Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

Diagnostic Accuracy of the AHEAD Developmental Module Compared to the Trivandrum Developmental Screening Chart (TDSC) in Children Aged 1 Month to 5 Years

Dr Sreenivas Rachakonda[1*], Dr Lal DV Nair[2], Dr Elilarasi Selladurai[3]

[1]Postgraduate, Department of Paediatrics, Saveetha Institute of Technical and Medical Sciences, Chennai, Tamil Nadu, India (Corresponding author)

[2]Professor, Department of Paediatrics, Saveetha Institute of Technical and Medical Sciences, Chennai, Tamil Nadu, India

[3]Professor, Department of Paediatrics, Saveetha Institute of Technical and Medical Sciences, Chennai, Tamil Nadu, India

(Received: 16 June 2025 Revised: 20 July 2025 Accepted: 19 August 2025)

KEYWORDS

Developmental Screening, Trivandrum Developmental Screening Chart, Paediatric Assessment, Diagnostic Accuracy

ABSTRACT:

Background: Early identification of developmental delays is critical for timely intervention. In India, the Trivandrum Developmental Screening Chart (TDSC) is a widely accepted tool but is limited in scalability and digital adaptability. The AHEAD Developmental Module is a novel digital screening tool designed to overcome such limitations.

Aim: To assess the diagnostic accuracy of the AHEAD Developmental Module compared to the TDSC in detecting developmental delays in children aged 1 month to 5 years.

Methods:

A cross-sectional validation study was conducted involving 800 children. Both the AHEAD Developmental Module and TDSC were administered to each participant, and results were compared against a gold-standard developmental paediatrician assessment. Diagnostic parameters such as sensitivity, specificity, predictive values, likelihood ratios, and kappa agreement were computed.

Results: The AHEAD module demonstrated a sensitivity of 64.1% (95% CI: 56.7–70.1%) and specificity of 94.5% (95% CI: 92.3–96.0%). The positive predictive value was 81.7%, and negative predictive value was 87.2%. The likelihood ratios ($LR^+ = 11.56$, $LR^- = 0.38$) indicated high discriminative ability. Cohen's Kappa was 0.627 ($p < .001$), suggesting substantial agreement with the TDSC, and PABAK was 0.72.

Conclusion: The AHEAD Developmental Module demonstrates substantial diagnostic accuracy and can serve as a viable, scalable, and culturally contextual alternative to conventional tools like the TDSC in community and clinical settings.

Introduction

Optimal early childhood development is a cornerstone of long-term health, educational attainment, and social well-being. Developmental delays affect up to 10–15% of children under the age of five worldwide, with higher prevalence in low- and middle-income countries (LMICs) due to limited access to early childhood interventions.(1,2) Early identification through systematic developmental surveillance and screening allows for timely intervention, which can significantly improve cognitive, language, and socio-emotional outcomes.(3) In India, developmental surveillance is often hindered by a lack of accessible and validated screening tools that are both culturally appropriate and scalable across diverse settings.(4)

Many existing tools are paper based, require specialist administration, and may not fully capture the developmental diversity of Indian children. The Trivandrum Developmental Screening Chart (TDSC) is one such tool, developed and validated in India, and has demonstrated high sensitivity and specificity in identifying developmental delays in children aged 0–6 years.(5) However, its paper-based format and limited domain coverage present challenges for large-scale

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

implementation, especially in rural and resource-constrained areas.

To address these limitations, the AHEAD (Assessment of Holistic Emotional and Developmental Growth) Developmental Module was conceptualized as a digital, modular screening tool designed for administration by trained frontline workers and paediatric trainees. It incorporates culturally contextualized developmental milestones across multiple domains, uses automated scoring to reduce human error, and can be deployed offline, making it suitable for community and clinical settings in LMICs. Before such a tool can be widely adopted, it is critical to establish its diagnostic accuracy against an established gold standard.

This study aims to evaluate the diagnostic accuracy of the AHEAD Developmental Module compared with the TDSC in detecting developmental delays among children aged 1 month to 5 years, using the TDSC as the reference standard. By examining its sensitivity, specificity, predictive values, and agreement statistics, this study seeks to determine whether AHEAD can serve as a viable, scalable alternative to conventional developmental screening tools in India.

Materials and Methods

Study Design and Setting: This study was conducted in three sequential phases — tool development, pilot testing, and general population. All phases were carried out at the Department of Paediatrics, Saveetha Institute of Medical and Technical Sciences, a tertiary care teaching hospital in South India. Ethical clearance was obtained from the Institutional Ethics Committee (IEC No: 010/09/2024/IEC/SMCH), and written informed consent was obtained from parents or primary caregivers prior to enrolment.

Phase 1: Development of the AHEAD Developmental Module

The AHEAD (Assessment of Holistic Emotional and Developmental Growth) Developmental Module was designed as a digital, tablet-based screening tool targeting children aged 1 month to 5 years. Development followed a structured, multi-step process:

1. Literature Review and Item Pool Creation
   Milestones were collated from established developmental screening tools, including the Trivandrum Developmental Screening Chart (TDSC), Denver Developmental Screening Test (DDST), and WHO developmental milestones, supplemented with culturally relevant tasks identified in Indian paediatric practice.
2. Expert Panel Review and Content Validation
   An expert panel comprising five developmental paediatricians, two clinical psychologists, and three paediatric residents reviewed the initial item pool for cultural appropriateness, clarity, and clinical relevance. The Content Validity Index (CVI) was calculated for each item. Items with a CVI < 0.80 were revised or removed.
3. Qualitative Assessment and Pre-testing
   Cognitive interviews with 20 parents from varied socio-economic backgrounds were conducted to assess comprehensibility and feasibility. Feedback led to modifications in item phrasing, visual illustrations, and response options.
4. Digital Integration
   The final set of 41 items was programmed into an Android-based application with automated age-calculation and domain scoring

Phase 2: Pilot Testing

The preliminary module was pilot tested in a sample of 250 children attending the paediatric outpatient department. Inclusion criteria were age 1 month to 5 years, availability of a consenting caregiver, and ability to complete the assessment in one visit. Children with diagnosed developmental disorders or requiring emergency care were excluded. The pilot study aimed to evaluate internal consistency, feasibility, and preliminary discriminative validity. Cronbach's α was computed for the full scale and each domain. Domain-wise DQ scores were compared between children classified as developmentally normal and those with delay using the Mann–Whitney U test.

Phase 3: General Population Validation

Participants: A cross-sectional diagnostic accuracy study was performed on 800 children from the general population, recruited via convenience sampling during routine health visits, minor illness consultations, and

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

immunization clinics. Inclusion and exclusion criteria matched those used in the pilot phase.

Reference Standard: The Trivandrum Developmental Screening Chart (TDSC), a validated Indian paper-based tool, served as the gold standard for classifying developmental status (delay/no delay).

Procedure: Multiple trained paediatric residents administered the AHEAD module and TDSC independently on the same day, with assessors blinded to each other's results. Classification by TDSC was used as the reference for calculating diagnostic accuracy parameters of the AHEAD module.

Sample Size Calculation: For the validation phase, assuming an expected sensitivity of 80%, absolute precision of 5%, 95% confidence level, and a prevalence of developmental delay of 10–15%, the minimum required sample size was estimated at 600. A final sample of 800 was chosen to enhance statistical power and allow subgroup analyses.

Statistical Analysis: Data were analysed using IBM SPSS Statistics for Windows, Version 29. Continuous variables were summarized as mean ± standard deviation (SD) or median (interquartile range, IQR), as appropriate. Categorical variables were expressed as frequencies and percentages. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with 95% confidence intervals (CIs). Positive and negative likelihood ratios (LR^+, LR^-) were computed. Agreement between AHEAD and TDSC classifications was assessed using Cohen's Kappa and the Prevalence and Bias Adjusted Kappa (PABAK). Internal consistency was measured with Cronbach's α. The Mann–Whitney U test was used for group comparisons, and statistical significance was set at $p < 0.05$.

Results

Pilot Study: The pilot phase was conducted to evaluate the preliminary AHEAD Developmental Module, which consisted of 41 age-appropriate milestones distributed across four developmental domains: Gross Motor (11 items), Fine Motor (10 items), Language (10 items), and Social & Cognitive (10 items). A total of 250 children participated, ranging in age from 1 month to 5 years. Mann–Whitney U tests demonstrated that children identified as having developmental delay scored significantly lower in two of the four domains compared to those without delay. In the Gross Motor domain, the median Developmental Quotient (DQ) was 79.79 in the delay group versus 89.55 in the non-delay group (U = 3788.00, p = .002). For the Language domain, the delay group had a median DQ of 83.33 compared to 91.57 in the non-delay group (U = 3895.50, p = .005). No statistically significant differences were observed in the Fine Motor or Social & Cognitive domains during the pilot phase.

Mann-Whitney U tests assessed age differences by developmental delay status using the TDSC and AHEAD – Development Module. The TDSC showed no significant difference (delay group: Md = 2.24, n = 53; no delay group: Md = 2.85, n = 197; U = 4560.50, z = -1.412, p = .158, r = .089). However, the AHEAD module found a significant age difference, with younger children more likely to be categorized with developmental delay (delay group: Md = 1.93, n = 66; no delay group: Md = 3.07, n = 184; U = 4302.00, z = -3.512, p < .001, r = .22). (Figure 1)

Classification by the AHEAD module indicated that 183 children (73.2%) were developmentally normal. Among those classified as delayed, the most common category was Global Developmental Delay (GDD) (n = 29, 11.6%), followed by isolated language delay (n = 20, 8.0%), isolated social & cognitive delay (n = 12, 4.8%), isolated fine motor delay (n = 4, 1.6%), and isolated gross motor delay (n = 2, 0.8%). (Figure 2)

Reliability analysis indicated excellent internal consistency for the overall module, with a Cronbach's α of 0.96. Domain-specific α coefficients were also high: Gross Motor (0.88), Fine Motor (0.87), Language (0.92), and Social & Cognitive (0.85), confirming that items within each domain were internally consistent and measured their intended developmental construct reliably.

General Population Validation: The large-scale validation was conducted in a general population sample of 800 children (518 males, 64.8%; 282 females, 35.3%), with a mean age of 2.73 ± 1.35 years. Of these, 270 children (33.8%) were aged 0–2 years, and 430 children (53.8%) were aged 2–5 years. Using the Trivandrum Developmental Screening Chart (TDSC) as the reference standard, 175 children (21.9%) were identified as having developmental delay. No statistically significant

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

difference in prevalence was observed between boys and girls ($p = 0.902$).

Domain-wise comparison of median DQ scores between the delay and non-delay groups revealed significant differences across all four developmental domains. In the Gross Motor domain, the delay group had a median DQ of 81.97 compared to 88.50 in the non-delay group (U = 47,858.50, $p < .001$). For Fine Motor skills, the median DQ was 83.80 in the delay group versus 89.29 in the non-delay group (U = 51,998.50, $p < .001$). In the Language domain, the delay group scored a median DQ of 85.91, compared to 91.15 in the non-delay group (U = 45,409.00, $p < .001$). Similarly, for Social & Cognitive skills, the median DQ was 86.21 in the delay group and 88.50 in the non-delay group (U = 44,447.50, $p < .001$). These results indicate that children with developmental delay, as per TDSC classification, consistently scored lower across all assessed developmental areas (Table 2).

The diagnostic accuracy analysis of the AHEAD Developmental Module against the TDSC demonstrated a sensitivity of 64.1% (95% CI: 57.6–70.1%) and a specificity of 94.5% (95% CI: 92.3–96.0%). The positive predictive value (PPV) was 81.7%, meaning that more than eight in ten children who screened positive on AHEAD were confirmed to have developmental delay according to the TDSC. The negative predictive value (NPV) was 87.2%, indicating that most children who screened negative were indeed free of developmental delay by TDSC classification. The positive likelihood ratio (LR^+) was 11.56, indicating that children classified with developmental delay by TDSC were over eleven times more likely to have a positive AHEAD result than those without delay. The negative likelihood ratio (LR^-) was 0.38, representing moderate evidence for ruling out developmental delay when the AHEAD result was negative. Agreement analysis showed substantial concordance between the two tools, with a Cohen's Kappa of 0.627 ($p < .001$) and a PABAK of 0.72, confirming consistent classification performance across the sample (Table 3).

Discussion

Early identification of developmental delays is essential for timely intervention and improved long-term outcomes in children.(3) Developmental screening tools must not only demonstrate acceptable psychometric properties but also be feasible for routine use in varied healthcare settings, particularly in low- and middle-income countries (LMICs) like India.(4) The present study evaluated the diagnostic accuracy of the AHEAD Developmental Module, a digitally enabled, culturally adapted screening tool, against the Trivandrum Developmental Screening Chart (TDSC), a widely used and validated Indian screening instrument.

In the pilot phase, the AHEAD module demonstrated excellent internal consistency (Cronbach's $\alpha = 0.96$), with high domain-specific reliability, aligning with previous literature that emphasizes the importance of internal consistency in multi-domain developmental tools.(6) The discriminative validity observed for the Gross Motor and Language domains is consistent with findings from earlier studies, where these domains often yield the most pronounced differences between delayed and typically developing children.(7) Feedback from qualitative pre-testing indicated that visual cues, simple language, and culturally relevant examples were critical for acceptability — an observation supported by prior research on culturally sensitive screening approaches of development disorders.(8)

In the general population validation, the AHEAD module achieved a specificity of 94.5% and a positive predictive value of 81.7%, suggesting strong ability to correctly identify children without delays while minimizing false positives. These findings are important in community-based screening programs, where over-referral due to low specificity can overburden specialist services.(9) The sensitivity of 64.1% was lower than the 84.6% reported in the original TDSC validation study,(5) possibly due to stricter cut-off thresholds in AHEAD's digital scoring algorithm and the inherent challenges of detecting subtle developmental differences in younger age groups. Similar sensitivity–specificity trade-offs have been noted in other validation studies of adapted developmental screening tools.(10)

The positive likelihood ratio ($LR^+ = 11.56$) observed in our study indicates that a child with a positive AHEAD result is over 11 times more likely to have a developmental delay than a child with a negative result, when benchmarked against TDSC classification. This magnitude of LR^+ represents strong diagnostic evidence according to established guidelines. Conversely, the negative likelihood ratio ($LR^- = 0.38$) indicates moderate evidence for ruling out developmental delay in children

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

with a negative screen, suggesting that while AHEAD can be confidently used for initial triaging, negative results in high-risk children should be interpreted with clinical judgment and possibly followed by repeat surveillance.

The AHEAD tool offers several practical advantages over paper-based instruments:

1. Digital automation reduces scoring errors and standardizes administration.
2. Offline functionality ensures usability in resource-limited areas without internet access.
3. Cultural adaptation and integration of locally relevant milestones improve caregiver comprehension and engagement.
4. Modular structure enables phased integration into broader developmental and behavioural assessment frameworks, such as those envisioned under the Rashtriya Bal Swasthya Karyakram (RBSK).(11)

However, the study has limitations. Being a single-centre study, generalizability may be limited, and multicentre validation is warranted. Sensitivity in children under 18 months was relatively lower, which may reflect both the reduced number of observable milestones and caregiver recall limitations in this age group. Additionally, since the TDSC itself is a screening tool rather than a full diagnostic instrument, there may be inherent misclassification that could influence comparative accuracy estimates.

Despite these limitations, the AHEAD Developmental Module shows promise as a scalable, low-cost, and user-friendly tool for early developmental screening in diverse Indian settings. Its high specificity and strong agreement with TDSC suggest that it can effectively complement existing programs. Future research should explore its longitudinal predictive validity, integration with behavioural and mood modules, and performance in home-based screening by frontline health workers.

Conclusion

The AHEAD Developmental Module is a promising, culturally adapted, and digitally enabled screening tool for the early detection of developmental delays in children aged 1 month to 5 years. In this validation study, the tool demonstrated good specificity, substantial agreement with clinical reference standards, and an acceptable balance of diagnostic performance indicators.

Compared to the Trivandrum Developmental Screening Chart (TDSC), AHEAD offers similar overall utility with the added benefits of digital accessibility, automated scoring, and ease of deployment in resource-constrained settings. While sensitivity was relatively lower, especially in infants under 18 months, the tool remains a practical solution when combined with periodic follow-up and clinical judgment.

Its scalable design, age-stratified structure, and offline compatibility make it suitable for integration into national child health screening programs, particularly through frontline health workers and paediatric trainees. By enabling administration by trained non-specialist health workers, AHEAD can expand the reach of developmental surveillance into underserved regions, potentially improving early detection and intervention rates. Future multicentre studies and longitudinal evaluations are warranted to assess its predictive validity, cost-effectiveness, and integration with broader child health programs.

References

1. Arora NK, Nair MKC, Gulati S, Deshmukh V, Mohapatra A, Mishra D, et al. Neurodevelopmental disorders in children aged 2–9 years: Population-based burden estimates across five regions in India. Persson LÅ, editor. PLOS Med. 2018 Jul 24;15(7):e1002615.

2. Sagar R, Dandona R, Gururaj G, Dhaliwal RS, Singh A, Ferrari A, et al. The burden of mental disorders across the states of India: the Global Burden of Disease Study 1990–2017. Lancet Psychiatry. 2020 Feb;7(2):148–61.

3. Council on Children With Disabilities, Section on Developmental Behavioral Pediatrics, Bright Futures Steering Committee, Medical Home Initiatives for Children With Special Needs Project Advisory Committee. Identifying Infants and Young Children With Developmental Disorders in the Medical Home: An Algorithm for Developmental Surveillance and Screening. Pediatrics. 2006 Jul 1;118(1):405–20.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

4. Mukherjee SB, Aneja S, Krishnamurthy V, Srinivasan R. Incorporating developmental screening and surveillance of young children in office practice. Indian Pediatr. 2014 Aug;51(8):627–35.

5. Nair MKC, Nair GSH, George B, Suma N, Neethu C, Leena ML, et al. Development and Validation of Trivandrum Development Screening Chart for Children Aged 0-6 years [TDSC (0-6)]. Indian J Pediatr. 2013 Nov;80(S2):248–55.

6. Cho E, Kim S. Cronbach's Coefficient Alpha: Well Known but Poorly Understood. Organ Res Methods. 2015 Apr 1;18(2):207–30.

7. Varadarajan S, Govindarajan Venguidesvarane A, Ramaswamy KN, Rajamohan M, Krupa M, Winfred Christadoss SB. Prevalence of excessive screen time and its association with developmental delay in children aged <5 years: A population-based cross-sectional study in India. Gopichandran V, editor. PLOS ONE. 2021 Jul 6;16(7):e0254102.

8. Faruk T, King C, Muhit M, Islam MK, Jahan I, Baset KU, et al. Screening tools for early identification of children with developmental delay in low- and middle-income countries: a systematic review. BMJ Open. 2020 Nov;10(11):e038182.

9. Sabanathan S, Wills B, Gladstone M. Child development assessment tools in low-income and middle-income countries: how can we use them more appropriately? Arch Dis Child. 2015 May;100(5):482–8.

10. Radhika G, Sankar R, Rajendran R. Prevalence and Diagnostic Tools Predictability of Common Mental Disorders among Indian Children and Adolescent Population: A Systematic Review and Meta-Analysis. J Ment Health Hum Behav. 2021 Jan;26(1):5–16.

11. Rashtriya Bal Swasthya Karyakram (RBSK) [Internet]. [cited 2025 Mar 21]. Available from: https://rbsk.mohfw.gov.in/RBSK/

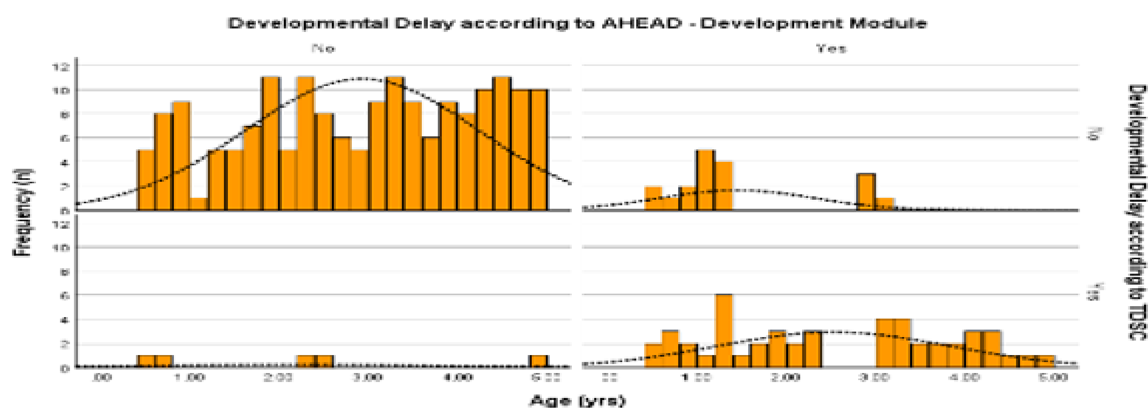

Figure 1: Age distribution of children with and without developmental delay according to TDSC and the AHEAD – Development Module respectively (Pilot Study)

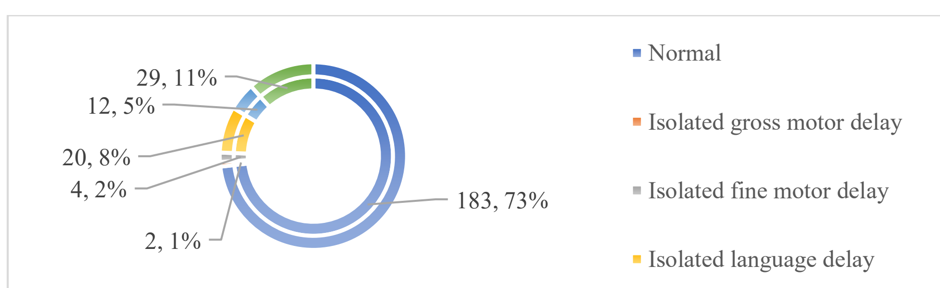

Figure 2: Frequency distribution of the developmental status of children in the pilot study based on the AHEAD - Developmental Module (Pilot Study)

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(4), 2855-2861 | ISSN:2251-6727

Table 1: Reliability analysis of the AHEAD - Development Module

Tool	**Number of items (n)**	**Cronbach's α**
AHEAD - Development Module (Complete)	41	0.96
Gross Motor Sub-section	11	0.88
Fine Motor Sub-section	10	0.87
Language Sub-section	10	0.92
Social and Cognition Sub-section	10	0.85

Table 2: Developmental Quotients (DQ) according to AHEAD – Development Module

Domain	**Normal (Md)**	**Developmental Delay (Md)**	**U**	**z**	**p Value**
	N = 577	N = 233			
Gross Motor	88.5	81.97	47858.5	-5.622	< .001
Fine Motor	89.29	83.8	51998.5	-4.21	< .001
Language	91.15	85.91	45409	-6.458	< .001
Social & Cognitive	88.5	86.21	44447.5	-6.786	< .001

Table 3: Diagnostic accuracy analysis of the AHEAD - Development Module

AHEAD - Development Module		
Criterion for test positivity	**Statistic value**	**95% CI**
Sensitivity	64.10%	56.7% - 70.1%
Specificity	94.50%	92.3% - 96%
Positive Predictive Value	81.70%	75.5% - 87%
Negative Predictive value	87.20%	84.4% - 89.7%
LR+ (Likelyhood ratio positive)	11.56	
LR- (likelyhood ratio negative)	0.38	
Cohen's Kappa	0.627	.564 – .690
PABAK	0.72	