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# Comparison of the predictive validity of the Alberta Infant Motor Scale and Infant Neurological International Battery in low-birth-weight infants: a prospective longitudinal study

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**Abstract**

**Introduction.** This study aims to test the predictive validity of the Infant Neurological International Battery (INFANIB) and the Alberta Infant Motor Scale (AIMS) against the Peabody Developmental Motor Scale-2 (PDMS-2) at 4, 8 and 12 months of age in low birth weight (LBW) infants.

**Methods.** Motor development in 18 LBW infants was examined prospectively at 4, 8 and 12 months. A professional investigator assessed the motor development of these infants using the AIMS, INFANIB and PDMS-2. The validity of the results was assessed using Friedman and Wilcoxon signed-rank tests on the total raw scores of PDMS-2, AIMS and INFANIB at the three distinct age points. The chi-square test was used to calculate the association between INFANIB and AIMS with PDMS-2 for normal and LBW infants at each age point.

**Results.** The INFANIB and AIMS scores were both associated with PDMS-2 at all three age points. However, INFANIB demonstrated a higher predictive validity for PDMS-2 in LBW infants than AIMS.

**Conclusions.** The INFANIB has greater predictive validity than AIMS for assessing motor outcomes in LBW infants at 4, 8 and 12 months.

**Key words:** Infant Neurological International Battery, Alberta Infant Motor Scale, motor outcomes, low birth weight infants, predictive validity, Peabody Developmental Motor Scale-2

## Introduction

Low birth weight (LBW) infants have a higher probability of experiencing gross motor delays [1]. Early identification of motor delays facilitates timely access to interventions, which can enhance developmental outcomes [2].

Standardised tools that are both valid and reliable, with consistent scoring systems, allow for the efficient referral of newborns to intervention programmes. In addition to validity, other key criteria for an assessment tool to be acceptable in clinical practice include test-retest reliability, low cost and quick administration [3].

Several evaluation tools are used in medical and research settings to predict motor development progression in high-risk infants, including Prechtl's General Movement Assessment, the Bayley Scales of Infant Development-III (BSID-III), the Peabody Developmental Motor Scale (PDMS-2), the Griffiths Scale of Infant Development (Griffiths III), the Alberta Infant Motor Scale (AIMS), the Infant Neurological International Battery (INFANIB) and the Harris Infant Neuromotor Test (HINT) [4]. Among these, PDMS-2 is used for infants from birth to six years of age, whereas AIMS and INFANIB are specifically designed to identify motor delays in LBW infants aged zero to two years [5] (Table 1).

The AIMS is an observational scale developed by a physiotherapist to assess an infant's motor development from birth until independent walking. It tests newborn movement ability in positions such as supine, prone, sitting and standing, comprising 58 items that evaluate the control and integrity of postural muscles. The AIMS has been validated against both the BSID and PDMS in Canadian children. It is preferred for evaluating gross motor development due to its affordability, ease of reproducibility, and ability to be administered quickly without excessive handling of the child [6].

Ellison et al. [8] developed INFANIB to assess the neuromotor development of infants aged 0 to 18 months. The 20-item scale includes five components: spasticity, head and trunk control, vestibular function, French angles and lower extremity function. It has excellent psychometric characteristics, with 90% specificity, 83% sensitivity, an Intraclass Correlation Coefficient of 0.90 and positive predictive value (PPV) and negative predictive value (NPV) of 79% and 93%, respectively [7]. It also shows satisfactory reliability and validity for evaluating gross motor development across different medical professional groups [9].

The PDMS-2 is a validated, norm-referenced scale used to assess early gross and fine motor abilities in high-risk children participating in early intervention programmes [10]. Physical therapists favour it due to its ease of administration, grading criteria and method for collecting reference data. The PDMS-2 scores reflect how closely an individual's performance aligns with the age-referenced population. It possesses the necessary psychometric properties to distinguish the presence or absence of motor impairments in children [11].

The predictive validity of INFANIB shows a sensitivity of 84.6%, specificity of 75.6%, PPV of 60.0% and NPV of 91.9% in preterm neonates. At a corrected age (CA) of 6–7 months ($n$ = 117), sensitivity is 100%, specificity is 91.7%, PPV is 82.5%, and NPV is 100%. INFANIB is recognised as a reliable measure for identifying gross motor impairment in preterm neonates at an early stage [12].

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Table 1. Characteristics of AIMS, INFANIB and PDMS-2 [5, 7]

| Characteristics | AIMS | INFANIB | PDMS-2 |
|---|---|---|---|
| Test type and purpose | discriminative, norm-referenced, evaluative for infants with delayed but not abnormal movement, predictive | discriminative, criterion-referenced, predictive, evaluative | discriminative, norm- and criterion-referenced, evaluative |
| International Classification function disability and Health Dimension | body structure and function: postural control<br>activity: motor performance | body structure and function: postural control, muscle tone, vestibular function | activity: gross motor and fine motor skills |
| Evaluation contents | gross motor | neurological | gross and fine motor |
| Scoring | motor percentiles | raw scores (factor and total scores) | motor quotient |
| Age range (months) | 0–18 | 0–18 | 0–72 |
| Number of subtests | 4 | 5 | 6 |
| Total items | 58 | 20 | 249 |
| Test requirements | record booklet | score sheet | record booklet + test kit |

AIMS – Alberta Infant Motor Scale
INFANIB – Infant Neurological International Battery
PDMS-2 – Peabody Developmental Motor Scale, 2nd ed.

The discriminant ability of INFANIB was assessed in Colombian preterm and LBW infants at 3, 6 and 9 months of CA to predict neurological outcomes at one year of CA, using the Griffiths III. The sensitivity and specificity of INFANIB were 62.2%, 76.1%; 77.5%, 74.4% and 77.2%, 91.1% at 3, 6 and 9 months, respectively. If the INFANIB test results are normal, infants should undergo close clinical monitoring; however, abnormal or transient results necessitate immediate intervention [13].

Therefore, rather than screening or diagnosing newborns, INFANIB is best used for quickly identifying individuals who would greatly benefit from early intervention. In addition, INFANIB scores at 3 and 6 months are particularly useful for identifying infants who require early intervention [13].

When the concurrent validity of AIMS and BSID III/GM for detecting impaired gross motor development in preterm newborns was evaluated, the BSID III/GM identified delayed gross motor development with a prevalence of 20.8%, while AIMS indicated a motor delay of 11.9% and 21.4% in the 5th and 10th percentiles, respectively. The authors concluded that the AIMS 10th percentile is more accurate in detecting delays in motor development [14].

Another study examined the predictive and concurrent validity of the BSID III motor scale and PDMS on full-term and healthy preterm infants and reported a high correlation (ranging from 0.78 to 0.96) between age-equivalent BSID III and PDMS2 gross motor scores [15].

Among LBW infants, a prospective clinical validation study reported a strong correlation between the BSID II Psychomotor Development Index and PDMS-2 Fine Motor ($r = 0.91$, $p < 0.001$) and Gross Motor ($r = 0.93$, $p < 0.001$) scores [16]. Prelinguistic children communicate through their necessary motor activities, which form the foundation for more advanced and mature development [17, 18]. An infant's motor skills appear in a predictable sequence and at a predictable chronological age, although the rate of development may vary [19, 20]. Consequently, the predictive validity of one scale over another may differ between a cross-sectional study design and a longitudinal one [21].

Data obtained from the National Family Health Survey on the influence of maternal factors on LBW in children indicates a greater association between regular antenatal check-ups, maternal nutrition (primarily iron deficiency) and delivery at a public health facility [22]. With improved awareness of the necessity of early intervention in LBW infants, health professionals are mainly involved in assessing infants to identify motor impairments. These assessments form the foundation for the design and development of therapy, as well as monitoring LBW infants' progress over time [11]. With prevalent proportions of LBW being reported from South Asian countries, India alone contributes to more than 40% of LBW infants being born in developing countries, and up to 50% in Asia [23]. Thus, a standardised assessment of LBW infants is of greater importance to identify the trajectory of their development and incorporate the appropriate rehabilitation methods.

As reported in the survey by Chokshi et al. [24], rehabilitation practices are more concerned with the cardiorespiratory health of infants admitted to the neonatal intensive care unit (NICU). Very limited attention has been given to the assessment of motor development in infants at the early stage of rehabilitation, especially in developing countries such as India. We believe that the easy access, administration and accuracy of the evaluation tools used will help address the reported shortcomings related to the reduced use of evaluation in infants with LBW during the early stages. With AIMS offering the advantage of visual guidance in its assessment and INFANIB being very quick to administer, we hypothesise that these assessment scales will be able to evaluate the changes over time in LBW infants, equivalent to PDMS-2 [6, 8]. In addition, to the best of our knowledge, no retrievable literature is available on the motor evaluation of LBW infants by AIMS and INFANIB alongside PDMS-2 in a longitudinal study design, especially involving LBW infants in India.

Considering the available literature, the current study aims to provide quicker assessments such as AIMS and INFANIB to predict motor abnormalities in LBW infants as accurately as PDMS-2. In addition, it will compare which of the two scales can better predict motor abilities over a period of one year in LBW infants in India.

## Subjects and methods

### Subjects

All participants were enrolled from a convenience, non-random sample. With an assumption of 90% sensitivity of AIMS compared to PDMS-2, 80% power, an 18% prevalence of LBW in the community, 95% confidence interval and an additional 10% non-response error, the total sample size was 53, derived using the following formula:

$$n = \frac{(Z^2_{1-\alpha/2})\ (S_N)\ (1 - S_N)}{(L^2)\ 18\%}$$

$S_N$ – sensitivity
L = 0.2 (precision)
$(Z^2_{1-\alpha/2}) = 1.96$.

The LBW infants were recruited through the immunisation clinic of Kasturba Medical College (KMC) and RAPCC Government Wenlock Hospitals in Mangaluru from December to March 2018, until data saturation was reached for the follow-up timeline of one year. The sample was recruited until the desired number was attained, and the parents were briefed about the study in their vernacular language. LBW infants (birth weight 2500 to >1500 g) who had previously been admitted to the NICU were included. LBW infants with a history of congenital deformities that would directly hinder scoring on the assessment, diagnosed metabolic disorders leading to growth retardation, genetic anomalies/syndromes or a 5-min APGAR score below 6 were excluded from the study.

### Data collection procedures

A postgraduate student, trained to administer the INFANIB, AIMS and PDMS-2 assessments on infants, performed the data collection. Appointments for the assessment were made at 4, 8 and 12 months of chronological age. From the date of inclusion to the age of 4 months, parents were verbally instructed to follow the guidelines provided by the healthcare professionals involved with the infant's well-being. The CA was obtained by subtracting the total gestation weeks from 37, and the remainder was subtracted by the chronological age of the LBW infant [13]. The assessment was carried out by the postgraduate student, and all infants were assessed at the Neuro-Sensory Developmental Unit, KMC Hospitals, Bejai; RAPCC Government Wenlock Hospital; and, on a few occasions, at the infants' homes. At each assessment schedule, the order of evaluation was AIMS, INFANIB and PDMS-2.

### Statistical analysis

The data were tested for normality using the Shapiro–Wilk test, and the Karl Pearson correlation coefficient was used to estimate the validity of AIMS and INFANIB scores with PDMS-2 raw scores. Although the data were normally distributed, to accommodate for the lower overall sample size, the comparison was made across the 3 age points of evaluation (i.e., 4-, 8- and 12-month scores of AIMS and INFANIB with PDMS-2) by the Friedman test, followed by post hoc analysis using the Wilcoxon signed rank test for categorical variables [32, 33]. Predictive correlations were calculated for the overall sample at each time point between AIMS (percentile) and INFANIB (degree of normality/abnormality) with PDMS-2 standard scores (average/below average) for all LBW infants by chi-square test.

## Results

Although the recruited sample consisted of 53 participants, the study observed significant attrition before the completion of the follow-up period. Among the 53 initially recruited, 13 infants passed away, and 22 parents failed to follow up on the scheduled assessment days and did not comply with the investigator's requests. Consequently, the final sample that completed the study was 18. The demographic characteristics of the LBW infants who completed the study duration are listed in Table 2.

A positive correlation was found at all three age points, indicating the reliability of INFANIB and AIMS scores with the raw scores of PDMS-2 (Table 3).

At each age point (4, 8 and 12 months), infants' motor performance was categorised as > 25$^{th}$ centile / < 25$^{th}$ centile for the AIMS, degree of normality/abnormality based on total scores for the INFANIB and standard scores to describe the child as average/below average on the PDMS-2 scales (Tables 4 and 5).

Table 2. Demographic characteristics of LBW infants

| Gender | Frequency [*n* (%)] | Birth weight (mean ± *SD*) |
|---|---|---|
| Male | 11 (61.1) | 1.680 ± 0.201 |
| Female | 7 (38.9) | 1.745 ± 0.214 |
| Total | 18 (100) | 1.705 ± 0.209 |

Correlation between AIMS, INFANIB and PDMS-2 at 4, 8 and 12 months

Table 3. Correlations between AIMS, INFANIB and PDMS-2 at three age points (*n* =18)

| | PDMS-2 4$^{th}$ M | PDMS-2 8$^{th}$ M | PDMS-2 12$^{th}$ M |
|---|---|---|---|
| AIMS-4$^{th}$ M | 0.860<br>0.000* | 0.733<br>0.001* | 0.753<br>0.000* |
| AIMS-8$^{th}$ M | 0.847<br>0.000* | 0.847<br>0.000* | 0.866<br>0.000* |
| AIMS-12$^{th}$ M | 0.812<br>0.000* | 0.874<br>0.000* | 0.928<br>0.000* |
| | PDMS-2 4$^{th}$ M | PDMS-2 8$^{th}$ M | PDMS-2 12$^{th}$ M |
| INFANIB-4$^{th}$ M | 0.800<br>0.000* | 0.737<br>0.000* | 0.705<br>0.001* |
| INFANIB-8$^{th}$ M | 0.857<br>0.000* | 0.925<br>0.000* | 0.901<br>0.000* |
| INFANIB-12$^{th}$ M | 0.840<br>0.000* | 0.903<br>0.000* | 0.884<br>0.000* |
| | INFANIB-4$^{th}$ M | INFANIB-8$^{th}$ M | INFANIB-12$^{th}$ M |
| AIMS-4$^{th}$ M | 0.901<br>0.000* | 0.782<br>0.000* | 0.680<br>0.002* |
| AIMS-8$^{th}$ M | 0.817<br>0.000* | 0.902<br>0.000* | 0.856<br>0.000* |
| AIMS-12$^{th}$ M | 0.755<br>0.000* | 0.892<br>0.000* | 0.878<br>0.000* |

M – months, AIMS – Alberta Infant Motor Scale
INFANIB – Infant Neurological International Battery
PDMS-2 – Peabody Developmental Motor Scale, 2 ed.
* significant

Table 4. Categorical analysis for the predictive validity of INFANIB and AIMS with PDMS-2 motor outcomes of abnormal ($n$ = 18) LBW infants

| | AIMS and INFANIB | | | AIMS and PDMS-2 | | | INFANIB and PDMS-2 | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (months) | 4 | 8 | 12 | 4 | 8 | 12 | 4 | 8 | 12 |
| Sensitivity (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Specificity (%) | 11.1 | 75.0 | 42.9 | 5.9 | 52.9 | 37.5 | 52.9 | 70.6 | 87.5 |
| PPV (%) | 52.9 | 66.7 | 33.3 | 5.9 | 11.1 | 16.7 | 11.1 | 16.7 | 50.0 |
| NPV (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

AIMS – Alberta Infant Motor Scale, INFANIB – Infant Neurological International Battery, PDMS-2 – Peabody Developmental Motor Scale, 2 ed., PPV – positive predictive value, NPV – negative predictive value

Table 5. Categorical analysis for the predictive validity of INFANIB and AIMS with PDMS-2 motor outcomes of normal ($n$ = 18) LBW infants

| | AIMS and INFANIB | | | AIMS and PDMS-2 | | | INFANIB and PDMS-2 | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (months) | 4 | 8 | 12 | 4 | 8 | 12 | 4 | 8 | 12 |
| Sensitivity (%) | 11.1 | 75.0 | 42.9 | 5.9 | 52.9 | 37.5 | 52.9 | 70.6 | 87.5 |
| Specificity (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| PPV (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| NPV (%) | 52.9 | 66.7 | 33.3 | 5.9 | 11.1 | 16.7 | 11.1 | 16.7 | 50.0 |

AIMS – Alberta Infant Motor Scale, INFANIB – Infant Neurological International Battery, PDMS-2 – Peabody Developmental Motor Scale, 2 ed., PPV – positive predictive value, NPV – negative predictive value

### Predictive validity of AIMS and INFANIB with PDMS-2 at 4, 8 and 12 months

Based on the cut-off values for abnormal LBW newborns, the current study shows superior sensitivity and NPV for both INFANIB and AIMS compared to PDMS-2 at all three age points. This suggests that INFANIB and AIMS can accurately identify true negatives, similar to PDMS-2, at all three age points (Table 4).

For abnormal LBW infants, the INFANIB and PDMS-2 specificity (52.9%, 70.6% and 87.5%) and PPV (11.1%, 16.7% and 50%) are higher than those of AIMS and PDMS-2 (5.9%, 52.9% and 37.5%) and (5.9%, 11.1% and 16.7%), respectively, at all three age points. In addition, between AIMS and INFANIB, specificity and PPV gradually increase with age, suggesting that INFANIB, has better specificity and PPV at later age points (Table 4).

For normal LBW newborns, the current study showed greater specificity and PPV for INFANIB and AIMS at all three age points, compared to PDMS-2 scores. This suggests that both AIMS and INFANIB are effective at identifying true positives, in alignment with PDMS-2, at all three age points.

For normal LBW infants, INFANIB and PDMS-2 sensitivity (52.9%, 70.6% and 87.5%) and NPV (11.1%, 16.7% and 50%) were higher than those of AIMS and PDMS-2 (5.9%, 52.9% and 37.5%) and (5.9%, 11.1% and 16.7%), respectively, at all three age points. Similarly, between AIMS and INFANIB, sensitivity and NPV gradually increase with age, suggesting that INFANIB has better sensitivity and NPV at later age points (Table 5).

## Discussion

This study evaluated the predictive validity of INFANIB and AIMS against PDMS-2 to predict motor abilities in LBW infants at 4, 8 and 12 months of age.

### Correlation between INFANIB, AIMS and PDMS-2 at 4, 8 and 12 months

In our study, a significant correlation was found between AIMS and PDMS-2 at 4 months (0.860, 0.733 and 0.753), 8 months (0.847, 0.847 and 0.866) and 12 months (0.812, 0.874 and 0.928); and between INFANIB and PDMS-2 at 4 months (0.800, 0.737 and 0.705), 8 months (0.857, 0.925 and 0.901) and 12 months (0.840, 0.903 and 0.884) for LBW infants (Table 3).

As reported by Piper et al. [25] and Jeng et al. [26], a strong correlation exists between AIMS and PDMS (0.99) and between AIMS and BSID (0.97) for healthy infants aged 0–13 months. Studies have also shown good correlations for at-risk infants: AIMS and BSID at 6 months (0.78) and 12 months (0.90) and AIMS and PDMS (0.98). Similarly, the current study's findings suggest a strong correlation between AIMS and PDMS-2 and INFANIB and PDMS-2 at the 4-, 8- and 12-month age points during longitudinal follow-ups in LBW infants (Table 3). This suggests that both AIMS and INFANIB have strong concurrent validity against PDMS-2 at these age intervals in LBW newborns. These findings are supported by Eliks et al. [30], who noted that this **S**trong correlation arises due to the presence of key components of gross motor function, such as crawling, walking with assistance, standing alone and essential developmental reflexes, as measured by the studied tools.

### Predictive validity of AIMS and INFANIB with PDMS-2 at 4, 8 and 12 months

In the current study, to detect motor abnormalities in LBW infants at the three age points (4, 8 and 12 months) for AIMS against PDMS-2, specificity was 5.9%, 52.9% and 37.5%, and PPV was 5.9%, 11.1%, and 16.7%. For INFANIB against PDMS-2, these were 52.9%, 70.6% and 87.5%; and 11.1%,

16.7% and 50.0%, respectively, along with higher sensitivity (100%) and NPV (100%). In Harris et al.'s study on AIMS against BSID-II in preterm infants (4–6.5 months old) at the < 5$^{th}$ centile indicated sensitivity was 12.3%, specificity was 94.3%, PPV was 58.3%, and NPV was 63.2%. At the <10$^{th}$ centile, sensitivity was 22.8%, specificity was 87.4%, PPV was 54.2%, and NPV was 63.3% [27].

A study involving preterm infants comparing INFANIB and PDMS at the 3, 7 and 10 months by Liao et al. reported sensitivity (76.9%, 84.6% and 84.6%), specificity (57.1%, 57.1% and 81%), PPV (35.7%, 37.9% and 57.9%) and NPV (88.9%, 92.3% and 94.4%). For full-term infants, sensitivity was 76.9%, 84.6% and 92.3%; specificity was 41.7%, 72.2% and 77.8%; PPV was 32.3%, 52.4% and 60%; and NPV was 83.3%, 92.9% and 96.6% [28]. Another study using INFANIB against the Griffiths III to examine high-risk infants at 3, 6 and 9 months reported sensitivity (62.2%, 77.5% and 77.2%), specificity (76.1%, 74.4% and 91.1%), PPV (10%, 12% and 28%) and NPV (98%, 98% and 99%) [13].

The current study's categorical analysis of AIMS and INFANIB showed that INFANIB has stronger specificity and PPV against PDMS-2 when predicting abnormalities. This finding is comparable to a study evaluating the HINT and AIMS' predictive validity against BSID-III at 4 to 12 months in typical and at-risk infants, which reported a higher predictive validity for HINT compared to AIMS [27].

The findings of this study involving LBW infants from 4 to 12 months of age suggest higher sensitivity, specificity, PPV and NPV for INFANIB compared to AIMS at all three age points against PDMS-2 (Table 3). This may be attributed to the essential characteristics of the scale itself. AIMS is an observational scale that analyses movements in four different postures, whereas INFANIB is a quantifiable outcome measure that evaluates the neurological status of an infant across five different factors (vestibular function, lower extremity reflexes and posture, head and trunk, spasticity and French angles). This study used PDMS-2 as the gold standard to test predictive validity [29]. The results of the current study indicate that INFANIB and AIMS have strong predictive validity versus PDMS-2 in LBW newborns. However, INFANIB demonstrated greater predictive validity than AIMS at 4, 8 and 12 months in LBW infants. Therefore, INFANIB can be recommended as an early screening tool for LBW newborns.

## Limitations

Although the results are favourable in relation to the study objectives, several limitations exist in the current research. By 12 months of age, there was significant panel attrition (greater than 50%), which is a common disadvantage of longitudinal studies [31]. The considerable loss to follow-up constitutes a major limitation in the current study. Therefore, it is important to consider the findings of this study as tentative and to be used as a guide for future research. Due to ethical considerations, it was challenging to implement early intervention strategies to promote developmental activities, particularly in infants with abnormalities, within the framework of the longitudinal study design.

## Conclusions

The evaluation tools, such as AIMS and INFANIB, demonstrated excellent correlation with PDMS-2 scores at 4, 8 and 12 months of age in LBW infants, effectively identifying motor development across one year. However, INFANIB had a higher predictive validity in comparison to AIMS against PDMS-2 in this population. Thus, we conclude that, although AIMS has good psychometric properties, INFANIB may be more useful for clinicians and researchers as a practical measure for identifying motor development abnormalities in LBW infants.

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## Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the institutional ethics committee of Kasturba Medical College, Mangaluru (approval No.: IEC/KMC/MLR/11-18/426).

## Informed consent

Informed consent has been obtained from all individuals included in this study. The parents or guardians were explained, and written informed consent was obtained from the willing parents before data collection as per the Declaration of Helsinki II.

## Disclosure statement

No author has any financial interest or received any financial benefit from this research.

## Conflicts of interest

The authors state no conflicts of interest.

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