A Review of Screening Tools for the Identification of Autism Spectrum Disorders and Developmental Delay in Infants and Young Children: Recommendations for Use in Low- and Middle-Income Countries

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Without intervention, developmental delay (DD) and autism spectrum disorders (ASDs) severely restrict children from reaching their developmental potential. Monitoring child development through the use of screening tools can help identify children who need further assessment or intervention. Screening has been widely encouraged to identify children with ASD or DD, and a large variety of screening instruments are suggested in the literature. There is a lack of consensus around which screening tools are most effective, especially where tools are used in cultures other than those in which they were created. We conducted a review of the literature for screening tools for DD and autism to make recommendations for tool selection and use in low- and middle-income countries (LMIC). We included 99 screening tools in the review and created profiles for each tool to evaluate their properties and determine which tools could be effectively used in various LMIC. Our review identified a substantial number (35 for DD and 6 for ASD) of screening tools from LMIC. We identified 10 tools which show promise for use across settings; these tools are brief, low-cost and can be implemented by paraprofessionals or lay community health workers. Routine screening is an important first step toward addressing the need for services in LMIC, but high-quality tools take time to be conceptualized, developed, piloted, and validated, before implementation can happen. A focus on improving the scientific rigor of early detection approaches and on enhancing the reach to underserved populations should be prioritized. ***Autism Research*** *2019, 12: 176–199.* © 2019 The Authors. *Autism Research published by International Society for Autism Research* published by Wiley Periodicals, Inc.

Lay Summary: Screening tools are short questionnaires or brief assessments used to identify children at risk of a developmental disability such as autism. Many screening tools exist, but there is uncertainty about which tools work best in non-Western cultures or low-resource settings. We reviewed over 90 screening tools to identify which tools can be easily used in these settings. Selecting tools that are affordable and easy to use will make it easier to identify and support children with developmental difficulties.

Keywords: developmental monitoring; screening tools; autism spectrum disorders; developmental disability; low- and middle-income countries

Introduction

Children who experience developmental disabilities are among the most vulnerable members of a society. Without intervention, these difficulties severely restrict children, both academically and socially, from reaching their developmental potential. Developmental delay (DD) and neurodevelopmental disorders such as autism spectrum disorders (ASDs) encompass a range of difficulties that infants and young children may experience in the areas of cognitive, language, social–emotional, behavioral, and neuromotor development (Bellman, Byrne, & Sege, 2013). The prevalence of global DD in children is reported as 1–3% (Bellman et al., 2013), while the global prevalence of ASDs is estimated to be 1 in 132 (Baxter et al., 2015). Children living in circumstances characterized by adversities such as poverty and malnutrition are also at significantly higher risk of experiencing disability (UNICEF, 2013; WHO, 2011). There are a paucity of community-based data on developmental status and disability from low- and middle-income countries (LMIC), despite the fact that most children with disability live in these countries (Durkin et al., 2015; WHO, 2013). Little is known about the epidemiology and clinical presentation of ASD in South-East Asia, South America, and Africa (Baxter et al., 2015; de Vries, 2016; Elsabbagh et al.,

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2012). For children who are developmentally delayed, prevalence rates are likely even higher than reported, since children with milder and more subtle signs are likely to go unnoticed (Sajedi, Vameghi, & Kraskian Mujembari, 2014). Given the increasing developmental burden in LMIC (Lawn et al., 2014), it is essential to identify at-risk and affected children as early as possible.

The under-identification of children with disabilities is of concern, as early identification and initiation of treatment have been shown to improve child outcomes for DD (Berlin, Brooks-Gunn, McCarton, & McCormick, 1998; Hwang, Chao, & Liu, 2013) and for autism (Filipek et al., 2000; Stahmer & Mandell, 2007). The World Health Organization (WHO, 2012) promotes developmental monitoring (also referred to as developmental surveillance by the American Academy of Pediatrics) as a process for the early detection of developmental difficulties, specifically for LMIC. One of the suggested ways of monitoring children's development is through formal screening for DD or neurodevelopmental disorders, as part of a step-wise approach to diagnosis and provision of care (American Academy of Pediatrics, 2006). Evidence from high-income countries (HIC) suggest that incorporating screening tools into routine health care visits can result in earlier and more accurate identification of children who need help, compared to relying on clinical impressions only (Hamilton, 2006; Sheldrick, Merchant, & Perrin, 2011). This may be particularly relevant for LMIC, where care providers are often less experienced in identifying DD or disorders (Desai & Mohite, 2011).

Regular screening during health care visits for autism or DD offers an easily administered means of early detection, while enabling referral for further evaluation and intervention where needed. However, despite its promise, early detection remains a challenge in both HIC and LMIC (Barton, Dumont-Mathieu, & Fein, 2012; Durkin et al., 2015; King et al., 2010; Macy et al., 2014). Identification is difficult in early life, when changes in development are rapid, domains overlap, and early signs are often subtle (Mukherjee, Aneja, Krishnamurthy, & Srinivasan, 2014). Both primary health care staff and caregivers in LMIC settings may have limited knowledge of more subtle delays or specific disorders such as autism. Autism is a prevalent and well-known neurodevelopmental disorder in HIC, but many communities in LMIC have little awareness of the disorder (Abubakar, Ssewanyana, & Newton, 2016), and affected children are less likely to be identified by primary care providers (Wallace et al., 2012). Also, establishing a relevant set of screening criteria to identify autism across different cultures and socio-economic backgrounds is difficult (Wallice & Pinto-Martin, 2008).

Screening requires adequate financial and human resources for implementation. Factors that may impede screening in LMIC include costs, lack of resources, staff limitations, and insufficient training (Morelli et al., 2014; Pinto-Martin, Dunkle, Earls, Fliedner, & Landes, 2005; Rydz et al., 2006; Sand et al., 2005). Importantly, screening needs to be linked to psychoeducation and counseling, follow-up services and treatment (Grossman et al., 2010; King et al., 2010). False-positive screen results can lead to unnecessary stigma, anxiety, and excess costs for the family and the health care system, whereas false-negative results can lead to delays in treatment and worse outcomes. Ideally, surveillance and screening would be the starting point of a comprehensive developmental monitoring process, whereby the screening results guide decisions about intervention services that may help mitigate or minimize the severity of a child's delay or disability (Ali, Mustafa, Balaji, & Poornima, 2013; Pinto-Martin et al., 2005; Zwaigenbaum et al., 2015).

Another barrier to early identification through screening revolves around the selection process of the screening instruments themselves (Drotar, Stancin, Dworkin, Sices, & Wood, 2008; Warren et al., 2016). Screening tools may be general, encompassing multiple domains (e.g., the Ages and Stages Questionnaire (ASQ-3), Abo El Elella, Tawfik, Abo El Fotoh, & Barseem, 2017) or specific to a disorder such as autism (e.g., the Modified Checklist for Autism in Toddlers Revised with Follow-up (M-CHAT-R/F); Robins et al., 2014). As awareness of concerns about child development and specifically autism has increased, screening has been widely encouraged to identify children with ASD or DD, accompanied by a large variety of instruments suggested in the literature (Moodie et al., 2014; Ringwalt, 2008; Rydz et al., 2006; Semrud-Clikeman et al., 2017). A lack of consensus exists around which screening tools will be most effective to detect developmental disability in different settings. While significant improvements have been made in the development, validation, and implementation of screening tools for use in LMIC, most tools have been developed in North America or Europe and are increasingly being used in cultures other than those in which they were created (Soto et al., 2015). There is a scarcity of validated tools available to identify children with autism in LMIC (Durkin et al., 2015) and Africa in particular (Abubakar et al., 2016).

An important challenge in early identification of developmental disability is having tools that respond to local differences, including cultural perceptions in meaning of disability (Fischer, Morris, & Martines, 2014). Cross-culturally appropriate and affordable tools with good psychometric properties remain limited (Goldfield & Yousafzai, 2018), and using tools developed in HIC for LMIC settings may not always be appropriate. Applying Western-based norms to other cultural contexts may be problematic, since there is a tendency to over-identify children as delayed. In addition, many of these tools are copyrighted and require permissions and payment for translation into other languages (Durkin et al., 2015), thus further limiting their use in LMIC. An ideal screening tool

for LMIC would be a brief, inexpensive tool with developmentally appropriate items and good psychometric properties (Goldfield & Yousafzai, 2018), available in local languages where it is used, validated on representative healthy children of the particular population, and requires minimal training (Lansdown et al., 1996). These criteria apply to tools used to detect autism, as well as more general DD. It is not clear which existing tools are best suited for this, or where further tool development and research is most needed. We conducted a review of the literature for screening tools for DD and ASD. This review had the following objectives:

1. Identify current screening instruments for DD and ASD.
2. Create screening tool profiles in order to consolidate the available information on characteristics and use.
3. Make recommendations for screening for DD and ASD in LMIC.

Methods

Search Strategy

We conducted online searches, using various databases (PubMed, Web of Science, EBSCO, and Google Scholar) to identify publications related to the identification of children with DD or ASD. The search was conducted in two phases, with each phase consisting of two parts. We conducted Phase 1 of the review in 2014; searching for tools published up to October 2014 (we did not specify a start date). Search terms included "screening," "screening tools," "autism spectrum disorders," "autism," "developmental delay," "developmental disability," and "low- and middle-income countries." In August 2017, we applied the same search terms to update the review, in order to identify and include new tools that have been developed or published since 2014. Given that in most of the peer-reviewed literature the name of the screening tool is not mentioned in the title or even as a key word, we also conducted individual searches to identify tools. Therefore, during each phase, the search for screening tools (Part 1) was followed by an individual search (Part 2), using the name of each tool identified in the general search results.

The initial search results generated a large volume of studies and reviews related to developmental screening processes and instruments. Search results yielded guidelines and recommendations for the use of screening tools to identify children with DD or ASD (e.g., American Academy of Pediatrics, 2006; Charman & Gotham, 2013; King et al., 2010) and reports of screening tools used in different populations (e.g., Barton et al., 2012; Bello, Quartey, & Appiah, 2013; Grossman et al., 2010; Perera, Wijewardena, & Aluthwelage, 2009). The search results included a large number of studies that described tool development and validation (e.g., Allen, Silove, Williams, & Hutchins, 2007; Bhave, Bhargava, & Kumar, 2010; Durkin et al., 1994, 1995) or adaptation of screening tools (e.g., Gladstone et al., 2008; Kakooza-Mwesige et al., 2014; Soto et al., 2015), as well as comparisons between screening tools (e.g., Mayes et al., 2009; Murray, Mayes, & Smith, 2011; Snow & Lecavalier, 2008). Using existing publications, as well as our focused literature search, we compiled an alphabetical list of all the tools used to identify children with DD and ASD. We used this list to conduct an individual search on each tool for more detailed information on the tool's properties. If any other tools were mentioned during the individual searches, they were added to the list and an individual search for the newly identified tool was also conducted. The inclusion criteria for screening tools were as follows:

1. Suitable for use with children between 0 and 7 years of age.
2. Studies on the tool's use published in English.
3. Intended use is screening or rapid assessment, not formal diagnosis.
4. Targets at least one of the following developmental domains: motor, language, cognitive, socio-emotional, or behavioral domains.
5. Information on the tool's performance available for a minimum of four characteristics (e.g., screening domain, age range, format, and items/length).

Because our focus was on developmental monitoring, we excluded tests used for diagnostic purposes such as the Autism Diagnostic Observation Schedule, the Mullen Scales of Early Learning, or the Bayley Scales of Infant Development. However, search parameters were relaxed for tools developed for LMIC because of the limited evidence-base from many of these countries. Tools that were designed to screen for children with specific disabilities (e.g., hearing or vision impairment) and tools designed for specialist settings such as inpatient rehabilitation centers were also excluded, as the purpose of the review was to identify screening tools that could be used effectively in general or at-risk populations. Information on screening was not always optimally available; therefore, the decision to include a particular tool was based on current best knowledge. Following the individual searches, some tools were removed because they had been replaced by a newer, improved version. An example of this was the Kilifi Developmental Checklist, used in Kenya to screen for DD, which had been replaced by the Kilifi Developmental Inventory (Abubakar, Holding, Van Baar, Newton, & van de Vijver, 2008).

Profiles for each tool were then created in order to determine the tool's feasibility for use in LMIC. We gathered the information on screening instruments from several sources. We consulted test reviews and articles that describe the psychometric properties published in peer-

reviewed journals, practice guidelines developed by professional societies, administration manuals, technical documents, and information from the test publishers or distributors. Profiles were populated with information, age ranges, whether the tool used a rater report (e.g., completed by parent or care provider) or direct assessment (e.g., observing the child's behavior), the instrument properties (number of items, type of response, reliability, and validity data) and information on cost, administration, and scoring. We also included information on the training involved in administration and the level of qualification required, if any. Where information was available on the tool's strengths and limitations, this was incorporated into the tool's profile as well. There was a considerable amount of contradictory information regarding some of the tools and their properties (e.g., time of administration, number of items, or the various training and administration requirements). In these cases, MM, MT, and CS came to a consensus about how to populate the profile.

Following this process, screening tools were divided according to those used to screen for ASD, more general DD and screening tools specifically developed for LMIC/non-Western settings. The final set of tools were organized into four categories (DD screening tools developed for LMIC and non-Western settings; general DD screening tools; ASD screening tools for LMIC and non-Western settings and ASD screening tools). The tools were collated into a table, and each tool was assessed according to areas screened for, age range, tool format (rater report or observation), length of test or the number of items, and the training required in order to administer and score the test. Checkmarks (√) in the columns were used to represent the presence of the following criteria:

1. *Specificity and Sensitivity data:*
   Tools that have both specificity and sensitivity data above 70% receive double checkmarks (√√). Tools with only one score above 70% received a single checkmark (√).
2. *Sample size:*
   If a tool was studied in a sample of 300 participants or more, it received a checkmark (√). According to Bujang and Adnan (2016), a sample of 300 participants is a sufficient rule-of-thumb to determine the specificity and sensitivity of most screening tests.
3. *Free:*
   If a tool is freely available for use, it received a checkmark (√). Tools that appear to be free (i.e., no purchase cost involved or tool described as low-cost), received a checkmark with an asterisk (√*) to indicate that it could potentially be implemented at no or low-cost outside of the research setting.
4. *Used in LMIC/non-Western settings:*
   If a tool has been adapted, validated, or developed for use in a low- or middle-income country, based on the World Bank classification of countries, it received a checkmark (√). Tools received a checkmark with an asterisk (√*) if the tool was designed for a non-Western setting or aboriginal populations within in a HIC.
5. *CHWs*:
   If there was evidence in the literature that the tool has been used for screening by a lay community health worker (CHW), it received a checkmark (√).

Results

A total of 99 screening tools were included in the review (Fig. 1). We identified 59 tools used to screen for more general DD, and 40 tools intended to screen for ASD. Thirty-five screening tools used to identify DD were developed specifically for LMIC/non-Western settings (Table 1), and 24 tools used for more general DD originated from HIC (Table 2). Only six ASD screening tools were developed specifically for LMIC/non-Western settings (Table 3), while the majority of ASD screening tools were developed in and for HIC (Table 4). Most tools have been developed in HIC (out of 58 screening tools from HIC—41 are from the USA and 3 from Canada). There are a number of screening tools used for DD from LMIC (35 tools), but ASD tools for LMIC remain limited (only six identified in our review).

Tools used to screen for ASD in LMIC are often derived from existing tools: for example, the HIVA screening tool used in Iran (Samadi & McConkey, 2014, 2015) includes items from the GARS-2 and the M-CHAT screening tools, while the Three-Item Direct Observation Screen (TIDOS; Oner et al., 2013) used in Turkey to screen for ASD in young children, combines the parent-report items from the Social Communication Questionnaire (SCQ; Allen et al., 2007; Chandler et al., 2007; Oosterling et al., 2010; Snow & Lecavalier, 2008) with three observational items. The 23-item screener used in Uganda (Kakooza-Mwesige et al., 2014) is an adaptation of the Ten Questions Screening Instrument (TQSI; Durkin et al., 1995), including an additional 13 items to identify children with ASD and to increase screening capability for visual, hearing, and seizure impairments. The Pictorial Autism Assessment Schedule (PAAS; Perera et al., 2017) used in Sri Lanka was an attempt to overcome cultural barriers to identifying symptoms of ASD by adding a visual aid to facilitate the recognition of autism.

Psychometric Data

Tools varied significantly in their psychometric performance and feasibility. Most studies sought to assess whether the screening instrument could differentiate the ASD (or DD) group from other groups. Sensitivity and

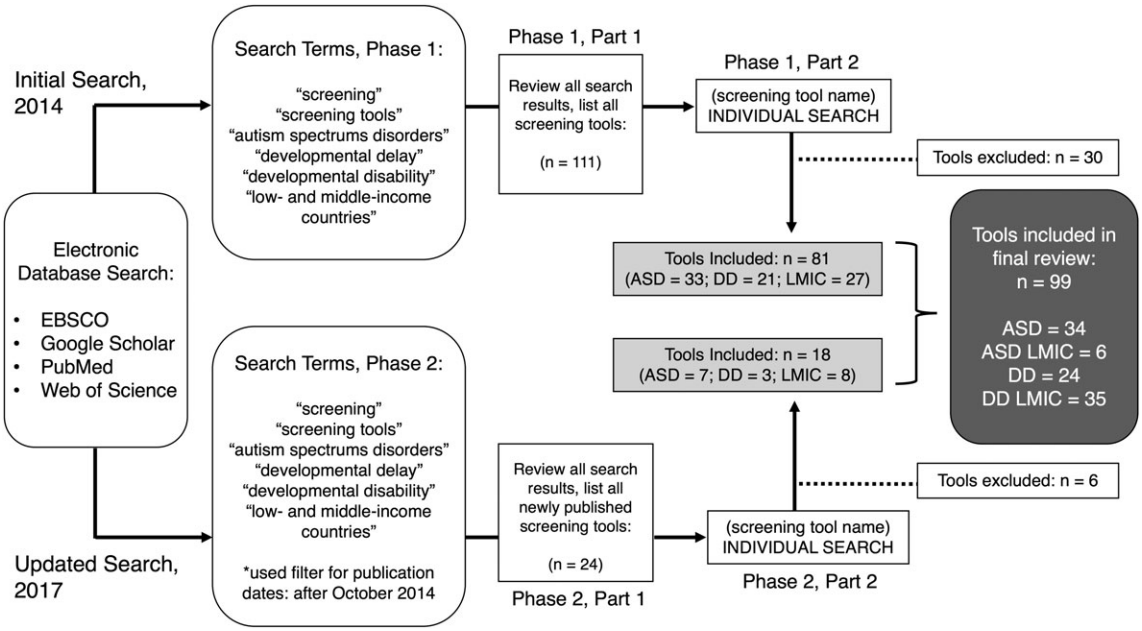

Figure 1. Search strategy and screening tools selected for inclusion.

specificity analysis were also widely used (primarily using the ROC curve), although small sample sizes often prevented comprehensive reliability or validity testing of screening tools. Over 80% of screening tools for DD were studied in a sample of 300 or more, while 70% of ASD tools were studied in a sample of 300 or more. Only 45% of tools for DD had both specificity and sensitivity data above 0.7, while over 70% of tools for ASD had specificity and sensitivity data above 0.7.

Cost and Access to the Instrument

Most of the tests developed and licensed in HIC are strictly protected by copyright. Examples of such tools are the Battelle Developmental Inventory Screening Tool (BDI-ST; Elbaum et al., 2010; Glascoe & Byrne, 1993), the Baby and Infant Screen for Children with aUtism Traits (Matson et al., 2010; Matson, Fodstad, et al., 2009; Matson, Wilkins, et al., 2009), or the Checklist for Autism Spectrum Disorders (Mayes et al., 2013). The majority of screening tools developed in the USA require payment for use (e.g., the ADEC, ASRS-SF, CARS-2, GARS-3, GADS, KADI, PDDST, SCQ, SRS-2, STAT, ASQ-3, BDI-ST, BINS, BITSEA, BRIGANCE-II, DDST, ECI-4, ESI-R, Greenspan, or PEDS). In many cases, a licensed psychologist is the only person that is permitted to purchase the tests from the publishing companies. Copyright laws prohibit any use of the tests (including photocopying) without explicit permission or purchase, which prevents many researchers working in LMIC from using these standardized tools. Furthermore, translation is not allowed without additional approval. Costs are often prohibitive for use in low-resource settings and screening at population level. A few exceptions that are freely available for download include the AQ, ASAS, A-TAQ, Childhood Asperger's Syndrome Test (CAST), M-CHAT R/F, ITC, POSI, SSI, BPSC, EDI, ESSENCE-Q, PPSC, PSC, and SWYC.

Adaptation and Translation for Use in LMIC

Methods used to translate or revalidate screening tools for different settings varied widely. Some tools developed in HIC have been adapted for use in LMIC, such as the ASQ, PEDS, and M-CHAT screening tools: The ASQ has been used in India (Chaudhari & Kadam, 2012; Juneja, Mohanty, Jain, & Ramji, 2012), Taiwan (Tsai, McClelland, Pratt, & Squires, 2006), Brazil (Filgueiras, Pires, Maisonette, & Landeira-Fernandez, 2013), Turkey (Kapci, Kucuker, & Uslu, 2010), Thailand (Saihong, 2010), and Iran (Vameghi et al., 2013). The PEDS has also been used to detect DD in LMIC (Woolfenden et al., 2014), and has been translated for use in Tanzania (Kosht-Fedyshin, 2006), India (Malhi & Singhi, 2002), Thailand (Theeranate & Chuengchitraks, 2005), and Indonesia (Gustawan & Machfudz, 2010). The M-CHAT remains one of the most widely used screening tools for the detection of autism and has been translated for use in Mexico (Albores-Gallo et al., 2012), Albania (Brennan, Fein, Como, Rathwell, & Chen, 2016), nine Arabic speaking countries (Seif Eldin et al., 2008), and Sri Lanka (Perera et al., 2009). However, in Sri Lanka, effort was made to examine the tool rather than just use it, and the M-CHAT demonstrated unacceptably low specificity (Perera et al., 2009). For an extensive review on the modification and adaption of tests for use in lower-income settings than those of the population the tests were standardized on,

Table 1. Screening Tools for Developmental Delay, Developed for LMIC/Non-Western Settings

Screening tool		References	Used to screen for	Used in	Age range (months/ years)	Rater (R)/ observation (O)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
12m	12-month screener	Biasini et al. (2015)	DD	India; Pakistan; Zambia	12 months	O	13 items	√√	√	√*	√	
ACCESS	ACCESS Portfolio	Wirz, Edwards, Flower, and Yousafzai (2005)	DD	Uganda; Sri Lanka	0–3 years	R + O	Varies by portfolio component		√	√*	√	√
AHC-DMAT	The Angkor Hospital for Children Developmental Milestones Tool	Ngoun, Stoey, van't Ende, and Kumar (2012)	NDD	Cambodia	1–6 years	R + O	140 items, 15–20 min			√*	√	
BDST	Baroda Development Screening Test for Infants	Phatak and Khurana (1991)	DD	India	0–30 months	R + O	54 items	√		√*	√	√
CDIIT	Comprehensive Developmental Inventory for Infants and Toddlers	Liao (2008)	DD	Taiwan	3–71 months	O	45–90 min	√√	√		√*	
CREDI	Caregiver-Reported Early Development Index	McCoy et al. (2017)	DD	Multiple LMIC	18–36 months	R	70 items, 20 min	√	√	√	√	√
DATA	Developmental Assessment Tool for Anganwadis	Nair et al. (2009)	DD	India	2–3 years	R + O	12 items		√	√*	√	√
DATA-II	Developmental Assessment Tool for Anganwadis-II	Nair and Russell (2013)	DD	India	3–4 years	R + O	12 items		√	√*	√	√
DMC-II	Developmental Milestones Chart –II	Prado et al. (2013); Scherzer (2009)	DD	Cambodia; Burkina Faso; Kenya	1 months–8 years	R + O	10–20 min		√	√*	√	√
DSQ	Developmental Screening Questionnaire	Khan et al. (2012)	DD	Bangladesh	0–2 years	R	8 items, 5 min	√		√*	√	√
DSS	Disability Screening Schedule	Chopra, Verma, and Seetheraman (1999)	DD	India	0–6 years	R + O	5 min	√√		√*	√	√
EAD-1	Abbreviated Developmental Scale	Velez van Meerbeke, Talero-Gutierrez, and Gonzalez-Reyes (2007)	DD	Colombia	0–60 months	R/O	30 items		√		√	
EAP-ECDS	East-Asia Pacific Early Child Development Scales	Rao et al. (2014)	DD	East-Asia Pacific	3–5 years	R + O	85 items	√	√		√	
Engle	Engle Scale and Survey	Verdisco, Cueto, Thompson, and Neuschmidt (2015)	DD	East-Asia Pacific	24–59 months	R + O	21 items (Form A); 22 items (Form B)		√	√	√	

(Continues)

Table 1. Continued

Screening tool		References	Used to screen for	Used in	Age range (months/ years)	Rater (R)/ observation (O)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
GMCD	Guide for Monitoring Child Development	Ertem et al. (2008)	DD	Turkey, India, South Africa, Argentina	0–3.5 years	R	7 items, 7–20 min	√√	√	√*	√	√
IBAS	Independent Behavior Assessment Scale	Munir, Zaman, and McConachie (1999)	DD	Bangladesh	2–9 years	O	188 items	√	√		√	
INCLEN-NDST	INCLEN Neurodevelopmental Screening Test	Gulati et al. (2014)	NDD ASD	India	2–9 years	R	39 items	√	√	√*	√	
INFANIB	Infant Neurological International Battery Test	Soleimani and Dadkhah (2007)	DD	Iran	4–18 months	O	20 items	√	√	√*	√	
Intergrowth-21	INTERGROWTH-21st Neurodevelopment Assessment	Fernandes et al. (2014)	DD	Brazil; Kenya; India; Italy; UK	22–26 months	R + O	53 items, 35–45 min	√√	√	√	√	√
KDI	Kilifi Developmental Inventory	Abubakar et al. (2008); Abubakar, Holding, van De Vijver, Bomu, and Van Baar (2010)	NDD	Kenya	6–35 months	O	69 activity items	√	√	√*	√	
Lucknow	Lucknow Development Screen	Bhave et al. (2010)	DD	India	6–24 months	R	27 items, 10 min	√√	√	√*	√	√
MDAT	Malawian Developmental Assessment Tool	Gladstone et al. (2008, 2010)	DD	Malawi	0–6 years	R + O	138 items, 30 min	√√	√	√*	√	√
MORBAS	Mongolian Rapid Baby Scale	Dagvadorj et al. (2015)	DD	Mongolia	0–42 months	R	161 items, 15 min	√		√*	√	√
MuSiC	Multidimensional Screening in Child Development	Brinkman et al. (2007)	DD	Taiwan	3–36 months	R	75 items	√√	√		√*	
NIMH-DSS	National Institute for the Mentally Handicapped Developmental Screening Schedule	Arya (1991)	DD	India	0–6 years		10 items	√√	V	√	√	√
PDST	Psychosocial Developmental Screening Test	Malik, Pradhan, and Prasuna (2007); Vazir, Naidu, Vidyasagar, Lansdown, and Reddy (1994)	DD	India	0–6 years	R + O	66 milestone items		√	√	√	√
Red Cross	Red Cross War Memorial Children's Hospital developmental screening tool	Boyede, Eley, and Donald (2016)	DD	South Africa	9–36 months	O	5–10 min	√		√	√	√
RNDA	Rapid Neurodevelopmental Assessment Tool	Khan et al. (2010, 2013, 2014)	ASD DD	Bangladesh	0–9 years	O	53 items, 30–45 min	√√	√	√	√	√

R-PDQ	Rapid Pre-Screening Denver Questionnaire	Awasthu and Pande (1997)	DD	India	0–6 years	R	20 min				√	√
RTHB	Road to Health Booklet Developmental Checklist	van der Linde (2015)	DD	South Africa	14 months–6 years	R	21 items	√		√	√	√
Shoklo	Shoklo Developmental Test	Haataja et al. (2002)	DD	Thailand	9–12 months	O	20 min	√	√	√*	√	√
TDSC	Trivandrum Developmental Screening Chart	Nair et al. (1991, 2013)	DD	India	0–2 years	O	17 items, 5 min	√√	√	√	√	√
TQSI	Ten Questions Screening Instrument	Durkin et al. (1994, 1995); Durkin, Hasan, and Hasan (1998); Thorburn et al. (1992)	DD	Multiple LMIC	2–9 years	R	10 items	√	√	√	√	√
TQP	Ten Questions Plus	Wu et al. (2012)	DD	Nepal	2–5 years	R	11 items		√	√*	√	√
Woodside	Woodside Screening Technique	Gupta and Patel (1991a, 1991b)	DD	India	6 weeks–24 months	R + O		√√	√	√*	√	√

Tools that appear to be free (i.e., no purchase cost involved or tool described as low-cost), received a checkmark with an asterisk (√*). Tools received a checkmark with an asterisk (√*) if the tool was designed for a non-Western setting or aboriginal populations within in a HIC.

see Fernald, Kariger, Engle, and Raikes (2009)'s toolkit for assessing early child development.

Training and Use by CHWs

We also included information on the training involved with administering screening tests. For screening tools that use a parent report format, this may seem arbitrary. For example, studies that used tools such as the First Year Inventory (Reznick, Baranek, Reavis, Watson, & Crais, 2007; Watson et al., 2007) or the Childhood Asperger's Syndrome Test (CAST; Scott et al., 2002; Williams et al., 2005) mailed the questionnaires to parents, and therefore no training was conducted for administration of the tool. Nonetheless, information on training procedures or stipulations about who can administer and score screening tests was an important consideration for this review, since we were looking specifically for tools that can be used by lay health workers in LMIC.

Of the 99 tools, only 26 had been used by CHWs and most of these were developed for LMIC. In HIC, administrators of screening tests are usually required to complete training on how to administer and score the test and are often professionals who regularly interact with children in some capacity (e.g., pediatricians, psychologists, or teachers). However, other personnel with relevant backgrounds (community health workers, social workers, etc.) can also be trained to conduct these tests (Fernald et al., 2009), even though there is limited literature available on tools from HIC used by lay health workers.

Selected Tools for Use in LMIC

From the tools included in the review and indexed as per the above indices, we selected 10 tools that adhered most closely to our feasibility criteria to screen children for ASD or DD in LMIC (Table 5). We selected tools that:

- Take 30 min or less to administer;
- Cover multiple domains of development;
- Are free to access and can be implemented at low cost;
- Can be implemented by paraprofessionals or lay community health workers;
- Have successfully been used/easily adapted for use in more than one LMIC.

For the screening and detection of ASD specifically, we identified three tools, namely the Modified Checklist for Autism in Toddlers, Revised with Follow-up (Robins et al., 2014), the PAAS, (Perera et al., 2009, 2017) and the TIDOS (Oner et al., 2013). To identify children with, or at risk of DD, we selected seven tools for use in LMIC, namely: the Guide for Monitoring Child Development (GMCD; Ertem et al., 2008); Malawi Developmental Assessment Tool (MDAT; Gladstone et al., 2010); Rapid Neurodevelopmental Assessment Tool (RNDA; Khan

Table 2. Screening Tools for Developmental Delay

Screening tool	References	Used to screen for	Used in	Age range (months/ years)	Rater (R)/ observation (O)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
ASQ Ages and Stages Questionnaire	Chaudhari and Kadam (2012); Deakin-Bell, Walker, and Badawi (2013); Kerstjens et al. (2009)	DD ASD	USA	1–66 months	R	30 items	√√	√		√	
ASQ: SE ASQ Social Emotional	Briggs et al. (2012); Jee et al. (2010)	SE	USA	3–66 months	R	+30 items (varies with age)	√√	√		√	
BDI-2 ST Battelle Developmental Inventory 2nd Edition Screening Tool	Elbaum, Gattamorta, and Penfied (2010); Glascoe and Byrne (1993)	DD	USA	0–95 months	R + O	96 items, 10–30 min	√√	√			
BINS Bayley Infant Neurodevelopment Screen	Aylward and Verhulst (2000)	NDD	USA	3–24 months	O	11–13 items, 10 min	√√	√		√	
BPSC Baby Pediatric Symptom Checklist	Sheldrick et al. (2013); Smith, Sheldrick, and Perrin (2013)	SE ASD	USA	2–18 months	R	12 items, 5 min		√	√	√	
Brigance-II Brigance-II Screens	Glascoe (2002); Glascoe and Brigance (2005)	DD	USA	0–90 months	R + O	8–10 items, 10–15 min	√√	√			
CDR-PQ Child Developmental Review Parent Questionnaire	Ireton (1996)	DD	USA	18–60 months	R	31 items	√	√			
CSBS-DP BS CSBS-DP Behaviour Sample	Wetherby, Allen, Cleary, Kublin, and Goldstein (2002); Wetherby, Goldstein, Cleary, Allen, and Kublin (2003)	DD	USA	6–24 months	O	30 min	√√	√		√	
CSBS-DP CQ CSBS-DP Caregiver Questionnaire	Wetherby et al. (2002, 2003)	DD	USA	6–24 months	R	15–25 min	√√	√			
DDST Denver-II Developmental Screening Tool	Frankenburg, Dodds, Archer, Shapiro, and Bresnick (1992); Glascoe et al. (1992); Wijedasa (2012)	DD	USA	0–6 years	R + O	125 items, 10–20 min	√	√		√	
ECI-4 Early Childhood Inventory-4th Edition	Sprafkin, Volpe, Gadow, Nolan, and Kelly (2002)	SE ASD	USA	3–5 years	R	108 items, 10–15 min		√		√	
EDI Early Development Instrument	Janus and Offord (2007)	DD	Canada	4–6 years	R	104 items, 20 min		√	√	√	
ERIC Early Report by Infant Caregivers	Schafer et al. (2014)	DD	UK	10–24 months	R + O	Described as brief	√√	√	√*		
ESI-R Early Screening Inventory-Revised	Meisels, Henderson, Liaw, Browning, and Have (1993)	DD	USA	3–6 years	R + O	25 items, 15–20 min	√√	√		√	

ESP	Early Screening Profiles	Lenkarski, Singer, Peters, and McIntosh (2001)	DD	USA	2–6 years	R + O	15–40 min		√			
ESSENCE-Q	ESSENCE-Questionnaire	Hatakenaka et al. (2016)	NDD	Sweden, Japan	Not specified	R	12 items	√		√	√*	
Greenspan	Greenspan Social Emotional Growth Chart	Greenspan (2004); Tede, Cohen, Riskin, and Tirosh (2016)	SE	USA	0–42 months	R	35 items, 10 min		√		√	
ITC (CSBS-DP)	Infant Toddler Checklist	Wetherby, Brosnan-Maddox, Peace, and Newton (2008)	DD ASD	USA	6–24 months	R	24 items, 5–10 min	√√	√	√		
PCQ	Parental Concerns Questionnaire	Schroeder et al. (2014)	DD	USA	4–48 months	R	15 items		√		√	√
PEDS	Parent's Evaluation of Developmental Status	Glascoe (1998); Woolfenden et al. (2014)	DD	USA	1 month–8 years	R	10 items, 10 min	√√	√		√	√
PEDS-DM	PEDS Developmental Milestones	Brothers and Glascoe (2008)	DD	USA	1 month–8 years	R	6–8 items, 5 min	√√	√			
PPSC	Preschool Pediatric Symptom Checklist	Sheldrick et al. (2012)	SE	USA	18–60 months	R	18 items, 5 min	√√	√	√	√	
PSC	Pediatric Symptom Checklist	Jellinek et al. (1988, 1999); Simonian and Tarnowski (2001)	SE	USA	4–16 years	R	35 items, 10–15 min	√√		√	√	
SWYC	Survey of Wellbeing of Young Children	Sheldrick and Perrin (2013)	DD	USA	2–60 months	R	15 min	√√	√	√	√	

Tools that appear to be free (i.e., no purchase cost involved or tool described as low-cost), received a checkmark with an asterisk (√*). Tools received a checkmark with an asterisk (√*) if the tool was designed for a non-Western setting or aboriginal populations within in a HIC.

Table 3. **Screening tools for ASD, developed for LMIC/non-Western settings**

	Screening tool	References	Used to screen for	Used in	Age range (months/years)	Rater (R)/ observation (0)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
23Q	23-item screener	Kakooza-Mwesige et al. (2014)	NDD ASD	Uganda	2–9 years	R	23 items	√	√	√	√	
HIVA	HIVA	Samadi and McConkey (2014, 2015)	ASD	Iran	3–11 years	R	10 items	√√	√	√	√	
INCLEN-ASD	INCLEN Diagnostic Tool for Autism Spectrum Disorder	Juneja et al. (2014)	ASD	India	2–9 years	R + 0	41 items, 45–60 min	√√		√*	√	
ISAA	Indian Scale for Assessment of Autism	Mukherjee, Malhotra, Aneja, Chakraborty, and Deshpande (2015); Patra and Arun (2011)	ASD	India	3–22 years	0	40 items, 15–20 min	√√	√	√	√	
PAAS	Pictorial Autism Assessment Schedule	Perera et al. (2009); Perera, Jeewandara, Seneviratne, and Guruge (2017)	ASD	Sri Lanka	18–48 months	R	21 items	√√		√*	√	
TIDOS	Three-Item Direct Observation Screen	Oner, Oner, and Munir (2013)	ASD	Turkey	18–60 months	R + 0	3 items (0), 40 items (R)	√√		√*	√	

Tools that appear to be free (i.e., no purchase cost involved or tool described as low-cost), received a checkmark with an asterisk (√*). Tools received a checkmark with an asterisk (√*) if the tool was designed for a non-Western setting or aboriginal populations within in a HIC.

et al., 2010, 2013, 2014); TQSI (Durkin et al., 1994, 1995, 1998; Thorburn et al., 1992); Caregiver-Reported Early Development Index (CREDI; McCoy et al., 2017); INTERGROWTH-21st Neurodevelopment Assessment (Fernandes et al., 2014), and the 12-month screener (Biasini et al., 2015). The Engle Scale and Survey (Verdisco et al., 2015) and the East-Asia Pacific Early Child Development Scales (EAP-ECDS; Rao et al., 2014) have been identified as promising tools, although limited information in the peer-reviewed literature is currently available.

Discussion

Monitoring child development through screening in LMIC can provide valuable data on rates of developmental difficulties in order to ensure interventions can be appropriately targeted, their effect monitored and the need for further interventions determined (Engle et al., 2007; Mung'ala-Odera & Newton, 2007). Identifying at-risk and affected children should be a key priority, especially for countries where children with DD or disability frequently remain undetected and untreated. The World Health Organization (WHO, 2012, 2013) has stated that developmental monitoring needs to be integrated in routine maternal and child health care, in the context of growth monitoring, early childhood development and provision of comprehensive care for children with specific needs and their families. In most LMIC, developmental surveillance is currently not a common feature of health service delivery, and there is a lack of standardized practice in screening of DD and ASD. A focus on improving the scientific rigor of early detection approaches and on enhancing the reach of such approaches to underserved populations should be prioritized (Daniels, Halladay, Shih, Elder, & Dawson, 2014).

The purpose of this review was to identify available tools from the literature used to screen children for ASD or more general DD, in order to make recommendations for tool selection and use in LMIC. The information on available tools provided here could inform decision-making related to developmental monitoring in LMIC, while considering heterogeneous realities, available resources and local health systems' capacities within different LMIC. We included over 90 different screening tools in our final review, and consolidated information on their properties to determine which tools could be effectively used for screening of either ASD or DD in various LMIC. An important challenge in early identification of developmental disability is having tools that respond to local differences, including cultural perceptions in meaning of disability and that can be used across countries (Fischer et al., 2014). As a result of the many challenges in determining cross-cultural validity of tests

Table 4. Screening tools for ASD

	Screening tool	References	Used to screen for	Used in	Age range (months/ years)	Rater (R)/ observation (O)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
ABC	Autism Behavior Checklist	Eaves and Williams (2006)	ASD	USA	2–14 years	R	57 items, 10–20 min	√√			√	
ADEC	Autism Detection in Early Childhood	Nah, Young, and Brewer (2014); Nah, Young, Brewer, and Berlingeri (2014)	ASD	Australia	1–3 years	O	16 items, 10–15 min	√√			√	
AOSI	Autism Observation Scale for Infants	Bryson, Zwaigenbaum, McDermott, Rombough, and Brian (2008); Zwaigenbaum et al. (2005)	ASD	Canada	6–18 months	O	18 items, 20 min			√*		
AQ	Autism Spectrum Quotient (Child Version)	Allison, Auyeung, and Baron-Cohen (2012); Auyeung, Baron-Cohen, Wheelwright, and Allison (2008)	ASD	UK	4–11 years	R	50 items, 20 min	√√	√	√		
ASAS	Australian Scale for Asperger's Syndrome	Garnett and Attwood (1997)	ASD	Australia	5 years+	R	27 items, 5 min			√*		
ASRS-SF	Autism Spectrum Rating Scales Short Form	Goldstein, Naglieri, Rzepa, and Williams (2012)	ASD	Sweden; UK	2–5 years	R	15 items, 5 min	√√	√			
ASSQ	Autism Spectrum Screening Questionnaire	Mattila et al. (2009); Posserud, Lundervold, and Gillberg (2006, 2009)	ASD	Canada	7–16 years	R	27 items, 10 min	√√	√	√*		
A-TAQ	Autism–Tics, AD/HD, and other Comorbidities (A–TAC) Inventory	Hansson et al. (2005); Larson et al. (2010, 2014)	ASD NDD	Sweden, Spain	6–19 years	R	96 items	√√	√	√		√
BISCUIT	Baby and Infant Screen for Children with aUtism Traits	Matson, Fodstad, Mahan, and Sevin (2009); Matson et al. (2009); Matson, Boisjoli, Hess, and Wilkins (2010)	ASD	USA	17–37 months	R	62 items (Part 1), 20 min	√√	√			
BITSEA	Brief Infant Toddler Social Emotional Assessment	Briggs-Gowan, Carter, Irwin, Wachtel, and Cicchetti (2004), Briggs-Gowan and Carter (2007)	DD ASD	USA	12–36 months	R	42 items, 7–10 min	√√	√		√	
CARS-2*	Childhood Autism Rating Scale 2nd Edition	Breidbord and Croudace (2013); Perry, Condillac, Freeman, Dunn-Geier, and Belair (2005)	ASD	USA	24 months+	O	15 items, 15 min	√√	√		√	
CASD	Checklist for Autism Spectrum Disorders	Mayes et al. (2009); Mayes, Black, and Tierrney (2013); Murray et al. (2011)	ASD	USA	1–16 years	R	30 items, 15 min	√√	√			

(Continues)

Table 4. Continued

Screening tool	References	Used to screen for	Used in	Age range (months/ years)	Rater (R)/ observation (O)	Nr. of items/ length of test	Sensitivity and specificity above 70	Sample > 300	Free	Used in LMIC	CHWs
CAST Childhood Asperger's Syndrome Test	Allison et al. (2007); Scott, Baron-Cohen, Bolton, and Brayne (2002); Williams et al. (2005)	ASD	UK	4–11 years	R	37 items, 20 min	√√	√	√*		
CESDD Checklist of Early Signs of Developmental Disorders	Dereu et al. (2010)	ASD	Belgium	3–36 months	R	12 items	√√	√	√*		
CHAT Checklist for Autism in Toddlers	Baird et al. (2000); Baron-Cohen, Allen, and Gillberg (1992);	ASD	UK	18–24 months	R + O	14 items, 5 min	√	√	√	√	
DBC-ASA Development Behavior Checklist-Autism Screening Algorithm	Brereton, Tonge, Mackinnon, and Einfeld (2002); Witwer and Lecavalier (2007)	ASD	Australia	4–18 years	R	29 items, 10–15 min	√	√			
DBC-ES Development Behavior Checklist-Early Screen	Gray and Tonge (2005); Gray, Tonge, Sweeney, and Einfeld (2008)	ASD	Australia	18–48 months	R	17 items, 10–15 min	√		√*		
ESAT Early Screening of Autistic Traits	Dietz, Swinkels, van Daalen, van Engeland, and Buitelaar (2006); Swinkels et al. (2006)	ASD	Netherlands	14–15 months	R	14 items, 5 min	√	√	√		
FYI First Year Inventory	Turner-Brown, Baranek, Reznick, Watson, and Crais (2013); Watson et al. (2007)	ASD	USA	12 months	R	63 items, 10 min	√	√	√*	√	
GADS Gilliam Asperger's Disorder Scale	Campbell (2005); Mayes et al. (2009, 2011)	ASD	USA	3–22 years	R	32 items, 5–10 min	√√	√			
GARS-3 Gilliam Autism Rating Scale 3rd Edition	Samadi and McConkey (2014)	ASD	USA	3–22 years	R	42 items, 5–10 min	√√	√		√	
KADI Krug Asperger's Disorder Index	Campbell (2005); Krug and Arick (2003)	ASD	USA	6–12 years	R	32 items, 15–20 min	√√				
M-CHAT Modified CHecklist for Autism in Toddlers	Robins, Fein, Barton, and Green (2001)	ASD	USA	16–30 months	R	23 items, 5–10 min	√√	√	√	√	
M-CHAT R/F Modified CHecklist for Autism Revised with Follow-Up	Robins et al. (2014)	ASD	USA	16–30 months	R	20 items	√√	√	√	√	
PDDST Pervasive Developmental Disorders Screening Test	Siegel (2004)	ASD	USA	12–48 months	R	22 items (St1), 14 items (St2)	√√	√			
POSI Parent's Observation of Social Interactions	Smith et al. (2013)	ASD	USA	16–30 months	R	7 items	√√	√	√	√	
Q-CHAT Quantitative Checklist for Autism in Toddlers	Allison et al. (2008)	ASD	USA	18–24 months	R	25 items, 5 min	√√	√	√		
RITA-T Rapid Interactive Screening Test for Autism in Toddlers	Choueiri and Wagner (2015)	ASD	USA	18–36 months	O	9 activities, 5–10 min	√√				
SCDC Social and Communication Disorders Checklist	Skuse, Mandy, and Scourfield (2005)	ASD	UK	5-17 years	R	12 items	√	√			

SCQ	Social Communication Questionnaire	Allen et al. (2007), Chandler et al. (2007); Oosterling et al. (2010); Snow and Lecavalier (2008)	ASD	USA	4 years	R	40 items, 10–15 min	√	√		√
SORF*	Systematic Observation of Red Flags	Wetherby et al. (2004)	ASD	USA	12–24 months	0	29 items, 30–40 min	√√	√		√
SSI	Screen for Social Interaction	Ghuman, Leone, Lecavalier, and Landa (2011)	ASD	USA	Toddler: 24–42 months Preschool: 43–61 months	R	Toddler: 21 items Preschool: 26 items	√√	√	√*	
SRS-2	Social Responsiveness Scale	Hus, Bishop, Gotham, Huerta, and Lord (2013)	ASD	USA	2.5–18 years	R	65 items, 15–20 min	√			√*
STAT*	Screening Tool for Autism in Toddlers	Stone, Coonrod, and Ousley (2000); Stone, Coonrod, Turner, and Pozdol (2004); Stone, McMahon, and Henderson (2008)	ASD	USA	24–35 months	0	12 items, 20 min	√√			

Level-2 screening tool; Tools that appear to be free (i.e., no purchase cost involved or tool described as low-cost), received a checkmark with an asterisk (√). Tools received a checkmark with an asterisk (√*) if the tool was designed for a non-Western setting or aboriginal populations within in a HIC.

developed in HIC, screening tools developed in local areas of study have accelerated, focusing on questions and testing methods that are culturally appropriate for children in LMIC (Semrud-Clikeman et al., 2017). Our review identified a substantial number (35 for DD and 6 for ASD) of screening tools from LMIC. We identified 10 tools which show promise for use across settings in LMIC. Three tools specifically for ASD (M-CHAT-R/F; PAAS; TIDOS) and seven for more general DD (CREDI; GMCD; INTERGROWTH-21st Neurodevelopmental Assessment; MDAT; RNDA; TQSI; 12-month screener) were selected. These tools most adequately adhered to our feasibility criteria to screen children for ASD or DD in these settings. Furthermore, the newly developed Engle Scale and Survey (Verdisco et al., 2015) and the EAP-ECDS (Rao et al., 2014) also show promise, although to the best of our knowledge no peer-review publications are currently available.

Despite its potential benefits, screening presents numerous challenges. In LMIC, many children do not regularly see medical or mental health professionals in the early years, making regular screening or surveillance difficult (Biasini et al., 2015). Community health workers have limited knowledge about age-appropriate developmental milestones and early warning signs, which means that problems are often only picked up when children come in contact with the primary health care system. Also, primary care staffs often have limited training and experience in recognition of early neurodevelopmental delays (Lian, Ho, Yeo, & Ho, 2003). The use of formal screening tools as part of developmental surveillance can assist health workers in this regard, but training and supervision need to accompany screening for it to be effectively implemented. Screening tools, including parent-report tools, should involve training and supervision for staff, particularly in terms of providing feedback of the screening results to caregivers. Given the human resource shortages in most LMIC, training community health workers to conduct screening and developmental surveillance is essential.

When selecting an existing screening tool, policy makers, researchers, and interventionists must consider its affordability, feasibility, and cultural appropriateness for the intended setting. The selection and validation of an appropriate screening tool requires considerable time and effort, research personnel, and financial resources (Mukherjee et al., 2014), and the adaptation process is more complex than simple translation. Determining the psychometric properties of a tool in a new context is expensive and requires research expertise and capacity. Tools comprised of a large number of items and that take more than 30 min to administer may further limit its feasibility for low resource settings. A large number of tools included in this review had over 100 items, challenging their usefulness for brief screening. In terms of

Table 5. Recommended list of tools for use in LMIC

Tool	Countries used	Age range	Format	Items	Cost/access	Training requirements	Comment
Screening for ASD:							
M-CHAT-R/F (Robins et al., 2014)	South Africa, Albania, Indonesia	16–30 months	Rater report	20 items with follow up section	Available for free download	Minimal, suitable for CHWs	Includes flow chart for follow-up questions that facilitates second stage of screening
PAAS (Perera et al., 2017)	Sri Lanka	18–48 months	Rater report, checklist	21 items	Not specified	Not specified	Each item on the checklist paired with a photograph that illustrates the message in text
TIDOS (Oner et al., 2013)	Turkey	18–60 months	Observation and rater report	3 observation items, 40 questions for parents	Not specified	Health professionals with experience in working with young children	Combines an observation of the child with the existing parent report screening tool, the Social Communication Questionnaire (SCQ; Allen et al., 2007; Oosterling et al., 2010)
Screening for DD:							
12-month screener (Biasini et al., 2015)	India, Pakistan, Zambia	12 months	Direct assessment	13 items	Not specified	Designed for primary health care professionals	Adapted from the Bayley Scales of Infant Development, with items selected from the 11–16 month age range
CREDI (McCoy et al., 2017	Multiple LMIC	18–36 months	Rater report	70 items, 20 min	Free	Minimal, suitable for CHWs	Additional research in diverse contexts and younger age groups needed to ensure the CREDI's utility prior to full dissemination
GMCD (Ertem et al., 2008)	Turkey, India, South Africa, Argentina	0–41 months	Rater report	7 items, 30 min	Free	Minimal, suitable for CHWs	Linked to further intervention through the Developmental Support Component
INTERGROWTH-21st (Fernandes et al., 2014)	Brazil, Kenya, India, Italy, UK	22–26 months	Rater report and direct assessment	53 items, takes 35–45 min	Free access	Minimal, suitable for CHWs	Measures the function of entire vision and auditory pathways, not merely specific components
MDAT (Gladstone et al., 2010)	Malawi	0–6 years	Rater report and direct assessment	34 items per domain, takes 30 min	Free, low cost to use	Minimal, suitable for CHWs	Includes clear pictorial representations for many items = easily understandable
RNDA (Khan et al., 2010, 2013, 2014)	Bangladesh	0–9 years	Direct assessment	53 items, 30–45 min	Free, low cost to use	Designed for use by "non-experts"	Different versions for different age groups; can be used to screen for ASD
TQSI (Durkin et al., 1994, 1995)	Multiple LMIC	2–9 years	Rater report	10 items, 5 min	Free	None specified, suitable for CHWs	Studied across variety of settings; less sensitive for milder delays
Promising newly developed tools:							
EAP-ECDS (Rao et al., 2014)	East-Asia Pacific	3–5 years	Rater report and direct assessment	85 items	Not specified	Experience in early child education	Test domains chosen based on the Early Learning and Developmental Standards (ELDS) of countries in the region
Engle Scale and Survey (Verdisco et al., 2015)	East-Asia Pacific	24–59 months	Rater report and direct assessment	21 items (Form A); 22 items (Form B)	Low cost to use	Some knowledge of ECD and short, hands-on training	Engle Scale and Survey part of the PRIDI package (The Regional Project on Child Development Indicators)

ASD: autism spectrum disorders; DD: developmental delay; CHWs: Community Health Workers; CREDI: Caregiver-Reported Early Development Index; EAP-ECDS: East-Asia Pacific Early Child Development Scales; GMCD: Guide for Monitoring Child Development; INTERGROWTH-21st: INTERGROWTH-21st Neurodevelopment Assessment; LMIC: Low- and middle-income countries; M-CHAT-R/F: Modified Checklist for Autism in Toddlers, Revised with Follow-Up; PAAS: Pictorial Autism Assessment Schedule; RNDA: Rapid Neurodevelopmental Assessment Tool; TQSI: Ten Questions Screening Instrument

administration, combining rater report with observation items in a screening tool may be beneficial for LMIC settings, given that both rater report and direct administration methods have drawbacks. Caregiver or parent reports may not be as reliable in LMIC due to poor literacy levels, lack of knowledge about milestones and the possibility of parents providing socially acceptable responses for fear of social stigma (Fernald et al., 2009; Robertson, Hatton, & Emerson, 2009; WHO, 2012). Checklists about milestones and caregiver concerns may not be sufficient to identify developmental disabilities in LMIC (De Lourdes et al., 2005). Although several observational or direct assessment screening tools have been developed, they may be too costly in time and effort for wide-scale use (Barton et al., 2012).

Routine screening will not be a panacea to the problem of non-detection. Not all children who screen positive for a DD or disability will be diagnosed, and not all children who screen negative are certainly clear of a diagnosis (Sheldrick & Garfinkel, 2017; Veldhuizen, 2017). If a child is screened and it is decided that they need to undergo formal assessment, there are very few specialists available who can make these assessments and reach a diagnostic decision. For example, in South Africa, families will typically wait 18 months for a basic diagnostic assessment for ASD in a specialist clinic (de Vries, 2016). Finally, linking screening and diagnosis with appropriate treatment services does not exist in many settings. If treatment and intervention is not available, screening may seem futile, especially to families and care providers (Collins et al., 2017). However, screening may provide crucial data as a means to understand the disease burden in order to plan and then monitor services. Routine screening is an important first step toward addressing the need for services in LMIC.

Limitations

Only publications in English were considered for inclusion, which may limit the generalizability of the findings. Given the large proportion of LMIC that do not have English as a primary language, it is possible that some promising tools may have been missed in this review. Second, tools were included in the review regardless of the size and quality of studies on screening tools. However, to account for this limitation, we included information in the tables on the sample size and specificity and sensitivity data reported in the studies. The search terms used in this review was broad, which means that tools designed for more specific delays or other neurodevelopmental disabilities may have been excluded. Finally, we included screening tools designed for population-level assessment, as well as for individual screening.

It should be noted that even the recommended tools have limitations. Previous studies using the MCHAT in Mexico (Albores-Gallo et al., 2012) and Egypt (Mohamed et al., 2016) have noted that there are cultural differences in responses, which may limit its acceptability for use in LMIC. However, we are recommending the MCHAT-R/F, which includes a simplified scoring procedure, paired with a flow chart with open-ended follow up questions that facilitate a second-stage screening process. The TQSI is only for children over the age of 2 years and has limited sensitivity for less severe disabilities. More research is needed on its use in more subtle DD. The RNDA has mixed sensitivity and specificity in the younger age group, and more research is needed from other countries. Although the MDAT has shown good sensitivity and specificity, it takes between 30 and 40 min to apply.

Conclusion

We suggest that great care needs to be taken when considering tools designed for research settings or diagnostic purposes as part of developmental monitoring efforts. This review was positioned broadly, in order to present findings of use to policy makers and interventionists considering screening as part of developmental monitoring in LMIC. Screening should ideally be conducted at two levels—routine general screening followed by a structured interview for those whose scores exceed a locally validated cut-off point. The adoption of strengths-based assessment and bio-psychosocial approaches whereby assets and risks in the family and broader environment are considered, and families are empowered with appropriate knowledge, skills and support, are recommended. An approach such as this will require substantial health system changes in most LMIC in order to deal with the scarcity of financial resources, low numbers of health workers skilled and trained in ASD and DD, cultural barriers to identification and the increasing costs of training. It will be important to remain mindful that high-quality tools take time to be conceptualized, developed, piloted, and validated, before implementation can happen. To do this, we will need expert centers across the globe that can compare novel instruments against "gold-standard" instruments. We should not risk introducing inferior quality tools into low-resource environments (de Vries, 2016). We believe that these profiles may assist researchers and practitioners to evaluate whether a developmental screening tool is appropriate, affordable, and feasible, while highlighting where further research or reporting is needed.

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