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Effect of a Mobile Dose Application on Medication Dose Accuracy and Time among NICU Nurses: A Quasi-Experimental Study

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ABSTRACT

Background: Pediatric patients are at greater risk of harm from medication errors than adults. Medication dose calculation is one of the primary and most critical responsibilities of nurses in the Neonatal Intensive Care Unit (NICU). **Objectives**: To assess the effectiveness of the MedCal application in improving medication dose-calculation accuracy and reducing medication calculation time among NICU nurses. **Methods:** A quasi-experimental design was conducted with control and intervention groups, with the latter using the MedCal application. The study was conducted at Al-Zahraa Teaching Hospital from December 2025 to March 2026. A non-probability convenience sample of 60 nurses was recruited. Dose-calculation accuracy and calculation time were assessed. Data were analyzed using IBM SPSS version 26.0. **Results:** The intervention group demonstrated a significant improvement in dose-calculation accuracy, increasing from 20% to 77.93% after using the MedCal application. The mean calculation time decreased to 138.29 ± 17.21 seconds, with 86.7% of nurses classified as efficient. In contrast, the control group showed no significant change in calculation time (188.60 ± 23.31 vs. 187.36 ± 22.88 seconds), with 50% of nurses classified as inefficient. **Conclusion:** The MedCal application significantly improved dose-calculation accuracy and reduced medication calculation time among NICU nurses. Future studies should evaluate the integration of the MedCal application with hospital medication protocols to further improve the quality and safety of medication administration, particularly for neonatal and pediatric patients.

Keywords: Dose Calculation Time; Medication Dose Accuracy; Mobile Application; Neonatal Intensive Care Unit (NICU)

INTRODUCTION

Pediatric patients are at increased risk of medication errors and associated harm because drug dosages are often determined based on body weight or body surface area, making the dose-calculation and administration processes more complex (Al-Shehri *et al*., 2026; Alghamdi *et al*., 2019). Pediatric patients should not be regarded as smaller versions of adults because their bodies undergo significant developmental changes that affect drug absorption, distribution, metabolism, and excretion (Zughaibi *et al*., 2024; D'Errico *et al*., 2022). Consequently, pediatric patients are more vulnerable to medication-related adverse effects and errors than adults, particularly when adult-formulated medications are used (Norouzi *et al*., 2025).

Medication errors have been associated with inadequate medication knowledge and insufficient skills in medication administration, particularly dose calculation, which is one of the primary responsibilities of nurses (Collado-González *et al*., 2024). Accurate preparation and administration of medications in pediatric patients are complex and time-consuming processes due to their specific physiological and clinical needs.

Nurses constitute the largest component of the healthcare workforce and play a central role in preventing and identifying adverse events (Afaya *et al*., 2021; Cicero *et al*., 2020). However, inadequate dose-calculation

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skills can make nurses vulnerable to difficulties in applying mathematical concepts. Previous studies have reported unsatisfactory medication-calculation performance among registered nurses, with an average accuracy of approximately 60%, while nearly half failed a basic numerical competency examination (Mulac *et al*., 2022; Pérez-Jover *et al*., 2019). Self-efficacy is also an important individual factor that can influence nurses' confidence and performance in completing clinical tasks (Chen *et al*., 2001).

Systematic reviews have indicated that mobile applications can reduce medication administration errors and increase nurses' adoption of digital tools. There is also a need for innovative approaches to reduce medication errors and dose-calculation time in pediatric and neonatal settings (Norouzi *et al*., 2023; Tabi *et al*., 2019). Applications incorporating artificial intelligence can provide step-by-step support for medication dose calculations under different clinical conditions. Therefore, this study aims to address this gap by assessing the effectiveness of the MedCal application in improving medication dose-calculation accuracy and reducing calculation time among nurses in the neonatal intensive care unit.

Aim of the Study

The main aim of this study is to assess the effectiveness of the MedCal app on the accuracy of medication dose and the time of calculation of dosage.

METHODOLOGY

Research Design

This study employed a quasi-experimental, non-randomized, two-group (study and control) pretest-posttest design with three repeated post-tests (Capili & Anastasi, 2024). The design was used to examine the effect of the MedCal mobile application on dose accuracy and calculation time among NICU nurses. It was selected to assess the relationship between the independent variable (the MedCal mobile application) and the dependent variables (dose-calculation accuracy and calculation time) (Maciejewski, 2020).

Setting

The study conducted in Al Kut City at the Wasit government's Al Zahraa Teaching Hospital was selected as a setting for this study because it is a public educational hospital that has NICU departments.

Sample

A non-probability convenience sampling technique was used due to feasibility constraints and to ensure the availability of eligible participants (Memon *et al*., 2025; Zrineh *et al*., 2026). The target sample size was 100 participants, calculated based on a population proportion of 50%, a 95% confidence level, and a 5% margin of error. However, during the data-collection period in the NICU, 60 nurses who met the inclusion criteria and agreed to participate were included in the study. This achieved sample represented 60% of the originally calculated target and reflects a common constraint in single-site clinical research, where eligibility is limited by unit size, shift rotations, and staff turnover (Memon *et al*., 2025; Zrineh *et al*., 2026). Despite this reduction, the achieved sample was adequate to detect the intervention effect, as reflected in the very large effect sizes obtained for calculation time (Kendall's W = 1.000 and 0.997; Table 2); the smaller-than-planned sample is, nonetheless, acknowledged as a limitation for generalizability in the limitations section. Participants were selected according to standardized inclusion criteria and a consistent recruitment procedure, as follows:

Inclusion Criteria

The sample included nurses working in pediatric critical care units who were responsible for medication administration, had less than three years of experience in pediatric patient care units, and had not previously participated in training courses on medication calculation.

Exclusion Criteria

The exclusion criteria included nurses with more than three years of experience in medication

administration in pediatric critical care units and those who had previously used a medication dose-calculation application during medication administration.

Study Instruments

Accuracy Rate

Medication dose-calculation accuracy was assessed by comparing the calculated dose with the standard reference dose (Baumann *et al*., 2019). The result was classified as correct when the calculated dose matched the reference dose and incorrect when it did not. The accuracy rate was calculated before and after using the MedCal application for both groups using the following formula:

$$\text{Accuracy Rate (\%)} = (\text{Number of Correct Calculations} / \text{Total Number of Calculations}) \times 100$$

Dose Calculation Time

A stopwatch was used to measure the time required for dose calculation and medication preparation during administration (Lopetegui *et al*., 2014; Norouzi *et al*., 2025). Timing started when the nurse began the calculation process and ended when the dose preparation was completed. The researcher recorded the time in seconds, while a co-observer independently monitored the process to improve measurement reliability and reduce observer bias.

Data Collection and Intervention

Medication calculation accuracy and calculation time were assessed among 60 participants divided into control and intervention groups. The study was conducted from December 15, 2025, to March 15, 2026. Participants were provided with a quiet environment and trained to use the MedCal application, which was developed in Arabic and English in collaboration with an information technology programmer to support pediatric medication dose calculation during preparation (Soeno *et al*., 2024).

Calculation time was measured using a stopwatch and verified by a co-observer. Each participant completed pretests and three posttests for two pediatric patients to assess changes in calculation accuracy and time. The intervention group used the MedCal application to calculate medication doses, and the results were compared with the prescribed medication orders to assess dose-calculation accuracy. The intervention lasted approximately 12 weeks, with two sessions per week, each lasting about 5 minutes. The study procedure is illustrated in Figure 2.

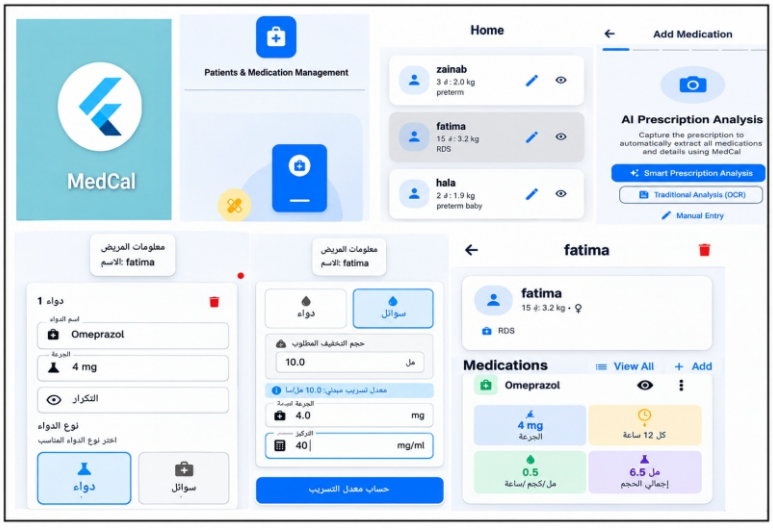


Figure 1: The Medication Calculation Process of the MedCal App

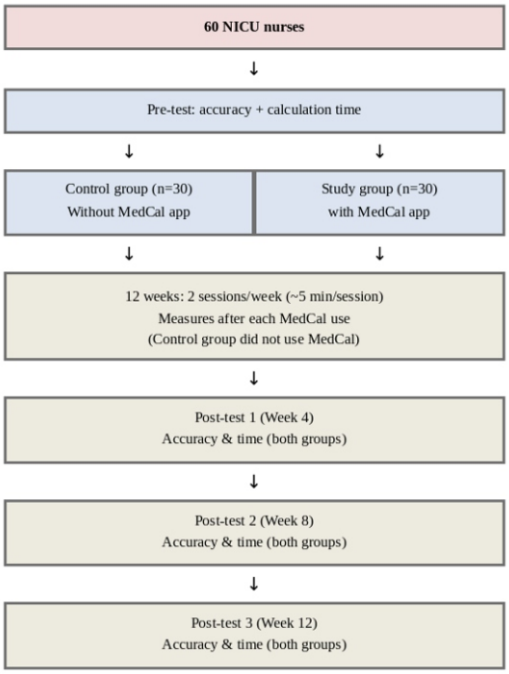


Figure 2: Intervention Process

Standardization of Intervention

Each intervention session followed a standardized protocol to ensure consistency among participants. The researcher provided a mobile phone with the MedCal application installed for participants to use. Before using the application, participants received training and instructions on its functions, and the researcher answered any questions related to its use. A physician was involved as a supervisor to oversee the intervention and support the appropriate use of the application.

Safety Measures and Monitoring

The researcher was involved in all the sessions with the physician of the department to assess the application use and to ensure the safety of use and prevent any potential harm, error.

Data Analysis

Descriptive statistics tests, such as frequency, percentage, mean, and standard deviation, were used to describe the nurses' sociodemographic characteristics, medication calculation accuracy, time consumption. Determine the normal distribution of the sample by The Kolmogorov–Smirnov test was used assess the normality distribution. The Friedman test was used to evaluate the effect of the MedCal app on time consumption. The data analyzed and interpreted through use (SPSS), version 26.0.

Ethical Consideration

The research obtained ethical clearance from the Ethical Research Committee at the College of Nursing, University of Baghdad, Iraq with reference number 39 on 25th November 2025, and from the Iraqi Ministry of Planning, Statistics and Geographic Information Systems, Center for Promotion and Publication with reference number 191/8/1/3/1 on 27th November 2025. The research also obtained ethical clearance from the Iraqi Ministry of Health/Wasit Health Directorate to conduct data collection at Al-Zahraa Teaching Hospital, Wasit City with reference number 4139 on 9th December 2025).

Written informed consent was obtained from all participants after they were informed about the study purpose, objectives, and potential benefits of the mobile application. Participants were informed that there was no financial compensation for participation and that all personal information would be kept confidential and used solely for research purposes.

RESULTS

Table 1: Description of Socio-demographic Characteristics of Nurses in the Study and Control Groups

Socio-demographic Data		Study Groups					
		Intervention		Control		Total	
		F	%	F	%	F	%
Sex	Male	11	36.7	9	30	20	33.35
	Female	19	63.3	21	70	40	66.7
Age	Mean± SD	25.8 ± 1.6		26.5 ± 2.8		26.1 ± 2.3	
Level of Education	Secondary School	11	36.7	9	30	20	33.3
	Diploma	13	43.3	15	50	28	46.7
	Bachelor	6	20	6	30	12	20.0
Total		**30 (100%)**		**30 (100%)**		**60 (100%)**	

The result in Table 1 presents the description of sociodemographic variables for nurses who participated in the study (study group, n=30 and control group, n=30); the findings reveal that the percentage of female nurses (66.7%) is relatively higher than the percentage of male nurses (33.35%) in the study sample. The average age for nurses Mean is 26.1 ± 2.3 in the study sample. The level of nurses' education to secondary school is 33.3%, diploma is 46.7%, and bachelor's is 20% in the study sample.

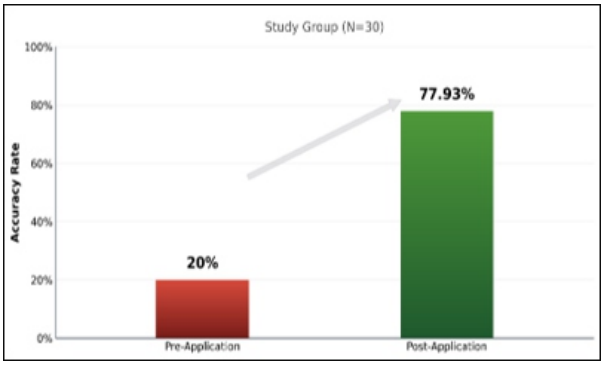


Figure 3: Accuracy Rates before and after MedCal App (Study Group, N=30)

Figure 3 shows the accuracy rate of medication calculation pre- and post-MedCal app; the findings indicate that at the baseline, the study group revealed an accuracy rate of 20%, while after application of the MedCal, the accuracy rate increased to 77.93%, indicating a marked improvement in dose calculation accuracy following use of the MedCal application.

The accuracy rate was reported as a descriptive measure rather than subjected to inferential statistical testing. This decision was grounded in the nature of the accuracy metric, which was computed using the following formula.

Accuracy Rate = (Number of Correct Responses / Total Number of Responses) × 100

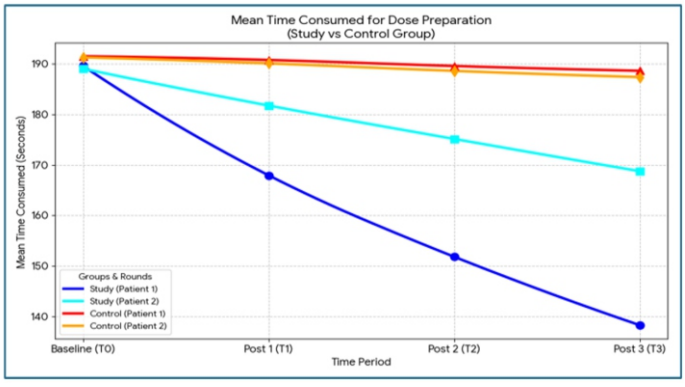


Figure 4: Time Consumed Per Second for Dose Preparation after MedCal App in Study and Control Groups

Figure 4 illustrates clear difference in time duration in app group for medication preparation time, while no obvious difference in control group.

Table 2: Significant Differences in Time Consumed for Dose Preparation and Calculation by Nurses before and after MedCal App for Study and Control Groups

Time Consumed (per second)			Descriptive Statistics				Friedman Test				
Groups	**Time (T)**		**M**	**SD**	**Min**	**Max**	**Mean Rank**	χ^2	***df***	***p*-value**	**Effect size***
Study (n=30)	**Patient (1)**	T0	189.5767	23.33440	132.20	243.60	4.00	90.000	3	**0.000**	**1.000**
		T1	167.9300	20.66143	120.00	219.70	3.00				
		T2	151.8200	18.46914	108.40	199.70	2.00				
		T3	138.2967	17.21682	96.70	186.10	1.00				
	Patient (2)	T0	189.0133	20.71241	156.70	219.90	4.00	89.709	3	**0.000**	**0.997**
		T1	181.7300	21.55745	148.30	216.40	2.98				
		T2	175.1233	21.50983	144.80	212.60	2.02				
		T3	168.7467	21.67337	134.60	205.60	1.00				
Control (n=30)	**Patient (1)**	T0	191.4867	22.58221	152.90	222.90	2.97	5.497	3	0.177	0.172
		T1	190.7400	23.22231	148.20	225.20	2.83				
		T2	189.5567	23.37266	148.00	226.10	2.42				
		T3	188.6033	23.31999	143.80	221.80	1.78				
	Patient (2)	T0	191.2633	22.99938	151.10	221.50	3.40	3.795	3	0.072	0.376
		T1	190.0700	22.66926	152.80	223.40	2.85				
		T2	188.5800	23.14656	149.80	224.10	2.15				
		T3	187.3633	22.99476	151.50	222.20	1.60				

*M: Mean of total score, SD: Standard deviation, Min: Minimum, max: maximum, χ^2: Chi-square, df: Degree of Freedom, P: probability, *Kendall's W*

Table 2 shows significant differences in the time required for dose calculation and preparation before and after using the MedCal application. In the study group, a statistically significant reduction in time was observed across all measurements (T0–T3) in both rounds (p = 0.000), with Chi-square values of 90.000 and 89.709, respectively. The mean time decreased from 189.5767 to 168.7467 seconds, while the mean rank decreased from 4.00 to 1.00, with large effect sizes (1.000 and 0.977), indicating the effectiveness of the MedCal application in improving nurses' efficiency in dose calculation and preparation. In contrast, the control group showed no statistically significant change in time consumption for dose calculation and preparation (p = 0.177 and 0.072), with small effect sizes (0.172 and 0.376).

DISCUSSION

Nurses play a crucial role in medication safety, as the medication-use process, including prescribing, preparation, dose calculation, administration, and monitoring, is complex and prone to errors, particularly in pediatric care (Afaya *et al*., 2021; Kellett *et al*., 2024). In the current study, most nurses in both groups held a diploma (46.7%), while bachelor's degree holders represented the lowest proportion (20.0%). Educational level may influence nurses' medication-related knowledge and dose-calculation skills. This is supported by Al-Nbabteh *et al*. (2024), who reported that 95% of nurses had not received adequate mathematical education during their nursing programs. Similarly, Kerari and Innab (2021) identified educational level as an important factor associated with medication administration errors. Other studies have emphasized the importance of nurses' knowledge in preventing medication errors and maintaining medication safety (Di Muzio *et al*., 2017; Hameed & Shawq, 2025). However, Rai and Devi (2019) reported that nurses' medication knowledge was not significantly influenced by demographic characteristics such as educational level. Mobile applications can support nurses by providing evidence-based information and improving clinical decision-making and performance (Alipour *et al*., 2025; Nezamdoust *et al*., 2022).

Females represented the majority of participants (66.7%), while males accounted for 33.3%. This finding is consistent with the predominance of females reported in the Iraqi nursing and midwifery workforce (World Health Organization, 2017). The nurses' mean age was 26.1 ± 2.3 years. Although age may not significantly affect medication administration skills, previous evidence suggests that limited work experience may increase the risk of medication administration errors (Mohammed *et al*., 2022).

A major finding of the current study was the improvement in medication dose-calculation accuracy

following use of the MedCal application. Accuracy increased from 20% before the intervention to 77.93% after its use, indicating that calculation errors were an important contributor to incorrect dosing. This finding suggests that mobile applications may hold potential value for supporting medication safety in pediatric and neonatal settings, although the present study did not directly measure medication-error rates or patient-safety outcomes. Baumann *et al*. (2019) reported that a mobile application was a feasible tool for reducing intravenous medication calculation and handling errors among anesthesiologists caring for adult and pediatric patients. Prior literature suggests that improving dose-calculation accuracy may contribute to medication safety and reduce preventable dosing-related harm (Al-Shehri *et al*., 2026; Norouzi *et al*., 2025), although this relationship was not directly examined in the current study.

Accurate pediatric dose calculation remains challenging because pediatric medications frequently require weight-based calculations, dilution, and manipulation of available formulations. Inaccurate calculations may increase the risk of medication errors and adverse effects (van der Zanden *et al*., 2020a). Cicero *et al*. (2020) reported that incorrect dosing accounted for a substantial proportion of potential adverse drug events among hospitalized children. Accordingly, mobile applications incorporating dose-calculation and dilution functions may help improve the quality and safety of medication administration (van der Zanden *et al*., 2020b). Previous studies have also demonstrated that mobile health applications can positively influence nurses' cognitive and behavioral performance related to medication safety (Apidi *et al*., 2017; Mazaheri *et al*., 2017), highlighting the potential role of technology in addressing medication-related challenges among pediatric nurses (Norouzi *et al*., 2023).

Regarding calculation and preparation time, the current study found that a considerable proportion of nurses initially demonstrated inefficient time consumption, with 50% and 53.3% in the study group classified as having inefficient time consumption. Following the intervention, the study group showed a statistically significant reduction in dose-calculation and preparation time in both rounds (p = 0.000). In contrast, no significant difference was observed in the control group (p = 0.177 and 0.072). These findings indicate that the MedCal application improved not only calculation accuracy but also the efficiency of the medication preparation process.

The findings are consistent with previous research demonstrating the benefits of mobile and clinical decision-support applications in pediatric medication administration. Siebert *et al*. (2017) found that the PedAMINES application reduced medication preparation and delivery time as well as medication errors during simulated pediatric cardiopulmonary resuscitation. Similarly, Matava *et al*. (2024) reported that pediatric dose calculations took longer without a clinical decision-support application than with the PediPain application. Higi *et al*. (2023) also found that clinical decision-support systems reduced the time required for dose preparation and calculation by approximately 45%. These findings support the current study's conclusion that the MedCal application can improve medication administration efficiency by reducing dose-calculation time, particularly in pediatric settings.

Overall, the current study demonstrates that the MedCal application can improve both medication dose-calculation accuracy and the time required for dose calculation and preparation. As dose-calculation accuracy and calculation time were the outcomes directly measured in this study, these findings indicate improved calculation performance among NICU nurses using the MedCal application. This study did not directly measure medication-error rates or patient-safety outcomes, and such measures should be evaluated in future research before broader claims about medication safety are made.

Limitations

The study has a several limitations due to the difficulty and complexities of medication preparation in different dosages, especially in the NICU. For example, the quasi-experimental and convenience samples decrease generalizability. In addition, the study conducted in the NICU one central hospital. The study duration is three months and considered relatively short; long-term effects are needed and, it needs to be apply in different hospitals with different departments. It's possible that the absence of blinding created bias in the evaluation of the results.

Future Scope

Future studies should evaluate the effectiveness of the MedCal application in larger and more diverse samples of pediatric nurses and across different healthcare settings. Further research could also examine its long-term effects on dose-calculation accuracy, medication administration time, and medication errors. Comparative studies with other digital clinical decision-support tools are recommended to determine the most effective approaches for improving medication safety in pediatric care.

CONCLUSION

Unsafe medication practices are a major source of preventable harm, particularly in NICUs, where complex dose calculations, frequent drug dilution, and narrow therapeutic ranges increase the risk of medication errors. In this study, the MedCal application significantly improved medication dose-calculation accuracy and shortened dose-calculation and preparation time among NICU nurses. As medication-error rates and patient-safety outcomes were not directly measured, these findings should be interpreted as evidence of improved calculation performance rather than a demonstrated reduction in actual medication errors or improved patient-safety outcomes. Future research should evaluate MedCal in larger, multicenter settings, assess its long-term effects on dose-calculation performance, and conduct randomized controlled trials that directly measure medication-error rates and patient-safety outcomes to confirm its clinical effectiveness.

CRediT Authorship Contribution Statement

E.A.K.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing Original Draft, Writing Review, Editing, Project Administration, **A.H.S.:** Conceptualization, Formal Analysis, and Supervision.

AI Assistance Declaration

During the preparation of this manuscript, the authors used AI only to assist with language editing and improving the clarity of the manuscript. The authors reviewed and edited the content and take full responsibility for the final version of the manuscript.

Conflict of Interest

The author declares having no conflict of interest.

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