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Original Research Article

Early Detection of Cerebral Palsy in Infants and Young Children Using the Denver Developmental Screening Test (DDST-II): A Hospital-Based Prospective Observational Study from Eastern India

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Abstract

Background: Cerebral palsy (CP) is a leading cause of childhood motor disability, and earlier identification enables timely referral to targeted early intervention during peak neuroplasticity. In many low- and middle-resource settings, access to specialized tools (e.g., General Movements Assessment or structured neurological examinations) may be limited, increasing the importance of feasible developmental screening approaches in routine pediatric services.

Aim: To evaluate the clinical utility and diagnostic performance of DDST-II for early detection of CP among infants and young children attending a tertiary-care teaching hospital.

Methods: This prospective observational study enrolled 115 infants/young children (0–24 months) attending pediatric services at Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India, between 25 February 2025 and 30 January 2026. DDST-II screening was performed by trained examiners across four domains. "Suspect/Untestable" screens were considered positive. CP diagnosis was confirmed by pediatric neurology assessment with supportive clinical/imaging correlation where available. Diagnostic indices and multivariable logistic regression were performed.

Results: CP was confirmed in 28/115 (24.3%) children. DDST-II screen positivity was observed in 40/115 (34.8%). Screen positivity demonstrated sensitivity 85.7%, specificity 81.6%, PPV 60.0%, and NPV 94.7% for CP detection. Gross motor delay predominated among CP cases (Figure 1). In multivariable analysis, NICU admission, low birth weight, neonatal seizures, and birth asphyxia were independently associated with CP (Table 4).

Conclusion: DDST-II, when integrated into a structured referral pathway, showed high sensitivity and strong rule-out value (high NPV) for CP detection. In resource-constrained settings, DDST-II can support earlier identification of high-risk children and prompt referral for confirmatory assessment and early intervention.

Keywords: Cerebral palsy; DDST-II; developmental screening; early diagnosis; infants.

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Introduction

Cerebral palsy (CP) represents a group of permanent disorders of movement and posture attributed to non-progressive disturbances in the developing fetal or infant brain, frequently accompanied by disturbances of sensation, cognition, communication, and behavior. Although the brain injury is non-progressive, the clinical manifestations evolve over time as the child develops, which historically contributed to delayed recognition and a later age at diagnosis in many health systems. Contemporary evidence emphasizes that earlier diagnosis is both achievable and clinically meaningful because early intervention can leverage heightened neuroplasticity during infancy and improve functional outcomes, participation, and family-centered goal attainment [1,3,7]. The global movement toward early identification of CP has been shaped by international consensus guidance that prioritizes systematic assessment pathways

based on risk stratification and age-specific tools. The 2017 international clinical practice guideline recommends combinations of neuroimaging, structured neurological examination, and age-appropriate motor assessments to support early detection of CP, particularly in high-risk infants [1]. However, implementation remains uneven, especially in low- and middle-resource contexts where access to specialized assessments, pediatric neurology workforce, standardized imaging pathways, and longitudinal follow-up infrastructure can be limited [2]. As a consequence, many children still receive diagnosis after the first year of life, and referral to early intervention may be delayed—precisely when intervention intensity and timing could be most advantageous [3,7].

Routine developmental surveillance and standardized screening are widely recommended components of pediatric preventive care, intended to identify children who may benefit from further evaluation and early support. Professional bodies recommend ongoing developmental surveillance at every health supervision visit, combined with validated developmental screening at defined ages in early childhood to identify developmental delays and disabilities promptly [4,10]. In clinical environments where referral pathways are constrained, a pragmatic screening tool that can be administered by trained pediatric staff and integrated within outpatient or immunization clinic workflows may facilitate earlier suspicion and triage for confirmatory evaluation. The Denver Developmental Screening Test, revised as Denver II / DDST-II, is a well-known screening instrument designed for children from birth to 6 years, covering four developmental domains: personal-social, fine motor-adaptive, language, and gross motor. DDST-II does not provide a definitive diagnosis but flags "suspect" performance patterns requiring further evaluation. Multiple studies have reported acceptable reliability and validity across populations, and the tool remains in use globally due to its feasibility, modest time requirement, and domain-based output that helps clinicians communicate concerns and plan referrals [5,8,16]. Notwithstanding these strengths, evidence for DDST-II specifically as a practical screening approach for early CP detection in routine tertiary-care pediatric services—especially in Indian settings—remains limited, and diagnostic performance may vary with case-mix, age at screening, and examiner training. CP early detection frameworks increasingly highlight specialized assessments such as General Movements Assessment and the Hammersmith Infant Neurological Examination because of their strong predictive validity in early infancy, particularly in high-risk cohorts [1,9]. Yet these tools require additional training, standardized scoring, and in some cases specific corrected age windows. Therefore, DDST-II may represent a pragmatic complementary approach in busy clinics: it can identify multi-domain developmental delay patterns, particularly gross and fine motor delays, that warrant expedited neurological assessment. In settings where infants present late or where developmental concerns are first raised by caregivers, a feasible screening tool may reduce missed opportunities for early referral.

The present study was conducted at Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India—a tertiary-care teaching hospital catering to a large catchment with varied perinatal risk profiles.

We hypothesized that DDST-II, implemented with standardized examiner training and integrated referral criteria, could support early suspicion of CP with clinically useful diagnostic indices. Accordingly, our primary objective was to evaluate the diagnostic performance of DDST-II screen positivity in detecting CP in infants and young children attending pediatric services. Secondary objectives included describing domain-specific delay patterns among screen-positive children and identifying clinical predictors associated with CP within the study cohort, thereby informing a context-appropriate early detection pathway [1,2,4].

Materials and Methods

Study Design and Setting: This prospective observational study was conducted in the pediatric services of Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India, over the period 25 February 2025 to 30 January 2026.

Participants and Eligibility: Infants and young children aged 0–24 months attending outpatient clinics and/or referred from neonatal follow-up services were eligible. Children with major congenital anomalies incompatible with DDST-II administration, progressive neurodegenerative disorders, or severe acute illness precluding assessment were excluded. A total of 115 participants were enrolled through consecutive sampling after caregiver consent.

Screening Tool and Procedure (DDST-II): DDST-II was administered by trained pediatric clinicians/therapists using age-adjusted items across four domains (gross motor, fine motor-adaptive, language, personal-social). Standard DDST-II scoring rules were followed. The screening outcome was categorized as Normal, Suspect, or Untestable. For diagnostic-performance analysis, Suspect/Untestable was treated as screen-positive, reflecting a need for expedited diagnostic evaluation.

Reference Standard: CP diagnosis was confirmed by pediatric neurology/experienced pediatric

clinician assessment based on history, standardized neurological examination, abnormal tone/reflex/posture patterns, motor milestone delay, and evolving motor phenotype over follow-up, with supportive neuroimaging when clinically indicated, consistent with early detection guidance emphasizing structured confirmation pathways [1,7]. Children without CP either had typical development or non-CP developmental concerns and were managed as per standard care with appropriate referrals.

Variables and outcomes: The primary outcome was confirmed CP (yes/no). Secondary outcomes included DDST-II domain delay patterns among screen-positive children and associations between CP and perinatal/neonatal risk factors (preterm birth, low birth weight, NICU admission, birth asphyxia, neonatal seizures, etc.).

Statistical Analysis: Categorical variables were summarized as frequency and percentage; continuous variables as mean ± standard deviation. DDST-II diagnostic indices (sensitivity, specificity, PPV, NPV, accuracy, likelihood ratios) were calculated using 2×2 contingency tables. Multivariable logistic regression was performed to estimate adjusted odds ratios (aOR) with 95% confidence intervals for selected clinically relevant predictors. A p value <0.05 was considered statistically significant.

Result

Table 1 presents the baseline demographic profile and perinatal risk factors of the 115 enrolled infants and young children, stratified by confirmed cerebral palsy (CP) status. The mean age at screening was similar between CP and non-CP groups (approximately 10 months). A slightly higher proportion of males was observed in the CP group. Perinatal risk factors such as low birth weight, NICU admission, neonatal seizures, birth asphyxia, and CNS infection were notably more frequent among children later diagnosed with CP compared with those without CP. These findings highlight the strong association between adverse neonatal events and the subsequent development of cerebral palsy in the study cohort.

Table 1: Baseline demographic and perinatal characteristics of study participants

Characteristic	CP (n=28)	No CP (n=87)
Age at screening (months), mean ± SD	10.1 ± 3.9	10.1 ± 4.1
Male sex	17 (60.7%)	48 (55.2%)
Preterm birth	13 (46.4%)	29 (33.3%)
Low birth weight (<2.5 kg)	19 (67.9%)	16 (18.4%)
NICU admission	20 (71.4%)	13 (14.9%)
Birth asphyxia (documented)	6 (21.4%)	4 (4.6%)
Neonatal seizures	7 (25.0%)	1 (1.1%)
Significant hyperbilirubinemia	4 (14.3%)	16 (18.4%)
CNS infection (neonatal/infant)	5 (17.9%)	3 (3.4%)

Table 2A summarizes the classification of children based on DDST-II screening outcomes (Normal, Suspect, and Untestable) in relation to confirmed cerebral palsy (CP). The majority of children without CP demonstrated normal DDST-II results, whereas most children later diagnosed with CP were categorized as suspect on screening. Only a very small proportion of participants were classified as untestable. This distribution indicates that DDST-II suspect findings were markedly more frequent among children with CP, supporting the usefulness of DDST-II as an initial screening tool for identifying infants and young children who require further neurological evaluation.

Table 2A: Distribution of DDST-II screening results according to cerebral palsy status

DDST-II classification	No CP	CP
Normal	71	4
Suspect	15	23
Untestable	1	1
Total	87	28

Table 2B presents the distribution of developmental delays across the four DDST-II domains among children who screened positive (suspect or untestable). Gross motor delay was the most frequent abnormality among children with confirmed cerebral palsy, followed by delays in the fine motor-adaptive domain. In contrast, children without CP who screened positive showed comparatively higher proportions of language delays. Personal-social delays were observed in smaller proportions in both groups. These findings suggest that gross motor impairment is the predominant developmental deficit associated with cerebral palsy, while language delays may

contribute to false-positive screening results in non-CP children.

Table 2B: Domain-specific developmental delays among screen-positive children

Domain with delay (among screen-positive)	CP (n=24)	No CP (n=16)
Gross motor	20 (83.3%)	1 (6.2%)
Fine motor-adaptive	13 (54.2%)	5 (31.2%)
Language	7 (29.2%)	8 (50.0%)
Personal-social	6 (25.0%)	3 (18.8%)

Table 3 summarizes the diagnostic accuracy of DDST-II screening for identifying cerebral palsy in the study population. When suspect or untestable results were considered screen-positive, DDST-II demonstrated high sensitivity and good specificity, indicating that the test was effective in identifying most children who were later diagnosed with cerebral palsy while correctly classifying a large proportion of children without the condition. The high negative predictive value suggests that children with a normal DDST-II result were unlikely to have cerebral palsy. Overall, these findings indicate that DDST-II is a useful early screening tool for detecting children at risk of cerebral palsy who require further neurological assessment and early intervention.

Table 3: Diagnostic performance of DDST-II for detection of cerebral palsy

Measure	Estimate
Sensitivity	85.7%
Specificity	81.6%
Positive predictive value (PPV)	60.0%
Negative predictive value (NPV)	94.7%
Overall accuracy	82.6%
Likelihood ratio (LR+)	4.66
Likelihood ratio (LR-)	0.18

Table 4 presents the results of multivariable logistic regression analysis evaluating perinatal and neonatal factors associated with the development of cerebral palsy. The analysis demonstrates that low birth weight, NICU admission, neonatal seizures, and birth asphyxia were independently associated with a significantly increased risk of cerebral palsy. Among these factors, NICU admission and neonatal seizures showed the strongest association, indicating a higher likelihood of neurological injury or complications during the neonatal period. These findings emphasize the importance of close developmental monitoring and early screening in infants with high-risk perinatal histories to facilitate early identification and timely intervention for cerebral palsy.

Table 4: Multivariable logistic regression analysis of predictors associated with cerebral palsy

Predictor	aOR (95% CI)	p value
Low birth weight	10.45 (2.40–45.55)	0.002
NICU admission	46.73 (8.18–266.91)	<0.001
Neonatal seizure	166.83 (9.41–2956.43)	<0.001
Birth asphyxia	12.50 (1.68–93.28)	0.014

Figure 1 illustrates the distribution of developmental delays across the four DDST-II domains among children who screened positive (suspect or untestable). The graph demonstrates that gross motor delay was markedly higher in children with confirmed cerebral palsy, highlighting the primary motor impairment characteristic of the condition. Delays in the fine motor-adaptive domain were also more common among CP cases, while language delays were relatively more frequent among non-CP children who screened positive.

Personal-social delays were observed in smaller proportions in both groups. Overall, the figure highlights the predominance of motor developmental deficits in children with cerebral palsy identified through DDST-II screening.

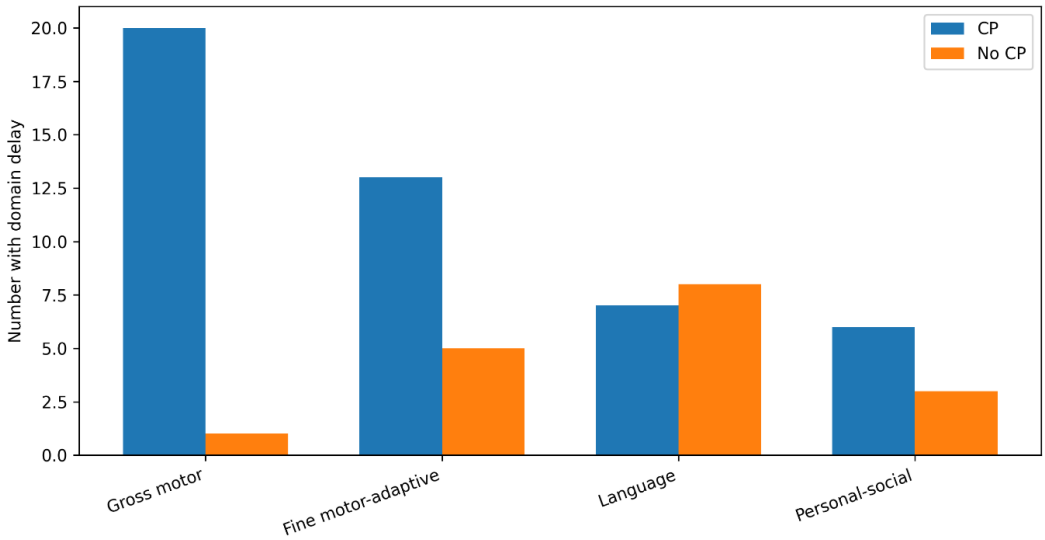

Figure 1: DDST-II domain delays among screen-positive children

Figure 2 presents the receiver operating characteristic (ROC) curve illustrating the diagnostic performance of DDST-II screening for detecting cerebral palsy in the study population. The curve demonstrates the relationship between sensitivity and 1–specificity across the diagnostic threshold. The area under the curve (AUC) indicates good discriminative ability of DDST-II in distinguishing children with cerebral palsy from those without the condition. The figure also compares the performance of DDST-II screening with a clinical risk model based on perinatal factors, showing that both approaches contribute to improved early identification of children at risk for cerebral palsy.

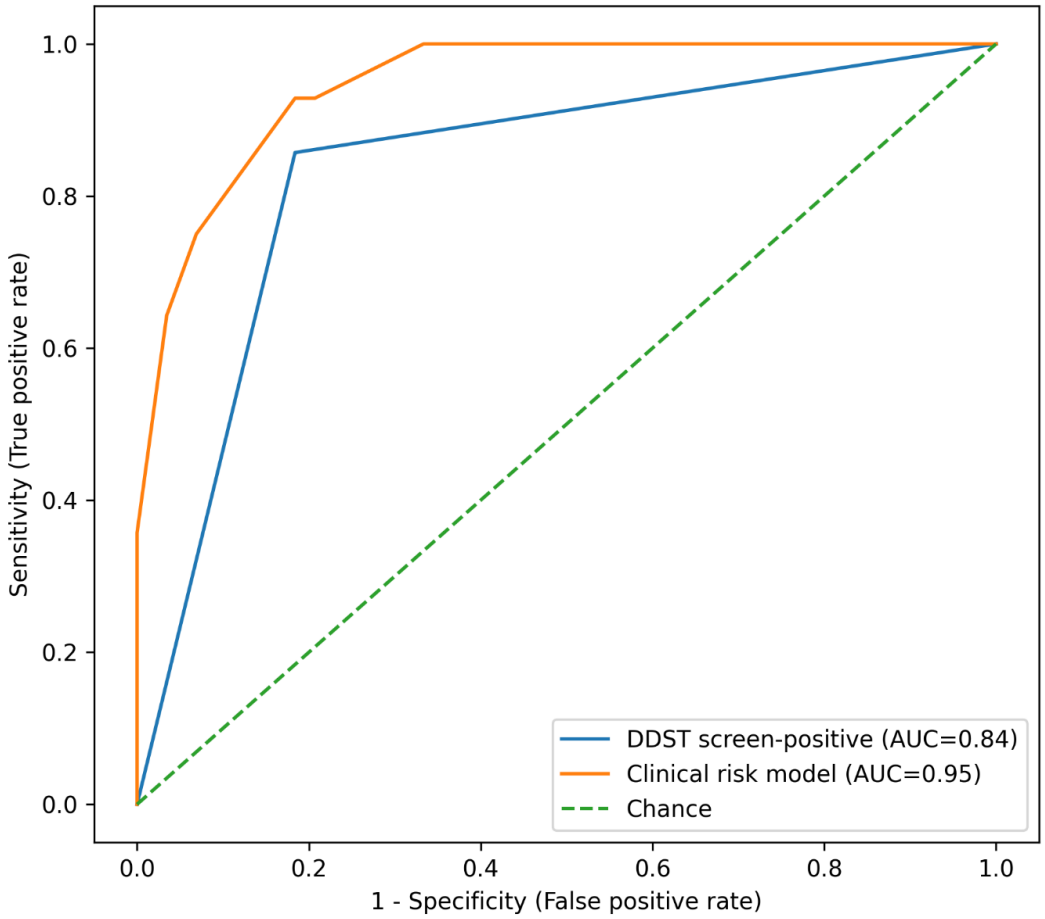

Figure 2: ROC curves for CP detection

Discussion

This hospital-based prospective observational study evaluated DDST-II as a pragmatic developmental screening approach for early suspicion of CP in infants and young children attending a tertiary-care teaching hospital in eastern India. The primary finding was that DDST-II screen positivity (Suspect/Untestable) demonstrated high sensitivity with strong negative predictive value, supporting its potential role as a triage tool to identify children who should undergo expedited confirmatory neurological assessment and referral to early intervention services. These findings align with the broader literature emphasizing that early identification pathways can reduce diagnostic delay and improve access to early, task-specific interventions during periods of maximal neuroplasticity [1,3,7].

International guidance underscores that CP can be detected earlier than traditionally practiced by combining clinical history and risk stratification with standardized assessments and neuroimaging when indicated [1]. However, real-world implementation is constrained by workforce training, tool availability, and the clinical throughput pressures typical of many high-volume pediatric services in low- and middle-resource settings [2]. In this context, DDST-II offers practical advantages: it is familiar to many pediatric teams, covers multiple developmental domains, and can be integrated into outpatient and follow-up clinics with structured examiner training. While DDST-II is not designed specifically for CP diagnosis, its ability to flag gross motor and fine motor-adaptive delay patterns provides a clinically meaningful signal for CP suspicion—particularly when gross motor delay is prominent and persistent.

The domain-level findings in our cohort were clinically intuitive. Among screen-positive children, gross motor delays were markedly more frequent in those confirmed with CP, whereas language delays were relatively more prominent in screen-positive non-CP children. This pattern is consistent with CP as a primarily motor disorder with frequent comorbidities but a motor phenotype that often dominates early presentation [7].

The observed profile supports the concept that DDST-II can provide not only a binary "refer" outcome but also domain-specific cues that may help clinicians prioritize motor-focused assessment and physiotherapy referral. Nevertheless, because DDST-II is a screening tool, false positives are expected, and some screen-positive non-CP children may represent transient delays, environmental disadvantage, hearing impairment, or other neurodevelopmental conditions that still warrant evaluation [4,10].

Our diagnostic indices demonstrate a particularly important property for screening: a high NPV, suggesting that a normal screen reduces the probability of CP within the assessed clinical context. This is valuable in busy services where clinicians must decide which children need urgent neurological referral versus watchful follow-up. At the same time, the PPV was moderate, reflecting expected limitations of a general developmental screening tool applied to a heterogeneous clinic population. These characteristics are consistent with broader evidence that developmental screening instruments are best used as part of structured pathways rather than stand-alone diagnostic tests [4,5]. Importantly, early detection guidelines emphasize that when clinical suspicion exists—especially in infants with known perinatal risk factors—clinicians should not delay referral awaiting definitive signs, and multi-tool approaches (e.g., structured neurological examinations and age-specific motor assessments) can improve accuracy [1,9].

The multivariable associations observed—low birth weight, NICU admission, neonatal seizures, and birth asphyxia—are well-recognized correlates of CP risk and likely reflect underlying brain injury or vulnerability in early development. These factors can assist clinicians in constructing a practical "high-risk registry" for prioritized follow-up, consistent with implementation studies showing that structured pathways and risk-based surveillance can reduce age at diagnosis and accelerate intervention access [2,3,17]. In practice, DDST-II may function most effectively when combined with risk stratification and clear referral thresholds, where high-risk infants with DDST concerns are fast-tracked for confirmatory assessment. This study should be interpreted in light of limitations typical of hospital-based observational research. As a single-center tertiary-care study, referral patterns may enrich risk profiles and affect performance estimates. Examiner training and inter-rater reliability, while addressed through structured administration, can influence DDST-II outcomes. Additionally, CP diagnosis in early life may evolve, and longitudinal confirmation remains essential [1,7]. Future work could compare DDST-II directly with evidence-based early CP assessments (e.g., GMA, HINE) or evaluate combined algorithms to optimize sensitivity and specificity across different age windows [9,17]. Despite these limitations, the findings support DDST-II as a feasible screening component within an early identification pathway, especially where specialized tools are not routinely available.

Overall, our study contributes context-relevant evidence supporting DDST-II integration into routine pediatric services for earlier CP suspicion

and referral. Establishing such pathways is consistent with global recommendations advocating timely identification and intervention to improve lifelong outcomes for children with CP and to support families through early counseling and therapy engagement [1,7].

Conclusion

DDST-II screening in infants and young children demonstrated high sensitivity and strong NPV for detecting CP in this tertiary-care cohort. When used with risk-factor stratification and a structured referral pathway, DDST-II can support earlier identification of children likely to have CP and facilitate timely confirmatory evaluation and early intervention in resource-constrained settings.

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