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Optimization of parents' skills in using portable pulse oximeter for early detection hypoxemia in toddlers with ARI

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Abstract

Background: Acute respiratory infection (ARI) particularly pneumonia, remain a leading cause of morbidity and mortality among toddlers globally and nationally. Hypoxemia is a life threatening complication of ARI that requires early, objective identification. Portable pulse oximeters provide a rapid, on-invasive method for oxygen saturation (SpO₂) monitoring at home, yet parental operational skill is often inadequate.

Purpose: To explore targeted educational interventions to optimize parental proficiency in early detection of respiratory distress among toddlers with ARI.

Method: This quantitative quasi-experimental study utilized a one-group pretest-posttest design involving 40 parents of toddlers with ARI at Kampung Baru Public Health Center, Medan, in 2026, selected via total sampling. Practical skills were measured using an 11 item observation checklist before and after interactive demonstration training. Data were analyzed using univariate statistics and the bivariate non-parametric Wilcoxon signed ranks test.

Results: Prior to intervention, 95.0%(n=38) of participants exhibited poor skills (mean score). The Wilcoxon test $Z = -3.177$ and $p < 0.05$.

Conclusion: The demonstration method significantly optimizes parents' skills in operating portable pulse oximeters for early hypoxemia detection in toddlers with ARI.

Keywords: ARI; Early Detection; Hypoxemia; Parent Skills; Portable Pulse Oximeter; Toddlers.

INTRODUCTION

Acute Respiratory Infections (ARI) remain among the most prevalent infectious diseases worldwide, encompassing a wide range of respiratory tract conditions caused by diverse microorganisms. Transmission typically occurs via droplets expelled during coughing or sneezing, as well as through contact with contaminated surfaces. Once inside the host, pathogens invade respiratory epithelial cells and trigger inflammatory responses (Pakadang et al., 2025). ARI is highly contagious and can manifest from mild illness to severe, life-threatening disease, consistently ranking as a leading cause of morbidity and mortality globally, particularly in developing countries.

Efforts to mitigate health risks in toddlers extend beyond physical monitoring and increasingly incorporate digital technologies to accelerate reporting and emergency management (Munthe et al., 2025; Kashyap & Marwaha, 2026). Parental competence in child health monitoring can be strengthened through education and demonstrations of medical device usage. Direct interventions have been shown to enhance parents' practical skills in applying health technologies for independent monitoring (Pangaribuan et al., 2024; Sinaga et al., 2023; Arini et al., 2025). Supporting evidence from Anonyma and Rahmawati (2023) demonstrated that structured oxygen saturation training significantly

improved psychomotor skills, enabling independent operation of oximeters. Such findings highlight the importance of stepwise demonstrations to achieve proficiency in portable pulse oximeter use among parents of toddlers with ARI (Anonyma & Rahmayanti, 2023).

Grounded in Lawrence Green's behavior theory, competence in health practices is shaped by predisposing factors such as age, education, and occupation (Notoatmodjo, 2007). The World Health Organization underscores the need to standardize parental education on portable pulse oximeter use for early detection of pediatric emergencies, while addressing technical challenges such as signal stability and sensor accuracy across diverse skin tones (World Health Organization, 2025).

Portable pulse oximeters provide rapid, non-invasive monitoring of oxygen saturation and pulse rate, facilitating early recognition of respiratory distress and hypoxemia in toddlers with ARI (Samosir et al., 2025; Sari et al., 2026; Lazzerini et al., 2015; Shah et al., 2017). Their advantages include painless measurement using red and infrared light sensors, making them safe and practical for routine use (Nemomssa & Raj, 2022). Independent monitoring by parents is particularly vital in regions such as North Sumatra, where early detection of respiratory distress can reduce child mortality rates (Sari et al., 2025).

Hypoxemia, defined as reduced arterial oxygen levels, often arises from respiratory disorders such as ventilation-perfusion mismatch, diffusion impairment, or airway obstruction, and is frequently associated with severe ARI, including pneumonia in toddlers (Fitriani et al., 2023; World Health Organization, 2024). Recognizing danger signs—such as tachypnea, chest indrawing, decreased consciousness, or inability to drink and breastfeed—is critical for timely medical intervention. Prompt management at this stage is essential to prevent progression to life-threatening pneumonia (Amiruddin et al., 2022).

While existing studies emphasize the effectiveness of health education and training in improving parental competence with portable pulse oximeters, limited evidence addresses the integration of structured, stepwise demonstrations tailored to

parental characteristics and contextual challenges in community settings. This gap underscores the need for research exploring targeted educational interventions to optimize parental proficiency in early detection of respiratory distress among toddlers with ARI.

RESEARCH METHOD

A quantitative quasi-experimental design with a One-Group Pretest-Posttest was employed. The study was conducted in the working area of Kampung Baru Public Health Center, Medan Maimun District, Medan City, North Sumatra Province, Indonesia, in 2026. The target population comprised parents caring for toddlers (aged 12–59 months) presenting with ARI at the health center. Utilizing a total sampling approach based on historical clinical registry data, 40 eligible parents were enrolled. Inclusion criteria encompassed parents who were literate, communicative, and willing to complete all education and evaluation phases. Exclusion criteria included severe emergency cases requiring immediate resuscitation and parents who were professional healthcare workers. The research procedure began with a baseline assessment (pre-test) evaluating baseline skills before receiving the intervention. The intervention consisted of structured health education on ARI and hypoxemia signs, followed by a step-by-step interactive demonstration covering 11 technical clinical steps. These steps included device preparation, checking and cleaning nail polish or dirt, proper probe placement on the toddler's finger, monitoring signal wave stability, reading percentage and pulse rate, and proper device storage. Following the intervention, a post-intervention assessment (post-test) was conducted using the same 11-item observation checklist (scored 0–11).

Univariate analysis generated frequency distributions, percentages, and mean skill scores. Data normality was tested using the Shapiro-Wilk test ($p = 0.000$, indicating non-normal distribution). Consequently, bivariate hypothesis testing was performed using the non-parametric Wilcoxon Signed Ranks Test at a significance level of $\alpha = 0.05$.

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RESEARCH RESULTS

Table 1. Demographic Characteristics of Participants (N=40)

Variables	Results
Age (Mean±SD)(Year)	(30.63±7.53)
<20	2/5.0
20-35	21/52.5
>35	17/42.5
Education Level (n/%)	
Elementary/Junior High School	15/37.5
Senior High School	21/52.5
College/University	4/10.0
Occupation (n/%)	
Housewife/Unemployed	37/92.5
Employed	3/7.5

Table 1 indicates that the participants' mean age was 30.63 years (SD ± 7.53). More than half were within the productive age range of 20–35 years (n = 21, 52.5%). The majority had completed secondary education (Senior High School, n = 21, 52.5%), and most were housewives or unemployed (n = 37, 92.5%).

Table 2. Parents Skills in Using Portable Pulse Oximeter Before and After Demonstration Intervention (N=40)

Skill Indicator	Intervention	
	Before (Pre-test)	After (Post-test)
Skill Category (n/%)		
Poor/Suboptimal	38/95.0	11/27.5
Good	2/5.0	29/72.5
Skill Score Statistics		
Mean ± SD	3.43±2.086	8.15±2.675
Minimum-Maximum Range	1-11	2-11

Table 2 indicates that parental skill performance was categorized into "Poor" (score < 8) and "Good" (score > 8) based on the 11-item observation checklist. At the pre-test baseline prior to the demonstration, 38 participants (95.0%) exhibited poor skills, and only 2 participants (5.0%) possessed good skills. The baseline mean skill score was exceptionally low at 3.43 ± 2.086 out of a maximum score of 11.

Following the demonstration-based educational intervention, a substantial increase in parental skill was observed during the post-test evaluation. Participants achieving a good skill level increased dramatically to 29 (72.5%), while those remaining in the poor category decreased to 11 (27.5%). The mean skill score improved by +4.72 points, reaching.

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Table 3. Bivariate Statistical Analysis

Measurement Group	N	Mean Rank	Sum of Ranks	Z-Value	p-value
Post-test-Pre-test				-3.177	0.001
Negative Ranks	4	2.50	10.00		
Positive Ranks	33	21.53	710.49		
Ties	3				

Bivariate statistical testing using the Wilcoxon Signed Ranks Test revealed that 33 participants experienced an increase in their skill score (positive ranks, mean rank = 21.53). Four participants showed a decrease in scores (negative ranks), and 3 participants showed no change (ties). The test statistic yielded $Z = -3.177$ with a two-tailed p-value of $p = 0.001$. Because $p = 0.001 < 0.05$, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted, confirming a statistically significant positive effect of the demonstration method on parental skill optimization.

DISCUSSION

The high proportion of parents displaying poor skills at baseline (95.0%) reflects a common barrier in adopting personal health monitoring technologies. Although pulse oximeters are now commercially accessible, they remain underutilized in households due to a lack of direct, practical guidance delivered to primary caregivers. Demographic findings indicate that prime reproductive age (20–35 years: 52.5%) and secondary education (52.5%) serve as vital predisposing factors facilitating health information processing. According to Lawrence Green's PRECEDE framework, productive age and adequate formal education foster cognitive flexibility and psychomotor coordination required to master new technical procedures. Furthermore, the fact that 92.5% of participants were housewives provides dedicated caregiving time at home to routinely monitor childhood health status. The success of the demonstration method lies in its multi-sensory approach. By combining visual observation, step-by-step modeling, and immediate supervised return-demonstration, it effectively builds motor memory. Consequently, complex clinical steps—such as ensuring clean fingernails, positioning the probe accurately, waiting 5–20 seconds for signal

stabilization, and interpreting SpO₂ values are effectively transformed into intuitive home competencies. Empowering parents with home SpO₂ monitoring creates a vital early warning system, preventing delayed medical referrals during acute respiratory distress.

The relatively large improvement in the present study may also be explained by the intervention's emphasis on demonstration and return-demonstration. Unlike information-only approaches, the intervention allowed parents to observe each technical step, practice it under supervision, and receive immediate correction. This is particularly relevant because the baseline score of 3.43 out of 11 indicates that most parents initially lacked mastery of several procedural components. The increase to 8.15 suggests that the intervention was able to translate information about hypoxemia and pulse oximetry into observable performance. Nevertheless, the presence of four negative ranks and three ties indicates that improvement was not universal, suggesting that individual differences in prior experience, confidence, education, attention during training, or ability to perform the procedure may influence the magnitude of benefit.

The proportion of participants reaching the desired competency level also compares meaningfully with other community-based education and technology interventions. Pangaribuan et al. (2024) reported that 72 of 75 mothers (96%) were able to use the SCATION application after an empowerment and technology-based intervention. Although the 96% figure is higher than the 72.5% good-skill rate observed in the present study, the outcomes are not directly equivalent because SCATION measured ability to use an application, whereas this study required parents to perform an 11-step clinical procedure involving device preparation, probe placement, signal stabilization,

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and interpretation of SpO₂. Similarly, Sinaga et al. (2023) emphasized empowerment of cadres and families to improve knowledge and motivation for toddler growth monitoring, supporting the broader pattern that hands-on, family-oriented education can strengthen caregivers' capacity to participate in child-health monitoring. Taken together, these studies suggest that practical training and technology-supported education can produce meaningful gains in caregiver capability, while the size of the observed change depends on the complexity and operational demands of the targeted skill.

The magnitude of change is broadly consistent with previous evidence that structured training can improve competence related to oxygen-saturation monitoring. Anonyma and Rahmayanti (2023), using a one-group pretest-posttest design with 40 respondents, reported a significant improvement in knowledge following training on 5M and oxygen-saturation measurement ($t = 10.20$, $p = 0.001$). When the reported t statistic is converted to a standardized paired-sample effect estimate ($d_z = t/\sqrt{n}$), the magnitude is approximately 1.61, which is numerically larger than the present study's Wilcoxon r of approximately 0.50. Direct comparison should nevertheless be made cautiously because the outcomes differ: Anonyma and Rahmayanti assessed COVID-19-related knowledge, whereas the present study assessed observed psychomotor skill in operating a pulse oximeter. The present findings therefore extend the previous evidence by demonstrating a substantial change in actual performance rather than knowledge alone.

The magnitude of improvement observed in this study suggests that the demonstration intervention produced a practically meaningful change in parental skill, not merely a statistically significant difference. The mean skill score increased by 4.72 points, from 3.43 (SD 2.086) before the intervention to 8.15 (SD 2.675) after the intervention, while 33 of 40 parents (82.5%) demonstrated an increase in their individual score. Based on the Wilcoxon statistic, the effect size can be estimated as $r = |Z|/\sqrt{N} = 3.177/\sqrt{40} \approx 0.50$, indicating a moderate-to-large magnitude of change. This interpretation strengthens the finding because the intervention moved participants from a predominantly poor-skill baseline (95.0%) to 72.5% classified as having good skills. However, because

the study used a one-group pretest-posttest design without a control group, the estimated effect should be interpreted as the magnitude of within-participant change rather than as a definitive causal effect of the demonstration alone.

LIMITATIONS

This study has several limitations that should be considered when interpreting the magnitude of the findings. First, the one-group pretest-posttest design did not include a control or comparison group; therefore, improvements cannot be attributed exclusively to the demonstration intervention because testing effects, repeated exposure to the checklist, or other external influences may have contributed to the change. Second, the sample was relatively small (40 parents) and was recruited through total sampling from a single public health center, which limits generalizability to parents in other communities and health-service settings. Third, the post-test was conducted after the intervention, so the study primarily demonstrates short-term skill acquisition and does not establish whether parents retain the skill over time or apply it accurately during actual episodes of respiratory illness at home. Finally, although the 11-item observation checklist captures important operational steps, the manuscript does not report its validity and reliability statistics; future studies should use validated instruments, larger samples, a control group where feasible, and follow-up assessments to determine the durability and real-world effectiveness of parental pulse-oximeter training.

CONCLUSION

Parental demographics at Kampung Baru Health Center are predominantly within the productive age group (20–35 years: 52.5%), high school educated (52.5%), and housewives (92.5%). The demonstration method significantly elevated parent skill performance from a baseline average score of 3.43 (95.0% poor) to a post-test average score of 8.15 (72.5% good). Statistical analysis (Wilcoxon Test $Z = -3.177$, $p = 0.001$) confirms that the demonstration method significantly optimizes parents' practical skills in using portable pulse oximeters for early hypoxemia detection in toddlers with ARI.

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