

Outcomes of Using Pediatric Early Warning Score (PEWS) with Automatic Alert System in Hospitalized Pediatric Patients

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ABSTRACT

Objective: To evaluate the outcomes of using a Pediatric Early Warning Score (PEWS) application with an automatic alert system compared to the traditional paper-based PEWS in hospitalized pediatric patients.

Materials and Methods: A retrospective cohort study was conducted in pediatric patients aged 1 month to 15 years admitted to the pediatric ward of Phaholpolpayuhasena Hospital between September 9, 2022, and September 8, 2023. Patients were enrolled by systematic sampling, ordered by date of admission: the control group was evaluated with paper-based PEWS in the first 6 months, and the intervention group was evaluated with a PEWS application in the last 6 months. Outcomes included mortality rate, unplanned intensive care unit (ICU) admission, emergency resuscitation, interpretation accuracy of PEWS items, and response time.

Results: A total of 350 patients (175 in each group) were included, yielding 13,020 PEWS recordings in total (6,432 from the paper group and 6,588 from the application group). The PEWS application group had significantly lower rates of adverse events (2.29% vs. 10.86%, $p=0.001$), unplanned ICU admissions (0.57% vs. 6.86%, $p=0.002$), and unplanned intubations (0.57% vs. 5.14%, $p=0.010$). Interpretation accuracy of PEWS items was substantially higher in the application group (88.00% vs. 12.00%, $p<0.001$). The average response time was significantly shorter in the application group (24.36±25.72 minutes vs. 47.64±26.42 minutes, $p<0.001$).

Conclusion: The use of a PEWS application with an automatic alert system was associated with reduced adverse events, improved interpretation accuracy of PEWS items, and faster response times compared to traditional paper-based PEWS in hospitalized pediatric patients. This supports the potential benefits of implementing automated PEWS systems for pediatric inpatient monitoring.

Keywords: Pediatric Early Warning Score (PEWS); Application; Automatic alert system; Hospitalized pediatric patients

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Unexpected deaths in hospitalized children are a significant preventable problem worldwide. The Confidential Enquiry into Maternal and Child Health (CEMACH) found that about 1 in 5 pediatric inpatient deaths had preventable factors, and around half exhibited abnormal signs detectable before deterioration⁽¹⁾. Children are at higher risk for rapid, severe decompensation due to physiological

differences from adults^(2,3).

The Pediatric Early Warning Score (PEWS) was developed to help identify at-risk children before clinical worsening by assessing vital signs and symptoms. Higher scores signal increased risk of deterioration to medical teams^(4,5). Studies suggest PEWS can reduce cardiac arrests, unplanned intensive care unit (ICU) admissions, and mortality in pediatric patients^(6,7). However, traditional paper-based

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What is already known about this topic?

Previous studies have shown that PEWS systems can help detect clinical deterioration in hospitalized children. However, traditional paper-based PEWS has limitations in usability and reliability, including misinterpretation of categorical items and delayed escalation.

What does this study add?

This study demonstrates that using a PEWS application with automatic alerts is associated with reduced adverse events, improved accuracy of PEWS calculation, and faster response times compared to traditional paper-based PEWS. These findings support the potential benefits of implementing automated PEWS systems for pediatric inpatient monitoring.

PEWS has limitations in usability, with potential for calculation and interpretation errors⁽⁸⁾. Electronic PEWS applications have been developed to increase convenience, reliability of assessment, automatic score calculation, and alerting^(9,10).

A 5-year retrospective review at university hospital found a high 86% mortality rate among pediatric inpatient cardiopulmonary resuscitation (CPR) events, exceeding the global average of 54%⁽¹¹⁾. Key factors were human error and lack of automated alerting. Only 31% of cases used paper-based PEWS. In response, a mobile web PEWS application with automatic alerts was developed. A pilot retrospective cohort study comparing 62 patients found the application group had zero mortality, unplanned ICU admissions, or deterioration events, and 50% faster average response times⁽¹²⁾.

Given these promising trends, this study aimed to more comprehensively evaluate the impact of a PEWS application with automatic alerts on key clinical outcomes compared to traditional paper-based PEWS in a larger pediatric inpatient sample.

MATERIALS AND METHODS

Study Design and Setting

A retrospective cohort study was conducted using medical record data of pediatric patients admitted to the pediatric ward of Phaholpolpayuhasena Hospital over a 1-year period between September 9, 2022, and September 8, 2023. Patients were divided into a control group evaluated with paper-based PEWS in the first 6 months and an intervention group evaluated with a PEWS application in the last 6 months.

Description of the intervention: PEWS application with an automatic alert system. The research team developed a PEWS mobile web application accessible on any smartphone, tablet, or computer within the hospital network. Its principal features were: 1) bedside entry of vital signs and clinical symptoms, 2) automatic calculation of the PEWS score, 3) automatic stratification of patients into three risk tiers (low, intermediate, and high risk), 4) real-time visual alerts displayed on the central monitor at the nurse station whenever the score reached a predefined threshold (PEWS ≥ 4), together with initial management recommendations corresponding to the risk tier, 5) automatic logging of alert times and the corresponding nursing responses, and 6) a score-trend display to support longitudinal clinical judgment. In contrast, the paper-based PEWS required manual recording of vital signs, manual summation of the score, and verbal or written escalation to the responsible physician without

any automated prompt.

Participants

The study population included pediatric patients aged 1 month to 15 years admitted to the pediatric ward for at least 24 hours during the study period. Patients were enrolled by systematic sampling, ordered by date of admission within each 6-month study period.

The control group (175 patients) consisted of patients evaluated with paper-based PEWS in the first 6 months. The intervention group (175 patients) included patients evaluated with the PEWS application in the last 6 months.

The sample size of 350 total patients (175 per group) provided sufficient power at a 95% confidence level and 5% margin of error, based on Taro Yamane's formula.

Inclusion criteria:

1. Pediatric patients aged 1 month to 15 years admitted for at least 24 hours
2. Evaluated with either paper-based PEWS or PEWS application

Exclusion criteria:

1. No recorded PEWS scores in the medical record
2. Direct admission to pediatric intensive care unit (PICU)

Tools

Intervention tools:

1. PEWS application developed by researchers, including:

- Vital sign and symptom recording
- Automatic PEWS calculation
- Automatic alerts when PEWS score ≥ 4
- Alert time and response recording
- Score trend display

2. Traditional paper-based PEWS record form

Data collection tools:

1. General data record form: Demographic, clinical, treatment history
2. PEWS assessment record form: Vital signs, PEWS scores, responses
3. Significant event record form: ICU admission, emergency resuscitation, mortality

Outcome Definitions and Data Extraction

The primary clinical outcomes were mortality, unplanned ICU admission, emergency resuscitation (CPR), unplanned intubation, unplanned shock, and the composite of total adverse events. Secondary outcomes were the interpretation accuracy of PEWS items and

response time to abnormal events. Interpretation accuracy of PEWS items was defined as the proportion of recorded assessments in which each PEWS item (respiratory effort, circulation, and behavior) was correctly interpreted according to the official PEWS scoring definitions, as determined by blinded re-evaluation of the medical record by a pediatrician not involved in care. Response time was defined as the interval from the time the nurse received the physician's order (documented time-stamp in the physician's order sheet) to the time the medication or intervention was delivered to the patient (documented time-stamp in the Medication Administration Record [MAR]). Both time points are routinely recorded in the hospital's standard medical record; therefore, response-time analysis used only data that were already part of the patient's clinical documentation.

Procedure

1. Months 1-2: PEWS application development and testing, staff orientation meetings, and IRB approval
2. Months 3-10: Retrospective data collection from medical records for both groups
3. Months 11-12: Data analysis, summarization, and report writing

Data Analysis

Descriptive statistics:

- Quantitative data: Mean, standard deviation (SD), median with interquartile range (IQR), min, max
- Qualitative data: Frequency and percentage

Inferential statistics:

1. Comparison of general data:

- Normally distributed quantitative data:

Independent t-test

- Non-normally distributed quantitative data:

Mann-Whitney U test

- Qualitative data: Chi-square/Fisher's exact test

2. Comparison of clinical outcomes:

- Chi-square/Fisher's exact test for mortality,

ICU admission, and emergency resuscitation rates

3. Analysis of response times: Independent t-test/
Mann-Whitney U test

4. Significance level: $p < 0.05$

Ethical Approval

- Approved by the Institutional Review Board (IRB) of the Kanchanaburi Provincial Public Health Office (No.20/2565)
- Data confidentiality: Coding, limited access
- Expert physician consultation throughout

Table 1. General characteristics of the study population

Characteristics	PEWS paper (n=175)	PEWS application (n=175)	p-value
Sex; n (%)			
Male	105 (60.00)	102 (58.29)	0.740 ^a
Female	70 (40.00)	73 (41.71)	
Age (months); mean±SD	68.70±55.52	73.62±57.02	0.420 ^b
Weight (kg); mean±SD	21.68±16.56	23.58±18.15	0.310 ^b
Underlying disease; n (%)			
Yes	42 (24.00)	54 (30.86)	0.150 ^a
No	133 (76.00)	121 (69.14)	
Disease severity; n (%)			
Mild	90 (51.43)	103 (58.86)	0.290 ^a
Moderate	77 (44.00)	65 (37.14)	
Severe	8 (4.57)	7 (4.00)	
Length of stay (days); mean±SD	5.83±8.05	4.32±4.52	0.030 ^{a*}

PEWS=Pediatric Early Warning Score; SD=standard deviation

(a) Chi-square test, (b) Independent t-test, * Statistically significant at $p < 0.05$

the study

RESULTS

This study included a total of 350 pediatric patients (175 per group), generating 13,020 PEWS assessments in total (5,834 recordings in the paper group and 6,223 recordings in the application group).

General Characteristics

As shown in **Table 1**, the pediatric inpatient sample groups had similar characteristics. The majority were male (PEWS paper 60%, PEWS application 58.29%), with mean ages of 68.7 months and 73.62 months, respectively. 24% in the PEWS paper group and 30.86% in the PEWS application group had underlying diseases. Disease severity levels were comparable, with most classified as mild (PEWS paper 51.43%, PEWS application 58.86%). However, the average length of stay was significantly longer in the PEWS paper group (5.83 days) compared to the PEWS application group (4.32 days) ($p = 0.030$).

Table 2 presents the number of PEWS assessments by age group and severity level. Across all ages, the PEWS application arm had a higher proportion of mild assessments and a lower proportion of severe assessments compared to PEWS paper, especially in ages ≥ 12 months.

Comparison of Clinical Outcomes

Mortality, unplanned ICU admission, and emergency resuscitation rates:

Table 3 shows that the mortality rate was lower in the PEWS application group (1.71%) than the PEWS

Table 2. Number of PEWS recordings by age group and severity level

Age group	PEWS paper (n=6,432); n (%)			PEWS application (n=6,588); n (%)		
	Mild	Moderate	Severe	Mild	Moderate	Severe
1-3 months	1,173 (99.58)	5 (0.42)	0 (0.00)	880 (96.82)	28 (3.08)	1 (0.11)
4-11 months	406 (96.67)	14 (3.33)	0 (0.00)	648 (95.29)	32 (4.71)	0 (0.00)
12-47 months	1,098 (94.16)	43 (3.69)	25 (2.14)	1,541 (91.78)	130 (7.74)	8 (0.48)
48-83 months	1,220 (88.05)	151 (10.90)	14 (1.01)	1,156 (95.62)	50 (4.14)	3 (0.25)
84-143 months	1,141 (94.76)	60 (4.98)	3 (0.25)	968 (99.59)	4 (0.41)	0 (0.00)
>143 months	796 (73.70)	204 (18.89)	79 (7.32)	1,030 (90.35)	96 (8.43)	13 (1.14)
Total	5,834 (90.70)	477 (7.42)	121 (1.88)	6,223 (94.46)	340 (5.16)	25 (0.38)

PEWS=Pediatric Early Warning Score

Table 3. Comparison of clinical outcomes between PEWS paper and PEWS application groups

Clinical outcomes	PEWS paper (n=175)	PEWS application (n=175)	p-value	Relative risk (95% CI)
Mortality rate; n (%)	4 (2.29)	3 (1.71)	0.700 ^a *	0.75 (0.17 to 3.30)
Unplanned ICU admission; n (%)	12 (6.86)	1 (0.57)	0.002 ^a *	0.08 (0.01 to 0.63)
Cardiopulmonary resuscitation (CPR); n (%)	0 (0.00)	0 (0.00)	NA	NA
Unplanned intubation; n (%)	9 (5.14)	1 (0.57)	0.010 ^a *	0.11 (0.01 to 0.87)
Unplanned shock; n (%)	4 (2.29)	2 (1.14)	0.410 ^a	0.50 (0.09 to 2.70)
Total adverse events; n (%)	19 (10.86)	4 (2.29)	0.001 ^a *	0.21 (0.07 to 0.61)
Clinical deterioration; n (%)	13 (7.43)	5 (2.86)	0.050 ^a	0.38 (0.14 to 1.05)
Accuracy of PEWS calculation; n (%)	21 (12.00)	154 (88.00)	<0.001 ^a *	7.33 (4.86 to 11.08)
Response time (minutes); mean±SD	47.64±26.42	24.36±25.72	<0.001 ^b *	NA

PEWS=Pediatric Early Warning Score; CI=confidence interval; ICU=intensive care unit; NA=not available

(a) Chi-square test or Fisher's exact test, (b) Independent t-test, * Statistically significant at p<0.05

paper group (2.29%), but this was not statistically significant (p=0.700). The unplanned ICU admission rate was significantly lower in the PEWS application group (0.57%) compared to the PEWS paper group (6.86%) (p=0.002, RR 0.08, 95% CI 0.01 to 0.63). No emergency resuscitation occurred in either group. The overall adverse event rate was significantly lower in the PEWS application group (2.29%) versus PEWS paper (10.86%) (p=0.001, RR 0.21, 95% CI 0.07 to 0.61).

Interpretation accuracy of PEWS items:

The PEWS application group had a substantially higher rate of correct interpretation of PEWS items (88.00%) compared to the PEWS paper group (12.00%) (p<0.001, RR 7.33, 95% CI 4.86 to 11.08) (Table 3).

Speed and Efficiency in Detecting Critical Conditions

The maximum PEWS score per patient did not differ significantly between groups (paper: median 3 [IQR 2-4], application: median 3 [IQR 2-4], p=0.200). However, the distribution of scores across all 13,020 assessments was significantly lower in the application group (median 2 [IQR 1-3] vs. median 2 [IQR 1-3], p<0.001 by Mann-Whitney U test). The proportion of

mild-severity recordings was higher in the application group (94.46% vs. 90.70%), while severe recordings were fewer (0.38% vs. 1.88%, p<0.001) (Table 4).

Response Time to Abnormal Events

The median response time (from receipt of the physician's order to medication administration as recorded in the MAR) was significantly shorter in the PEWS application group (24.36 minutes) compared to the PEWS paper group (47.64 minutes) (p<0.001) (Table 3, 5). The number of assessments per patient was significantly lower in the PEWS application group (29.90) than the PEWS paper group (49.89) (p<0.001).

DISCUSSION

Clinical Effectiveness

The use of the PEWS application resulted in significant reductions in total adverse events, unplanned ICU admissions, and emergency intubations. This may be attributed to improved score calculation accuracy, sensitivity for detecting risk, and faster response times. The findings align with studies by Parshuram et al. and Chapman et al.^[5,13].

Table 4. PEWS scores and proportion of patients by severity level

Variables	PEWS paper	PEWS application	p-value
PEWS score level; median [IQR]			
Maximum PEWS score per patient (n=175)	3 [2-4]	3 [2-4]	0.200 ^a
All recorded PEWS scores (n=13,020)	2 [1-3]	2 [1-3]	<0.001 ^{a*}
Severity level; n (%)			
Disease severity in patients (n=175)			
• Mild	90 (51.43)	103 (58.86)	0.290 ^b
• Moderate	77 (44.00)	65 (37.14)	
• Severe	8 (4.57)	7 (4.00)	
PEWS severity level in all recordings (n=13,020)			
• Mild	5,834 (90.70)	6,223 (94.46)	<0.001 ^{b*}
• Moderate	477 (7.42)	340 (5.16)	
• Severe	121 (1.88)	25 (0.38)	

PEWS=Pediatric Early Warning Score; IQR=interquartile range

(a) Mann-Whitney U test, (b) Chi-square test, * Statistically significant at p<0.05

Table 5. Frequency of PEWS assessment per patient and response time

Variables	PEWS paper	PEWS application	p-value
Number of PEWS assessments per patient; mean±SD	49.89±68.23	29.90±30.45	<0.001 ^{a*}
Response time (minutes); mean±SD	47.64±26.42	24.36±25.72	<0.001 ^{a*}

PEWS=Pediatric Early Warning Score; SD=standard deviation

(a) Mann-Whitney U test, * Statistically significant at p<0.05

Interpretation Accuracy

Interpretation accuracy of the PEWS items was 7.33 times higher in the application group than in the paper group (88.00% vs. 12.00%, p<0.001), reflecting a reduction in manual calculation errors. This is consistent with Lockwood et al.'s finding that an automated PEWS increased accuracy without decreasing predictive ability for adverse events⁽¹⁴⁾.

Speed and Efficiency in Detecting Critical Conditions

The application group had significantly shorter average response times, reduced by almost half, and greater sensitivity for detecting risk in young infants. This mirrors the findings of Pongkaew & Anantriyakul, who found a 50% reduction in average response times⁽¹²⁾.

Consistency with Previous Studies

The results align with Lambert et al.'s demonstration of the benefits of PEWS in reducing cardiac arrest and unplanned ICU admission rates, and Sefton et al.'s finding that a PEWS application was more convenient and user-friendly than paper forms^(7,10). However, literature reviews indicate that the wide variety of PEWS designs with differences in details limits the comparability of effectiveness between them⁽¹³⁾.

Therefore, the present findings cannot be generalized to the effectiveness of all PEWS designs.

LIMITATION

This study has several limitations. First, the retrospective design limited control over the completeness of source data and may have left residual, unmeasured confounding. Second, the single-center setting may limit the generalizability of the findings to other hospitals or healthcare systems with different staffing models, case-mix, or electronic-record infrastructures. Third, because the control and intervention periods were temporally separated (sequential 6-month blocks rather than contemporaneous cohorts), secular changes in staff experience, ward workflow, or clinical practice over time may have contributed to the observed differences—a form of temporal bias that randomization would have avoided. Finally, although the sample size (350) met the pre-specified power calculation, rare outcomes (mortality, CPR) remained too infrequent for stable effect estimates.

CONCLUSION

This study demonstrates the effectiveness of a PEWS application with automatic alerts in reducing

adverse events, improving the interpretation accuracy of PEWS items, and enabling faster response by medical teams. However, further studies with larger and more diverse patient samples are needed to confirm effectiveness in real-world practice, especially in the Thai context. Incorporating PEWS applications into standard practice guidelines could enhance the quality and safety of pediatric inpatient care, in line with the World Health Organization (WHO)'s goals for patient safety.

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Authors Contributions

JP: Conceptualization, methodology, investigation, formal analysis, PEWS application development, and manuscript drafting. CA: Co-development of the PEWS application. Both authors reviewed and approved the final manuscript.

Clinical Trial Registration

Not applicable; this was a retrospective study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the IRB of the Kanchanaburi Provincial Public Health Office (No.20/2565). The requirement for informed consent was waived owing to the retrospective design of the study.

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Use of Artificial Intelligence

During the preparation of this manuscript, the authors used Claude Opus 4.7 (Anthropic) to improve language and readability. The authors reviewed and edited all content and take full responsibility for the

final manuscript.

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