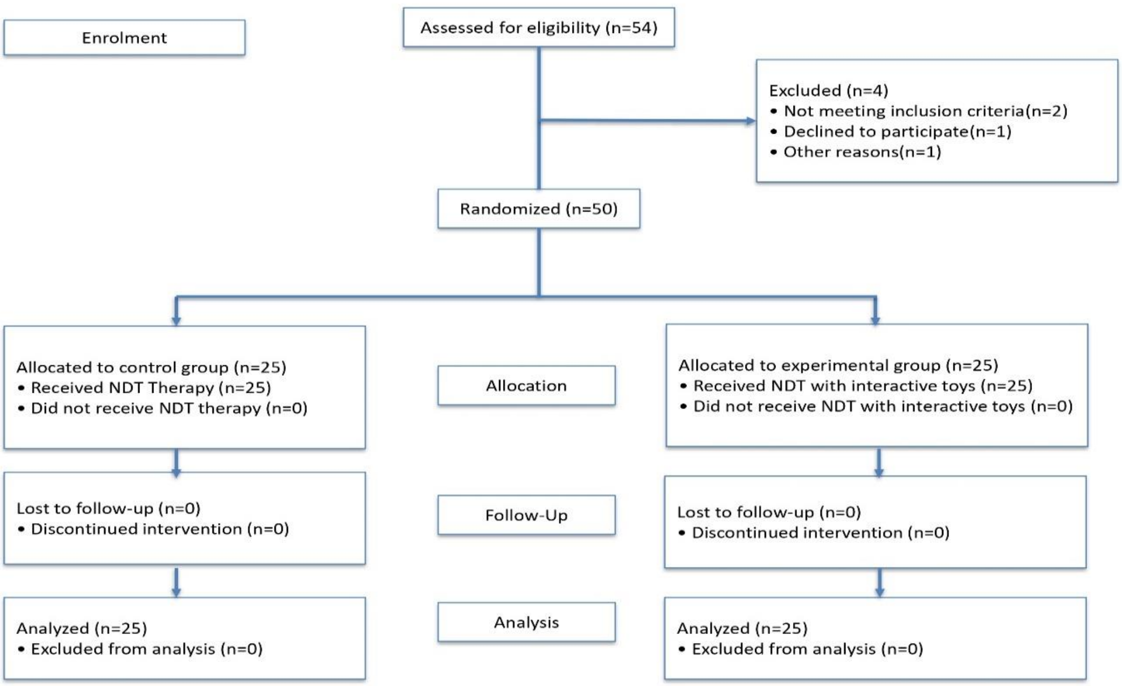
METHODOLOGY

A parallel design randomised control trial with an allocation ratio of 1:1 was conducted from March 2021 to April 2022 in Karad, Maharashtra, India. Approval for the study was obtained from the Krishna Institute of Physiotherapy's Institutional Ethical Committee (KIPT/Sl no. 579, dated 16 July 2021). Participants recruited and included were infants diagnosed with high risk to cerebral palsy by pediatrician, between age group of 0- 6, who were permanent residents of Karad and interested in participating as well as willing to provide written informed consent. Infants with age more than 6 months, history of or diagnosis with any birth defect or congenital abnormality, or who had undergone any surgery in the previous three months, were excluded. All participants provided written informed consent.

A total of 53 infants were enrolled into the study. Among them only 50 infants completed the protocol. They were randomly allocated to receive Neurodevelopmental therapy (control group) or a Neurodevelopmental therapy along with interventional toys (experimental group), for 12 weeks. Details of these interventions are provided in the supplemental material. In addition to these interventions, both groups of parents also received a patient education, which has been shown to improve awareness of benefits of exercise. The experimental group received a combined exercise protocol i.e. NDT with interventional toys. The allocation was performed by a person from an external source who is not involved in the study and using block randomization of varying block sizes to minimize bias. At entry into the study, a baseline evaluation of demographic parameters and outcomes was performed. Motor performance was assessed using the GMOS-R Scale and TIMP. All outcomes were reassessed at the end of 12 weeks.

Sample size was calculated based on the study by Fan et al., aiming to detect a 35.55-meter difference in the TIMP with a 30% attrition rate. The minimum sample size per group was 23, with 80% power and 95% confidence. Data analysis was conducted using SPSS version 22.0, with demographics summarized using descriptive statistics. Paired and unpaired t-tests were used to analyze dependent and independent variables, respectively, following normality testing with the Kolmogorov-Smirnov test.

Figure 1: CONSORT Flowchart



RESULT

A total of 50 high-risk infants were enrolled and evenly distributed into two groups (n=25 each). The baseline characteristics of Group A (NDT with interactive toys) and Group B (NDT only) were comparable (Table 8.1). The mean age was 19.34±16.14 months in Group A and 30.50±13.68 months in Group B. Gender distribution showed a higher proportion of males in Group B (64%) compared to Group A (48%). The mean birth weights were similar between groups (2.60±0.62 kg in Group A and 2.59±0.56 kg in Group B). Common neonatal risk factors included birth asphyxia, convulsions, hypoglycemia, and respiratory distress, with no statistically significant intergroup differences observed in these distributions (Graph 8.2).

In Group A, which received NDT intervention along with interactive toys, there was a statistically significant improvement in motor performance (Table 8.2). The GMOS-R scores increased from 19.28±3.42 to 26.00±3.67 (t=22.60, p<0.0001), and TIMP scores improved from 33.76±10.56 to 48.08±16.11 (t=8.161, p<0.0001). These results indicate a significant enhancement in motor function following the intervention (Graph 8.3).

Similarly, Group B, which received NDT alone, also showed statistically significant improvement, though to a lesser extent (Table 8.3). GMOS-R scores increased from 20.28±3.39 to 23.20±3.23 (t=11.627, p<0.0001), and TIMP scores rose from 34.60±10.40 to 39.36±10.06 (t=5.33, p<0.0001). However, the magnitude of change was smaller compared to Group A (Graph 8.4).

Post-intervention comparisons between the two groups demonstrated that Group A achieved significantly better outcomes than Group B across both motor performance measures (Table 8.4). The post-intervention GMOS-R scores were significantly higher in Group A (26.00±3.67) than in Group B (23.20±3.23), with a t-value of 2.863 and a p-value of 0.0062. TIMP scores were also significantly higher in Group A (48.08±16.11) compared to Group B (39.36±10.06), with a t-value of 2.295 and a p-value of 0.0261 (Graph 8.5).

These findings highlight the superior effectiveness of combining NDT with interactive toys in improving motor performance among high-risk infants, as opposed to NDT alone.

Table No.1- Comparison of baseline characteristics of Experimental group and Control group.

Baseline values	Experimental Group (n=25)	Control Group (n=25)
Age, mean (SD)	19.34±16.14	30.50±13.68
Gender, n%		
Female	13(52)	9(36)
Male	12(48)	16(64)
Birth weight, mean(SD)	2.60±0.62	2.59±0.56
Risk factors, n%		
Birth asphyxia	12	13
Convulsions	7	4
hyperbilirubinemia	2	4
RD	2	5
Hydrocephalus	0	1
Low birth weight	1	0
Meconium Aspiration	2	3
Hypoglycemia	7	4
Intraparenchymal haemorrhage	1	0
Periventricular leucomalacia	1	0

Graph no. 1- Risk factors

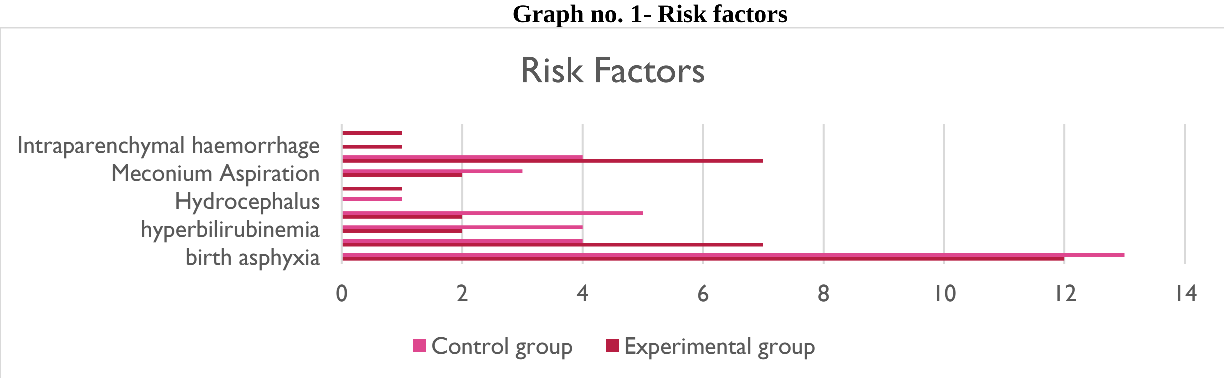


Table No.2– Comparison of pre and post values of outcome measures using paired t test within Experimental group presenting NDT with interventional toys in high risk infant.

Parameters	Outcome Measure	Values of Experimental Group		t - value	p-value
		Pre Mean ±SD	Post Mean±SD		
Motor performance	GMOS-R	19.28±3.42	26.00±3.67	22.60	<0.0001
	TIMP	33.76±10.56	48.08±16.11	8.161	<0.0001

Graph no.2- Comparison of pre and post values of outcome measures using paired t test within Experimental group presenting NDT with interventional toys in high risk infant.

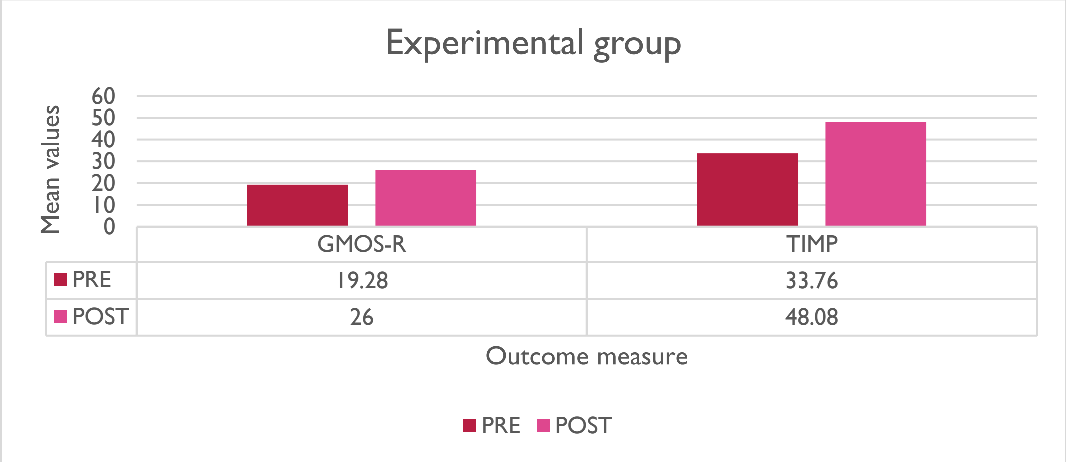


Table no.3- Comparison of pre and post values of outcome measures using paired t test within control group presenting NDT intervention for high risk infant

Parameters	Outcome Measure	Values of Control Group		t - value	p-value
		Pre Mean±SD	Post Mean±SD		
Motor performance	GMOS-R	20.28±3.39	23.20±3.23	11.627	<0.0001
	TIMP	34.60±10.40	39.36±10.06	5.33	<0.0001

Graph No. 3- Comparison of pre and post values of outcome measures using paired t test within control group presenting NDT intervention for high risk infant

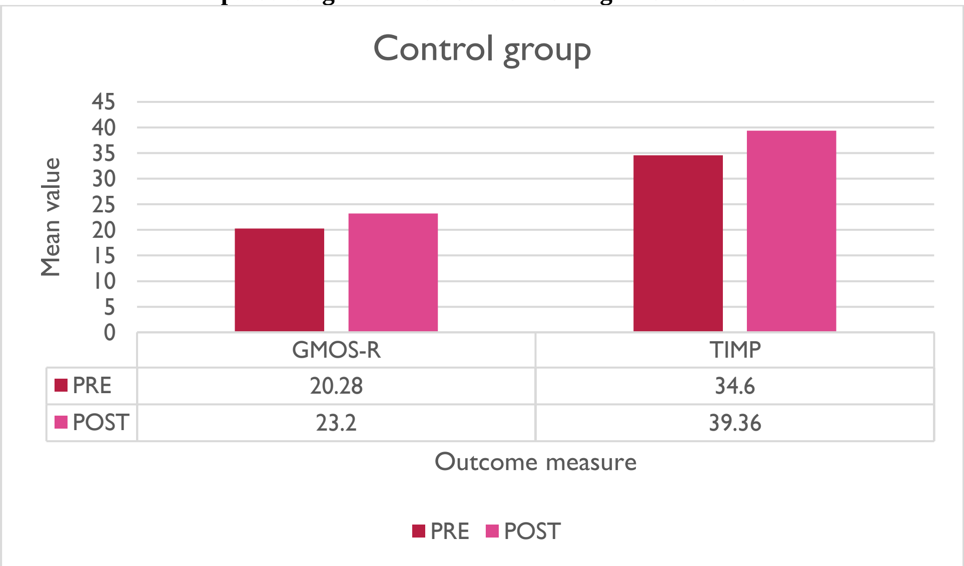
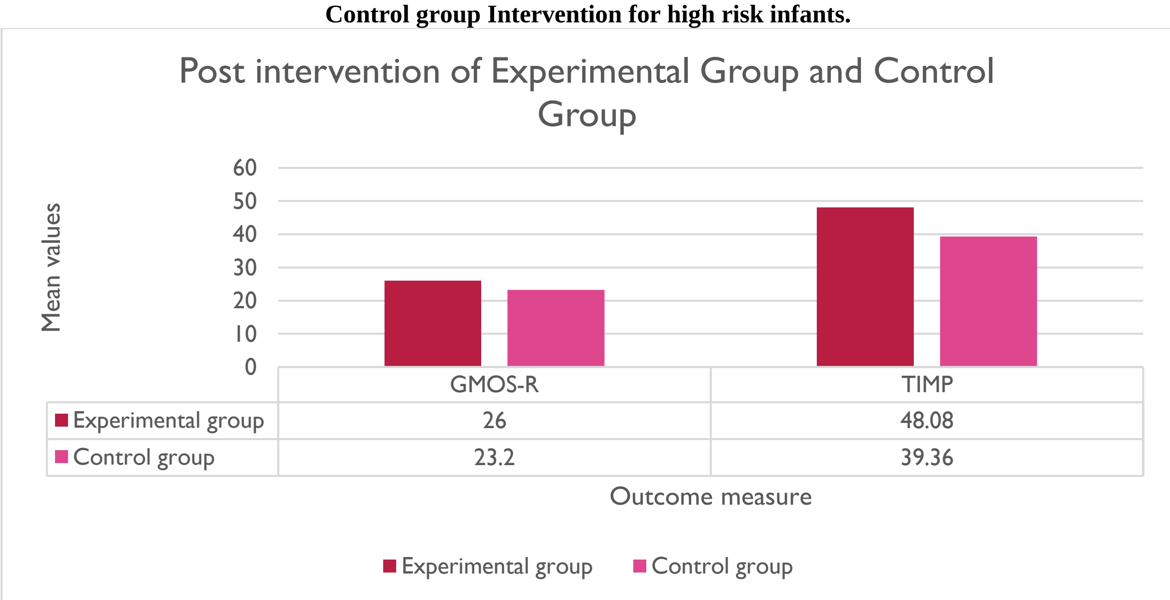


Table no.4– Comparison of post values of outcome measures using an unpaired t test between Experimental Group and Control group Intervention for high risk infants.

Parameters	Outcome Measure	Post Intervention Values		t - value	p-value
		Experimental Group	Control Group		
		Mean ±SD	Mean ±SD		
otor formance	GMOS-R	26.00±3.674	23.20±3.227	2.863	0.0062
	TIMP	48.08±16.11	39.36±10.06	2.295	0.0261

Graph no. 4- Comparison of post values of outcome measures using an unpaired t test between Experimental Group and Control group Intervention for high risk infants.



DISCUSSION

NDT along with interventional toys appears to lead to improved motor outcomes when compared with the similar dose of NDT intervention only. This is evidenced in motor performance outcome measure of TIMP as well as GMOS-R.

In this study, NDT with interventional toys was conducted immediately after diagnosis (within seven days of birth) in the training group. This was compared with the control group, which underwent NDT intervention only after diagnosis (within seven days of birth). The results showed that the scores of TIMP and GMOS-R scale all increased gradually as the infants' monthly age increased. The training group had higher scores than the control group, indicating that early active motor intervention is more beneficial to the development of the motor system and nerves in the infant brain, and promotes normal growth and development of muscle and bone.

In early intervention, TIMP is considered to be an appropriate method for diagnosis of infants who are at risk for developmental delay or disabilities. TIMP is highly sensitive to small changes in motor performance, making it a useful clinical tool for assessing developmental change[17].

Our study found statistically significant improvements in Test of Infant Motor Performance (TIMP) scores following a structured 3-month intervention involving Neurodevelopmental Treatment (NDT) in combination with interventional toys. The intervention targeted infants with birth complications who were classified as high risk for cerebral palsy (CP). The integration of therapist-led NDT and purposeful play appeared to facilitate motor learning by enhancing postural control, movement quality, and engagement core principles of early neurodevelopmental support.

Dos Anjos FR et al.[18] explored the effects of early physical activity and hydrotherapy in preterm infants. Although their study utilized therapeutic techniques, it did not show significant improvement in TIMP scores. This may be attributed to the early timing of their intervention (32–34 weeks PMA), a phase where infants are often not developmentally ready for active engagement in therapy. Moreover, the intervention duration was short, which may have limited its impact. In contrast, our intervention was initiated during early infancy, lasted three months, and included developmentally appropriate stimuli, likely contributing to the more favorable outcomes observed. Letzkus et al.[19] investigated parent-administered multimodal interventions in very low birthweight infants. Despite the emphasis on family involvement, the study reported no significant changes in TIMP scores. The delivery of interventions by caregivers who may vary in technique and consistency could have influenced the outcomes. Unlike their model, our study involved therapist-guided sessions, ensuring correct NDT handling, structured facilitation, and tailored toy use to encourage purposeful movement. This professional oversight and standardization may explain the superior motor gains in our findings. Dusing et al.[9] conducted a pilot randomized controlled trial evaluating a play-based developmental intervention during the transition from NICU to home. Although they noted positive trends in motor development, TIMP score improvements did not reach statistical significance. Their study involved shorter duration and a smaller sample size, and focused on play-based exploration without therapeutic handling. In contrast, our intervention not only used toys but also integrated NDT techniques, emphasizing specific postural transitions and guided motor activities. This combination may have provided a stronger developmental stimulus, resulting in more pronounced improvements. Norman et al.[20] provided a retrospective analysis identifying perinatal risk factors associated with low TIMP scores in preterm infants. Although not interventional, their findings underscore the vulnerability of certain infants and the importance of early assessment. Our study complements theirs by demonstrating that timely intervention in similarly high-risk infants can significantly improve motor outcomes. This supports the notion that early identification must be followed by action, and that tools like TIMP can effectively guide and evaluate such efforts.

The combination of NDT and interventional toys appears to be a powerful approach for enhancing early motor development in high-risk infants. NDT techniques provide the foundational postural support and movement facilitation, while toys encourage motivation, purposeful interaction, and active exploration[21–23]. This synergy likely supports both neuroplastic adaptation and behavioral engagement, leading to more meaningful and lasting motor progress[22].

This study also reaffirms the TIMP's value not just as a predictive assessment, but as a sensitive tool to monitor intervention outcomes. It captures subtle yet clinically relevant changes in motor performance, making it highly suitable for both research and clinical settings.

Our study found that, in addition to significant improvements in TIMP scores, participants also showed notable gains in the General Movement Optimality Score-Revised (GMOS-R), with many infants demonstrating normal fidgety movements by the 3-month follow-up. This outcome is especially encouraging given the high-risk status of the sample infants with birth complications who were considered at elevated risk for cerebral palsy (CP). The improvements in GMOS-R reinforce the effectiveness of our intervention, which combined Neurodevelopmental Treatment (NDT) techniques with the use of interventional toys, emphasizing structured, therapist-led motor facilitation and enriched sensory engagement.

The GMOS-R is a validated tool that evaluates the quality of general movements and is considered highly predictive of neurodevelopmental outcomes, particularly CP[24]. Improvements in GMOS-R especially the emergence of normal fidgety movements are associated with more favorable motor trajectories[25]. In our study, the intervention may have supported the neuromotor substrates underlying general movement patterns by enhancing postural control, initiating spontaneous movement sequences, and fostering symmetrical limb use key goals of both NDT and the GMOS-R framework[26].

Our findings are consistent with recent literature emphasizing the importance of early intervention for improving GMOS-R scores. For instance, a 2023 prospective study assessing preterm infants (≤32 weeks gestation) found that early, individualized intervention based on GMOS-R screening was associated with improved developmental outcomes at one year[26]. While that study utilized parent-guided home programs with professional supervision[27], our study's use of direct therapist involvement in delivering NDT and guided toy interaction likely contributed to more consistent and intensive stimulation, potentially accounting for the robust gains in motor performance.

Unlike some previous interventional studies using GMOS-R[25], which focused primarily on home-based caregiver training, our structured in-clinic approach allowed for more controlled application of motor learning principles. This included hands-on facilitation of transitions (e.g., supine to prone)[27], guided midline orientation, and active exploration with toys[28], all of which may contribute to the emergence and refinement of general movements, particularly the highly predictive fidgety movements seen at 3 months[29].

Moreover, the presence of normal fidgety movements post-intervention supports the idea that targeted therapies can influence not only functional skill acquisition but also underlying neuromotor organization[30], which is what GMOS-R aims to capture. The observed improvements highlight the potential for therapeutic input to shift developmental trajectories in high-risk infants, potentially reducing long-term motor impairments[22].

Although there is a growing body of research using the GMOS-R as a diagnostic or predictive tool, its use in interventional studies remains limited. Therefore, our study contributes meaningfully to this emerging field by demonstrating that GMOS-R can serve not only as a prognostic marker but also as a sensitive outcome measure for early motor interventions. Our findings suggest that interventions aimed at improving general movement quality especially those involving active handling and engagement can be effective in optimizing early motor patterns in at-risk populations.

This study explored the effectiveness of a structured, therapist-led early intervention combining Neurodevelopmental Treatment (NDT) with interventional toys in infants at high risk for cerebral palsy due to birth complications. Over the course of three months, the intervention led to statistically significant improvements in both the Test of Infant Motor Performance (TIMP) and the General Movement Optimality Score-Revised (GMOS-R), indicating enhanced motor control and improved neuromotor integrity.

The significant improvement in TIMP scores aligns with findings from Dusing et al. (2018)[9], who demonstrated better motor and developmental outcomes in high-risk infants receiving early developmental support compared to usual care. However, Dusing's intervention was more home-based and exploratory, whereas our intervention was structured and therapist-driven, possibly contributing to more consistent motor gains across participants. Similarly, Letzkus et al. (2021)[19] reported that early motor-focused interventions in preterm infants were associated with improved motor scores, reinforcing the importance of intervention during sensitive periods of neuroplasticity which supports the positive direction of our findings.

Our study also adds to the growing body of evidence on the importance of qualitative motor assessment. The significant changes in GMOS-R scores, including normalization of fidgety movements in a substantial portion of participants, reflect positive changes in the quality and complexity of spontaneous movements[30]. This aligns with findings by Fan et al. (2021)[31], who showed that even a single session of physiotherapy can enhance the quality of general movements in high-risk neonates. Our results extend these findings by demonstrating that a longer, more intensive intervention yields sustained and more pronounced changes in general movement patterns. Moreover, Dos Anjos et al. (2022)[18] and Letzkus et al. (2024)[19] emphasized the importance of sensory-motor stimulation and caregiver involvement in promoting development in preterm infants. While those studies focused on caregiver-led or multi-sensory approaches, our findings highlight that clinician-administered NDT combined with engaging toys can also effectively stimulate the sensorimotor systems of high-risk infants. Importantly, our study shares common ground with Hyun et al. (2023)[32], who demonstrated that a parent-administered sensorimotor intervention (PASI) improved oral feeding performance and TIMP scores in preterm infants. Although their intervention focused on oral-motor coordination and was caregiver-driven, both studies reinforce that early sensorimotor stimulation—whether delivered by parents or therapists—can have a measurable impact on motor development. Our study further adds the dimension of qualitative motor evaluation through GMOS-R, providing a more holistic understanding of neuromotor progress.

Taken together, the improvements observed in both quantitative (TIMP) and qualitative (GMOS-R) motor outcomes reinforce the value of comprehensive early intervention programs. The dual approach of structured handling (via NDT) and purposeful motor exploration (via toys) likely provided enriched sensory and motor experiences that facilitated neuroplastic changes during a critical developmental window[33].

Studies have shown that infants with cystic periventricular leukomalacia have an ~85% chance of being diagnosed with cerebral palsy, while infants with a term stroke have a chance of about 30%[34]. This indicates that infants at high risk of cerebral palsy have a high risk of developmental impairment, and that early intervention is essential. In early childhood, when brain plasticity is at its peak, many of these infants respond well to intervention[7], which can maximize developmental trajectory changes up to adulthood[35]. However, in most clinical settings, the average age of diagnosis of cerebral palsy is two years or later[36]. Thus, many children do not receive ultra-early intervention. Even where early diagnosis is possible, early intervention remains a significant challenge for many parents. Children under three years of age are at the most consequential stages of brain development. The earlier the intervention, the better the clinical effect[37]. Therefore, clinicians must endeavour to diagnose children who show clinical characteristics of cerebral palsy, and who are at high risk of cerebral palsy, before the age of one. If early adverse factors negatively impact the infant's brain, these negative consequences can most effectively be averted in early life[38].

Infants with CP continue to develop and "gain" raw score points over time, but are not expected to perform within the "normal range" but rather fall further behind peers over time[39]. On average NDT with interventional toys participants, did not fall as far behind as those in NDT only in this study implying that characteristics of adding interventional toys could be "protective". Preterm infants may experience various negative consequences, such as cognitive, motor, language, and social impairments[40–42], and their natural developmental trajectory may lag behind that of full-term infants[43,44].

In these efforts, parental education and guidance is essential. Parents' active participation and mastery of the key points of NDT operation leads to significant improvement in the quality of neonatal exercise training[45]. Parent and caregiver teaching is a primary role of therapists in the NICU. Research on educating parents to interpret the meaning of their infant's behavioral cues and developmental status has been shown to reduce parental stress and improve parental mental health[46].

CONCLUSION

The study highlights the effectiveness of combining hands-on therapeutic handling with purposeful play in supporting both the quantitative and qualitative aspects of early motor development. The improvements in TIMP scores reflect gains in postural control and functional movement, while the normalization of GMOS-R scores suggests enhanced neuromotor organization and developmental trajectory. This dual-outcome approach not only strengthens the evidence for early intervention in high-risk infants but also supports the use of both TIMP and GMOS-R as complementary tools for assessing therapeutic impact. In a landscape where early detection and intervention are critical, this study adds valuable insight into how targeted therapies can influence developmental outcomes during a sensitive period of brain plasticity.

LIMITATIONS

The study was short termed and follow-up was not conducted after 12 weeks to determine the diagnosis of the Cerebral Palsy.

RECOMMENDATION

Future research should aim to validate these findings in larger cohorts, explore long-term functional outcomes, and investigate how caregiver involvement and home-based components can be integrated with professional-led programs to maximize developmental gains.

REFERENCES

1. Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy, April 2005. *Dev Med Child Neurol*. 2005;47(8):571-576. doi:10.1017/S001216220500112X
2. Smithers-Sheedy H, McIntyre S, Gibson C, et al. A special supplement: findings from the Australian Cerebral Palsy Register, birth years 1993 to 2006. *Dev Med Child Neurol*. 2016;58(S2):5-10. doi:10.1111/dmcn.13026
3. Chawanpaiboon S, Vogel JP, Moller AB, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37-e46. doi:10.1016/S2214-109X(18)30451-0
4. Colaizy TT, Poindexter BB, McDonald SA, et al. Neurodevelopmental Outcomes of Extremely Preterm Infants Fed Donor Milk or Preterm Infant Formula: A Randomized Clinical Trial. *JAMA*. 2024;331(7):582. doi:10.1001/jama.2023.27693
5. Pascal A, Govaert P, Oostra A, Naulaers G, Ortibus E, Van Den Broeck C. Neurodevelopmental outcome in very preterm and very-low-birthweight infants born over the past decade: a meta-analytic review. *Dev Med Child Neurol*. 2018;60(4):342-355. doi:10.1111/dmcn.13675
6. Rogers EE, Hintz SR. Early neurodevelopmental outcomes of extremely preterm infants. *Semin Perinatol*. 2016;40(8):497-509. doi:10.1053/j.semperi.2016.09.002
7. Johnston MV, Ishida A, Ishida WN, Matsushita HB, Nishimura A, Tsuji M. Plasticity and injury in the developing brain. *Brain Dev*. 2009;31(1):1-10. doi:10.1016/j.braindev.2008.03.014
8. Chung EH, Chou J, Brown KA. Neurodevelopmental outcomes of preterm infants: a recent literature review. *Transl Pediatr*. 2020;9(S1):S3-S8. doi:10.21037/tp.2019.09.10
9. Dusing SC, Tripathi T, Marcinowski EC, Thacker LR, Brown LF, Hendricks-Muñoz KD. Supporting play exploration and early developmental intervention versus usual care to enhance development outcomes during the transition from the neonatal intensive care unit to home: a pilot randomized controlled trial. *BMC Pediatr*. 2018;18(1):46. doi:10.1186/s12887-018-1011-4
10. Guralnick MJ. Early Intervention for Children with Intellectual Disabilities: Current Knowledge and Future Prospects*. *J Appl Res Intellect Disabil*. 2005;18(4):313-324. doi:10.1111/j.1468-3148.2005.00270.x
11. Anderson V, Spencer-Smith M, Wood A. Do children really recover better? Neurobehavioural plasticity after early brain insult. *Brain*. 2011;134(8):2197-2221. doi:10.1093/brain/awr103
12. Puthussery S, Chutiyami M, Tseng PC, Kilby L, Kapadia J. Effectiveness of early intervention programs for parents of preterm infants: a meta-review of systematic reviews. *BMC Pediatr*. 2018;18(1):223. doi:10.1186/s12887-018-1205-9
13. Morgan C, Novak I, Dale RC, Guzzetta A, Badawi N. Single blind randomised controlled trial of GAME (Goals Activity Motor Enrichment) in infants at high risk of cerebral palsy. *Res Dev Disabil*. 2016;55:256-267. doi:10.1016/j.ridd.2016.04.005
14. Chattopadhyay N. Home-based Early Intervention for Children with Neurodevelopmental Disorders by Community Therapy Providers Supported by a Specialized Mobile Application in Purulia, West Bengal. *Indian Pediatr Case Rep*. 2022;2(2):68-72. doi:10.4103/ipcares.ipcares_67_22
15. Song IG. Neurodevelopmental outcomes of preterm infants. *Clin Exp Pediatr*. 2023;66(7):281-287. doi:10.3345/cep.2022.00822
16. Novak I, Morgan C, Adde L, et al. Early, Accurate Diagnosis and Early Intervention in Cerebral Palsy: Advances in Diagnosis and Treatment. *JAMA Pediatr*. 2017;171(9):897. doi:10.1001/jamapediatrics.2017.1689
17. Kim SA, Lee YJ, Lee YG. Predictive Value of Test of Infant Motor Performance for Infants based on Correlation between TIMP and Bayley Scales of Infant Development. *Ann Rehabil Med*. 2011;35(6):860. doi:10.5535/arm.2011.35.6.860
18. Dos Anjos FR, Nakato AM, Hembecker PK, Nohama P, Sarquis ALF. Effects of hydrotherapy and tactile-kinesthetic stimulation on weight gain of preterm infants admitted in the Neonatal Intensive Care Unit. *J Pediatr (Rio J)*. 2022;98(2):155-160. doi:10.1016/j.jped.2021.04.011
19. Letzkus L, Conaway M, Daugherty R, Hook M, Zanelli S. A randomized-controlled trial of parent-administered interventions to improve short-term motor outcomes in hospitalized very low birthweight infants. *J Neonatal-Perinat Med*. 2024;17(5):637-645. doi:10.3233/NPM-230206
20. Norman M, Nilsson D, Trygg J, Håkansson S. Perinatal risk factors for mortality in very preterm infants—A nationwide, population-based discriminant analysis. *Acta Paediatr*. 2022;111(8):1526-1535. doi:10.1111/apa.16356
21. Blauw-Hospers CH, Hadders-Algra M. A systematic review of the effects of early intervention on motor development. *Dev Med Child Neurol*. 2005;47(6):421-432. doi:10.1017/S0012162205000824
22. Hadders-Algra M. Early Diagnosis and Early Intervention in Cerebral Palsy. *Front Neurol*. 2014;5. doi:10.3389/fneur.2014.00185
23. Lobo MA, Galloway JC. Enhanced Handling and Positioning in Early Infancy Advances Development Throughout the First Year. *Child Dev*. 2012;83(4):1290-1302. doi:10.1111/j.1467-8624.2012.01772.x
24. Prechtl HFR. General movement assessment as a method of developmental neurology: new paradigms and their consequences The 1999 Ronnie MacKeith Lecture. *Dev Med Child Neurol*. 2001;43(12):836. doi:10.1017/S0012162201001529
25. Ustad T, Fjørtoft T, Øberg GK. General movement optimality score and general movements trajectories following early parent-administrated physiotherapy in the neonatal intensive care unit. *Early Hum Dev*. 2021;163:105488. doi:10.1016/j.earlhumdev.2021.105488

26. Morgan C, Fetters L, Adde L, et al. Early Intervention for Children Aged 0 to 2 Years With or at High Risk of Cerebral Palsy: International Clinical Practice Guideline Based on Systematic Reviews. *JAMA Pediatr*. 2021;175(8):846. doi:10.1001/jamapediatrics.2021.0878
27. Harbourne RT, Willett S, Kyvelidou A, Deffeyes J, Stergiou N. A Comparison of Interventions for Children With Cerebral Palsy to Improve Sitting Postural Control: A Clinical Trial. *Phys Ther*. 2010;90(12):1881-1898. doi:10.2522/ptj.2010132
28. Bhat AN, Galloway JC. Toy-oriented changes during early arm movements: Hand kinematics. *Infant Behav Dev*. 2006;29(3):358-372. doi:10.1016/j.infbeh.2006.01.005
29. Einspieler C, Bos AF, Krieber-Tomantschger M, et al. Cerebral Palsy: Early Markers of Clinical Phenotype and Functional Outcome. *J Clin Med*. 2019;8(10):1616. doi:10.3390/jcm8101616
30. Einspieler C, Bos AF, Libertus ME, Marschik PB. The General Movement Assessment Helps Us to Identify Preterm Infants at Risk for Cognitive Dysfunction. *Front Psychol*. 2016;7:406. doi:10.3389/fpsyg.2016.00406
31. Fan J, Wang J, Zhang X, et al. A home-based, post-discharge early intervention program promotes motor development and physical growth in the early preterm infants: a prospective, randomized controlled trial. *BMC Pediatr*. 2021;21(1):162. doi:10.1186/s12887-021-02627-x
32. Hyun SE, Kwon JY, Hong BY, et al. Early Neurodevelopmental Assessments of Neonates Discharged From the Neonatal Intensive Care Unit: A Physiatrist’s Perspective. *Ann Rehabil Med*. 2023;47(3):147-161. doi:10.5535/arm.23038
33. Morgan C, Novak I, Badawi N. Enriched Environments and Motor Outcomes in Cerebral Palsy: Systematic Review and Meta-analysis. *Pediatrics*. 2013;132(3):e735-e746. doi:10.1542/peds.2012-3985
34. Volpe JJ. Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *Lancet Neurol*. 2009;8(1):110-124. doi:10.1016/S1474-4422(08)70294-1
35. Kolb B, Gibb R. Brain plasticity and behaviour in the developing brain. *J Can Acad Child Adolesc Psychiatry J Acad Can Psychiatr Enfant Adolesc*. 2011;20(4):265-276.
36. McIntyre S, Morgan C, Walker K, Novak I. Cerebral Palsy—Don’t Delay. *Dev Disabil Res Rev*. 2011;17(2):114-129. doi:10.1002/ddrr.1106
37. Morgan C, Novak I, Dale RC, Badawi N. Optimising motor learning in infants at high risk of cerebral palsy: a pilot study. *BMC Pediatr*. 2015;15(1):30. doi:10.1186/s12887-015-0347-2
38. Burstein O, Zevin Z, Geva R. Preterm Birth and the Development of Visual Attention During the First 2 Years of Life: A Systematic Review and Meta-analysis. *JAMA Netw Open*. 2021;4(3):e213687. doi:10.1001/jamanetworkopen.2021.3687
39. Rosenbaum PL, Walter SD, Hanna SE, et al. Prognosis for Gross Motor Function in Cerebral Palsy: Creation of Motor Development Curves. *JAMA*. 2002;288(11):1357. doi:10.1001/jama.288.11.1357
40. Aylward GP. Neurodevelopmental Outcomes of Infants Born Prematurely. *J Dev Behav Pediatr*. 2014;35(6):394-407. doi:10.1097/01.DBP.0000452240.39511.d4
41. Tsai AJ, Lasky RE, John SD, Evans PW, Kennedy KA. Predictors of neurodevelopmental outcomes in preterm infants with intraparenchymal hemorrhage. *J Perinatol*. 2014;34(5):399-404. doi:10.1038/jp.2014.21
42. Linsell L, Johnson S, Wolke D, et al. Cognitive trajectories from infancy to early adulthood following birth before 26 weeks of gestation: a prospective, population-based cohort study. *Arch Dis Child*. 2018;103(4):363-370. doi:10.1136/archdischild-2017-313414
43. Allen MC. Neurodevelopmental outcomes of preterm infants. *Curr Opin Neurol*. 2008;21(2):123-128. doi:10.1097/WCO.0b013e3282f88bb4
44. Meijer EJ, Hermans KHM, Zwanenburg A, et al. Functional connectivity in preterm infants derived from EEG coherence analysis. *Eur J Paediatr Neurol*. 2014;18(6):780-789. doi:10.1016/j.ejpn.2014.08.003
45. Sant N, Hotwani R, Palaskar P, Naqvi WM, Arora SP. Effectiveness of Early Physiotherapy in an Infant With a High Risk of Developmental Delay. *Cureus*. Published online July 23, 2021. doi:10.7759/cureus.16581
46. Aita M, De Clifford Faugère G, Lavallée A, et al. Effectiveness of interventions on early neurodevelopment of preterm infants: a systematic review and meta-analysis. *BMC Pediatr*. 2021;21(1):210. doi:10.1186/s12887-021-02559-6