Validation of Rapid Neurodevelopmental Assessment for 2- to 5-Year-Old Children in Bangladesh

WHAT’S KNOWN ON THIS SUBJECT: In inverse proportion to the steadily declining under-5 mortality rate, prevalence of childhood disability has doubled in the past decade in Bangladesh. The Rapid Neurodevelopmental Assessment (RNDA) tool has been shown to be reliable and valid for assessment of a range of neurodevelopmental impairments (NDIs) and disabilities in children younger than 2 years. There is currently a lack of professional expertise for assessing NDIs in 2- to 5-year-old children in low- and middle-income countries.

WHAT THIS STUDY ADDS: We developed a set of instruments as part of the RNDA for administration by a single professional with experience in child development to assess >2- to 5-year-old children for a wide range of NDIs. The tool was acceptable to mothers, interrater reliability was high, and proportions of children with NDIs were elevated among the lowest income groups and in stunted children, demonstrating discriminant validity. The RNDA was valid for identifying >2- to 5-year-old children with a range of NDIs, especially in cognitive, behavior, and motor functions. Validity of the RNDA for vision, hearing, and seizure disorders needs further research.

OBJECTIVE: Validate a tool to determine neurodevelopmental impairments (NDIs) in >2- to 5-year-old children in a country with limited child development expertise.

METHODS: Rapid Neurodevelopmental Assessment (RNDA) is a tool designed to detect functional status and NDIs across multiple neurodevelopmental domains. Validity was determined in 77 children enrolled by door-to-door sampling in Dhaka and who were administered the RNDA by 1 of 6 testers (4 developmental therapists, 2 special education teachers) and simultaneously administered a test of adaptive behavior (AB; Independent Behavior Assessment Scale) and intelligence quotient (IQ) tests (Bayley Scales of Infant Development II, Stanford Binet Intelligence Scale). Validity of the RNDA for vision, hearing, and seizure disorders needs further research.

RESULTS: Interrater reliability ranged from good to excellent. There were significant differences in AB in mean percentile scores on the Independent Behavior Assessment Scale for motor (P = .0001), socialization (P = .001), communication (P = .001), and full-scale (P = .001) scores in children with ≥1 NDI (“any NDI”) versus no NDI. Significant differences in those with versus those without “any NDI” were found on IQ scores. Sensitivity and specificity for “significant difficulties” (defined as AB z-scores < −2 SDs and/or IQ < 70) and “mild difficulties included” (AB z-scores < −1 SD and/or IQ < 83) were 90% and 60% and 80% and 76%, respectively.

CONCLUSIONS: The RNDA validity results are promising for use by child care professionals in field and clinical settings, but the tool needs further replication and refinement for assessment of specific impairments of vision, hearing, and seizures. Pediatrics 2013;131:e486–e494

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KEY WORDS: neurodevelopment, impairment, disability, assessment, surveillance

ABBREVIATIONS
AB—adaptive behavior
BPF—Bangladesh Protibondhi Foundation
BSID—Bayley Scales of Infant Development
IBAS—Independent Behavior Assessment Scale
ICF—International Classification of Function
IQ—inelligence quotient
LAMI—low and middle income
NDI—neurodevelopmental impairment
RNDA—Rapid Neurodevelopmental Assessment
SBIS—Stanford Binet Intelligence Scale
TQ—Ten Questions
WPPSI—Wechsler Preschool and Primary Scales of Intelligence

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Bangladesh is considered to be on track to reach Millennium Development Goal 4 for child survival because under-5 mortality rates have fallen from 150 per 1000 in 1990 to 65 per 1000 in 2010. Conversely, the proportion of children at risk of disability has risen dramatically from an estimated 8% in 1988 to 18% in 2005. The prevailing scenario poses a grim picture for the future of Bangladeshi children. Forty-five percent of all children do not complete primary school, and only 4% of children with disabilities are within the formal schooling system. Most children with neurodevelopmental impairments (NDIs) remain unrecognized due to lack of systematic surveillance of toddlers and preschool-aged children and the limited number and spread of rehabilitation programs.

Available systems of developmental surveillance have proven to be too specialized for application to country-wide programs. For example, a 2-stage procedure of home-based screening for childhood disabilities by frontline workers, followed by a multiphase assessment of children aged 2 to 9 years, although validated across cultures, has proven to be too expert-dependent to be feasible for use by most countries. As a result, even though the Ten Questions (TQ) is the most frequently used home-based screening tool worldwide, children’s specific functional limitations, which are important for planning appropriate intervention programs, remain largely undiagnosed due to the lack of professionals who can apply existing tools and lack of validated tools to identify specific problems.

There is a need, therefore, for simplifying protracted neurodevelopmental assessment procedures that are currently designed for use by highly trained professionals but are not practical for countries where there is limited available expertise. In acknowledgment of the temporal relationship between impairments (ie, temporary functional limitation) and disabilities (ie, permanent functional limitation) as defined by the International Classification of Functioning (ICF) of the World Health Organization, there is a need to identify specific NDIs in at-risk children to prevent or ameliorate progression to disabilities.

We developed the Rapid Neurodevelopmental Assessment (RNDA) tool for use in children from birth to age 5 years. It was validated previously for use in children aged <2 years. In the current study, we report on validation of the tool for use by child care professionals to comprehensively assess children aged >2 to 5 years for a range of NDIs.

**METHODS**

**RNDA for >2- to 5-year-olds**

The RNDA consists of 5 forms, 1 each for the following age groups: 25 to <30 months, 30 to <36 months, 36 to <42 months, 42 to <48 months, and 48 to 60 months. Items are arranged under the following developmental domains: gross motor, fine motor, vision, hearing, speech (expressive language), cognition, behavior, and seizures. All items were designed for administration by a single tester. Individual items considered for inclusion in the tool were those found to be age-referenced in assessment procedures worldwide and those from our own clinical experience, referenced by neurodevelopmental functional domains (Supplemental Table 4). The age for testing a particular item is the “average age or upper limit” for achievement of that item, to provide a “catch-up period” for children from high-risk environments. For each item, an age range is provided during which achievement of that item is equally applicable. Successful completion of an item is considered to be “age appropriate,” whereas non-completion is recorded by decreasing levels of competence as “mild,” “moderate,” or “severe” impairment. Complete forms for the 25- to <30-month and 48- to 60-month age groups are provided in Supplemental Tables 5 and 6, respectively. The RNDA comes with a pictorially demonstrated user manual in which the parameters of all assessments are detailed.

Additional information collected before administration of the RNDA includes the following: (1) determination of gestational and chronological age; (2) a short history including sociodemographic information, birth history, nutritional information, and any health or developmental concerns of care providers; (3) anthropometric measurements; and (4) a general physical examination. Administration and scoring of the RNDA take, on average, ~30 minutes, compared with a comprehensive multidisciplinary neurodevelopmental assessment by a physician and a psychologist, which would take ~3 hours.

A Summary Sheet is completed at the end of the assessment. A yes/no format is used to record “impairments” (defined as “problems in body function or structure as a significant deviation or loss which may be temporary or permanent” according to the ICF) in each of the 8 domains. To adapt the ICF for use in children, items have been taken from both the category of “body functions” (eg, global psychosocial, attention, emotions, intellectual, seeing, hearing) and “activities” (eg, gross motor, fine motor, communication, self-care). For every NDI, severity is recorded on the basis of criteria provided in the RNDA forms. Severity ratings are not reported in this article.

**Testers**

Testers were 6 child care professionals experienced in providing holistic intervention to children with NDIs, each with a minimum work experience of 4 years. Four were developmental therapists (ie, generic therapists with...
training, but no formal degree, in a combination of physio-, occupational, and speech and language therapy, within a developmental framework) and 2 were special education teachers (ie, Masters in Special Education but with no previous experience in conducting neurodevelopmental assessments). Because the underlying concept of the test is based on observation of functional abilities of children by professionals with some (but not necessarily extensive) experience in children's development, it was assumed that the testers would be able to administer the RNDA validly, irrespective of their varied professional backgrounds. A 2-week training course for the testers was conducted on the procedures (by Drs Muslima and Khan).

**Reliability**

**Study Population**

Children who were either siblings of those attending an inclusive preprimary or primary school of the Bangladesh Protibondhi Foundation (BPF) or who lived in the adjacent community were invited by convenience sampling for testing on the RNDA.

**RNDA Administration**

The RNDA was administered by 1 main tester at a time, whereas others observed the procedure and marked the child’s functions on the RNDA Summary Sheet, without consultation with each other. Each tester administered the RNDA to ≥2 children.

**Validity**

**Study Population**

An initial door-to-door blanket screening of households with children aged ≤9 years for NDIs was conducted in the following 2 urban wards within Dhaka, the capital of Bangladesh: Mirpur (ward number 7) and Malibag (ward number 54) to ascertain prevalence and to validate screening and assessment tools on the basis of a 2-stage study design of “rare disorders”.

Sample size was determined from a previous survey of 2- to 9-year-olds across Bangladesh where 21% “screen positivity” was found. Community workers with ≥10 years of schooling visited these households to conduct interviews with mothers with the use of a screening tool for children aged ≤2 years, and an adapted version of the TQ for 2- to 9-year-olds, which includes an additional question on behavior: (Supplemental Table 7). Of the 1000 children, 339 aged >2 to 5 years were screened, of whom 45 (13.3%) screened positive. All screen-positives and a subsample of age- and gender-matched screen-negatives were invited to the BPF school closest to their residence for assessment on the RNDA.

**Gold Standard II: Intelligence Quotient Tests**

Tests for measurement of intelligence quotient (IQ) were administered by psychologists. Three tests were used according to the child's chronological age: (1) for children aged 24 to 43 months, an adapted version of the Bayley Scales of Infant Development (BSID) II; (2) for 44- to 47-month-olds, an adapted version of the nonverbal section of the Stanford Binet Intelligence Scale (SBIS); and (3) for 48- to 60-month-olds, a version adapted for research studies (Supplemental Information) of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI). The Mental Developmental Index, Psychomotor Development Index, and Behavior Rating Scale were determined from the BSID II; The Standard Age Score was derived from the SBIS; and Verbal IQ, Performance IQ, Processing Speech Quotient, and Full Scale IQ were taken from the WPPSI.

The rationale behind the structure of the test includes universal items adapted from Western AB scales, taking into consideration that many children may not have access to formal learning facilities. Through maternal recall and some direct testing, children were evaluated on the following 4 subscales: motor, socialization, communication, and activities of daily living. Norms are presented as means and SDs and as percentile ranks for each of the subscales in each age group. A full-scale score and percentile rank were also calculated.

The test has been used widely in various contexts, such as validation of the TQ in Bangladesh and other countries, determining outcomes in randomized controlled trials of home-based intervention of children with cerebral palsy, and to follow up cohorts of preterm children.
Gold Standard III: AB and IQ Combined

Two composite scores were computed. They included (1) “significant difficulties” (ie, all children with $AB \geq -2$ SD $z$-scores versus $<-2$ SD $z$-scores and/or IQ $\geq 70$ vs $<70$) and (2) “mild difficulties included” (ie, all children with $AB \geq -1$ SD $z$-scores versus $<-1$ SD $z$-scores and/or IQ $\geq 85$ vs $<85$).

Data Management and Analysis

Interrater Reliability

$\kappa$ Coefficients of agreement$^{52}$ were calculated for each developmental domain by cross-tabulating the results of the main tester with each of the 5 other testers in the 8 developmental domains, recorded on the Summary Sheet. Mean $\kappa$ scores between all testers were then calculated.

Validity

Acceptance of the RNDA by mothers and children and compliance in taking part in the assessment procedure were considered the face validity.$^{53}$ The ability of the RNDA to differentiate between children from families in the lowest versus the highest quartile of income, and those with stunting versus normal height for age, 2 of the commonest risk factors for developmental delay and impairments,$^{54}$ were considered its discriminant validity.$^{55}$

RNDA outcomes (ie, NDI) by specific developmental domain and “any NDI” if a child was positive for $\geq 1$ NDI were cross-tabulated with outcomes percentile scores on the 4 subscales and the full scale of the IBAS (Gold Standard I), with mean scores of administered IQ tests (Gold Standard II), and with a composite score combining AB and IQ (Gold Standard III) to ascertain concurrent validity.$^{52}$

Ethical Considerations

For all children assessed by using the RNDA, a written consent form was signed by literate mothers, whereas verbal consent was taken for those who were nonliterate. Logistic support (ie, travel cost and lunch) was provided to the families for attending the assessment session. All children found to have an NDI were offered services appropriate to their condition.

The research protocol was approved by the Affairs of the Nongovernmental Organization Bureau, Chief Advisor’s Office, Government of Bangladesh (permission letter dated December 23, 2008; reference: ANB/Application-2/BPF/163/2008-1869).

RESULTS

Reliability

Study Population

Fourteen children living adjacent to the BPF were invited for administration of the RNDA; 43% were from the lowest income families, and 50% were female (Table 1). According to the assessment results of the senior-most tester (Dr Begum), 9 of 14 (64.3%) children had $\geq 1$ NDI, with specific impairments in the following domains: 1 child, gross motor; 1 child, fine motor; 1 child, vision; 4 children, speech; 6 children, cognitive; and 2 children each with behavioral impairments and seizures. None of the children had a hearing impairment.

Interrater Reliability

Mean $\kappa$ coefficient in the individual domains between the 6 testers showed complete agreement (1.00; 95% confidence interval: 1.00, 1.00) in gross motor, fine motor, vision, hearing, speech, cognition, and seizures and

TABLE 1 Household and Child Characteristics of the Study Populations Administered the RNDA for Testing Reliability and Validity

<table>
<thead>
<tr>
<th>Study, Household, and Maternal Variables</th>
<th>Reliability Study (n = 14 children)</th>
<th>Validity Study (n = 77 children)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study site</td>
<td>Urban, Dhaka city</td>
<td>Two urban wards within Dhaka city</td>
</tr>
<tr>
<td>Sampling procedure</td>
<td>Convenience sample</td>
<td>Door-to-door home-based screening</td>
</tr>
<tr>
<td>Mean (SD) age of study children, y</td>
<td>3.93 (1.7)</td>
<td>3.46 (0.78)</td>
</tr>
<tr>
<td>Female, %</td>
<td>50</td>
<td>49.4</td>
</tr>
<tr>
<td>Household income in Taka, 70 Taka=1 USD, n (%)</td>
<td>6 (43)</td>
<td>33 (45.8)</td>
</tr>
<tr>
<td>&lt;$5000</td>
<td>8 (57)</td>
<td>39 (54.2)</td>
</tr>
<tr>
<td>$\geq 5000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s education, n (%)</td>
<td>Not recorded</td>
<td></td>
</tr>
<tr>
<td>No schooling</td>
<td>10 (15.9)</td>
<td></td>
</tr>
<tr>
<td>Primary school</td>
<td>30 (41.7)</td>
<td></td>
</tr>
<tr>
<td>Middle school</td>
<td>11 (15.3)</td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>10 (15.3)</td>
<td></td>
</tr>
<tr>
<td>Graduate</td>
<td>11 (15.3)</td>
<td></td>
</tr>
<tr>
<td>Mother’s literacy (ability to read a newspaper), n (%)</td>
<td>6 (42.9)</td>
<td>16 (22.2)</td>
</tr>
<tr>
<td>Cannot read</td>
<td>8 (57.1)</td>
<td>31 (45.1)</td>
</tr>
<tr>
<td>Can read with difficulty</td>
<td>No information</td>
<td>25 (34.7)</td>
</tr>
<tr>
<td>Can read easily</td>
<td>No information</td>
<td></td>
</tr>
<tr>
<td>Was the child stunted, n (%)</td>
<td>No information</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>24 (31.2)</td>
<td>50 (64.9)</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td>3 (3.9)</td>
</tr>
<tr>
<td>On home-based at-risk for a neurodevelopmental impairment, n (%)</td>
<td>Not done</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>45 (58.4)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>32 (41.6)</td>
<td></td>
</tr>
<tr>
<td>Neurodevelopmental impairments of the assessed children, n (%)</td>
<td>5 (35.7)</td>
<td>42 (54.5)</td>
</tr>
<tr>
<td>No neurodevelopmental impairment</td>
<td>9 (64.3)</td>
<td>35 (45.5)</td>
</tr>
</tbody>
</table>
good agreement for behavior (0.76; 95% confidence interval: 0.53, 0.98).

Validity

Study Population

Forty-five children who were screen-positive and 32 who were screen-negative for NDIs in the door-to-door survey were administered the RNDA (Table 1). There were no significant differences in their age or gender distribution. Almost half (46%) were from the lowest income families; 14% of fathers had had no schooling, and 22% of mothers were nonliterate; and 50 (65%) of the children were stunted.

Face Validity

Face validity of the RNDA was good, because the procedure was well accepted by the testers, mothers, and children. There were no noncompliant cases or refusals.

Discriminant Validity

Significantly more children with stunting (29 of 50) compared with those without stunting (3 of 24) were identified by the RNDA to have NDIs (P = .0001); likewise, more children from the lowest income families (19 of 33) had NDIs compared with those from the highest income families (14 of 39) (P = .054).

Concurrent Validity: Comparison With Gold Standard I or IBAS

Seventy-six children were administered the IBAS. On the RNDA, NDIs (ie, ≥1 impairment) were found in 35 children. Figure 1 shows the significant differences in mean percentile scores on motor (no impairment, mean = 45.37; impairment, mean = 20.79; P = .0001), socialization (no impairment, mean = 52.80; impairment, mean = 29.21; P = .001), communication (no impairment, mean = 51.46; impairment, mean = 29.09; P = .001), and full-scale (no impairment, mean = 40.98; impairment, mean = 21.08; P = .001) IBAS scores in children with ≥1 NDIs compared with those without an NDI. There was also a 10-point, non–statistically significant difference in mean percentile scores on activities of daily living in those with NDIs (mean score = 29.50) compared with those without (mean score = 39.76) (P = .093).

There were differences in IBAS scores between those who had specific impairments in gross motor functions (16 of 76) (no impairment, mean = 37.25; impairment, mean = 10.67; P = .001), behavior (12 of 76) (no impairment, mean = 35.88; impairment, mean = 9.09; P = .003), cognition (26 of 76) (no impairment, mean = 37.73; impairment, mean = 13.50; P = .019), and fine motor (8 of 76) (no impairment, mean = 33.90; impairment, mean = 12.86; P = .039) functions.

Concurrent Validity: Comparison With Gold Standard II or IQ Tests

There were significant differences in the Mental Developmental Index (P = .0001), Psychomotor Development Index (P = .004), and Behavior Rating Scale (P = .006) scores by neurodevelopmental status among the 45 children who were administered the BSID; and in the Full Scale IQ (P = .040), Processing Speech Quotient (P = .012), and Verbal IQ (P = .042) scores in the 25 children who were administered the WPPSI (Table 2). Of the 5 children administered the SBIS, mean Standard Age Score performance score of 4 children with no NDIs was 101.25 compared with 75.0 in the 1 child with an NDI (P = .164).

Concurrent Validity: Comparison With Gold Standard III, ie, AB and IQ Combined Scores

Sensitivity and specificity were calculated for “any (≥1) NDI” on the RNDA and for specific impairments compared with 2 composite cutoff scores combining AB and IQ results, ie, Gold Standard III (Table 3). Results were best for “any NDIs.” Most children with significant difficulties were identified (sensitivity of 90%), although with
a trade-off for specificity (60%). On the other hand, when milder difficulties were included, although sensitivity was slightly lower (80%), specificity increased to 78%. For specific impairments, sensitivity for identifying significant difficulties and when milder difficulties were included was highest for cognition (80% and 60%, respectively) and lowest for seizures (10% and 20%, respectively). There was only 1 child with hearing impairment who was identified by the RNDA. No vision impairment was identified in the study.

**DISCUSSION**

The data presented in this article provide evidence for the potential use of the RNDA by child care professionals to rapidly ascertain neurodevelopmental status in a range of functional domains in 2- to 5-year-old children.

**Reliability**

The high interrater reliability between child care professionals was similar to that found previously for the RNDA in children aged ≤2 years. Presently, there are other indicators of applicability of the RNDA when used by lesser trained professionals both within clinical practice and in large surveys. For example, developmental therapists regularly administer the RNDA in Well Baby Clinics across Bangladesh to identify children at risk of NDIs within government-sponsored Child Development Centers (“Shishu Bikash Kendra” in Bangla55; and UNICEF Bhutan has trained >60 primary school teachers to conduct assessments of ~1500 children aged 2 to 5 years, after a group of 6 senior professionals (including a pediatrician, special educator, child psychiatrist, physiotherapist, statistician, and UNICEF personnel).

**TABLE 2** Any Impairment With the RNDA by Psychometric Tests Administered by Chronological Age

<table>
<thead>
<tr>
<th>Psychometric Test and Number of Children (mean age in months; SD, min, max)</th>
<th>Test Item</th>
<th>NDI s in the Assessed Children (Number of Children)</th>
<th>Mean Score</th>
<th>( \chi^2 )</th>
<th>F</th>
<th>df</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayley Scales for Infant Development (BSID-II, 1993) 45 (34.95; 5.08, 24.38, 43.97)</td>
<td>MDI</td>
<td>No impairment (25)</td>
<td>94.68</td>
<td>NA</td>
<td>16.694</td>
<td>NA</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>Any impairment (20)</td>
<td>78.80</td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PDI</td>
<td>No impairment (25)</td>
<td>103.44</td>
<td>NA</td>
<td>9.168</td>
<td>NA</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Any impairment (20)</td>
<td>80.55</td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BRS</td>
<td>No impairment (25)</td>
<td>Categorical variable( ^{c} )</td>
<td>12.372</td>
<td>NA</td>
<td>2</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Any impairment (20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Total SAS (performance)</td>
<td>No impairment (4)</td>
<td>101.25</td>
<td>NA</td>
<td>3.857</td>
<td>4</td>
<td>0.144</td>
</tr>
<tr>
<td></td>
<td>Any impairment (1)</td>
<td>75.00</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Stanford Binet Intelligence Scale (SBIS, 4th ed) 5 (47.79; 3.98, 45.36, 53.26)</td>
<td>VIQ</td>
<td>No impairment (12)</td>
<td>94.92</td>
<td>NA</td>
<td>4.65</td>
<td>24</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>Any impairment (13)</td>
<td>84.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIQ</td>
<td>No impairment (12)</td>
<td>86.50</td>
<td>NA</td>
<td>2.359</td>
<td>24</td>
<td>0.138</td>
</tr>
<tr>
<td></td>
<td>Any impairment (13)</td>
<td>76.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PSQ</td>
<td>No impairment (12)</td>
<td>68.25</td>
<td>NA</td>
<td>7.446</td>
<td>24</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>Any impairment (13)</td>
<td>56.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSIQ</td>
<td>No impairment (12)</td>
<td>89.83</td>
<td>NA</td>
<td>4.757</td>
<td>24</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td>Any impairment (13)</td>
<td>77.54</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\( ^{a} \) Psychometric tests not conducted in 4 children.

\( ^{b} \) Sensitivity and Specificity.

\( ^{c} \) Derived for all continuous variables using ANOVA, except BRS (see footnote \( c \)).

\( ^{d} \) The BRS was a categorical variable, cross-tabulation; 7 children with behavior problems on the RNDA, all identified by the BRS (5 = nonoptimal, 2 = questionable).

**TABLE 3** Sensitivity and Specificity of the RNDA for Specific Neurodevelopmental Impairments and “Any” (≥1) Impairment Compared With 2 Cutoffs on the Gold Standard: “Mild Difficulties Included” and “Significant Difficulties Included” (\( N = 77 \))

<table>
<thead>
<tr>
<th>Neurodevelopmental Impairments (Number of Children with Impairments)</th>
<th>Mild Difficulties Included( ^{a} )</th>
<th>Significant Difficulties( ^{b} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (95% CI)</td>
<td>Specificity (95% CI)</td>
</tr>
<tr>
<td>Gross motor (( n = 16 ))</td>
<td>0.48 (0.28, 0.64)</td>
<td>0.95 (0.88, 1.00)</td>
</tr>
<tr>
<td>Fine motor (( n = 8 ))</td>
<td>0.16 (0.03, 0.50)</td>
<td>0.95 (0.88, 1.00)</td>
</tr>
<tr>
<td>Vision( ^{a} ) (( n = 0 ))</td>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>Hearing( ^{a} ) (( n = 1 ))</td>
<td>0.03 (0, 0.09)</td>
<td>1.00 (1.00, 1.00)</td>
</tr>
<tr>
<td>Speech (( n = 11 ))</td>
<td>0.33 (0.16, 0.50)</td>
<td>0.97 (0.93, 1.00)</td>
</tr>
<tr>
<td>Cognition (( n = 26 ))</td>
<td>0.60 (0.42, 0.77)</td>
<td>0.82 (0.71, 0.85)</td>
</tr>
<tr>
<td>Behavior (( n = 12 ))</td>
<td>0.33 (0.16, 0.50)</td>
<td>0.95 (0.89, 1.00)</td>
</tr>
<tr>
<td>Seizures (( n = 8 ))</td>
<td>0.20 (0.05, 0.34)</td>
<td>0.95 (0.89, 1.00)</td>
</tr>
<tr>
<td>Any (( n = 35 ))</td>
<td>0.80 (0.65, 0.94)</td>
<td>0.76 (0.63, 0.88)</td>
</tr>
</tbody>
</table>

\( \text{CI, 95\% confidence interval; NC, not calculable.} \)

\( ^{a} \) Based on a composite score combining the IBAS (\( \geq 1 \text{ SD} \) vs \( < 1 \text{ SD} \)) and/or IQ (\( \geq 85 \text{ vs} < 85 \text{ scores}.\)

\( ^{b} \) Based on a composite score combining the IBAS (\( \geq 2 \text{ SD} \) vs \( < 2 \text{ SD} \)) and/or IQ (\( \geq 70 \text{ vs} < 70 \text{ scores}.\)

\( ^{c} \) Not calculated. There were no children in the study population who were identified with vision impairment.

\( ^{d} \) One girl, age 40 months, was identified on the RNDA with hearing impairment with associated motor and cognitive impairments with the BSID II: Mental Development Index = 50, Psychomotor Development Index = 50.
were trained by the authors (Drs Khan, Muslma, Shilpi, and Begum) in Bangladesh. Validation of use of the RNDA by primary school teachers in Bhutan will be published separately.

Validity

Sociodemographic characteristics of the population were close to national statistics, except that 65% of children were stunted compared with the national average of 36%. The RNDA was able to identify a range of specific NDIs, which ideally would be accomplished by combining detailed IQ tests with tests for AB and medical assessment by physicians in both clinical and field settings. This process, however, is unachievable in low and middle-income (LAMI) countries. The significant correlation, therefore, between “any NDI” on the RNDA results and the overall results from tests of AB (Fig 1) and IQ tests (Table 2), and between specific types of NDIs and subscales in the test for AB, especially motor and socialization, which were found to be important indicators of poor development in other studies, indicates the applicability of the tool where psychologists and physicians are unavailable.

Furthermore, sensitivity and specificity results of the RNDA (Table 3) indicate its potential usefulness in field and clinical settings. If community-based populations are to be evaluated, then the tool is able to identify with high sensitivity (80%) and good specificity (78%) children with a range of NDIs, including those in the milder grades of severity. Thus, the RNDA can be recommended as an adjunct to large preschool Early Childhood Development initiatives and in population-based screening programs where it is not feasible to include a second stage assessment in LAMI countries, as is currently being applied by primary school teachers in Bhutan. Within clinical practice, use of the RNDA for identifying serious difficulties among children at high risk, eg, in Government-sponsored Child Development Centers or where rehabilitation for significant disabilities is an objective, can also be considered, because sensitivity was highest (90%) for this category of children. However, due to lower specificity for serious NDIs (60%), overreferrals are expected. Although a significant proportion may have mild problems, potential overburdening of services requires consideration.

Significantly more children from poor, disadvantaged backgrounds, and those who were stunted, were identified with NDIs, which is an indicator of good discriminant validity, ie, that populations with different sociodemographic vulnerabilities could be distinguished by the tool. The discriminant validity of tools has been used to identify sociodemographic differences in school readiness so that appropriate early interventions can close the gap in children’s skills. The potential use of the RNDA in an LAMI country with chronic child malnutrition cannot be overemphasized.

Ready acceptance by the mothers and children of the assessment procedure indicates good face validity and may be used as a starting point to provide information on positive parenting, early stimulation, and school preparedness to families.

Study limitations need to be considered. First, the reliability study was conducted in a small convenience sample and needs strengthening with a larger sample size. Second, sensitivity for serious impairments needs to be improved to identify the 10% who remained unrecognized. Third, although another study has reported significant correlation between visual impairments on the RNDA and ophthalmologic examination results, the use of the RNDA for identifying sensory impairments and for seizure disorders needs further study. Fourth, multidisciplinary assessment that included child health physicians might have strengthened the Gold Standard.

CONCLUSIONS

The RNDA has the potential to be used as a neurodevelopmental assessment measure by lesser trained professionals in countries with limited expertise. The findings build on a previous study that revealed the validity of the RNDA in children <2 years, and thus extends the evidence base for use of the RNDA to children <5 years old. However, its validity in identifying impairment of hearing and vision and seizure disorders as well as its validity by severity grading for specific types of NDIs need further confirmation in future studies.

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We thank all of the community workers and child health professionals who participated in this study for their tireless efforts; without their dedication, this study would not have been possible. We also express our gratitude to all mothers, children, and families who have taken part in the study.

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