


BMJ Open Screening tools for early identification of children with developmental delay in low- and middle-income countries: a systematic review

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ABSTRACT

Objective To systematically review, identify and report the screening tools used for early identification of developmental delay in low- and middle-income countries.

Design Systematic review.

Data sources Four bibliographic databases: Medline (1946 to 13 July 2020), Embase (1974 to 13 July 2020), Scopus (1823 to 11 July 2020) and PsycINFO (1987 to July week 1 2020).

Eligibility criteria Peer-reviewed original articles published in English addressing validated culturally sensitive developmental screening tools among children aged <5 years were included in this review.

Data extraction and synthesis One author (CK, medical librarian) developed the search strategy. Three authors conducted the database search (phase I: CK; phase II: IJ and MKI). Three authors (TF, IJ and MKI) independently screened the title and abstracts. TF, MKI and GK independently performed the full-text review of the screened articles. During each step of the study selection process, disagreements were resolved through discussion. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement was used to guide the systematic review. Data extraction and analysis were performed using MS Excel. Meta-analysis was not possible due to heterogeneity of the study findings.

Results We identified 3349 articles, of which 18 studies from 10 countries, reporting 16 screening tools, were selected for qualitative synthesis. Six cultural contexts were explored. Twelve general, two motor and two speech-language tools were identified. Seven of them found to be parent-completed ones. Five screening tools (American Speech-Language and Hearing Association, Guide for Monitoring Child Development, Infant Neurological International Battery, New Delhi-Development Screening Questionnaire and Woodside Screening Technique) reported relatively higher sensitivity (82.5%–100%) and specificity (83%–98.93%).

Conclusions Limited number of culturally sensitive developmental screening tools were validated for children aged <5 years in low- and middle-income countries. Revising existing screening tools in different ethnic and cultural settings and subsequent validation with normative value should be a research priority.

Strengths and limitations of this study

- This review puts together extensive literature searches on original studies (both observational and experimental) conducted among under-5 children from low- and middle-income countries reporting standardisation, validity (in terms of sensitivity and specificity) of developmental screening tools in early diagnosis of developmental delay.
- Meta-analysis was not possible due to the heterogeneity of the study setting and findings.
- Critical evaluation of the available screening tools in terms of diagnostic accuracy was not possible to perform due to the unavailability of the necessary information.

INTRODUCTION

Developmental delay is a condition where children exhibit significant variation in achieving developmental milestones as expected for their actual or adjusted age.^{1–3} Complications at birth including premature birth; brain trauma and encephalitis; severe medical problems after birth; inborn metabolic errors; genetic or chromosomal abnormalities; inadequate stimulation; malnutrition; iron deficiency anaemia; chronic illness; adverse environmental, familiar and psychological states may lead to developmental delay.^{4–6} Although the condition itself may not be permanent, it can provide a foundation for recognising children who might have more severe and permanent health conditions, that is, developmental disabilities. Apart from developmental delay, developmental disability is considered as a severe, chronic disability originating at birth or during childhood, expected to continue indefinitely, and substantially restricts the individual's functioning in several major life activities.^{2,7} Examples of developmental disabilities include autism spectrum disorder,

behavioural disorders, cerebral palsy, Down syndrome, fetal alcohol syndrome, intellectual disability and so on. As a predictive of above-mentioned learning, movement and behavioural disorders, it is possible to identify developmental delay to a great extent during the preschool period (ie, before the age of 5 years) with the help of well-validated screening tools.^{8,9} There is a long-term financial impact on society in terms of healthcare, educational support and other special services related to developmental delay and/or disability. This is because the affected children require substantial resources and increased cost over their lifespan compared with those without such conditions.¹⁰ This further accentuates the significance of early identification to initiate appropriate interventions and/or rehabilitations with the intention of preventing further delays, stimulating emerging skills and creating a more encouraging and protective surroundings.⁵

In the last few decades, successful implementation of WHO's key health services¹¹ regarding 'The Countdown to 2015 Initiatives' resulted in the reduction of the neonatal mortality rate from 37 deaths per 1000 live births in 1990 to 19 per 1000 live births in 2016, worldwide with a projection of further future reductions.^{12,13} Among the survivors, >250 million under-5 children from low- and middle-income countries (LMICs) are not fulfilling their developmental potential in cognitive, motor and social-emotional domains due to poor nutrition, poverty and conflicts.^{4,14-16} In addition to them, there is an undetected number of surviving children suffering from various forms of developmental delay presumably due to brain injury during the fetal, perinatal and postneonatal period.¹⁷ We have discovered that, with time, while the neonatal mortality rate is reducing, the prevalence of developmental delay is gradually increasing (by analysing the data generated from two nation-wide population-based retrospective studies conducted in Taiwan) (see online supplemental figure S1).^{18,19}

Monitoring, screening and surveillance have been found effective to track a child's developmental progress. As a means of tracking a child's developmental progress, developmental monitoring is the ordinary observation of child's developmental advancement performed by parents/caregivers. On the contrary, developmental screening aims to identify specific developmental concern by doctors/healthcare professionals using brief questionnaire/checklist. When such activity is performed on a regular basis during routine health check-ups, it is termed as developmental surveillance.^{20,21} Among them, developmental screening is the first step of the comprehensive diagnostic procedure for secondary prevention and early identification of developmental delay.^{16,22,23} Thus, a well-validated developmental screening tool is very important. The standardised tools available from western countries provide well-validated assessment in their own settings. However, the transfer of such western-based tools to non-western countries is linked with substantial limitations in terms of score interpretation and feasibility of their use in resource-constrained settings such as in LMICs.²⁴ In

the high-income countries, early identification of developmental delay is considered as mandatory part of good healthcare practice, which is recommended by the American Academy of Paediatrics.¹⁶ In contrast, in LMICs, most teaching and training programmes of health professionals are still concentrated on acute illness and growth aspects of children rather than a developmental perspective, resulting in limited attention in developmental delay.¹⁶ Also, in these geographical areas, parents and caregivers with strong cultural beliefs and superstitions regarding health remain ignorant of the child's developmental deficit and about the future impact of the condition.²⁵ The combined effect of these two factors often results in overlooking or delaying of the diagnosis of developmental concerns.

The perspective on developmental disability varies from one culture to another. Along with economic, geographical, social factors, it often becomes a barrier to healthcare accessibility for children with disability.²⁶ In Chinese culture, having children with disability is often considered shameful for the family. In Southeast Asian cultures, parents often face social deprivation due to the stigma related to developmental disability.²⁷ Moreover, cultural believe often holds control over treatment approaches for developmental delay or disabilities, including: (1) whether to seek help or not; (2) which treatment option to choose; (3) parental expectations for their child; (4) interpersonal relationship between caregiver and healthcare professionals and so on.²⁸ One of the biggest challenges in early identification of developmental delay or disability is providing culturally sensitive screening tools, which include cultural perception of delay and/or disability and easily adaptable across the various cultural/nation.²⁴ Among the developmental domains, social development is culturally specific and difficult to adapt, whereas the gross motor domain is easier to adapt culturally.²⁹

The purpose of this study was to look for the screening tools which have been used and validated for early identification of developmental delay in LMICs, to report how effective they are for early identification of developmental delay in terms of validity, and to identify areas for future research.

MATERIALS AND METHODS

Data sources and search strategy

To locate items on screening tools for early identification of developmental delay among children in LMICs, the search strategy was developed by an experienced medical librarian (CK). Literature search was conducted in two phases (phase I up to March 2018: CK; phase II up to July 2020: IJ and MKI) in four bibliographic databases. The databases searched were: OVID Medline (1946 to 13 July 2020), OVID Embase (1974 to 13 July 2020), Scopus (1823 to 11 July 2020) and PsycINFO (1987 to July week 1 2020). Search terms included database-specific thesaurus terms where available such as 'Mass Screening',

'Diagnosis', 'Surveys and Questionnaires', 'Neurodevelopmental Disorders', 'Motor Disorders', 'Cerebral Palsy', 'Cognitive Dysfunction' and 'Communication Disorders' as well as relevant associated text word terms. These were combined with LMIC terms and infant, child and adolescent terms. To minimise the introduction of bias, no publication date and language limits were used. The date of the latest search was 13 July 2020. The Medline search strategy could be found in online supplemental table S1.

In addition to bibliographic database searches, we manually checked the reference lists of recent systematic reviews^{30 31} as well as articles included in the full-text review. We also contacted experts in the relevant field to identify any additional studies or information.

Selection criteria

Study inclusion criteria were: (1) children aged <5 years who were at risk of developmental delay; (2) original studies (both observational and experimental); (3) study where single, as well as multiple developmental domains, were examined; (4) studies conducted only in LMICs. The exclusion criteria were: (1) studies conducted on diagnosed cases of developmental delay; (2) studies focusing on autism spectrum disorder and other behavioural disorders; (3) studies conducted among HIV exposed children; (4) studies on developmental delay among children aged >5 years; (5) interventional studies on developmental delay; (6) studies on developmental delay published before 1946; (7) article published in languages other than English; (8) conference papers, letter to the editor, protocols, systematic reviews and ongoing studies; (9) study conducted among children of eligible ethnic origin but in different country settings (ie, children adopted from LMICs but study conducted in high-income countries). List of key definitions regarding study selection are available in online supplemental table S2.

All the under-5 children who were not previously diagnosed with any neurodevelopmental delay or disability, were considered as 'at risk of developmental delay'. Studies where overall or categorised (based on different age group/cut-off score) sensitivity-specificity of screening tools were examined and clearly reported, were considered as validated. We did not discriminate among screening, monitoring and surveillance tools. If any of those tools were validated for screening developmental delay among under-5 children, considered eligible for inclusion. Tools which were declared as assessment tools by the developer themselves as well as studies where a tool was used for developmental assessment by the researchers, were excluded from the review.

When we had searched the keywords 'Autism Spectrum Disorder' and 'Developmental Delay' in the medical databases, the number of search items were as follows: (i) OVID Medline-9320: 12402; (ii) OVID Embase-21750: 7506; (iii) Scopus-20675: 7530 and (iv) PsycINFO-17130: 3067, respectively, which is a bit alarming. We have excluded autism and other behavioural disorders from the study to provide undivided attention to developmental

delay. Apart from scientific community, parents and caregivers of LMICs are more familiar with the term autism spectrum disorder compared with developmental delay. Which is evident from growing concerns regarding speech-language and behavioural domains of child development compared with rest of the domains.³² We believe, to ensure successful developmental screening/surveillance programme in LMICs in the long run, and more importantly, to raise public awareness about developmental delay, we need to work more in this area than we used to.

LMICs consist of countries belonging to three World Bank income groups (low, lower-middle and upper-middle) of WHO's Member States. The classification is based on the estimated per capita gross national income. We have used the World Bank's country classifications by income level (2020–2021) in this review.^{33 34}

Study selection, data extraction and quality appraisal

We carried out the following steps to decide on the studies: (1) searching the above-mentioned databases using similar search strategy (CK, IJ, MKI); (2) deduplicating and merging search results using the EndNote bibliographic software (TF); (3) examining titles and abstracts to remove obviously irrelevant reports (TF, IJ, MKI); (4) retrieving and examining the full-text reports of eligible studies (TF, MKI, GK); (5) applying the selection criteria on the shortlisted articles (TF, GK); (6) making final decisions on study inclusion and proceeding for data collection. Extracted information included: publication year, the country where the study was conducted, the name of the screening tool, the gold standard tool(s) against which the screening tool was validated, study design, study setting, sample size, sampling technique, the age of the participants, selection criteria and sensitivity-specificity of the screening tools. During each step of the study selection process, disagreements were resolved through discussion. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, including 27-item PRISMA checklist to guide the systematic review.³⁵ The quality of the selected studies was assessed using the Quality Assessment Tool for Diagnostic Accuracy Studies-2³⁶ (see online supplemental table S3) and Newcastle-Ottawa Scale for cross-sectional studies³⁷ (see online supplemental table S4).

Data analysis

Individual study findings were reported including the country, study design, study setting, sample size, sampling technique, proportions and age range of participants, sensitivity-specificity of the developmental screening tools, etc. Data extraction and analysis were performed using MS Excel. We were unable to perform a meta-analysis due to the heterogeneity of the study setting and findings.

Protocol registration

The protocol of this systematic review has been registered in PROSPERO (registration number: CRD42018095232).

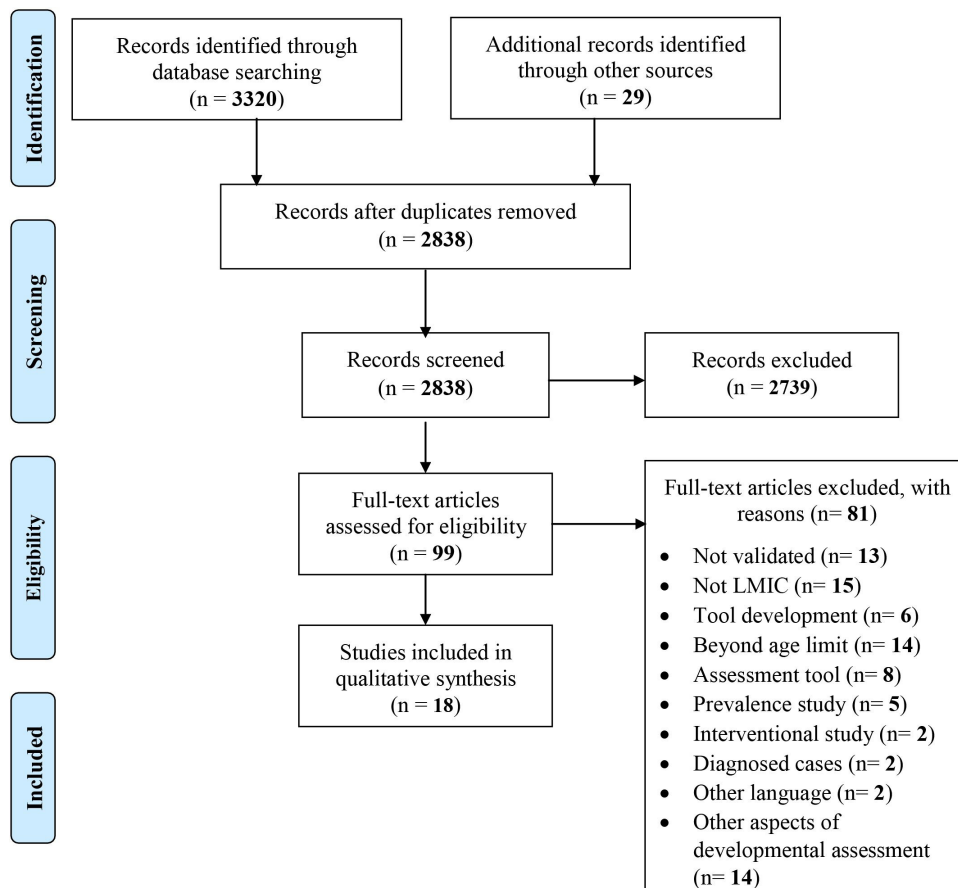


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. LMIC, low- and middle-income countries.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Search results

The initial search retrieved 3349 records. We have found 3320 records from four bibliographic databases (1555 from OVID Medline, 1317 from OVID Embase, 348 from Scopus and 100 from PsycINFO). Twenty-nine records were located by reviewing the reference lists of recent systematic reviews, fully extracted articles and consulting expert researchers in this area. There were 2838 records once duplicates were removed. Following the screening of title and abstracts for articles, which described the validation of tools to screen developmental delay among children, 99 articles were selected for further evaluation. After further review and application of selection criteria, 18 articles were selected for inclusion in study.^{38–55} A PRISMA flow diagram has been prepared to illustrate the study selection process (as shown in [figure 1](#)).

Summary of the included studies

All of the 18 studies included for qualitative synthesis were original articles published in English, with a publication

date range from 1991 to 2020 inclusive. Eight studies originated in ‘South Asia’,^{38 41 44 46 48 51 54 55} four from ‘East Asia and Pacific’,^{39 47 49 50} three from ‘sub-Saharan Africa’,^{45 52 53} one study each from the ‘Middle East and North Africa’,⁴³ ‘Latin America and Caribbean’,⁴⁰ and ‘Europe and Central Asia’⁴² region of the World Bank. In total, 16 developmental screening tools were used in 10 countries. Among the 16 screening tools, American Speech-Language and Hearing Association (ASHA), Language Evaluation Scale Trivandrum for 0–3 years LEST (LEST 0–3) focus on language domain; Infant Neurological International Battery (INFANIB) and Little Developmental Coordination Disorder Questionnaire (Little DCDQ) work on motor domains. The remaining tools are for general developmental screening. A brief description of the selected screening tools has been provided in [table 1](#).

Participant characteristics

All the studies involved males and females; age ranged between 0 and 5 years. The smallest sample size was 53 and the largest was 1945. The studies explored the following cultural contexts: East Asia and Pacific (China, Mongolia and Thailand), Europe and Central Asia (Turkey), Latin America and the Caribbean (Brazil), Middle East and North Africa (Iran), South Asia (Bangladesh, India),

Table 1 Brief description of the selected screening tools

Screening tool	Country of origin	Study country	Concerned age	Parent-reported version	Questionnaire type	Number of questionnaires	Number of items	Developmental domain	Validated against
General screening tools									
Ages and Stages Questionnaire (ASQ)	USA	India, China	1–66 months	Yes	Q & A	21 age sets	30 items per set	Communication, gross motor, fine motor, problem solving, personal-social	Developmental Assessment Scales for Indian Infants (DASII) ³⁸ Bayley Scales of Infant Development (BSID-III) ³⁹
Development Screening Questionnaire (DSQ)	Bangladesh	Bangladesh	0–24 months	No	Q & A	24 age sets	8 questions per set	Gross motor, fine motor, vision, hearing, cognition, socialisation, behaviour and speech	Rapid Neurodevelopmental Assessment (RNDA) ⁴¹
Guide for Monitoring Child Development (GMCD)	Turkey	Turkey	0–3.5 years	Yes	Q & A	Single	7 items	Expressive language and communication, receptive language, fine and gross motor, social-emotional, self-help	Bayley Scales of Infant Development (BSID-II) ⁴²
Lucknow Developmental Screen (LDS)	India	India	0–24 months	Yes	Chart	Single	27 item	Motor, mental, language, social	Developmental Assessment Scales for Indian Infants (DASII) ⁴⁶ Vineland Social Maturity Scale ⁴⁶
Mongolian Rapid Baby Scale (MORBAS)	Mongolia	Mongolia	0–42 months	No	Written	Single	161 item	Cognitive, receptive communication, expressive communication, fine motor, gross motor, social-emotional, adaptive behaviour	Bayley Scales of Infant and Toddler Development (BSID-III) ⁴⁷
New Delhi-Development Screening Questionnaire (ND-DSQ)	India	India	9–18 months	Yes	Q & A	2 age sets	20 items	General screening tool (domains not explicitly mentioned)	Developmental Assessment Scales for Indian Infants (DASII) ⁴⁸
Parent Evaluation of Developmental Status (PEDS)	USA	Thailand	0–8 years	Yes	Q & A	Single	10 items	Global/cognitive, speech/ expressive language, receptive language, behaviour, social-emotional, school, self-help, fine motor, gross motor, other	Parent Evaluation of Developmental Status: Developmental Milestones, Assessment Level ⁴⁹ Mullen Scales of Early Learning ⁵⁰
Rapid Prescreening Denver Questionnaire (R-PDQ)	USA	India	0–6 years	No	Q & A	4 age sets	25 items	Gross motor, fine motor activity, personal-social, language	Denver Developmental Screening Test (DDST) ⁵¹
Road to Health Booklet Developmental Checklist (RTHB-DC)	South Africa	South Africa	14 weeks to 6 years	No	Checklist	Single	21 items	Gross motor, fine motor, communication, vision, hearing	Parent Evaluation of Developmental Status (PEDS) ⁵² Parent Evaluation of Developmental Status: Developmental Milestones ⁵²

Continued

Table 1 Continued

Screening tool	Country of origin	Study country	Concerned age	Parent-reported version	Questionnaire type	Number of questionnaires	Number of items	Developmental domain	Validated against
Ten Questions Screening Instrument (TQSI)	Multiple	Benin	2–9 years	Yes	Q & A	Single	10 items	Vision, hearing, seizure, cognition, motor	Mullen Scales of Early Learning ⁵³
Trivandrum Developmental Screening Chart (TDSC)	India	India	0–2 years	No	Chart	Single	17 items	Mental, motor, vision, hearing	Denver Developmental Screening Test (DDST) ⁵⁴
Woodside System Screening Technique (WSST)	Scotland	India	0–4 years	No	Chart	Single	70 items	Social, hearing and language, vision and fine motor, gross motor	Gesell's Developmental Schedules (GDS) ⁵⁵
Language screening tools									
American Speech-Language and Hearing Association (ASHA)	USA	Brazil	0–5 years	No	Q & A	7 age sets	6–13 items	Language reception and expression	Child Language Test in Phonology, Vocabulary, Fluency and Pragmatics (ABFW) ⁴⁰
Language Evaluation Scale Trivandrum for 0–3 years (LEST 0-3)	India	India	0–3 years	No	Chart	Single	33 items	Speech and language	Receptive Expressive Emergent Language Scale (REELS) ⁴⁴
Motor screening tools									
Infant Neurological International Battery (INFANIB)	USA	Iran	0–18 months	No	Not found	Single	20 items	Gross motor	Developmental Assessment by Paediatric Neurologist ⁴³
Little Developmental Coordination Disorder Questionnaire (Little DCDDQ)	Israel	South Africa	3–5 years	Yes	Q & A	Single	15 items	Gross motor, fine motor	Movement Assessment Battery for Children-2 (MABC-2) ⁴⁵

*ABFW: Child Language Test in Phonology, Vocabulary, Fluency and Pragmatics. Originally known as "Teste de Linguagem Infantil nas Áreas de Fonologia, Vocabulário, Fluência e Pragmática" (Portuguese Brazilian)

sub-Saharan Africa (Benin, South Africa). Selection criteria used for participation in those studies are stated in online supplemental table S5.

Study characteristics

All the included studies were cross-sectional in nature. Among the 18 studies, one study was conducted in the community and tertiary hospital simultaneously,⁵⁴ 8 were conducted in the tertiary hospital,^{38 42 43 46–50} 5 were conducted in the community^{39 40 44 51 55} and 1 study each was conducted in a nursery school setting⁴⁵ and primary healthcare clinic setting.⁵² In the remaining two studies, screening was done in the community followed by a hospital-based detailed assessment in one⁴¹ and primary healthcare clinic-based assessment in another.⁵³

Validated screening tools

The Ages and Stages Questionnaire

This is a parent-completed questionnaire that could be used as a general developmental screening tool. The Ages and Stages Questionnaire (ASQ) was designed and developed by J. Squires and D. Bricker, at the University of Oregon and can be completed in 12–18 min.⁵⁶ The questionnaire has 30 items focusing on five domains of child development, named gross motor, fine motor, problem-solving, communication and personal-social. Obtaining lower scores than the cut-off in any domain is considered as 'screen positive'. The latest version of ASQ, ASQ-III, has 21 sets of questionnaires, appropriate for children aged 1–66 months.⁵⁷ In the study by Juneja *et al*, a Hindi adaptation of an older version of ASQ, (ASQ-II, which had 19 sets of questionnaires for 4–60 months aged children) was used in a convenience sample of 200 children divided into four age groups: 4, 10, 18 and 24 months, in a tertiary hospital setting.³⁸ Each age group consisted of 30 low-risk and 20 high-risk children. High-risk status was determined by the presence of any of the following risk factors: prematurity, low birth weight, history of neonatal hospitalisation, history of central nervous system infection, history of afebrile seizure, diagnosed cases of developmental disorder and chromosomal abnormalities. Children without these risk factors were treated as being in the low-risk group. Eventually, 4, 10, 18 and 24 months questionnaires of ASQ-II were validated against 'Developmental Assessment Scales for Indian Infants (DASII)', considered as a gold standard for developmental assessment tool among Indian children.³⁸ The overall sensitivity and specificity of ASQ-II for Indian children were found to be 83.3% and 75.4%, respectively.

In the study by Yue *et al*, Chinese adaptation of ASQ-3 was used among 1831 children aged 5–24 months in a cluster random sample from rural China. Eventually, the tool was validated against the Bayley Scales of Infant and Toddler Development-III. Overall sensitivity and specificity of ASQ-III found to be 76.52% and 40.97%, respectively. The authors suggested to avoid using ASQ-III for children lower than 13 months of age as well as children

whose primary caregiver are not their mother, due to poor performance in those group of children.³⁹

American Speech-Language and Hearing Association Screening Tool

The ASHA was designed and developed to screen out under-5 children for language delay in receptive and expressive language domain. There are seven age sets consisting of 6–13 questions per age set. Cut-off score for screen positive result varies from one age set to another. In general, if a child gets more than two negative answers in any domain will be considered as 'screen positive'. In the study conducted by Dias *et al*, 1000 under-5 children were screened for language delay during a polio vaccination campaign in São Paulo, Brazil by using the tool. Later detailed assessment was conducted using the Child Language Test in Phonology, Vocabulary, Fluency and Pragmatics (ABFW). ASHA found to have excellent sensitivity and specificity (82.5% and 98.93%, respectively) against ABFW Child Language Test.⁴⁰ The authors recommended to adapt the instrument for bilingual children as well as validating it in larger sample size.

Development Screening Questionnaire

The Development Screening Questionnaire (DSQ) was designed and developed in Bangladesh, to be administered to mothers of children from birth to 24 months of age to screen their child's neurodevelopmental status. The DSQ has 24 age sets with 8 questions per set related to eight functional domains, named: gross motor, fine motor, vision, hearing, cognition, socialisation, behaviour and speech.⁴¹ Any child found to be positive on one or more functional domain is considered 'screen positive'. In a study conducted in urban Bangladesh, a random sample of 197 children aged 0–24 months was screened in the community with DSQ, and then a detailed developmental assessment was done in a tertiary hospital with the help of the 'Rapid Neurodevelopmental Assessment' tool as the gold standard. Overall sensitivity and specificity of DSQ for Bangladeshi children under 2 years was found to be 47.1% and 97.2%, respectively.⁴¹ Despite moderate sensitivity, the DSQ might be advantageous for resource-poor settings due to its high specificity.

Guide for Monitoring Child Development

The Guide for Monitoring Child Development (GMCD) was designed and developed in Turkey to monitor development of children aged 0–3.5 years in LMICs. The tool consists of 7 open-ended questions focusing on the following domains: expressive language and communication, receptive language, fine and gross motor, social-emotional, self-help. Children declared screened positive if they failed to demonstrate one or more age-appropriate milestones. In a study conducted by Ertem *et al*, GMCD was validated against Bayley Scales of Infant Development (BSID-II) in a random sample 79 Turkish children of 1–24 months of age. The overall sensitivity and specificity of GMCD were found to be 88% and 93%, respectively.⁴²

Infant Neurological International Battery

The INFANIB was established by Ellison and Browning in 1985 to assess the gross motor function of children aged 0–18 months. The tool contains 20 items focusing on spasticity, vestibular function, head and trunk, French angles and legs.⁵⁸ In the study by Soleimani and Dadkhah, a consecutive sample of 6150 children were screened using INFANIB and classified as normal, transiently abnormal and abnormal. To validate the tool, a random sample of 153 children from the above-mentioned groups were assessed by paediatric neurologists. It was found that overall sensitivity and specificity of INFANIB for Iranian children were 90% and 83%, respectively.⁴³

Language Evaluation Scale Trivandrum

Designed and developed at the Child Development Centre of the Trivandrum Government Medical College, India, Language Evaluation Scale Trivandrum (LEST 0–3) is a 33 items screening tool to screen out language delay among children aged 0–3 years.⁴⁴ The LEST 0–3 was validated against the ‘Receptive-Expressive Emergent Language Scale’ tool as a gold standard in a community sample of 643 Indian children aged 0–36 months. To decide on the best possible combination, researchers considered both ‘one item delay’ and ‘two items delay’ as screen positive. When one item delay considered as screen positive, sensitivity and specificity of LEST 0–3 found to be 95.8% and 77.5%, respectively. Similarly, when two items delay measured as screen positive, the sensitivity and specificity obtained as 66.7% and 94.8%, respectively.⁴⁴ It should be noted that the original version of Receptive-Expressive Emergent Language Scale (1971) was used in this study for validation due to the lack of age-appropriate language assessment tool for language delay.

Little Developmental Coordination Disorder Questionnaire

The Little Developmental Coordination Disorder Questionnaire (Little DCDQ) was developed by Rithman *et al* in Israel to assess gross motor and fine motor function of children between 3 and 5 years of age. It is a parent-reported questionnaire with 15 items under three main components, control during execution, fine motor execution and overall coordination.⁴⁵ The Little DCDQ was validated against the Movement Assessment Battery for Children-2 as a gold standard in a group of 53 South African preschoolers between 3 and 5 years of age, with Afrikaans, Tswana or English-speaking parents.⁴⁵ With 57.14% sensitivity and 81.25% specificity, Little DCDQ had the potential to be used in South African culture, however, some adjustments would be required.

Lucknow Development Screen

The Lucknow Development Screen (LDS) was developed in CSM Medical University, Lucknow, India, using selected milestones from Baroda Development Screening Test. It is a 27 items chart format tool, covering four domains namely motor, mental, language and social. Suitable for children aged 0–24 months. The LDS is

said to be easily administrable by interviewing parents or caregiver.⁴⁶ In a study conducted in India, the LDS tool was validated against the DASII and the Vineland Social Maturity Scale. They administered the tool to mothers of a sample of 142 children, aged between 6 and 24 months, attending Paediatric Outpatients or Neurology Clinic of CSM Medical University, Lucknow, India. The screening tool was translated into Hindi for easy understanding and administration. For three children among the sample size of 142, Vineland Social Maturity scale was used as a gold standard, as DASII could not be applied to them. It is claimed that the LDS has a great potential to be used as a community screening tool among Indian children, with an overall sensitivity of 95.9% and specificity 73.1%.⁴⁶

Mongolian Rapid Baby Scale

The Mongolian Rapid Baby Scale (MORBAS) is a written developmental screening test, designed and developed in Mongolia. It has 161 items arranged under seven developmental domains, namely gross motor, fine motor, cognitive, expressive language, receptive language, social-emotional and adaptive behaviour. The tool is suitable for children aged 0–42 months.⁴⁷ In a study conducted in Mongolia, MORBAS was administered in a convenience sample of 150 Mongolian children aged 0–42 months and thus validated against the Bayley Scales of Infant and Toddler Development-III (BSID-III). With sensitivity 81.8% and specificity 52.3%,⁴⁷ MORBAS could be useful in the long run to screen out children for early intervention and rehabilitation.

New Delhi-Development Screening Questionnaire

The New Delhi-Development Screening Questionnaire (ND-DSQ) was developed by Jain *et al*, at Chacha Nehru Bal Chikitsalaya, a tertiary hospital of northern India. ND-DSQ has 20 items, two age sets (9 and 18 months) and applicable for children aged 9–18 months.⁴⁸ The items mentioned were milestone specific. Thus, no explicit mention of the developmental domains was found. In the study by Jain *et al*, ND-DSQ was validated against DASII in a convenience sample of 200 children aged 9 and 18 months (with 100 children per age group). It was established that the 9-month questionnaire was 100% sensitive and 87.2% specific for Indian children. Correspondingly, the 18 months questionnaire was validated with 91.4% sensitivity and 88.7% specificity.⁴⁸ As a newly developed tool, the ND-DSQ is promising to be useful for Indian and similar cultural settings.

Parent Evaluation of Developmental Status

This tool was developed in 1997 by F. P. Glascoe at Tennessee, USA.⁵⁹ It is the only screening tool available to date that addresses parent’s concern about children’s development in the following domains: gross motor, fine motor, cognitive, expressive language, receptive language, behaviour, social-emotional, self-help, school and other.⁶⁰ It has ten open-ended questions under 10 areas of parental concerns, applicable for children aged

0–8 years. The other category allows parents to express concerns not already addressed under previous categories. This unique property makes Parent Evaluation of Developmental Status (PEDS) unique as a developmental screening tool. In PEDS, parental concerns are labelled as ‘predictive’ (significant) and ‘non-predictive’ (non-significant). Thus, children are screened as low-risk, moderate-risk and high-risk group if they have no or non-predictive concerns, one predictive concern and two predictive concerns, respectively.⁴⁹

In the study by Chunusuwan *et al*, the PEDS-Thai was validated against the ‘Parent Evaluation of Developmental Status: Developmental Milestones, Assessment Level’ in a tertiary hospital. A convenience sample of 266 children of 9, 18 and 30 months of age was selected. Screen positive children were assembled as ‘high-risk’ (≥ 2 significant concerns) and ‘moderate-risk or high-risk’ (≥ 1 significant concern) group. Sensitivity and specificity of PEDS against Parent Evaluation of Developmental Status: Developmental Milestones, Assessment Level for the high-risk group was established as 27.7% and 93.0%, respectively. For moderate-risk or high-risk group, the tool was 67.7% sensitive and 60.7% specific.⁴⁹ In order to avoid unnecessary/over-referral, the authors suggested to practice second stage evaluation (using Parent Evaluation of Developmental Status: Developmental Milestones, ASQ, Denver-II etc.) alongside/after PEDS screening.

In another study by Wantanakorn *et al*, they validated the PEDS-Thai against the Mullen Scales of Early Learning tool as a gold standard in a convenience sample of 137 children aged 18–36 months in another tertiary hospital. It was found that the PEDS-Thai is a promising tool for Thai cultural backgrounds with overall sensitivity of 92.8% and specificity 49.2%.⁵⁰ According to the authors, ‘the relatively low specificity of PEDS seen here may be because of the excessive concern of parents regarding their child’s development, especially who are in relatively high socioeconomic status’. The selection bias of participants was mentioned as the major limitation of the study. Thus, they advised further evaluation of the diagnostic performances of the tool using a representative sample of the population.

Rapid Prescreening Denver Questionnaire

The Rapid Prescreening Denver Questionnaire (R-PDQ) is a general developmental screening tool covering four developmental domains: gross motor, fine motor activity, personal-social and language.⁵¹ It has four age sets applicable for children aged 0–6 years: 0–9 months, 9–24 months, 2–4 years and 4–6 years. Each questionnaire contained 25 items. To score a child, the responding person had to keep answering the questions until there were three negative responses under a specific domain. In the study by Awasthi *et al*, the 2–4 years questionnaire of R-PDQ was validated against the Denver Developmental Screening Test. The study participants were randomly selected 126 children living in urban slums of Lucknow, India. To validate the tool, when a delay in more than

one domain was considered as the cut-off, the tool was revealed to be 100% sensitive and 7.8% specific. Similarly, when a delay in more than two domains was considered as the cut-off, the sensitivity and specificity were found to be 18.2% and 42.6%, respectively.⁵¹ Inconvenient validity and high referral rate compared with US children were explained by the presence of various ‘difficult to interpret’ questions and Denver Developmental Screening Test being an unsuitable gold standard for R-PDQ.

Road to Health Booklet Developmental Checklist

The Road to Health Booklet Developmental Checklist (RTHB-DC) was prepared as an integrated part of The Road to Health Booklet, the revised version of which was introduced in October 2010. RTHB-DC is the only developmental surveillance and screening tool, currently implemented nationally in South Africa. The tool consists of 21 questions covering gross motor, fine motor, communication, vision and hearing domains. The checklist is applicable for children aged 14 weeks to 6 years.⁶¹ In the study by van der Linde *et al*, RTHB-DC was validated against PEDS and Parent Evaluation of Developmental Status: Developmental Milestones tools. The sample size was 201, consisting of children aged 6–12 months. In a primary healthcare clinic setting in South Africa, the sensitivity of the tool was found to be very low, that is, 25% compared with reasonably high specificity of 91%.⁵² Further development of the tool has been suggested by the authors incorporating consistent age gaps and inclusion of all developmental domains.

Ten Questions Screening Instrument

The Ten Questions Screening Instrument (TQSI) was developed in 1984 as part of a pilot study conducted by the University of Columbia, USA, for use in resource-poor countries.^{62 63} TQSI is a parent-reported tool comprising 10 questions addressing motor, cognitive, vision, hearing and seizure status. A child is considered screen positive if any of the questions are found to be positive. The tool is appropriate for children aged 2–9 years. In a study by Koura *et al*, the TQSI was validated against the Mullen Scales of Early Learning in a sample of 357 children aged 12 months.⁵³ The participants were the offspring of the mothers who were enrolled in the ‘Malaria in Pregnancy Preventive Alternative Drugs’ trial. To adjust the tool for that age group, researchers had excluded the language domain which is applicable for children above 2 years. In that study, screening was done in the community followed by a detailed assessment done in the health centre. It was found that the overall tool had reasonably high sensitivity (81%) but poor specificity (31%) for children of Benin. This is compared with the 76.5% sensitivity and 75.7% specificity where only the motor domain was considered.⁵³ Mullen Scales of Early Learning was used due to lack of a gold standard assessment tool for the Beninese population. The result suggests that the TQSI tool might be useful for resource-poor settings to screen out moderate to severe delay in motor function.



Trivandrum Developmental Screening Chart

The Trivandrum Developmental Screening Chart (TDSC) was designed and developed by Nair *et al* in 1991 in Child Development Center, Kerala, India. The chart contains 17 items under four developmental domains—mental, motor, vision and hearing; applicable for children under 2 years of age.⁵⁴ If a child fails to achieve any item appropriate for his chronological age, considered as screened positive. In a study conducted by Nair *et al*, TDSC was validated against Denver Developmental Screening Test (DDST) simultaneously in community as well as hospital settings in a cluster random sample of 1945 Indian children aged <2 years. Overall sensitivity and specificity of TDSC found to be 66.7% and 78.8%, respectively.⁵⁴ The authors recommended to use the chart for mass screening of developmental delay among under-2 children in resource-poor settings.

Woodside Screening Technique

The Woodside Screening Technique (WSST) was designed and developed in Glasgow, Scotland in the year 1976. The tool consists of 70 items covering social, hearing and language, vision and fine motor and gross motor domains, suitable for children under 4 years of age.⁵⁵ In a study conducted by Gupta and Patel, WSST was validated against Gesell's Developmental Schedules (GDS) in a random sample of 619 children aged 6 weeks–2 years from Jabalpur, India. Overall sensitivity and specificity of WSST found to be 83% and 88%, respectively.⁵⁵

The major findings of this systematic review are presented in [table 2](#). We have classified the eligible tools into two broad categories—'Parents/Caregiver Reported Tools' and 'Direct Child Testing/Observation Tools'. The tools/studies which were not included in this review as they did not meet the selection criteria, are enlisted along with the reasons for rejection in online supplemental table S6.

DISCUSSION

To the best of our knowledge, this is the first systematic review which attempts to find the available screening tools for early identification of children with developmental delay in LMICs. Although some systematic reviews were found who considered developmental assessment tools requiring professional experts with a special office setup,⁶⁴ screening neurodevelopmental disability irrespective of age limit and diagnosis (eg, developmental delay, global developmental delay, cerebral palsy, autism spectrum disorder, attention deficit hyperactivity disorder, epilepsy and so on),⁶⁵ or reflected high-income country context.⁸ We have also observed a study in which both screening and assessment tools have been systematically rated for accuracy and feasibility to use in LMICs,³⁰ where information was significantly dependent on World Bank's toolkit and inventory on early child development tools,⁶⁶ rather than being obtained from systematic search through databases. In contrast, the purpose

of this review was to systematically look for the available studies where screening tools were used exclusively for early identification (limited to children under 5 years of age) of developmental delay in the LMICs region where all types of study settings (ie, from household to health facilities) were addressed in order to go for early intervention and rehabilitation of the screened cases. Therefore, the unique contribution of this review is to be able to report those screening tools exclusively designed for screening of developmental delay at the earliest possible time in both single and multiple domains.

Research gaps and future directions

Several research gaps have been identified in the reported studies. Primarily, there was a lack of standard terminologies to indicate the developmental domains. The examples of synonymous domain names are as follows: (i) cognitive: cognition, cognitive, global, mental, problem solving and so on^{38 39 41 46 47 49 50 53 54}; (ii) language: communication, expressive communication, expressive language, language, receptive communication, receptive language, speech, speech and language and so on^{38–42 44 46 47 49–51}; (iii) psychosocial: adaptive behaviour, behaviour, personal-social, self-help, social, social-emotional, socialisation and so on.^{38 39 41 42 46 47 49–51 55} Apart from those, few researchers incorporated unconventional developmental domains in their tools, such as: hearing, school, seizure, vision and so on.^{49 50 52–55} Secondly, there was a lack of standard proxy measures to define the screen-positive cases. Currently available examples of proxy measures are as follows: overall scores,^{38 39} number of negative answers,⁴⁰ number of milestones,⁴² number of items,^{44 54} number of functional domains,⁵¹ number of significant concerns^{49 50} and so on. These two factors together, often make the screening results incomprehensible to health professionals who are not familiar with the tool in question. Moreover, it is neither possible to convert nor compare the test scores between separate screening tools, for better understanding. Many of the tools developed in English-speaking countries might not be suitable for non-English-speaking countries due to different socio-cultural backgrounds and problematic translation.^{67–69} These issues might become a barrier for early identification and rehabilitation of developmental delay from the service providers' end. Lastly, several studies reported that the expected sensitivity-specificity was not achieved due to the lack of validated gold standard assessment tool for the particular culture in question.^{44 51 53} To the best of our knowledge, there is a lack of WHO's centralised initiatives, as well as no global regulatory body is currently working in this regard. Majority of the developmental assessment tools found in this review were established for high-income countries (BSID, DDST, REELS, GDS, MABC-2 and so on). Only three of them were designed and developed in LMICs (ABFW, DAASII and RNDA). None of the studies using assessment tools designed for high-income countries, provided information on cultural adaptation. However, Parveen *et al*, took the initiative to

Table 2 Major findings from the selected studies used in this review

Ref.	Country	Screening tool	Gold standard	Study	Participants	Key findings
Parents/Caregiver reported tools						
General screening tools						
38	India	Ages and Stages Questionnaire II (ASQ-II)	Developmental Assessment Scales for Indian Infants (DASII)	Design: cross-sectional Setting: hospital	Sample: 200 Age: 4, 10, 18 and 24 months Convenience sample	Overall Sensitivity 83.3% Specificity 75.4%
39	China	Ages and Stages Questionnaire III (ASQ-III)	Bayley Scales of Infant Development (BSID-III)	Design: cross-sectional Setting: community	Sample: 1831 Age: 5–24 months Cluster random sample	Overall Sensitivity 76.52% Specificity 40.97%
42	Turkey	Guide for Monitoring Child Development (GMCD)	Bayley Scales of Infant Development (BSID-II)	Design: cross-sectional Setting: hospital	Sample: 79 Age: 1–24 months Random sample	Overall Sensitivity 88% Specificity 93%
46	India	Lucknow Development Screen/Developmental Assessment Scales for Indian Infants (DASII)	Developmental Assessment Scales for Indian Infants (DASII)	Design: cross-sectional Setting: hospital	Sample: 142 Age: 6–24 months Convenience sample	Overall Sensitivity 95.9% Specificity 73.1%
48	India	New Delhi-Development Screening Questionnaire (ND-DSQ)	Vineland Social Maturity Scale Developmental Assessment Scales for Indian Infants (DASII)	Design: cross-sectional Setting: hospital	Sample: 200 Age: 9 and 18 months Convenience sample	9 months Sensitivity 100% Specificity 87.2% Sensitivity 91.4% Specificity 88.7%
49	Thailand	Parent Evaluation of Developmental Status (PEDS)	Parent Evaluation of Developmental Status: Developmental Milestones, Assessment Level	Design: cross-sectional Setting: hospital	Sample: 266 Age: 9, 18 and 30 months Convenience sample	≥1 significant concern Sensitivity 67.7% Specificity 60.7% Sensitivity 27.7% Specificity 93.0%
50	Thailand	Parent Evaluation of Developmental Status (PEDS-Thai)	Mullen Scales of Early Learning	Design: cross-sectional Setting: hospital	Sample: 137 Age: 18–30 months Convenience sample	Overall Sensitivity 92.8% Specificity 49.2%

Continued

Table 2 Continued

Ref.	Country	Screening tool	Gold standard	Study	Participants	Key findings
53	Benin	Ten Questions Screening Instrument (TQS)	Mullen Scales of Early Learning	Design: cross-sectional Setting: household Assessment: health centre	Sample: 357 Age: 12 months Random sample	Motor Sensitivity 76.5% Specificity 75.7% Sensitivity 81% Specificity 31%
Motor screening tools						
45	South Africa	Little Developmental Coordination Disorder Questionnaire (Little DCDQ)	Movement Assessment Battery for Children-2 (MABC-2)	Design: cross-sectional Setting: nursery schools	Sample: 53 Age: 3–5 years Convenience sample	Overall Sensitivity 57.14% Specificity 81.25%
Direct child testing/observation tools						
General screening tools						
41	Bangladesh	Development Screening Questionnaire (DSQ)	Rapid Neurodevelopmental Assessment (RNDA)	Design: cross-sectional Setting: screening-household Assessment: hospital	Sample: 197 Age: 0–2 years Random sample	Overall Sensitivity 47.1% Specificity 97.2%
47	Mongolia	Mongolian Rapid Baby Scale (MORBAS)	Bayley Scales of Infant and Toddler Development-III (BSID-III)	Design: cross-sectional Setting: hospital	Sample: 150 Age: 0 month 16 days–42 months 15 days Convenience sample	Overall Sensitivity 81.8% Specificity 52.3%
51	India	Revised Prescreening Denver Questionnaire (R-PDQ)	Denver Developmental Screening Test (DDST)	Design: cross-sectional Setting: community	Sample: 126 Age: 2–4 years Cluster random sample	Delay in ≥1 domain Sensitivity 100% Specificity 7.8% Sensitivity 18.2% Specificity 42.6%
52	South Africa	Road to Health Booklet Developmental Checklist (RTHB-DC)	Parent Evaluation of Developmental Status (PEDS)	Design: comparative cross-sectional within-subject Setting: Primary Health Centre clinics	Sample: 201 Age: 6–12 months Convenience sample	Overall Sensitivity 25% Specificity 91%
Parent Evaluation of Developmental Status: Developmental Milestones						

Continued

Table 2 Continued

Ref.	Country	Screening tool	Gold standard	Study	Participants	Key findings
54	India	Trivandrum Developmental Screening Chart (TDSC)	Denver Developmental Screening Test (DDST)	Design: cross-sectional Setting: hospital+community	Sample: 1945 Age: 0–2 years Cluster random sample	Overall Sensitivity 66.7% Specificity 78.8%
55	India	Woodside Screening Technique (WSST)	Gesell's Developmental Schedules (GDS)	Design: cross-sectional Setting: community	Sample: 619 Age: 6 weeks–2 years Random sample	Overall Sensitivity 83% Specificity 88%
Language screening tools						
40	Brazil	American Speech-Language and Hearing Association (ASHA)	Child Language Test in Phonology, Vocabulary, Fluency and Pragmatics (ABFW)	Design: cross-sectional Setting: community	Sample: 1000 Age: 0–5 years Random sample	Overall Sensitivity 82.5% Specificity 98.93%
44	India	Language Evaluation Scale Trivandrum for 0–3 years (LEST 0–3)	Receptive Expressive Emergent Language Scale (REELS)	Design: cross-sectional Setting: community	Sample: 643 Age: 0–3 years Cluster random sample	One item delay Sensitivity 95.8% Specificity 77.5% Two item delay Sensitivity 66.7% Specificity 94.8%
Motor screening tools						
43	Iran	Infant Neurological International Battery (INFANIB)	Developmental Assessment by Paediatric Neurologist	Design: cross-sectional Setting: hospital	Sample: 153 Age: 4–18 months Random sample	Overall Sensitivity 90% Specificity 83%

culturally adapt Bayley Scales of Infant Development-Second Edition (BSID-II) items for Bangladeshi infants.⁷⁰ Example of culture-sensitive BSID-II items for Bangladeshi infants are presented in online supplemental table S7. Future research work should focus on developing or adapting developmental assessment tools to be efficiently used as gold standard for LMICs.

In this systematic review, we had observed East Asian and Pacific, European and Central Asian, Latin American and the Caribbean, Middle East and North African, South Asian and sub-Saharan cultural contexts among the eligible studies, although the number of countries engaged in similar studies are alarmingly low compared with the number of LMICs in total.³⁴ This reveals the urgent need for valid and culturally sensitive screening tools for the rest of the LMICs. Among the 16 eligible screening tools, half of them were developed in LMICs (DSQ, GMCD, LEST 0–3, LDS, MORBAS, ND-DSQ, RTHB-DC and TDSC) and another half were developed in high-income countries (ASHA, ASQ, INFANIB, Little DCDQ, PEDS, R-PDQ, TQSI and WSST). We have found the majority of the culturally sensitive tools translated in their native language. Still, for multilingual countries like Benin, Ethiopia, India and so on, the necessity of translating the tools in regional languages remains high. None of the LMICs has been found to be engaged in collecting nationally representative longitudinal data on the prevalence of developmental delay, which is vital for disease projection. The gathering of nationally representative prevalence data in linguistic, social, ethnic and cultural subgroups would allow the validation of customised developmental screening tools according to disease burden. Greater customisation to respect the diverse cultural norms⁷¹ of a particular community, will also most likely result in greater acceptance^{72 73} of the screening process, which is crucial for the success of a large-scale surveillance programme.

While planning surveillance programme for resource-poor settings, additional factors should be kept in mind. According to Gupta and Patel, lack of furniture as well as staircase at home often results in exhibition of delayed gross motor skills due to lack of practice. Similarly, being heavily dependent on recall method is also problematic, as it is burdensome for parents with no or minimal education.⁵⁵ To overcome these issues, Ertem *et al* suggested to target very young children for developmental screening/surveillance. As earlier we can screen the children, higher the chances of attaining similar milestones at similar ages despite cultural differences.⁴²

Promising quasi-validated tool

We have found quite a few promising screening tools suitable for early identification of developmental delay. Unfortunately, could not include them as the studies did not fulfil our selection criteria. One of the quasi-validated tools is Neonatal Oral Motor Assessment Scale (NOMAS). NOMAS is a commonly used neonatal feeding evaluation which is developed by Marjorie Meyer Palmer in 1985.

The NOMAS is the only available neonatal feeding evaluation that can be used for the term or preterm infants and for breast or bottle-fed infants. This is a 28-items observational checklist for tongue and jaw movement. Following the observation of non-nutritive sucking, oral feeding for the first 2 min are evaluated.⁷⁴ In a study conducted in Taiwan by Tsai *et al*, 2010, the predictive validity of NOMAS was assessed against BSID-II in a group of 27 preterm infants without brain lesion to demonstrate neurodevelopmental outcome at 6 months and 12 months of corrected age.⁷⁵

Suitable screening tools for primary healthcare setting

Out of the 16 eligible screening tools, we would recommend two screening tools feasible enough to be used for developmental surveillance at the primary healthcare setting. They are ASQ and PEDS. Both are parent-completed screening tools. Their strong points are: PEDS requires bare minimum additional materials and for ASQ, it provides 21 sets of questionnaires for 21 age groups. Besides, both are very easy to administer. We can easily build up a surveillance system using these tools. Where health workers can carry out screening at households using single PEDS questionnaire for all, then screened positive cases can be referred to the primary healthcare centres to conduct secondary screening with age-specific ASQ questionnaire. Basic properties of ASQ and PEDS are stated in the online supplemental table S8.⁷⁶

Limitations

Despite our best efforts, there were several limitations to this study. This study was limited to articles published in the English language only due to constraints in resources and time. In this study, we exclude children who had developmental delay due to HIV exposure or autism spectrum disorder or other behavioural disorders. Although these children also suffer from varying degrees of developmental delay, the pathogenesis behind those delays is closely related to the diseases.^{77 78} Moreover, conventionally it takes >2 years of age to diagnose a child with autism spectrum disorder and hence the age range of currently available autism screening tools starts later than general developmental screening tools (eg, Modified Checklist for Autism in Toddlers: 16–30 months; where ASQ-III: 1–66 months). This conflicts with the objectives of our study to ensure early diagnosis of developmental delay. So, with respect to other neurodevelopmental disorders, we preferred to focus exclusively on developmental delay in our study. Although it is very difficult to rule out the possibility of undiagnosed cases of autism being included among all the developmentally delayed children, as none of the studies reported so. Moreover, we were unable to critically appraise the available screening tools in terms of diagnostic accuracy due to the unavailability of the necessary information, which is quite reasonable as Boggs *et al* also reported that authors tend to provide validity information very briefly and evidence on accuracy are most difficult to obtain.³⁰ We are hopeful to conduct

subsequent systematic review and meta-analysis on geographical region/country/domain-specific screening tools and their psychometric properties based on the information obtained from this study.

Recommendations

1. A global regulatory body should be formed to standardise the terminologies and cut-off scores of available and future screening tools to improve comprehensiveness and interpretation of test results, simultaneously ensuring better correlation between results obtained from different screening tools.
2. Future research work should focus on revising existing screening as well as assessment tools in different ethnic and cultural perspectives and validate them in the respective normative sample as well as conducting systematic reviews based on individual screening tools in different cultural settings.
3. We also recommend ensuring nationwide routine developmental surveillance programmes in LMICs using culturally sensitive tools to identify and treat developmental delay as early as possible. Developmental screening at the time of routine immunisation schedule could be a possible way to integrate this with an existing successful public health programme in LMICs. This timing would be both cost-effective and maximise response rates.

CONCLUSIONS

Developmental screening is required for early diagnosis of developmental delays in infants and young children in LMICs to enable early intervention and rehabilitation. In order to do this, culturally sensitive, easy-to-administer screening tools with good psychometric properties are needed. We observed that there is a lack of culturally sensitive developmental screening tools validated among under-5 children in LMICs. However, we have found eight screening tools with relatively high sensitivity and specificity. We also identified key research gaps and consequently proposed a few recommendations for overcoming those gaps. These include (but not limited to) global standardisation of terminologies and cut-off scores for screening tools, revising existing tools according to diverse cultural norms and validating them in the respective normative sample and finally ensuring nationwide routine developmental surveillance programmes in LMICs using culturally sensitive tools. To execute so, we have suggested a health worker-centred screening system consisting of ASQ and PEDS. Therefore, future research should focus on enabling the caregivers, health workers and therapists to assist in children with developmental delays in LMICs to reach their full developmental potential.

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