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Original Research Article

Impact of neonatal jaundice and neurological complications on developmental outcomes among children under 3 years of age

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ABSTRACT

Background: Neurodevelopmental delay (NDD) remains major concern in early childhood, particularly among infants exposed to perinatal complications. Neonatal jaundice (NJ) and neurological complications (NC) are common in high-risk infants and can adversely affect brain development, yet detailed clinical profiling of developmental domains in such populations is limited in hospital-based Indian settings.
Methods: In this study, we assessed patterns of NDD using the Developmental Assessment Scale for Indian Infants (DASII) in a cohort of 30 children aged up to 30 months attending tertiary care centre in Vadodara, Gujarat. Children were grouped based on clinical profiles into Group-I, those with NJ and/or NC and Group-II, those with other medical conditions.
Results: The median age at assessment was 21.3 months. NC (60%) and NJ (43.3%) were the most common perinatal conditions, with frequent overlap. Overall, children showed marked developmental delay, with median motor and mental developmental quotient (DQ) of 47 and 42, respectively. Mental developmental impairment was consistently greater and less variable than motor impairment across both groups. Moderate to severe delay was observed in 50% children in motor domain and 70% in mental domain. Children in Group-I showed more uniform and pronounced impairment, particularly in mental domain. Cluster-wise analysis revealed predominant deficits in body control and manipulation in motor domain, and social interaction and imitative behaviour in mental domain.
Conclusion: These findings highlight the significant impact of early-life neurological and bilirubin-related insults on child development and underscore the importance of early identification and targeted intervention using culturally appropriate tools such as DASII.

Keywords: Neurodevelopmental delay, DASII, Neonatal jaundice, Neurological complications, Developmental quotient

INTRODUCTION

NDD in early childhood is influenced by wide range of biological and environmental risk factors. These include perinatal complications such as birth asphyxia, respiratory distress, haemolytic conditions, jaundice and convulsions (seizures), all of which can adversely affect brain developmental and functional outcomes.[1,2] In early childhood, particularly within first five years of life, any delay in achieving expected milestones in cognitive, Motor or socio-emotional domains reflects underlying neurological impairment, which may have long-term consequences on learning and independence. Globally, it is estimated that approximately 200 million children

under five exhibits significant NDD, with nearly 86% of these cases occurring in developing countries.[5,6] More recent estimates further suggest that up to 250 million children under five years are at risk of not reaching their developmental potential, largely due to undernutrition, poverty, and inadequate early-life stimulation.[7] In India, studies indicate that prevalence of NDD among children under two ranges between 1.5% and 2.5%.[5] These estimates likely underestimate true burden, as many cases remain undetected without systematic screening.

Among various risk factors, neonatal jaundice (NJ) and neurological complications (NC) are recognized as major contributors to NDD.[8-10] NJ is the most common newborn disease, marked by yellow pigmentation of skin and sclera resulting from hyperbilirubinemia.[8,11] NJ affects 60-80% of newborns globally and remains major preventable cause of neurotoxicity in LMICs, including India, where delayed diagnosis and limited access to timely phototherapy or exchange transfusion increase risk of permanent injury.[12,13] In high-risk cohorts, hyperbilirubinemia contributes to NDD in substantial proportion, with studies linking severe jaundice to cerebral palsy and cognitive impairments.[14,15] In Indian NICU follow-up data, NJ has been reported in 20-40% of high-risk infants with subsequent NDD, highlighting its significant contribution to adverse outcomes.[8,16]

NC, including seizures, birth asphyxia and encephalopathy, represent another major pathway to adverse neurodevelopmental outcomes.[17,18] Neonatal seizures, often indicative of underlying brain injury, are associated with long-term outcomes such as epilepsy (upto 32%) and NDD (upto 43%).[19,20] In high-risk Indian-infants, NC are documented in 20–40% of those with NDD and frequently coexist with conditions such as NJ, further exacerbating vulnerability through excitotoxicity and neuroinflammation.[16,21]

These perinatal insults often overlap in vulnerable infants, creating additive risks for long-term neurodevelopmental impairment. Give this high burden and multifactorial etiology, early identification of NDD is critical to enable timely intervention and improve long-term outcomes. Standardized developmental assessment tools play a key role in this process. Although, international tools such as bayley scales of infant development (BSID) are widely used, their applicability is resource-limited settings is constrained by cost and cultural variability. In contrast, developmental assessment scale for indian infants (DASII), an indigenously standardized adaptation of BSID, is culturally appropriate and widely used tool for assessing Motor and Mental development in Indian children 22–25.

Despite its widespread clinical use, detailed domain- and cluster-specific developmental profiles associated with these complications remain limited. Therefore, present study aimed to characterize neurodevelopmental profiles using DASII, with particular emphasis on understanding the impact of NJ and NC on severity and pattern of NDD.

METHODS

Study design and setting

This was hospital-based cross-sectional study. This study was designed to evaluate the impact of NJ and NC on neurodevelopmental outcomes in children aged up to three years. This study was conducted in Department of Clinical Child Psychology (DCCP), KGPCH, Vadodara, Gujarat between April 2025 and February 2026.

Study population

Children under three years of age who were attended to DCCP, were included in study. The final study group was made based on the following inclusion and exclusion criteria:

Inclusion criteria

Children who were suspected of having developmental concerns based on parental reports or routine milestone checks were considered for inclusion.

Exclusion criteria

Children who have age-appropriate development were excluded from study. Children with medical instability were excluded. Parents or legal guardians unwilling to participate were not included in study.

Sample size justification

This was hospital-based, cross-sectional observational study conducted over fixed study period of eleven months. All eligible children aged up to three years with confirmed NDD attending to DCCP and meeting inclusion criteria during study period were consecutively enrolled. Total of 30 children constituted final study cohort.

Study groups

Based on clinical profile of study participants, children were categorized into two clinical groups.

Group-I

Children with NJ and/or NC.

Group-II

Children with other medical complications.

Data collection and assessment

Data were collected at KGPCH. NDD in children was evaluated using DASII. It comprises 163 and 67 items for Motor and Mental developmental assessment. Motor domain is assigned to five clusters, i.e., Neck-control (I),

Body control (II), locomotion-1 (III), locomotion-2 (IV) and manipulation (V). Mental domain is assigned to ten clusters, i.e., cognizance-visual (I), cognizance-auditory (II), reaching and manipulation (III), memory (IV), social-imitative behaviour (V), language-1 (VI), language-2 (VII), understanding of relationship (VIII), differentiation-use, shape and movements (IX), and manual dexterity (X). Motor and Mental developmental age, Motor and Mental developmental quotients (DQs) were evaluated. Information regarding chronological age, severity classification and cluster-wise deficits within each domain were recorded.

The scoring criteria for severity of Motor and Mental DQ was as followed 22,23,26: DQ>85 considered as normal, 71-85 as borderline and ≤70 as delay (51-70: mild, 36-50: moderate and ≤35: severe).

Clinical variables

Data on gestational age, mode of delivery, neonatal history, NICU admission, birth cry pattern, maternal and child medical history were recorded from clinical reports.

Ethical considerations

Ethical clearance was obtained from Institutional Ethics Committee (IEC) from Kashiben Gordhandas Patel Children Hospital (KGPCH), Vadodara, Gujarat prior to commencement, and written informed consent was obtained from parents or legal guardians of all participating children. Participants' identities were remained anonymous throughout study. This study was conducted under observation and support of Dr. Ronak Pandit at KGPCH.

Statistical analysis

Collected data were analysed using GraphPad Prism (Version 8.4.2). Data were analysed using descriptive statistics. Continuous variables were summarized as mean±standard deviation (SD) and median with interquartile range (IQR). Categorical variables were presented as frequencies and percentages.

RESULTS

Participant characteristics

Total of 30 patients met the inclusion criteria and 56.7% of them were male (Table 1). Median chronological age of the children at the time of assessment was 21.3 months, with an IQR of 11.90 to 26.93 months. Study population was included 26.7% of infants (Birth to 1 year) and 73.3% of toddlers (1 to 3 years). More than half of the children (60%) were born by C-Section with 73.33% children were normal (term, 8.5-9.5). The majority (90%) of the children were cried immediately after birth. About 26.7% children were admitted in NICU.

Neonatal and maternal medical history

Table 2 summarizes the distribution of neonatal complications observed in the children (Figure 1). Neurological complications were the most frequent category, affecting 18 children (60% of total cohort), followed by neonatal jaundice affecting 13 children (43.3%). Neurological complications including convulsions (13.33%), encephalopathy (3.33%), down syndrome (10.0%), spasticity (6.67%), left occipital plagiocephaly (3.33%), hypertonia (3.33%), head lag (3.33%), birth asphyxia (6.67%), cerebral palsy (3.33%), cerebral oedema (3.33%) and west syndrome (3.33%). Inflammatory complications, primarily sepsis were noted in 6 children (20.0%). Respiratory complications were reported in 8 children (26.7%), including respiratory distress (20.0%), pneumonia (3.33%) and throat infection (3.33%). Metabolic disturbances were documented in 4 cases (13.33%), comprising hypoglycaemia (6.67%), hypothyroidism (3.33%) and methylmalonic acidaemia (3.33%).

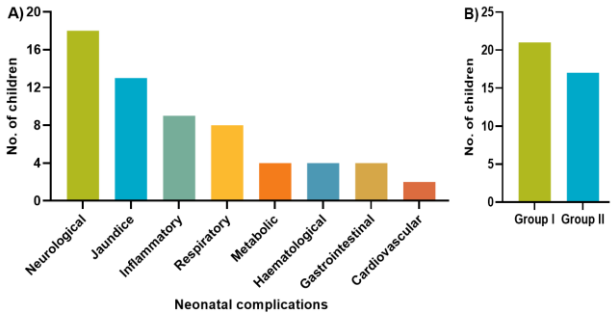

Figure 1 (A and B): Neonatal complications among children with neurodevelopmental delay. Bar chart showing the distribution of documented neonatal complications in the study cohort (n=30). Neonatal jaundice and neurological complications were the most frequent categories, followed by respiratory, inflammatory and metabolic complications. Cardiovascular and gastrointestinal complications were the least frequently reported. Clinical groups; Group I (n=21): Children with neonatal jaundice and neurological complications and Group II (n=17): Children with other medical complications. Multiple complications were present in several children.

Haematological complications were observed in 4 children (13.3%), including anaemia (10.0%) and RH incompatibility (3.3%). Gastrointestinal problems were recorded in 4 cases (13.3%), including chronic constipation, dehydration, feeding intolerance, and grade 3 cleft palate and lip, each affecting 1 child (3.33%). Cardiovascular issues were present in 2 cases, including atrial septal defect and hole in heart, each affecting 3.33% of children.

These complications frequently overlapped, with many children experiencing multiple insults (e.g., combination of jaundice, respiratory distress and down syndrome).

Maternal medical history revealed that about 13.3% of children were born to mothers with a documented history of high blood pressure during pregnancy. Approximately 10% of children were born to mothers with a history of premature rupture of membranes, indicating early drainage of amniotic (placental) fluid.

Based on the clinical relevance, participants were categorized into two groups for descriptive comparison. Group-I included children with neonatal jaundice and/or neurological complications, as these conditions directly affect the central nervous system and are known to increase the risk of neurodevelopmental impairment. Group-II included children with other medical complications that may influence development indirectly. This clinical grouping was used to allow meaningful clinical comparison within a small and heterogenous study population. Although neonatal jaundice and neurological complications were each observed in 13 and 17 children, respectively, these conditions were overlapped in 9 children. Therefore, Group-I comprised 21 unique children. Similarly, several children in Group-II had more than one medical complication, resulting in total of 17 unique children in this group.

Developmental age and quotient

Despite a median chronological age of 20.8 months (IQR 11.90-26.93), children demonstrated marked developmental delay in both motor and mental domain. Median motor developmental age was 8.3 months (IQR 4.725-17.25), while median mental developmental age was 8.1 months (IQR 3.2-11.13) in the overall study cohort. Mean motor DQ was 52.80±24.19, whereas mean mental DQ was 42.13±15.41. Correspondingly, the median motor DQ was 47 (IQR 31-72), and the median mental DQ was 42 (IQR 31.75-52) (Figure 2).

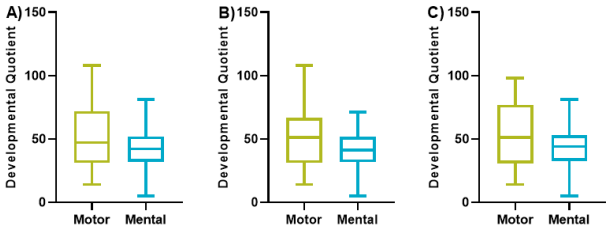

Figure 2: Distribution of motor and mental developmental quotients. Box-and-whisker plot illustrating the motor and mental developmental quotients (DQ) for overall study cohort (n=30), Group I (n=21) and C) Group II (n=17). Boxes represent the IQR with median values indicated, and whiskers extend accordingly to Tukey's method. Across the overall and both clinical groups, mental developmental quotients (DQ) were consistently lower and less variable than motor DQ, indicating greater impairment.

Children in Group-I demonstrated substantial impairment in both domains. Median motor developmental age was 8.3 months (IQR 4.2-13.35), while median mental developmental age was 8.8 (IQR 2.75-10.5) in Group-I. The median motor DQ was 51 (IQR 31-66.5), while the median mental DQ was 41 (IQR 31.5-51.5). Mean motor DQ was 51.43±2 4.83, whereas mean mental DQ was 40.90±14.99 in Group-I. Median motor developmental age was 9.3 months (IQR 4.55-27.7), while median mental developmental age was 9.9 (IQR 3.75-12.5) in Group-II. In Group-II, the median motor DQ was 51 (IQR 30.5-77.0), and the median mental DQ was 44 (IQR 32.5-53).

In Group-II, the mean motor DQ was 52.59±25.63, whereas mean mental DQ was 43.24±17.54. In overall cohort and both clinical groups, the mental domain demonstrated a lower median DQ and narrower IQR compared with the motor domain, indicating greater impairment. Compared to Group-I, both motor and mental DQ values in Group-II showed greater variability, indicating more heterogenous pattern of developmental involvement among children with non-neurological complications. Group-I showed relatively more uniform impairment in the mental domain, reflected by narrower IQR, consistent with conditions directly affecting the central nervous system.

Group-II exhibited wider variability in both motor and mental DQ, suggesting less consistent and potentially indirect effects on neurodevelopment. Across both groups, mental DQ remained comparable to or lower than motor DQ, highlighting the vulnerability of mental developmental functions.

Severity distribution of neurodevelopmental delay

In the motor domain, borderline delay was observed in 4 (13.33%) children, mild delay in 7 (23.33%), moderate delay in 5 (16.67%) and severe delay in 10 (33.33%) among the study cohort (Figure 3), while in the mental domain, borderline delay was present in 2 (6.67%), mild delay in 7 (23.33%), moderate delay in 12 (40%) and severe delay in 9 (30%) children. Overall, moderate to severe delay was observed in 50% of children in the motor domain and 70% in the mental domain, reflecting higher burden of severity in mental developmental functioning.

In Group-I motor domain, borderline delay was observed in 1 (4.8%), mild delay in 7 (33.3%), moderate delay in 2 (9.5%) and severe delay in 8 (38.1%) children, while in the mental domain, borderline delay was observed in 1 (4.8), mild delay in 5 (23.8%), moderate delay in 9 (42.8%) and severe delay in 6 (28.6%) children. In Group-I, moderate to severe delay was observed in 47.6% of children in the motor domain and 71.4% in the mental domain, reflecting higher burden of severity in mental developmental functioning.

In Group-II motor domain, borderline delay was observed in 2 (11.8%), mild delay in 4 (23.5%), moderate delay in 2 (11.8%) and severe delay in 6 (35.3%) children, while in the mental domain, borderline delay was observed in 1 (5.9%), mild delay in 6 (35.3), moderate delay in 5 (29.4%) and severe delay in 5 (29.4%) children. In Group-II, moderate to severe delay was observed in 47% of children in the motor domain and 58.8% in the mental domain, reflecting higher burden of severity in mental developmental functioning.

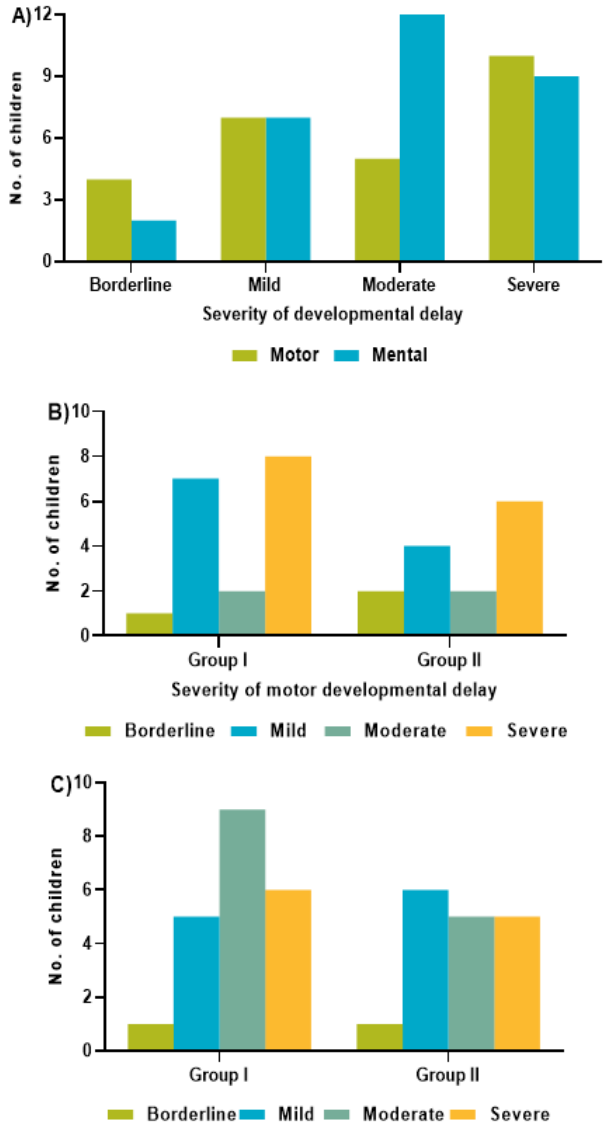

Figure 3 (A-C): Severity distribution of neurodevelopmental delay assessed using DASII. Overall severity distribution of motor and mental developmental delay in the study cohort (n=23). Severity distribution of motor and mental developmental delay across two clinical groups; Group I (n=21) and Group II (n=17). Across groups, moderate to severe delay predominated in Group I, with mental developmental delay demonstrating greater severity compared to motor developmental delay.

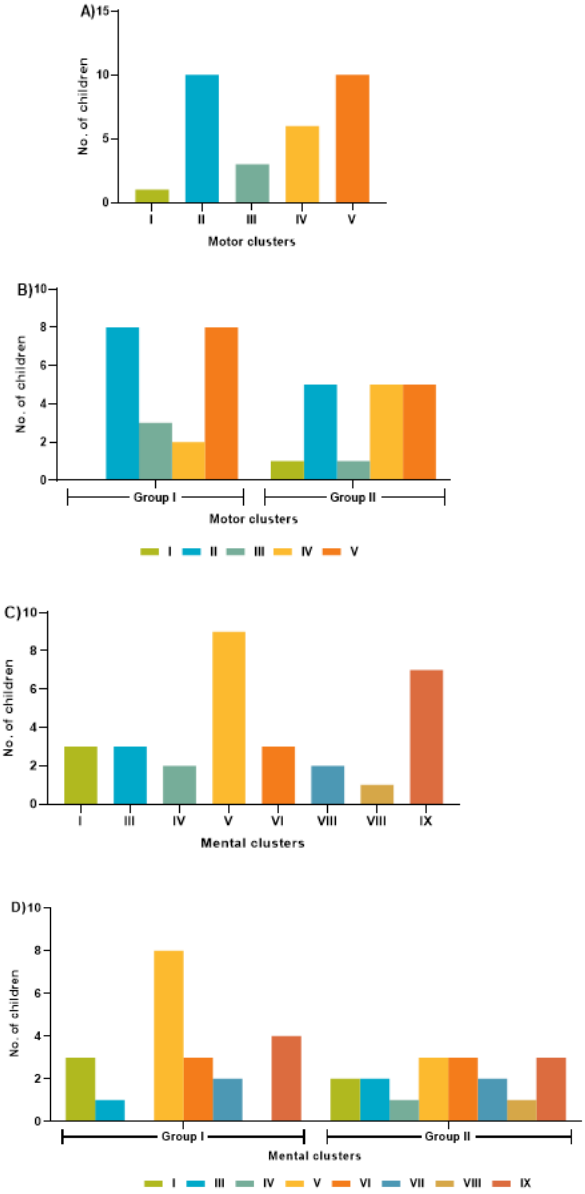

Figure 4 (A-D): Cluster-wise distribution of motor and mental developmental deficits. Frequency of affected motor clusters in the overall study cohort (n=23). Comparison of motor cluster involvement between two clinical groups; Group I (n=21) and Group II (n=17). Cluster II (body control) and V (manipulation) were the most frequently affected motor clusters. Frequency of affected mental clusters in the overall study cohort (n=23). Comparison of mental cluster involvement between two clinical groups; Group I (n=21) and Group II (n=17). Cluster V (social interaction and imitative behaviour) was the most frequently affected mental

Cluster-wise developmental patterns

Analysis of DASII clusters revealed domain-specific patterns of impairment (Table 5). Figure 4 presents the distribution of children exhibiting delay across the motor

and mental clusters in overall study cohort as well as in both clinical groups. In the entire cohort (Figure 4A), motor delays were most prevalent in cluster II (body control) and cluster V (manipulation), each affecting 10 children (33.33%). This was indicating that difficulties with postural stability and fine motor precision were the predominant motor challenges. When stratified by clinical groups (Figure 4B), distinct profile emerged. Group-I demonstrated a higher relative frequency of delay in motor cluster I (body control) and cluster V (manipulation), each affecting 8 children (38.1%). Neck control remained unaffected. In contrast, Group-II showed a more distributed pattern, with motor cluster II (body control), cluster IV (locomotion 2) and cluster V (manipulation) still prominent (each affecting 5 children, 29.4%). Motor cluster I (neck control) and cluster III (coordinated movements) were less frequently delayed, affecting 1 child (5.9%).

In the mental domain, cluster V (social interaction and imitative behaviour) was the most affected in overall study cohort (30%), followed by cluster IX (differentiation by use, shape and comprehension) affecting 7 children (23.33%) (Figure 4C). In Group-I, mental cluster V was the most affected cluster, affecting 38.1% children, followed by cluster IX (differentiation by use, shape and movements), affecting 4 children (19%), then cluster I (cognizance-visual) and VI (language 1), each affecting 3 children (14.3%) (Figure 4D). In Group-II, mental deficits in clusters V, VI and IX affected 3 children (17.6%). Mental cluster II (cognizance-auditory) and X (manual dexterity), remained unaffected in both overall study cohort and clinical groups.

Table 1: Background characteristics of enrolled patients.

Characteristics	N (%)
Gender	
Male	17 (56.7)
Female	13 (43.3)
Age at assessment (in months)	
Median (IQR)	21.3 (11.90 – 26.93)
Age of onset	
Infants (Birth to 1 year)	8 (26.7)
Toddlers (1 to 3 years)	22 (73.3)
Mode of delivery	
Normal (Vaginal)	12 (40.0)
Caesarean (C-Section)	18 (60.0)
Classification based on gestational age	
Pre-term	7 (23.33)
Normal (Term)	22 (73.33)
Post-term	1 (3.33)
Birth cry pattern	
Immediate cry	27 (90.0)
Cried after a month	2 (6.7)
Cried after rubbing	1 (3.3)
NICU admission	8 (26.7)

Table 2: Neonatal complications.

Complications	N (%)	Complications	N (%)
Neurological complications	18 (60.0)	**Respiratory complications**	8 (26.7)
Convulsions	4 (13.33)	Respiratory distress	6 (20.0)
Encephalopathy	1 (3.33)	Pneumonia	1 (3.33)
Down syndrome	3 (10.0)	Throat infection	1 (3.33)
Spasticity	2 (6.67)	**Inflammatory complications**	9 (30.0)
Left occipital plagiocephaly	1 (3.33)	Sepsis	6 (20.0)
Hypertonia	1 (3.33)	High grade fever	3 (10.0)
Head lag	1 (3.33)	**Metabolic complications**	4 (13.33)
Birth asphyxia	2 (6.67)	Hypoglycaemia	2 (6.67)
Cerebral palsy	1 (3.33)	Hypothyroidism	1 (3.33)
Cerebral oedema	1 (3.33)	Methylmalonic acidaemia	1 (3.33)
West syndrome	1 (3.33)	**Haematological complications**	4 (13.33)

Continued.

Complications	N (%)	Complications	N (%)
Neonatal jaundice	13 (43.3)	Anaemia	3 (10.0)
Gastrointestinal complications	4 (13.3)	RH incompatibility	1 (3.33)
Chronic constipation	1 (3.33)	**Cardiovascular complications**	2 (6.7)
Dehydration	1 (3.33)	Atrial septal defect	1 (3.33)
Feeding intolerance	1 (3.33)	Hole in heart	1 (3.33)
Grade 3 cleft palate and lip	1 (3.33)		

Table 3: Developmental outcomes assessed using DASII.

	Overall (n=30)		Group I (n=21)		Group II (n=17)	
Domain	**Motor**	**Mental**	**Motor**	**Mental**	**Motor**	**Mental**
Developmental age (months)						
Median	8.3	8.1	8.3	8.8	9.3	9.9
IQR	4.725-17.25	3.2-11.13	4.2-13.35	2.75-10.5	4.55-27.7	3.75-12.5
Developmental quotient (DQ)						
Median	47	42	51	41	51	44
IQR	31.0-72.0	31.75-52.0	31.0-66.5	31.5-51.5	30.5-77.0	32.5-53.0
Mean	52.80±24.19	42.13±15.41	51.43±24.83	40.90±14.99	52.59±25.63	43.24±17.54

Table 4: Severity distribution by domain.

Severity	Motor domain, N (%)			Mental domain, N (%)		
	Overall (n=30)	**Group I (n=21)**	**Group II (n=17)**	**Overall (n=30)**	**Group I (n=21)**	**Group II (n=17)**
Normal	4 (13.33)	3 (14.3)	3 (17.6)	0 (0)	0 (0)	0 (0)
Borderline	4 (13.33)	1 (4.8)	2 (11.8)	2 (6.67)	1 (4.8)	1 (5.9)
Mild	7 (23.33)	7 (33.3)	4 (23.5)	7 (23.33)	5 (23.8)	6 (35.3)
Moderate	5 (16.67)	2 (9.5)	2 (11.8)	12 (40.0)	9 (42.8)	5 (29.4)
Severe	10 (33.33)	8 (38.1)	6 (35.3)	9 (30.0)	6 (28.6)	5 (29.4)

Table 5: Cluster-wise distribution of developmental deficits.

Domains and clusters		Developmental delay, N (%)		
		Overall (n=30)	**Group I (n=21)**	**Group II (n=17)**
Motor domain				
I	Neck control	1 (3.33)	0 (0)	1 (5.9)
II	Body control	10 (33.33)	8 (38.1)	5 (29.4)
III	Locomotion 1 (Coordinated movements)	3 (10.0)	3 (14.3)	1 (5.9)
IV	Locomotion 2 (Skills)	6 (20.0)	2 (9.5)	5 (29.4)
V	Manipulation	10 (33.33)	8 (38.1)	5 (29.4)
Mental domain				
I	Cognizance-visual	3 (10.0)	3 (14.3)	2 (11.8)
II	Cognizance-auditory	0 (0)	0 (0)	0 (0)
III	Reaching and manipulation	3 (10.0)	1 (4.8)	2 (11.8)
IV	Memory	2 (6.67)	0 (0)	1 (5.9)
V	Social interaction and imitative behaviour	9 (30.0)	8 (38.1)	3 (17.6)
VI	Language 1 (Vocalization, speech and communication)	3 (10.0)	3 (14.3)	3 (17.6)
VII	Language 2 (Vocabulary and comprehension)	2 (6.67)	2 (9.5)	2 (11.8)
VIII	Understanding of relationship	1 (3.33)	0 (0)	1 (5.9)
IX	Differentiation by use, shape and movements	7 (23.33)	4 (19.0)	3 (17.6)
X	Manual dexterity	0 (0)	0 (0)	0 (0)

DISCUSSION

This hospital-based cross-sectional study demonstrates substantial burden of NDD in cohort of high-risk infants and toddlers evaluated using DASII at tertiary-care centre in Vadodara, Gujarat. NJ and NC were the predominant perinatal risk factors, documented in 43.3 and 60% of cohort, respectively and frequently co-existing. These findings are consisted with Indian NICU follow-up studies, where hyperbilirubinemia and neurological insults (such as convulsions and encephalopathy) remain leading contributors to adverse developmental outcomes.[8,16,21]

The overall developmental profile revealed marked discrepancy between chronological age (median 21.3 months) and attained developmental age, with median motor and mental age of 8.3 and 8.1 months, respectively. Mental DQ was consistently lower than Motor DQ across total cohort and within both clinical groups. This differential impairment aligns with known pathophysiology of bilirubin neurotoxicity, which preferentially affects basal ganglia, hippocampus and auditory pathways, as well as diffuse cortical-subcortical disruption caused by neonatal encephalopathy and seizures.[2,12,14,15] Similar patterns of greater Mental than Motor delay have been reported in Indian high-risk cohorts.[16,21]

NC are one of the main reasons of NDD. NC, including convulsions and encephalopathy, represent the major pathway to adverse neurodevelopmental outcomes. In this study, children with neurological problems (Group-I) demonstrated relatively more uniform impairment in Mental domain, consistent with direct brain injury. Neonatal convulsions are marker of underlying cerebral dysfunction and have been associated with long-term outcomes such as cerebral palsy and global NDD.[27]

The role of NJ as contributor to NDD is well established.[8,28] In the study, jaundice was among the second most frequently observed conditions and often coexisted with other complications. Hyperbilirubinemia, particularly when severe or inadequately treated, can lead to bilirubin-induced neurological dysfunction.[2] These pathophysiological mechanisms may explain prominent deficits observed in higher-order Mental domains, including social interaction and imitative behaviour, and language-related functions in this cohort. Previous studies from LMIC settings have similarly highlighted contribution of NJ to long-term neurodevelopmental impairment, especially in settings where early detection and timely management remain suboptimal.[12,13] The co-existence of jaundice and NC in several children in this cohort likely reflects overlapping mechanisms of injury, including excitotoxicity, oxidative stress and neuroinflammation, which may act synergistically to worsen developmental outcomes.

In contrast, children in Group-II, who had other systemic complications such as respiratory, metabolic, inflammatory or cardiovascular conditions, demonstrated greater variability in both Motor and Mental DQs. This heterogeneity likely reflects indirect or secondary effects on brain development, mediated through factors such as hypoxia, metabolic instability or systemic illness. While these conditions are recognized contributors to NDD, their impact is often less predictable and may depend on severity, duration and timing of insult. The severity distribution further supports observation of substantial developmental burden in this cohort. A high proportion of children demonstrated moderate to severe delay, particularly in Mental domain. These findings are consistent with previous report from tertiary-care settings, where children presenting for developmental evaluation often represent more severe cases due to referral bias.[29] The absence of borderline cases in Mental domain further suggests that many children are identified at stage when delays are already well established.

Cluster-wise analysis provided clinically important granularity. In Motor domain, Body control and manipulation emerged as the most affected clusters (each 33.3%), indicating impairment in postural stability and fine Motor precision. These deficits were significantly more prevalent in Group-I (NJ and/or NC), reaching 38.1% for both clusters. Neck-control, by contrast, remained relatively spared, consistent with preservation of early brainstem-mediated functions. In Mental domain, social-imitative behaviour was the single most affected cluster (30% overall, 38.1% in Group-I), followed by differentiation by use, shape and movements (23.3%). The selective impairment of early social reciprocity and symbolic functions in Group-I mirrors findings from studies on bilirubin-induced neurologic dysfunction and neonatal seizures, where higher-order integrative networks appear particularly vulnerable.[18-20]

These results add to the existing literature by providing cluster-specific insights using DASII in contemporary Indian tertiary-care setting. while global studies have documented strong associations between NJ/NC and later cerebral palsy and NDD domain- and cluster-level data from India remain limited. The present findings extend earlier observations by demonstrating that the highest burden falls on control, manipulation and social-imitative behaviour, domains critical for functional independence and early learning.[14,14,16,19,21]

This study has several limitations. The relatively small sample size and single-centre design limit the generalizability of the findings. The cross-sectional nature of the study precludes assessment of developmental trajectories and long-term outcomes. Additionally, the study population represents a clinically referred cohort, which may overestimate the severity of developmental delay compared with community-based samples. The presence of overlapping complications

further limits the ability to attribute outcomes to specific etiologies.

Despite these limitations, the study provides clinically relevant insights into the pattern and severity of neurodevelopmental delay in high-risk Indian infants. The findings underscore the importance of early identification and targeted intervention, particularly for children with neonatal jaundice and neurological complications. Strengthening neonatal screening, timely management of jaundice and structured developmental follow-up programs may help reduce the burden of long-term neurodevelopmental impairment in this population.

CONCLUSION

In conclusion, this study demonstrates a substantial burden of neurodevelopmental delay among high-risk children, with more pronounced impairment in the mental domain compared to motor development. Neonatal jaundice and neurological complications, which directly affect the central nervous system, were associated with more consistent and severe developmental deficits, particularly in cognitive and socio-communicative functions. Cluster-wise analysis further highlighted vulnerabilities in body control, manipulation and social interaction domains. These findings underscore the importance of early identification and structured developmental assessment using culturally appropriate tools such as DASII. Strengthening neonatal care, timely management of high-risk conditions and implementation of targeted early intervention programs are essential to improve long-term neurodevelopmental outcomes in this population.

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