Pediatric RESEARCH

SYSTEMATIC REVIEW

Predictive efficacy of the Braden Q Scale for pediatric pressure ulcer risk assessment in the PICU: a meta-analysis

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BACKGROUND: Risk assessment is recommended as the foremost step in the prevention of pressure ulcers. This study aimed to evaluate the predictive efficacy of the Braden Q Scale for the assessment of pediatric pressure ulcer risk in the pediatric intensive care unit (PICU).

METHODS: Six databases were searched. A meta-analysis was performed using Meta DiSc 1.4.

RESULTS: Seven studies were included, with a total of 1273 cases and 72 pressure ulcers. The meta-analysis showed that the pooled sensitivity and specificity of the Braden Q Scale for PICU patients were 0.72 and 0.60 (95% confidence interval (CI): 0.60–0.82; 0.57–0.63), respectively. The pooled positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio were 1.69, 0.62, and 3.34 (95% CI: 1.18–2.42; 0.40–0.94; 1.47–7.61), respectively. The area under the curve of summary receiver operating characteristics was 69.18%, and the *Q* index was 0.6464.

CONCLUSION: The Braden Q Scale predicted pressure ulcer risk in the PICU with moderate accuracy. More testing for the Braden QD Scale's performance is needed, taking into account the impact of the interventions. In the future, it will be necessary to look for and improve pediatric pressure ulcer risk assessment tools.

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INTRODUCTION

A number of multicenter studies[1–6] have shown that the prevalence of pressure ulcers (PUs) in hospitalized children is approximately 1.4 to 13.5%, and the prevalence rate is as high as 12 to 43% in high-risk departments such as intensive care units, operating rooms, and neurosurgery. Among PUs in hospitalized children, 35.6–80% are stage I.

Risk assessment is recommended as the foremost step in the prevention of PUs, and effective prevention and intervention can only be carried out based on appropriate and accurate assessment.[7,8] The 2014 international guidelines published by the National Pressure Ulcer Advisory Panel (NPUAP), the European Pressure Ulcer Advisory Panel (EPUAP), and the Pan Pacific Pressure Injury Alliance (PPPIP)[9] specifically emphasized the need to "Conduct a structured risk assessment as soon as possible (but within a maximum of 8 h after admission) to identify individuals at risk of developing PUs." Therefore, when assessing risk, we must select a tool that is appropriate to the population and is valid and reliable.[9,10] Related research on PU risk assessment in children started late, and most assessment tools were improved based on studies of adults. The quality and effectiveness of these assessment tools were inconclusive. Some studies considered that there was currently no scale that could make optimal clinical decisions regarding PU risk assessment in children. The application effect of each scale needs further study.[11–13] The Braden Q Scale was modified and developed on the basis of the Braden Scale by Curley et al.[14] and Quigley and Curley.[15] It is a PU assessment scale specifically designed for pediatric populations and is widely used, especially in pediatric intensive care units (PICUs). Compared to the general population of hospitalized children, critically ill children will always have a higher risk of skin breakdown.[16] In Mainland China, the Braden Q Scale is the most widely used tool for assessing children's PU risk. It comprises seven subscales designed to rank the factors that contribute to PU risk: (1) sensory perception, (2) skin moisture, (3) activity, (4) friction and shear, (5) mobility, (6) nutritional status, and (7) tissue oxygenation and perfusion. All subscales are set to 1–4 points, with lower numbers indicating greater risk and higher scores indicating lower risks. The scores of all the subscale are summed to obtain the total score, which varies from 7 (high risk) to 28 (low risk). The Braden Q Scale in the original source was recommended for children from 21 days to 8 years, and for PUs excluding stage I. But many studies have applied it to children of all ages, and to PUs of all stages, so we would like to know the predictive efficacy of the Braden Q Scale in different ages and different stages.

Aim

This paper performed a meta-analysis of the predictive efficacy of the Braden Q Scale and provided a theoretical reference for finding a scientific and effective tool for assessing children's risk of PUs in the PICU.

METHOD

Search strategy

We researched databases including PubMed, Cochrane Library, Embase, China National Knowledge Infrastructure (China), VIP Chinese Medical Journal Database (China), and Wanfang Med

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Online (China). The search period was from database inception to October 2017. We used the following terms as keywords: pressure ulcer/decubitus ulcer/pressure injury/skin ulcer/bed sores, risk assessment/assessment scale/Braden Q, and pediatric/children. The search strategy combined subject words and free words that were supplemented by hand searching and document tracing. The search formula adopted the Boolean logic method, and the search words were linked by "AND" or "OR." We selected published and unpublished articles written in Chinese or English. The database searches and study selections were conducted independently by two reviewers.

Inclusion criteria

(1) The patients' age was younger than 18 years while in the PICU, and no PUs were present at the time of admission assessment. (2) The studies were published in Chinese or English. (3) The definition and staging of PU followed clear standards: that is, the published guidelines by NPUAP, EPUAP, or other organizations. (4) The risk of PUs in hospitalized children was assessed using the Braden Q Scale.

Exclusion criteria

Literature reviews, repeated reports, and reports with incomplete information.

Assessment of methodological quality

Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2)[17] was used to evaluate the methodological quality of the included papers using Review Manager 5.3 software. QUADAS-2 consists of four domains: patient selection, index test(s), reference standard, flow, and timing. All four domains were evaluated for the risk of bias, and the first three were evaluated for clinical applicability. The relevant landmark issues included in each part were rated on three levels: "yes," "no," and "unclear." The articles were graded "high," "low," and "unclear" in terms of risk of bias and clinical applicability. Two evaluators independently evaluated each included article using these criteria. After independently evaluating the quality of all the articles, the evaluators compared their screening and evaluation results. When a disagreement occurred, the two evaluators discussed the issues until they reached consensus or asked a third party to decide whether to include the article.

Data extraction

Authors, year, study country, population age and sex, sample (including total sample size and the proportion of the sample with PU, stage I PU, medical device-related (MDR) PU), Braden Q Scale cut-off score, the included heart diseases, PU reference standard and outcome index for the Braden Q Scale prediction [true-positive number (TP), false-positive number (FP), false-negative number (FN), true-negative number (TN)] were extracted and summarized descriptively in one table by one reviewer. A second reviewer checked the data for all studies.

Data synthesis and interpretation

A meta-analysis of the study data was performed using the Meta DiSc 1.4 software. The combined predictive efficacy data [sensitivity (SEN), specificity (SPE), positive likelihood ratio (PLR), negative likelihood ratio (NLR), and diagnostic odds ratio (DOR)], area under the curve (AUC) of summary receiver operating characteristics (SROC) were determined. SEN is the proportion of high-risk patients who are correctly identified as having PUs. SPE is the proportion of low-risk patients who are correctly identified as not having PUs. PLR and NLR describe the discriminatory properties of positive and negative test results, respectively. Likelihood ratios state how many times more likely particular test results are in patients with disease than in those without disease.[18] The DOR is a statistic used to provide a summary of the performance of diagnostic tests and augment the comparison between study results. It combines SEN, SPE, PLR, and NLR to convey how much greater the probability is that a positive test result will indicate the event of interest.[18] The predictive/diagnostic value was judged by the AUC of SROC. The larger the AUC of SROC, the better the predictive efficacy. A 95% confidence interval (95% CI) was used to analyze and interpret the data.

First, the I^2 test and Q test were used to determine whether there was heterogeneity among the studies. If $P > 0.01$ and $I^2 < 50\%$, there was no heterogeneity, and the fixed-effect model was used. If $P < 0.01$ and $I^2 < 25\%$, there was no heterogeneity; if $25\% < I^2 < 50\%$, the heterogeneity was considered low; if $50\% < I^2 < 75\%$,

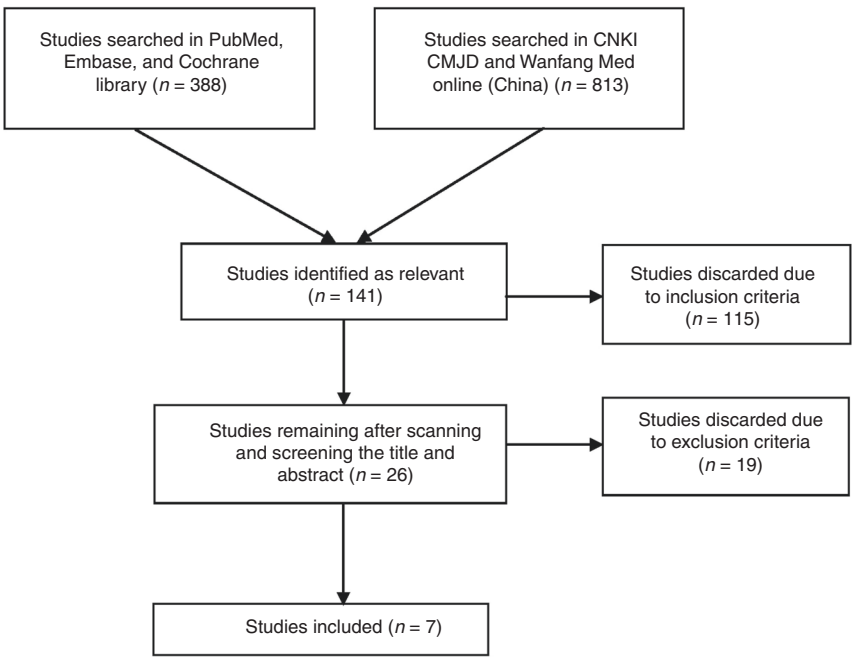

Fig. 1 Study identification and selection process. The diagram for search strategy and selected studies

Table 1. Characteristics of the included studies

Authors	Ref.	Country	Age range (mean) (years)	Male/female (*n*)	Sample size (*n*)	With PU (*n*)	Stage I PU (*n*)	With MDR PU (*n*)	Cut-off score	Included heart disease patients	PU reference standard	TP (*n*)	FP (*n*)	FN (*n*)	TN (*n*)
Curley et al.	14	US	0.06–8 (3 ± 2.42)	193/129	322	25	0	Unknown	16	No	NPUAP (1989)	22	124	3	173
Gu et al.	20	CHN	0.13–7 (1.5)	86/47	133	7	Unknown	0	15	Yes	NPUAP (1989)	2	3	5	123
Feng et al.	21	CHN	Unknown (3.60 ± 4.34)	73/40	113	8	7	3	19	Unknown	NPUAP (1989)	5	55	3	50
Lu et al.	22	CHN	1–15 (unknown)	92/53	145	9	9	3	17	Yes	NPUAP (1989)	6	89	3	47
Tume et al.	16	UK	0.06–8 (unknown)	Unknown	282	2	Unknown	0	16	No	EPUAP	2	75	0	205
Shen et al.	23	CHN	1–12 (6.4 ± 1.6)	48/32	80	7	4	2	17	Unknown	NPUAP (1989)	5	48	2	25
Lu et al. (2015)	24	CHN	0.06–8 (4)	125/73	198	14	12	Unknown	19	Yes	NPUAP (1989)	10	86	4	98

PU pressure ulcer, *MDR* medical device related, *TN* true-negative number, *FP* false-positive number, *FN* false-negative number, *NPUAP* National Pressure Ulcer Advisory Panel, *EPUAP* European Pressure Ulcer Advisory Panel

some heterogeneity existed; and if $I^2 > 75\%$, high heterogeneity was present. If heterogeneity existed, the random effects model (REM) was selected for the meta-analysis,[19] and subgroup analyses could be used to eliminate as much heterogeneity as possible. Significant clinical heterogeneity indicated a need to rethink the literature inclusion criteria: if the heterogeneity was too great and the source could not be judged, a descriptive analysis was used.

RESULTS

The flow diagram of the identification and selection of articles is presented in Fig. 1. The initial search identified 141 related articles whose full text was obtained for detailed analysis; 115 were excluded based on predefined inclusion and exclusion criteria, and 19 were excluded because they reported different scales, were published in different languages, were performed in other settings, and had incomplete information. Finally, seven articles[14,16,20–24] were included in this meta-analysis. All the studies were cohort studies, of which three were in English and four were in Mandarin Chinese. The four studies in Mandarin Chinese all used the Mandarin version of Braden Q Scale. A total of 1273 patients were included, 133 cases of PU occurred, and 72 cases of PU were included in the meta-analysis. The reason for the 61 PUs excluded is that Curley's study calculated the predictive probabilities only for stage II or worse PUs. The characteristics of the included articles are shown in Table 1.

The quality assessment is summarized in Figs. 2 and 3. Overall, most of the studies were identified as having high quality or a low risk of bias across the four domains evaluated by the QUADAS-2. The Spearman's correlation coefficient was −0.018. The *P* value was 0.969, showing no threshold effect. The heterogeneity across the studies after meta-analysis was significant in the SPE and the PLR ($I^2 = 96.8$ and 76.7%) using the REM.

There was enough information to pool accuracy estimates for the Braden Q Scale. The forest plots of these studies with their pooled estimates and 95% CI can be found in Fig. 4. The overall pooled SEN and SPE were 0.72 (95% CI: 0.60–0.82) and 0.60 (95% CI: 0.57–0.63), respectively. PLR was 1.69 (95% CI: 1.18–2.42), NLR was 0.62 (95% CI: 0.40–0.94), and DOR was 3.34 (95% CI: 1.47–7.61).The corresponding SROC curve with AUC was 69.18%. The *Q* index was 0.6464 (Fig. 5).

The heterogeneity among the studies was substantial; therefore, subgroup analysis was an option. The heterogeneity could be explained by the population age, Braden Q Scale cut-off score, PU reference standard, or the included heart diseases. The results of the subgroup analysis are shown in Table 2. One study assessed the PUs of PICU patients according to the EPUAP standard. Two studies included cases for which the presence of heart disease was not mentioned.

DISCUSSION

This meta-analysis included seven studies involving a total of 1273 children with 72 PUs in the PICU. The pooled SEN and SPE of the Braden Q Scale for predicting pediatric PU risk in the PICU were 0.72 and 0.60, respectively. An SPE that is not high enough may lead to insufficient prediction. In summary, these results suggested an ordinary predictive efficacy.

Furthermore, the corresponding SROC curve with AUC was 69.18%, which indicated that the Braden Q Scale had relatively moderate accuracy for predicting pediatric PU risk in the PICU. According to epidemiological principles, effective risk assessment tools must demonstrate high predictive efficacy, including high SEN, SPE, reliability, and ease of use. The predictive/diagnostic value was judged by the AUC of SROC: AUC ≤50% indicates that a diagnostic test was worthless; between 50 and 70% indicates that the accuracy of the diagnostic test is low; between 70 and 90% indicates that the accuracy is moderate; and >90% indicates that

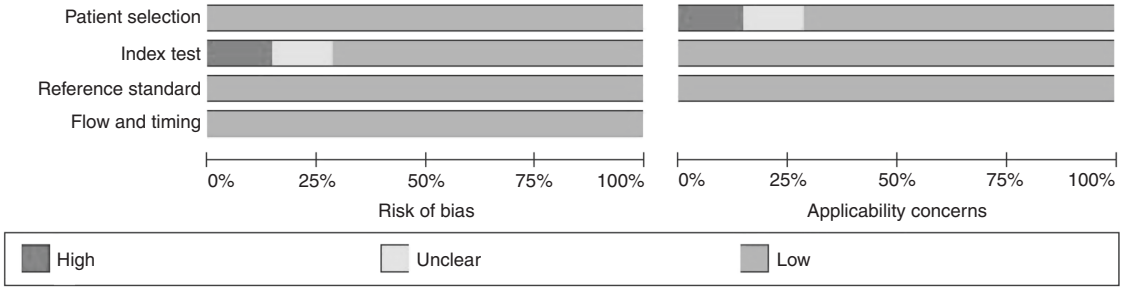

Fig. 2 Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) risk of bias and applicability concerns graph. Reporting quality assessment results for the included studies by QUADAS-2

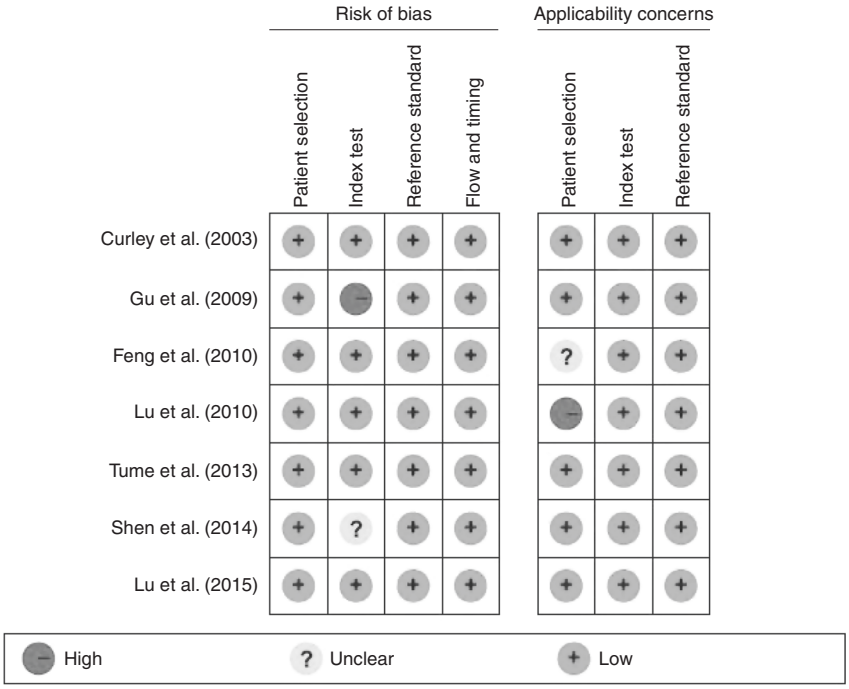

Fig. 3 Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) summary of risk of bias and applicability concerns. Reporting quality assessment results for the included studies by QUADAS-2

the diagnostic accuracy is high. In summary, the closer the AUC is to 1 (i.e., as the curve moves closer to the upper left corner), the higher the predictive/diagnostic accuracy.

We concluded that the studies were heterogeneous, probably due to the population age, the Braden Q Scale cut-off score, the PU reference standard, the inclusion of heart disease patients, and other variables. Therefore, these causes were considered in the subgroup analysis to explain heterogeneity. Although some of the heterogeneity remained according to the results of the subgroup analysis, the predictive efficacy was significantly improved. In the age subgroup, the pooled SEN, SPE, DOR, and AUC of the 21 days–8 years group, which was higher than that of the 0–18 years age group and the total pooled results, predicted PU risk (Table 2). At 21 days of age, the neonate's skin reaches relative maturity, regardless of the infant's gestational age at birth,[25] and the American Heart Association considers that clinical treatment for children >8 years old is very similar to that of adults.[14] Therefore, the age ranges of PU assessment scales for children should be specified; the Braden Q Scale is also recommended for children from 21 days to 8 years.[14] Regarding the cut-off score of the Braden Q Scale subgroup, the pooled SEN, SPE, DOR, and AUC of the 15–16 point group were higher than those of the >16 group; furthermore, the total pooled results (Table 2) indicated that as the Braden Q Scale score decreased, its predictive efficacy increased, but the overall predictive accuracy remained at a moderate level. Quigley and Curley's study[15] indicated that children considered at low risk for PU scored an average of 25 on the Braden Q Scale, children at moderate risk scored an average of 21, and children at high risk for skin breakdown scored an average of 16. Confidence intervals showed that children with a Braden Q score 23 were considered at risk for PUs. Recent studies[26] indicated that the benefit of preventing PUs exceeds the risk posed by implementing preventative interventions in a low-risk group, so identifying a risk threshold that maximizes the TP rate (high SEN) is necessary.

In addition, the reference standards for the definition and staging of pediatric PU that are most commonly used in clinical practice are those published by the NPUAP or the EPUAP. The clinical staffs included in the study were all trained in standardization, but did not know how effective the training was. Because both of these reference standards rely on subjective judgment based on visual inspection and lack support from objective indicators, they are susceptible to staff members' professional knowledge, clinical experience, and attitudes and behaviors. This

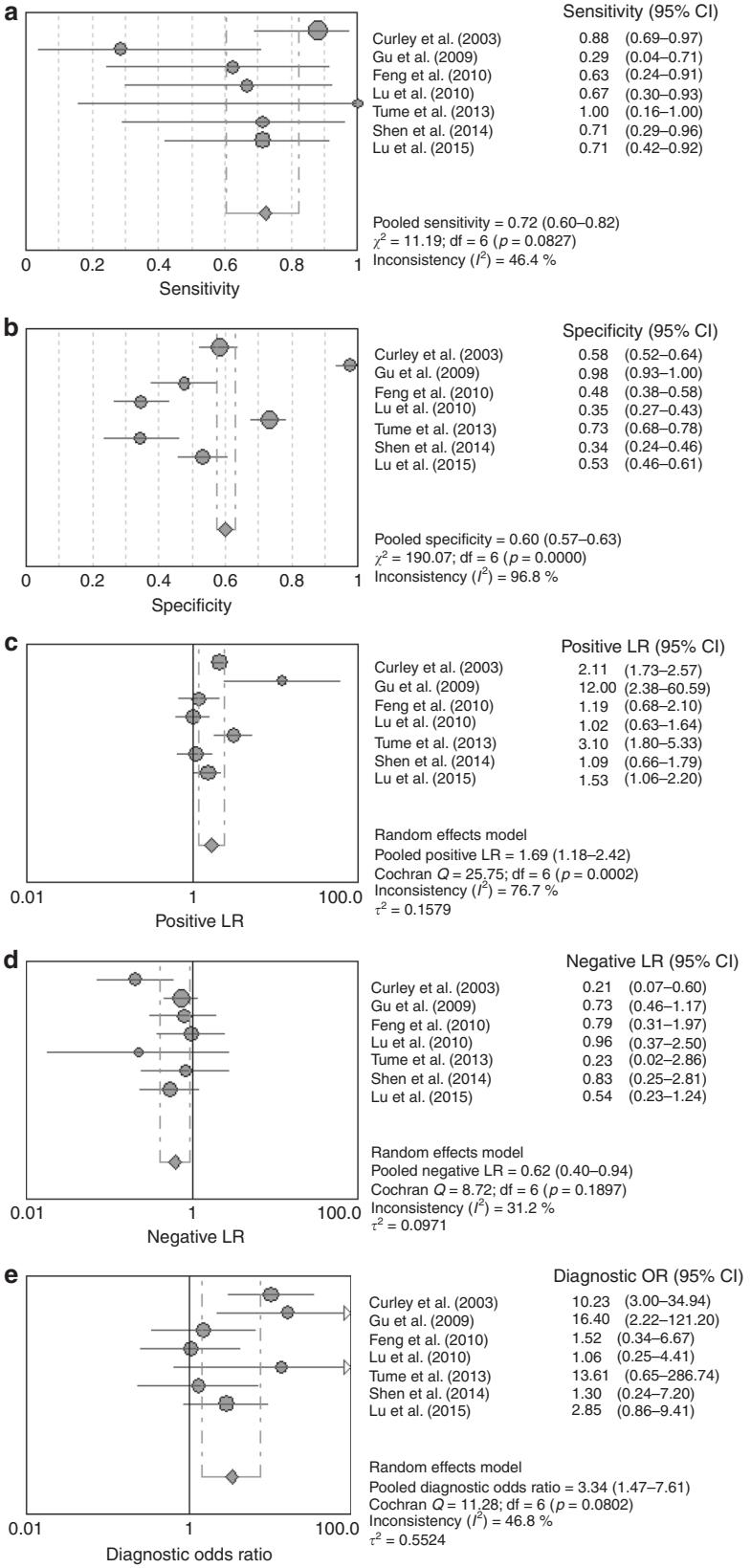

Fig. 4 Forest plots of pooled predictive efficacy data. **a** Meta-analysis of the Braden Q Scale sensitivity (SEN) analysis, **b** meta-analysis of the Braden Q Scale specificity (SPE) analysis, **c** meta-analysis of the Braden Q Scale positive likelihood ratio (PLR) analysis, **d** meta-analysis of the Braden Q Scale negative likelihood ratio (NLR) analysis, and **e** meta-analysis of the Braden Q Scale diagnostic odds ratio (DOR) analysis

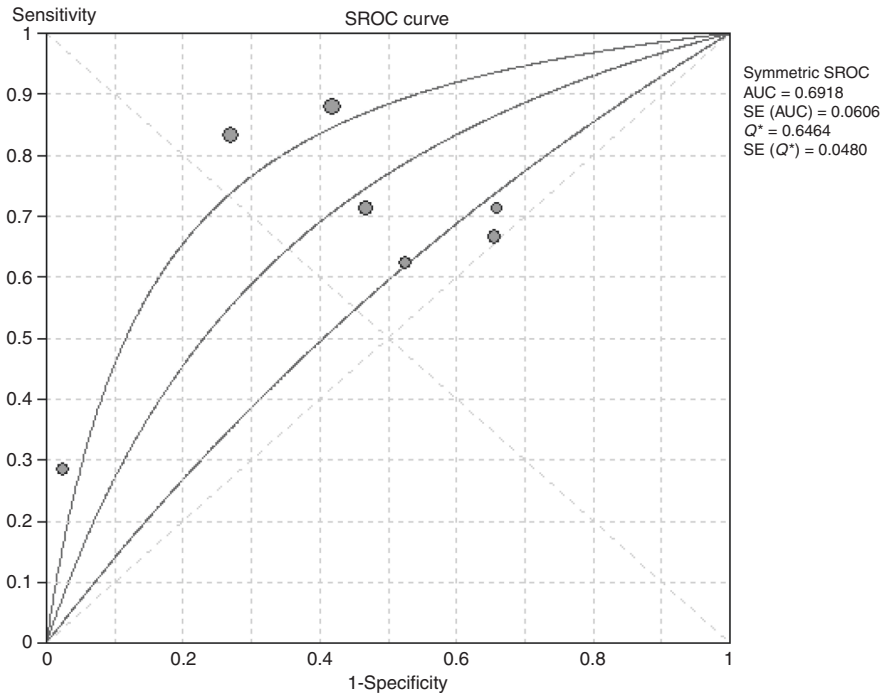

Fig. 5 Summary receiver operating characteristics (SROC) curves of sensitivity (SEN) and specificity (SPE) for the Braden Q Scale

Table 2. Subgroup analysis of the Braden Q Scale

Subgroup	*n*	SEN (95% CI)	I^2 (%)/*P*	SPE (95% CI)	I^2 (%)/*P*	DOR (95% CI)	I^2 (%)/*P*	AUC (95% CI)	*Q**
Population age									
21 days–8 years	4	0.75 (0.60–0.86)	71.5/0.015	0.68 (0.64–0.71)	97.2/0.000	6.83 (2.96–15.74)	11.8/0.334	78.54	0.7232
0–18 years	3	0.67 (0.45–0.84)	0.0/0.935	0.39 (0.33–0.44)	60.5/0.080	1.27 (0.53–3.06)	0.0/0.942	53.96	0.5297
Braden Q Scale cut-off score									
≤16	3	0.76 (0.59–0.89)	80.7/0.006	0.71 (0.68–0.75)	97.7/0.000	11.84 (4.40–31.85)	0.0/0.913	84.32	0.7748
>16	4	0.68 (0.51–0.82)	0.0/0.973	0.44 (0.40–0.49)	79.7/0.002	1.69 (0.83–3.43)	0.0/0.739	58.64	0.5650
PU reference standard									
NPUAP	6	0.71 (0.59–0.82)	49.3/0.079	0.56 (0.53–0.59)	96.9/0.000	3.06 (1.29–7.26)	51.9/0.065	67.89	0.6362
Included heart disease patients									
No	2	0.89 (0.71–0.98)	0.0/0.484	0.66 (0.61–0.69)	93.1/0.000	10.58 (3.49–32.07)	0.0/0.865	83.31	0.7654
Yes	3	0.60 (0.41–0.77)	47.3/0.150	0.60 (0.55–0.65)	98.6/0.000	3.15 (0.81–12.32)	59.3/0.086	68.32	0.6396

SEN sensitivity, *SEP* specificity, *CI* confidence interval, *DOR* diagnostic odds ratio, *AUC* area under the curve, *PU* pressure ulcer, *NPUAP* National Pressure Ulcer Advisory Panel

may be the main reason heterogeneity exists. This situation could be improved via a more standardized approach to research, suggesting that more scientific and effective tools for the diagnosis of pediatric PUs should be developed and implemented in the future. The included papers also indicated that the patients assessed as at high risk in the PICU had received standardized prevention and management strategies based on the national and international guidelines. We also could not know how effective the intervention is. Interventions offered to children in the PICU once they have been risk assessed might alter the predictive efficacy of the Braden Q immediately. Therefore, clinical staff should receive more professional and standardized training, constantly update the training content, and timely evaluate the training effect. It is necessary to test the efficacy of interventions.

The initial predictive validity study of the Braden Q Scale only included immobility-related PUs in children in the PICU and excluded patients with congenital heart disease.[14] In this meta-analysis, two studies excluded patients with heart disease, three

studies included patients with heart disease, and two studies did not mention whether the patients had heart disease. In the subgroup analysis, the pooled SEN, SPE, DOR, and AUC when the heart disease patients group was excluded were higher than the results when the heart disease patients were included and the total pooled results (Table 2). Even with its widespread use, the Braden Q Scale still has several important limitations.[26] It does not address MDR PUs. The initial validity study excluded several pediatric cohorts, such as neonates, adolescents, and patients with congenital heart disease. A recent study[26] found that the Braden QD Scale, a revised and simplified version of the Braden Q Scale, was developed using a diverse sample of hospitalized pediatric patients and predicted both immobility-related and MDR PUs. At a cut-off score of 13, the Braden QD Scale was found to have an SEN of 0.86 and an SPE of 0.59. However, more testing of its performance is needed.

Whether the Braden Q Scale or Braden QD Scale is used, clinical staff should provide appropriate interventions according to the results of each subscale assessment of the instrument and not just the total score. The purpose of risk assessment is to address pressure, shear stress, and related risk factors so that they can be mitigated and removed and PUs can be prevented.

CONCLUSION

At present, it is generally believed that the development of PU is determined by many factors, such as the microenvironment, nutrition, tissue perfusion, the local soft tissue situation, and other comorbidities.[27] A number of studies[11,28–32] have proven that many objective indicators are risk factors for PUs. However, most of the current PU risk assessment tools for children were based on adults. Not only did current tools not include all of the critical risk factors, but most of the items relied on subjective judgment. Most of the instruments also lacked risk factor assessments for children of all ages. It is likely that implementation of interventions reduces the predictive efficacy of the tool. Therefore, tools such as the Braden Q Scale should not be the only element used to assess children's risk of PU.[13] Although the new Braden QD Scale performs slightly better than the Braden Q Scale,[26] it is not widely used. Future research on the Braden QD Scale is necessary and should take into account the impact of the interventions. It is also a challenge to colleagues planning research in this area. We recommend the joint assessment of the risk factors for clinically objective indicators based on evidence-based assessment models and the identification of PU risk through big data mining.[33,34]

LIMITATIONS

This study evaluated the predictive efficacy of the Braden Q Scale for the assessing the risk of pediatric PUs via meta-analysis, but there were some limitations: (1) the quality of the included research was uneven and may have a certain risk of bias. Because of the lack of included research data, it is impossible to accurately discuss the effects of stage I PU and MDR PU on the results. (2) The literature included in this study had some heterogeneity due to its methodological and clinical judgment problems, but the main reason for heterogeneity could be inferred through subgroup analysis. (3) The literature was relatively rare. The scope of the study will continue to be expanded, and the deficiencies of this study will be further addressed.

AUTHOR CONTRIBUTIONS

Chun, X.: Conceived and designed the study, acquisition and interpretation of data, revised the manuscript, and finalized the manuscript. Lin, Y.: Design, interpretation of data, revised the manuscript, and finalized the manuscript. Ma, JX.: Interpretation of data and revised the manuscript. He, J.: Analysis and interpretation of data, and revised the manuscript. Ye, LY.: Acquisition of data and revised manuscript. Yang, HM.: Analysis of data, revised manuscript.

ADDITIONAL INFORMATION

Competing interests: The authors declare no competing interests.

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