DOI: 10.7860/JCDR/2025/78639.21043

Original Article

Paediatrics Section

Comparative Analysis of Three Pain Scales for Evaluation of Procedural Pain in Neonates: A Cross-sectional Study

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ABSTRACT

Introduction: Neonates frequently undergo painful procedures in the Neonatal Intensive Care Unit (NICU), necessitating reliable Pain Assessment Tools (PAT). While various pain scales exist, no single tool is universally accepted due to differences in validity and clinical applicability.

Aim: To compare the validity and internal consistency of Neonatal Infant Pain Scale (NIPS), Premature Infant Pain Profile Assessment Revised (PIPP-R), Douleur Aigue Nouveau-né (DAN) scale, for assessing procedural pain in neonates before, during and after a heel prick procedure.

Materials and Methods: A cross-sectional study was conducted among 60 term neonates in a rural teaching hospital. The neonates underwent a heel prick procedure and pain scores were assessed using NIPS, DAN and PIPP-R at four time points: baseline, 30 seconds, two minutes and four minutes postprocedure. Construct validity was evaluated using repeated measures Analysis of Variance (ANOVA), concurrent validity by Pearson correlation and internal consistency by Cronbach's alpha. Coefficient of variation was analysed to assess scale precision.

Results: All three pain scales demonstrated peak pain scores at 30 seconds postheel prick, with a subsequent decline over time. NIPS and DAN exhibited high concurrent validity (r=0.939 at 30s, r=0.860 at 2 minutes). Cronbach's alpha for NIPS, DAN and PIPP-R at 30 seconds was 0.808, 0.919 and 0.805, respectively, indicating high internal consistency. The removal of physiological parameters (heart rate, SpO_2) from PIPP-R significantly improved its internal consistency (Cronbach's alpha increased from 0.805 to 0.917 at 30s and from 0.822 to 0.906 at 2 minutes), whereas using only physiological parameters yielded low or negative alpha values. PIPP-R had the lowest coefficient of variation, indicating the highest precision, while DAN had the highest.

Conclusion: NIPS and DAN have good concurrent validity between them. PIPP-R had the least coefficient of variation and hence most precise. DAN has high internal consistency across the timelines.

Keywords: Facial expressions, Neonatal infant pain scale, Pain scales validity

INTRODUCTION

Neonates undergo multiple painful procedures and interventions during day-to-day care in NICU. Hence, pain assessment in neonates and its further management is an important consideration for providing comprehensive care to neonates. Evidence suggests that repetitive painful procedures can have detrimental effects on both short-term and long-term neurological development of neonates [1-3]. Areas of concern when neonates experience frequent or uncontrolled pain include altered brain development, neurodevelopment, perception of pain and regulation of stress [4-6]. Since neonates cannot express their pain verbally, they are dependent on their caregivers to recognise the presence of pain and its intensity and respond appropriately to reduce the pain [7].

Pain in neonates is widely assessed with help of pain scales, which contain changes in behavioural parameters such as facial expressions, limb movements, vocal expressions and certain physiological parameters like heart rate, breathing pattern, SpO_2. The pain scales are classified as unidimensional and multidimensional based on the parameters included. Commonly used pain scales for acute procedural pain include NIPS, PIPP-R, DAN score Scale, Neonatal Pain Agitation and Sedation Scale (N-PASS), Neonatal Infant Acute Pain Assessment Scale (NIAPAS), PAT etc. Despite availability of many pain scales for assessment of neonatal pain, a gold standard has not yet been developed due to limited validity, reliability and clinical utility of existing tools [8].

Also, evidence from research reveals that there is a need for further education of healthcare providers to enable them to assess neonates for pain and provide an appropriate response [9]. With the above background, this study was done to compare three neonatal pain scales-NIPS, DAN and PIPP-R-regarding their validity in the assessment of pain in neonates before, during and after an acute painful procedure.

MATERIALS AND METHODS

This cross-sectional study was conducted among neonates of a rural teaching hospital in India from July 2021 to December 2021. Prior approval by the Institutional Ethics Committee (IEC) (Approval/MIMS/EC/16/IV/2K21(6/9)).

Inclusion criteria: Term healthy neonates (neonates ≥37 weeks of gestational age) requiring heel prick procedure for monitoring hypoglycaemia, as seen in low-birth-weight neonates and Infant of Diabetic Mothers (IDM) were include in the study.

Exclusion criteria: Neonates who require resuscitation at birth, neonates on life support like Continuous Positive Airway Pressure (CPAP)/ventilator, neonates with congenital anomalies pertaining to head and face (e.g., cleft lip/palate), sick neonates (e.g., sepsis, neonatal seizures) and neonates whose parents refused to provide consent for the study were excluded from this study.

Sample size calculation: Since this is a repeated measures design, we used the formula:

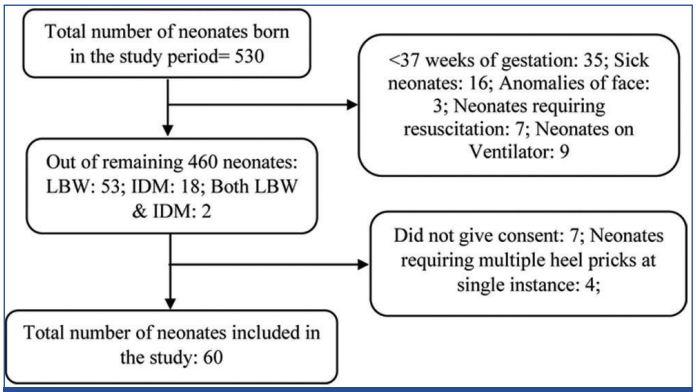
$$n=\{(Z\alpha/2+Z\beta)^2\times2\times\sigma^2\}/\Delta^2$$

where,

$Z\alpha/2=1.96$ (for 5% significance level); $Z\beta=0.84$for 80% power); $\sigma=$ Standard deviation taken as 2.0; $\Delta=$Clinically, significant difference in pain scores taken as 2.0 [10].

The sample size came to a total of 48 neonates. Adding a 10% dropout rate, it was decided to proceed with a sample size of 60 neonates.

The screening of neonates as per the inclusion criteria above is explained in [Table/Fig-1]. Sixty neonates were selected based on the inclusion and exclusion criteria. The heel prick was performed in Prechtl stage 4/5 [11] of the quiet wakefulness state of the baby. Throughout the procedure, (duration 20 minutes), the neonate was placed under radiant warmer in the postnatal ward to ensure adequate warmth and comfort. Neonates were fed one hour before the procedure and their diapers were changed. These neonate underwent heel prick procedure only once for assessment of pain [12]. Any neonate requiring multiple heel pricks at a single instance for checking capillary blood glucose were excluded, as it may interfere with the assessment of pain. Two mL of expressed breast milk taken from the neonate's mother was administered by a nurse and a heel prick was performed two minutes after it.



[Table/Fig-1]: Algorithm for screening and selection of neonates for study.
LBW: Low birth weight; IDM: Infants of diabetic mothers

One of the researchers involved, documented the baseline heart rate and SpO_2 levels using a monitor before the procedure and then at 30 seconds, two minutes and after four minutes of the heel prick. Following standard operating procedure guidelines, the heel prick on the outer aspect of the heel was done by a nurse using a 26 G lancet. Another researcher recorded videos of the neonates. Behavioural responses of the neonate before starting the procedure till five minutes postprocedure were recorded. The pain scales were administered at four timelines to the neonate by the second researcher based on the videos at the following timelines: before the heel prick procedure (baseline), at 30 seconds, two minutes and four minutes of the procedure and documented based on the videos. The following scales were administered to the neonates:

NIPS [13]: It consists of six indicators: six behavioural indicators. It is scored with a 0, 1, or 2. Interpretation: 0-1= no pain; 2= mild pain; 3-4= moderate pain; 5-7= severe pain.

PIPP-R [14]: It includes scores for gestational age, four behavioural parameters (all involving facial responses) and two physiological parameters.

DAN scale [15]: The DAN score scale is a simple scale with three behavioural parameters such as limb movements, vocal and facial expressions.

STATISTICAL ANALYSIS

The data was recorded and analysed by using Statistical Package for the Social Sciences (SPSS) software version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics such as mean, Standard Deviation (SD) and percentages were used to analyse data. The construct validity was measured by the repeated ANOVA test in four timelines of pain level measurement (before, during and after blood collection), followed by the Bonferroni post-hoc test to identify the differences between phases. The construct validity of an instrument was considered significantly good if the p-value<0.05.

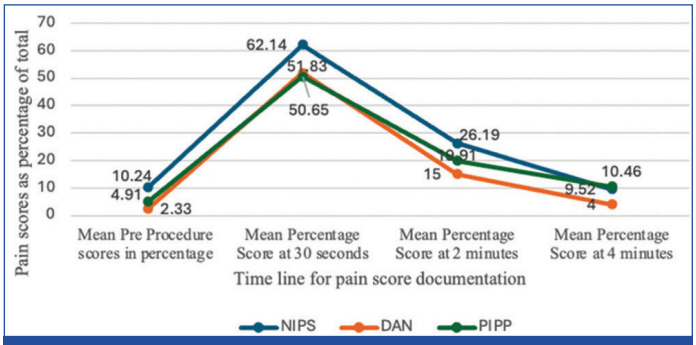
Concurrent validity was performed to see the correlation between items of statement of each instrument using the Pearson correlation test. Internal consistency was assessed using the Cronbach's alpha test and was considered to be good if the Cronbach's alpha value was >0.80 and excellent if the value ranged between 0.80 and 0.90 [16,17]. The coefficient of variation of the scales was analysed to understand the precision of the scale.

RESULTS

The baseline demographic characteristics of 60 neonates included in this study are described in [Table/Fig-2]. The construct validity of the pain scales was assessed using repeated ANOVA and post-hoc tests. It was observed that all three scales had peak pain scores at 30 seconds of procedure, which decreased uniformly later. The comparison of the mean scores at various timelines is shown in [Table/Fig-3,4].

Characteristics	No. of neonates; n (%)
No. of male neonates	31 (51.67)
No. of female neonates	29 (48.33)
Mean weight of neonates±SD in grams	2425.73±379.84
No. of low-birth-weight neonates	44 (73.33)
Infant of diabetic mothers	20 (33.33)
Mean gestational age±SD in weeks	38.06±0.95

[Table/Fig-2]: Baseline characteristics of neonates.
SD: Standard deviation



[Table/Fig-3]: Graph depicting the pain score percentages at various timelines.

Pain scales	Mean±SD at various timelines				p-value by repeated ANOVA
	Preprocedure	At 30 seconds	At 2 minutes	At 4 minutes	
NIPS	0.716±0.88	4.35±2.34	1.83±1.85	0.67±0.95	<0.00001
DAN	0.23±0.56	5.18±3.79	1.5±2.27	0.4±1.14	<0.0001*
PIPP-R	0.83±1.11	9.12±2.94	3.58±3.17	1.83±1.60	<0.0001*

[Table/Fig-4]: Scores of NIPS, DAN and PIPP-R scales across various timelines.
NIPS: Neonatal infant pain scale; DAN: Douleur Aigue Nouveau-né score Scale; PIPP-R: Premature infant pain scale revised; SD: Standard deviation. * Bonferroni post-hoc test showed significant difference for comparison of means between all timelines for NIPS, PIPP-R and DAN scales except between means at pre procedure and at four minutes of PIPP-R and DAN scales.

Concurrent validity between the scales was done using Pearson test as shown in [Table/Fig-5]. NIPS and DAN scales had strong correlation at 30 seconds of procedure, two minutes and four minutes, while correlation between PIPP-R and DAN and between NIPS and PIPP-R, showed moderate correlation at 30 seconds, two minutes and four minutes.

	Preprocedure (r value; p-value)	At 30 seconds (r value; p-value)	At 2 minutes (r value; p-value)	At 4 minutes (r value; p-value)
NIPS and DAN	0.37; 0.0033	0.939; <0.00001	0.860; <0.00001	0.705; <0.00001
PIPP-R and DAN	0.01; 0.945	0.45; 0.0003	0.59; ; <0.00001	0.47; <0.0001
NIPS and PIPP-R	0.12; 0.3615	0.43; 0.00061	0.51; 0.00003	0.50; 0.00003

[Table/Fig-5]: Concurrent validity between pain scales.
NIPS: Neonatal infant pain scale; DAN: Douleur Aigue Nouveau-né score Scale; PIPP-R: Premature infant pain scale

DAN scale had highest reliability among all scales at 30 seconds [Table/Fig-6]. When Cronbach's alpha was calculated for PIPP-R, both with and without including the physiological parameters of heart rate and SpO_2, it increased from 0.805 to 0.917 at 30 seconds and from 0.822 to 0.906 at two minutes after procedure. Cronbach's alpha of PIPP score at 30 seconds and at two minutes with only physiological parameters of heart rate and SpO_2, were 0.330 and 0.129, respectively. At four minutes, many subjects had pain scores of zero. Hence, evaluating internal consistency at four minutes to see whether the items in the scale are consistently measuring pain cannot add value and Cronbach's alpha cannot be calculated. Hence, the statistics were done at 30 seconds and at two minutes and not at baseline and four minutes.

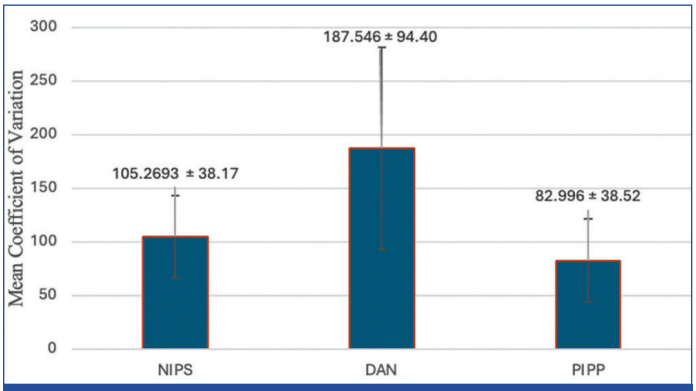
Pain scales	Cron Bach's Alpha at 30 seconds	Cron Bach's Alpha at 2 minutes
NIPS	0.808	0.762
DAN	0.919	0.850
PIPP-R	0.805	0.822

[Table/Fig-6]: Internal consistency of various pain scales at 30 seconds and at two minutes after procedure.
NIPS: Neonatal infant pain scale; DAN: Douleur Aigue Nouveau-né score Scale; PIPP-R: Premature infant pain scale

The highest coefficients of variation were observed at the four minutes into the procedure for both NIPS and DAN [Table/Fig-7]. PIPP-R had the lowest coefficient of variation (82.99±38.52), while DAN had the highest (187.54±94.4) overall coefficient of variation [Table/Fig-8].

Pain scales	(CV%) Preprocedure	(CV%) At 30 seconds	(CV%) At 2 minutes	(CV%) At 4 minutes
NIPS	123.44	54.01	101.01	142.61
DAN	241.53	73.09	151.08	284.48
PIPP-R	125.88	32.24	88.59	85.28

[Table/Fig-7]: Individual Coefficient of Variation in relation to various points in timelines.
NIPS: Neonatal infant pain scale; DAN: Douleur Aigue Nouveau-né score Scale; PIPP-R: Premature infant pain scale; CV: Coefficient of variation



[Table/Fig-8]: Overall coefficient of variation of pain scales.

DISCUSSION

The results showed that the highest level of pain was observed at 30 seconds of heel prick by lancet, while the lowest level of pain was perceived before the start of procedure. All the three scales showed remarkably high construct validity. NIPS and DAN had high concurrent validity at 30 seconds and at two minutes of procedure. All three scales had high internal consistency. PIPP-R had the lowest coefficient of variation, while DAN had the highest.

Exposure to pain in neonates is associated with adverse short- and long-term outcomes [1-3]. Hence, a comprehensive pain tool for assessment and incorporation into daily use during care of neonates forms a fundamental pillar for providing holistic care to them.

In this study, NIPS had high construct validity (p-value <0.00001) across all four timelines measured. Septiana N et al., reported similar results, where they compared NIPS, NIAPAS and PAT and found NIPS to have high construct validity [18]. Xie W et al., also compared the Neonatal Facial Coding System (NFCS), NIPS, DAN and PIPP scales among 111 preterm neonates and found that all the scales had significant difference between median pain scores across various timelines of measurement of pain by Kruskal-Wallis test [19].

The concurrent validity of NIPS and DAN was highest at 30 seconds into the procedure (r=0.939), followed by r=0.860 at two minutes of procedure. Like the present study, Xie W et al., also demonstrated high correlation (Spearman rank correlation - rho=0.84-0.931) between NIPS and DAN at various timelines of before, during and after blood sample collection in neonates in their study [19].

All the three scales had high internal consistency, with Cronbach's alpha values ranging from 0.80 to 0.919. Xie W et al., similarly reported high Cronbach's alpha values for the NIPS, DAN and PIPP-R scales as 0.824, 0.869 and 0.861, respectively, in their study of 111 preterm neonates [19]. In addition, Septiana N et al., reported a high Cronbach alpha of 0.896 for NIPS scale when they compared NIPS, NIAPAS and PAT during their study on 30 neonates with mean gestational age of 33.6 weeks [18].

In the present study, the effect of removing physiological parameters (heart rate and oxygen saturation) from PIPP-R was further explored. It was observed that the Cronbach's alpha for PIPP-R increased from 0.805 to 0.917 at 30 seconds and from 0.822 to 0.906 at two minutes when only behavioural parameters were considered. However, when Cronbach's alpha was calculated for only two physiological parameters, the values were low, suggesting poor internal consistency. This indicates that the addition of physiological indicators, while intended to provide a more comprehensive assessment, may introduce variability and reduce the scale's reliability in term neonates.

Similar observations have been noted in previous studies, where physiological parameters in neonatal pain scales were found to be more susceptible to external factors such as environmental stimuli, neonatal state and individual variations, rather than being direct reflections of pain intensity [19,20]. The weak reliability of physiological parameters alone suggests that neonatal pain assessment may be more precise when utilising facial expressions and behavioural indicators, as seen with the NIPS and DAN scales.

The improved internal consistency of the PIPP-R scale when using only behavioural parameters suggests that, in stable term neonates, physiological indicators may add heterogeneity without providing substantial benefit. This aligns with previous research suggesting that behavioural responses are the most consistent indicators of pain in neonates [21,22].

In this study, PIPP-R had the lowest coefficient of variation (82.9±38.52). This shows that among the three scales, PIPP-R is the most precise pain scale. Spasojevic S and Bregun-Doronjski A, observed that PIPP-R had least coefficient of variation (42.7±14.3) among NIPS, DAN, NPAS and PIPP-R scales in a study on 360 neonates [20].

DAN is a unidimensional pain scale constructed solely on behavioural parameters of facial expression, limb movements and vocal expression, each having three or four subgradations [15]. Although DAN had good construct validity, concurrent validity and internal consistency, it exhibited the highest coefficient of variation. Also, grading behaviour as mild, moderate, or very pronounced for facial expressions and limb movements is difficult to interpret and judge clinically.

NIPS is a unidimensional pain scale with six behavioural parameters each with two or three gradations [13]. It had high construct validity and concurrent validity, but lesser internal consistency than the other two scales. It had moderately high coefficient of variation which made it less precise. PIPP-R is a multidimensional pain scale developed for assessment of acute pain in both preterm and term neonates [14]. It has two physiological and four behavioural parameters with

four gradations and also has gestational age as contextual indicator. This scale has high construct validity and content validity and the least coefficient of variation making it the most precise scale among the three scales compared here.

This study highlights that the reliability of PIPP-R improves significantly when physiological parameters (heart rate and SpO_2) are excluded, reinforcing the idea that facial expressions and behavioural states alone may provide a more precise measure of neonatal pain in term neonates. This suggests that modifications to PIPP-R for term neonates-specifically, excluding physiological parameters-could enhance its reliability while maintaining its ability to detect pain responses.

The advantage of this scale is that every gradation of each parameter is defined by time, quantity and quality of expected and hence makes it quite specific and sensitive to the changes observed and decreases variability.

Limitation(s)

This study did not include content validity of the scales, as all the three scales have been widely used in clinical settings. The inter-rater reliability was also not included in the study.

CONCLUSION(S)

NIPS and DAN have good concurrent validity between them. PIPP-R has the least coefficient of variation and hence most precise. DAN has high internal consistency across the timelines. When physiological parameters are removed from PIPP-R, the internal consistency increase to that close to DAN scale. PIPP-R scale has high internal consistency without physiological parameters. Use of PIPP-R without physiological parameters needs to be explored further and validated.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Feb 17, 2025
- Manual Googling: Mar 18, 2025
- iThenticate Software: Apr 05, 2025 (8%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 16, 2025**
Date of Peer Review: **Mar 07, 2025**
Date of Acceptance: **Apr 08, 2025**
Date of Publishing: **Jun 01, 2025**