Review Article

# Clinical Simulation in Nursing Students' Safe Medication Administration: A Systematic Review



## Abstract

**Background:** Nursing students' safe medication administration is a crucial aspect of ensuring patient safety. Clinical simulation is a novel teaching method applied to reduce factors threatening medication safety in the education of nursing students. Therefore, the aim of the present study was to conduct a review study in this field. **Materials and Methods:** The present review was conducted using keywords of education, clinical competence, medication safety, medication error, nursing student, clinical simulation, and educational strategies. Suitable articles published between 2000 and 2023 were systematically searched in various national and international online databases, including SID, Magiran, Ovid, Scopus, Web of Science, PubMed, ProQuest, and Google Scholar in both English and Persian languages. **Results:** A total of 855 articles were retrieved from the initial search findings. After eliminating duplicate and irrelevant articles based on predetermined criteria, a qualitative selection was conducted using CONSORT, MMAT, and JBI critical appraisal checklists. Ultimately, a selection of 11 articles was made, specifically focusing on medication safety education for nursing students through clinical simulation. The findings showed that using clinical simulation improved medication safety and safety knowledge among nursing students. Additionally, this approach was found to enhance their competence in medication administration. **Conclusions:** Based on the findings, clinical simulation is a safe and effective approach for enhancing nursing students' proficiency in medication safety and administration. Therefore, it is recommended that nursing education authorities implement these findings to improve nursing students' knowledge, performance, and competency in safely administering medications.

**Keywords:** *Administration, education, medication errors, nursing, safety, simulation training, students*

**Amir Shahzeydi[1], Mansour Dianati[2], Faramarz Kalhor[3,4]**

*[1]Pediatric Cardiovascular Research Center, Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Trauma Nursing Research Center, Faculty of Nursing, Kashan University of Medical Sciences, Kashan, Iran, [3]PhD Student in Nursing, Trauma Nursing Research Center, Faculty of Nursing and Midwifery, Kashan University of Medical Science, Kashan, Iran, [4]Nursing and Midwifery Care Research Center, Faculty of Nursing and Midwifery, Isfahan University of Medical Sciences, Isfahan, Iran*

***Address for correspondence:***
*Mr. Faramarz Kalhor, PhD Student in Nursing, Trauma Nursing Research Center, Faculty of Nursing and Midwifery, Kashan University of Medical Science, Kashan, Iran; Nursing and Midwifery Care Research Center, Faculty of Nursing and Midwifery, Isfahan University of Medical Sciences, Isfahan, Iran.*
*E-mail: faramarz@nm.mui.ac.ir*

## Introduction

Clinical simulation has gained attention as an educational method in recent decades[1] and has become a popular tool for education.[2] Simulation is the process of recreating or representing a real object, subject, or situation. This technique, which accurately reflects reality, has the advantage of being harmless to participants.[3] Reality simulations in nursing are clinical environments that aim to showcase procedures, decision making, and critical thinking skills. These simulations employ techniques such as role-playing and the use of interactive videos or mannequins.[4] Simulation-based learning offers a realistic and interactive learning environment that enhances real-time judgment practice, communication, and psychomotor skills. It has the potential to enhance understanding of the material and enhance task performance.[5] Simulation-based learning has been shown to improve students' learning efficiency and is now integrated into regular nursing curricula.[6] Nursing students who engage in simulations experience enhanced knowledge, self-confidence, satisfaction, and readiness to engage in critical thinking. Additionally, individuals can also improve their problem-solving abilities, communication skills, cooperation, leadership, and delegation skills.[7] According to a study by Yuan *et al*.,[8] the simulation method has been shown to enhance clinical and psychomotor skills, increase knowledge, decrease the time needed to achieve competence, and promote safe practice among students. In the field of nursing science, safe medication administration is an area where these characteristics are particularly important.[9]



**How to cite this article:** Shahzeydi A, Dianati M, Kalhor F. Clinical simulation in nursing students' safe medication administration: A systematic review. Iran J Nurs Midwifery Res 2024;29:522-9.

**Submitted:** 20-Oct-2023. **Revised:** 22-May-2024. **Accepted:** 16-Jun-2024. **Published:** 04-Sep-2024.

**Access this article online**

**Website:** https://journals.lww.com/jnmr

**DOI:** 10.4103/ijnmr.ijnmr_323_23

**Quick Response Code:**

Safe administration of medication is a critical component in the prevention of medical errors and the promotion of patient safety.[10] The significance of error-free medication and medication safety has been emphasized by the World Health Organization since March 2017, as indicated by their prioritization of this issue.[11] Medication errors are considered fundamental breaches of medication safety[12] and are defined as "preventable incidents that have the potential to inflict harm to the patient or result in inappropriate medication use".[13] In various healthcare settings, studies have indicated that the incidence of medication errors ranges from 19% to 70%.[14] In the United States, the mortality rates for various causes of death are as follows: AIDS claims the lives of 15,000 individuals annually, breast cancer accounts for 4,200 deaths, and accidents result in 43,000 fatalities. However, it is alarming to note that medical errors contribute to a significantly higher annual death toll of 98,000, with medication errors alone responsible for 7,000 of these fatalities.[15] In underdeveloped and developing countries, acquiring precise statistics on medication errors is typically challenging. However, it is evident that the incidence of medication errors in these countries is also significant.[16] Medication errors in healthcare facilities have been found to impose a substantial financial burden on patients, with costs ranging from $32.59 to $136.40. Additionally, these errors have been found to significantly impact the length of hospital stays, resulting in an increase in hospitalization ranging from 4.6 to 10.3 days per patient.[17] These errors have a detrimental effect on patients, their families, healthcare professionals, and the overall quality of healthcare.[18] In various studies, it has been observed that medication errors can have detrimental consequences. However, a significant number of these errors have been identified as preventable.[15] Medication errors are widely recognized as one of the most prevalent errors committed by nursing students.[19,20] Despite the explicit prohibition on students independently administering medication during their internship, a study conducted by Simonsen *et al*.[21] revealed a notable occurrence of medication errors. Specifically, between 26% and 40% of all procedures were performed by these students. Among the contributing factors to medication errors in students, several key factors can be identified, including anxiety, low self-confidence, inadequate clinical skills, insufficient proficiency in group work, and a lack of knowledge.[20,22] In a comprehensive study examining over 1,300 instances of student medication errors in the United States, it was found that 51% of these errors were linked to performance deficiencies, while 27% were attributed to a lack of knowledge.[23]

Given the extensive nature of studying medications and their intricacies, there is a mounting apprehension that the undergraduate nursing curriculum may not sufficiently equip students for this crucial task.[22] They fail to assume accountability for drug administration[20] in a manner consistent with the conclusions drawn by Jarvill *et al*.,[24] who found that nursing students lack the essential skills to administer medications upon completion of their studies. Therefore, the necessity for novel educational approaches is apparent in this particular domain.[25] Regarding the impact of the clinical simulation method on nursing students' medication management, it is worth noting that while some nursing researchers have reported positive results,[26] there remains a dearth of comprehensive research examining its effects on enhancing safety, knowledge, and pharmaceutical performance.[27] Therefore, given the considerable importance of nursing students' medication performance in ensuring patient safety, the existing shortcomings in their proficiency in this area, the substantial positive influence of clinical simulation in improving the quality of their education, the lack of a comprehensive article that provides comprehensive information on this method, and the crucial role that review articles play in offering reliable educational evidence, we undertook a review study to investigate the impact of clinical simulation in nursing students' safe medication administration.

## Materials and Methods

The current narrative review was conducted using the keywords "education," "clinical competence," "medication safety," "medication error," "nursing student," "clinical simulation," and "educational strategies" in both Persian and English languages. Eligible articles published between 2000 and 2023 were systematically searched in various national and international databases, including the SID and Magiran national databases, as well as the Ovid, Scopus, Web of Science, MEDLINE, CINAHL, EMBASE, ProQuest, and Google Scholar international databases. Following the initial article selection conducted by the first reviewer, subsequent verification was conducted by the final reviewer. Duplicate studies were excluded. Two reviewers participated in the review process. The titles, abstracts, and full text of the articles were screened in a manner that guaranteed independent evaluation.

Experimental or semiexperimental articles, written in English or Persian and matched with the objective of the study, were included, while articles whose full text was not available, systematic review studies, and meta-analyses were excluded. The first search stage using the mentioned keywords and the appropriate search strategy led to 855 articles of which 220 were excluded due to overlapping databases, simultaneous indexing of articles in several databases, and duplicate titles. The remaining 635 articles underwent abstract screening, resulting in the exclusion of 593 articles based on the inclusion criteria. From the remaining 42 articles, 28 were removed due to lack of access to the full text and ambiguous results. Additionally, three articles were excluded based on qualitative evaluation using CONSORT 2010 Statement,[28] the Mixed Methods Appraisal Tool (MMAT),[29] and JBI Critical Appraisal

Checklist for Quasi-Experimental Studies.[30] This resulted in a total of 11 articles for the final review and extraction of relevant data, which is in line with the research objectives [Diagram 1].

### Ethical considerations

The researchers took care to avoid any form of plagiarism while writing the manuscript. The analysis of the results was conducted with complete honesty and integrity. They ensured that there was no data fabrication and that the data were not manipulated for personal benefit.

## Results

Eleven studies, all published in English, were included in the final review [Table 1]. Some studies were conducted on second-year[2,31] and third-year nursing[20] students, one was carried out on master's and bachelor's students together,[32] and an interdisciplinary study focused on nursing, pharmacy, and medical students,[33] while some did not mention the students' educational level. All studies were conducted on both genders, and most of them employed a two-group semiexperimental method with only two studies using a single-group design[32,33] and another one using a mixed method.[31]

Different measurement tools were used, including the Medication Safety Critical Element Checklist (MSCEC) and the standard questionnaire of medication safety knowledge,[10,20] the standard checklist of medication administration safety[26] Medication Administration Safety Assessment Tool (MASAT),[31] the Medication Administration Procedure (MAP) questionnaire,[2] the Teamwork Attitudes Questionnaire (TTAQ),[33] and researcher-made checklists.

### Clinical simulation in nursing students' safe medication administration and knowledge

A study conducted using a 4-week intervention in the form of three scenarios indicated significantly higher medication

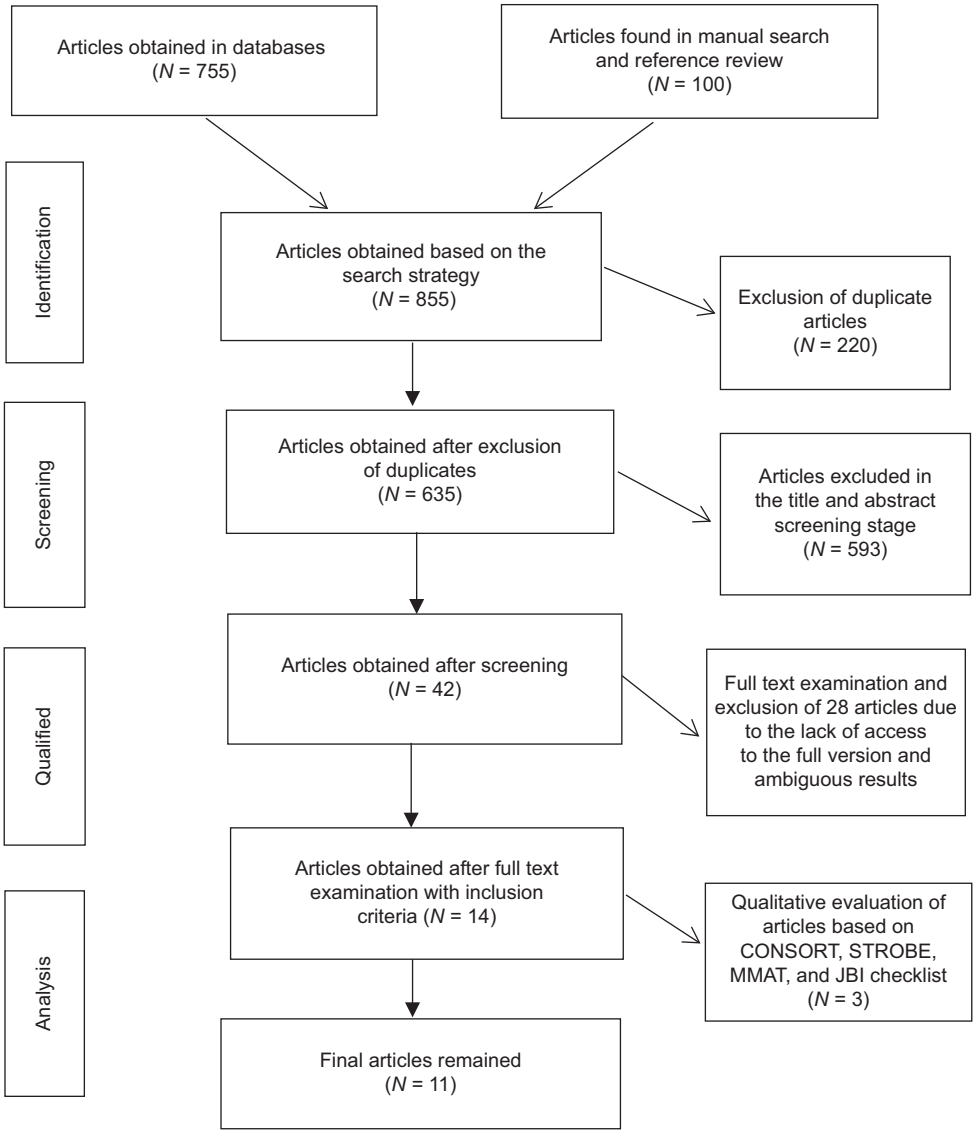


**Diagram 1: PRISMA diagram of the inclusion and exclusion of the reviewed articles**

**Table 1: Characteristics of the reviewed articles**

| Research Type | Author(s) | Title | Sample Size | Year | Results |
|---|---|---|---|---|---|
| A two-group experimental design | Kinney & Henderson | Comparison of Low Fidelity Simulation Learning Strategy with Traditional Lecture | 42 | 2008 | Clinical simulation increased the pharmaceutical knowledge score of the students, but this increase was not significant compared to the control group. |
| A two-group semiexperimental design | Sanko & McKay | Impact of Simulation-Enhanced Pharmacology Education in Prelicensure Nursing Education | 120 | 2017 | Clinical simulation increases the competence and ability of nursing students in correct medication administration. |
| Pilot study | Molloy | Reinforcing medication administration through student- directed simulation | 8 | 2017 | Simulation is an effective strategy to improve students' medication learning and competence |
| A two-group experimental design | Mariani *et al*. | Medication Safety Simulation to Assess Student Knowledge and Competence | 86 | 2017 | The difference in the scores of medication safety and medication safety knowledge increased significantly in the intervention group in which the clinical simulation method was implemented compared to the control group. However, the patient's safety score did not change significantly in the three areas. |
| Semiexperimental design | Dubovi *et al*. | Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation | 129 | 2017 | The results showed significantly higher conceptual and procedural knowledge learning gains with the Pharmacology Inter-Leaved Learning Virtual Reality (PILL-VR) simulation compared to studying via lecture-based curriculum. |
| A two-group experimental design | Jarvill *et al*. | Effect of simulation on nursing students' medication administration competence. | 85 | 2018 | The simulation improved nursing student medication administration competence. Nurse educators should consider simulation a useful strategy in preparing nurses for safe medication administration practices. |
| Semiexperimental design | Motycka *et al*. | Using inter-professional medication management simulations to impact student attitudes toward teamwork to prevent medication errors | 48 | 2018 | Collaborative work in a team while exposed to some medication management scenarios enhances teamwork attitudes and potentially improves performance. Based on the positive initial results, plans have begun to extend the experience to other campuses and include a wider group of students. |
| A two-group semiexperimental design | Kuo *et al*. | Comparison of the effects of simulation training and problem-based scenarios on the improvement of graduating nursing students to speak up about medication errors: A quasi-experimental study | 93 | 2020 | Simulation training showed more-significant improvements than problem-based scenarios. Nursing schools and hospitals should incorporate simulation training or at least problem-based scenarios to improve medication safety. |
| A two-group semiexperimental design | Craig *et al*. | Simulation strategies to increase nursing student clinical competence in safe medication administration practices: A quasi- experimental study | 83 | 2021 | Findings show that educators should consider high fidelity simulation as an evidence-based teaching strategy to engage students in understanding and implementing medication safety practices in the clinical setting. |

*Contd...*

**Table 1: Contd...**

| Research Type | Author(s) | Title | Sample Size | Year | Results |
|---|---|---|---|---|---|
| mixed-methods design (quantitative and qualitative methodologies) | Pol-Castañeda *et al*. | Use of simulation to improve nursing students' medication administration competence: a mixed-method study | 179 | 2022 | Simulation is a useful tool for drug administration in students, it fills the gap between theory and practice and increases patient safety. |
| A two-group quasi-experimental design | Saastamoinen *et al*. | Impact of 3D Simulation Game as a Method to Learn Medication Administration Process: Intervention Research for Nursing Students | 123 | 2022 | The 3D simulation game is suitable for learning the medication administration and can be used as a valid method to evaluate the knowledge of medication administration among nursing students. |



safety scores in the intervention group receiving simulation compared to the control group. However, the changes in the medication safety knowledge score were not significant despite its increase in both groups.[20] Another study used 3D glasses to create a simulated environment in which the students imagined themselves in real-world conditions and decided what to do next. As shown by the results, the students' medication knowledge increased more than those who received the training in the form of a simple lecture.[2] In the same vein, Jarvill *et al*.[26] designed a scenario based on oral medication, indicating a significant increase in the medication safety of students in the simulation compared to the control group. Similarly, according to a study that implemented a simulation method for the intervention group and examined their self-reported medication safety competence until graduation, there were significant differences in the scores of the control and intervention groups.[34] A study conducted by Mariani *et al*.[10] used the medication scenario related to a middle-aged man with internal bleeding and expected the students to administer medication to him over a 20-minute period. The intervention group showed significantly higher scores of medication safety and medication safety knowledge compared to the control group, although the changes in the patient's safety score were not statistically significant. A study, comprising a nursing, a pharmacy, and a medical student in each group, showed a significant increase in collaborative safe medication administration attitudes after exposure to the simulation program.[33] A study conducted to compare the simulation method with a scenario based on medication errors revealed higher effectiveness of the former, although both methods were effective.[35] In the study of Pol-Castaneda *et al*.,[31] who used three scenarios to apply simulation for safe medication administration, this method improved all aspects of the six rights except documentation. Likewise, based on the study of Saastamoinen *et al*.,[36] the use of simulation in the form of a game also leads to an increase in safe medication skills. However, in the study of Kinney *et al*.,[37] clinical simulation did not significantly increase the medication knowledge score of the intervention compared to the control group.

## Discussion

The findings of the present study demonstrate that the educational method of simulation is effective in improving students' medication safety. Engaging students in clinical practice through standard scenarios in simulated laboratories with a realistic clinical environment enhances their skills without the stress of causing harm.

A review study examining the effect of clinical simulation on nursing education found several challenges for its implementation, including time-consuming scenario design, fear of technology, increased workload, limited time for student learning and planning, a large number of students, insufficient supervision, and lack of a suitable curriculum. However, it was emphasized that most of these challenges could be addressed, making this method suitable to deal with many problems.[38] According to a meta-analysis by Shin *et al*.[27] investigating the effect of clinical simulation on nursing education, this method can improve learning and psychomotor skills more effectively than traditional methods. Similarly, Eyikara and Baykara[39] found that simulation provides a safe learning environment in nursing education, enhances knowledge, and helps train skilled nursing professionals. However, a systematic review by Adib-Hajbaghery *et al*.[40] found that clinical simulation did not impact the critical thinking of nursing students in eight studies.

Most research reviewed in the present study indicates that clinical simulation leads to an increase in medication safety among students during medication administration and enhances their knowledge of medication safety. However, some studies did not confirm the effectiveness of clinical simulation in improving patient safety based on medication safety.[10] In the same vein, Kinney *et al*.[37] implemented the lecture method for the control and intervention groups, while clinical simulation was only provided for the intervention group. Although the score of medication knowledge increased immediately postintervention compared to preintervention with clinical simulation, no significant differences were found between the scores of the two groups after a 4-month follow-up. This result could be attributed to short-term positive learning effects of

low-fidelity simulation, necessitating replication and further research on maximizing the use of such strategies.

The research conducted in this field also had some weaknesses. For example, two studies were carried out without a control group,[32,33] while more coherent and decisive results are obtained using a control group. Similarly, a study in which master's students supervised undergraduate students used a very small sample size (n = 8), which was divided into two groups (n = 4),[32] adversely affecting the validity of the results. In the study by Pol-Castañeda *et al*.,[31] which was a mixed method study with a qualitative and quantitative approach and is considered unique in this sense, each student in each group administered medication. Craig *et al*.[20] selected a control and intervention group to investigate clinical simulation during 4 weeks with 3 scenarios. Both control and invention groups received clinical simulation in the first week, while the second week was allocated to clinical simulation for the intervention and clinical environment for the control. Both groups were exposed to the clinical environment in the third and clinical simulation in the fourth week. Therefore, the control group also received the training related to this method in the first and fourth week, which could be a confounding factor because the control group also received clinical simulation training. Jarvill *et al*.[26] divided students of the same semester into two control and intervention groups, providing the intervention group with simulation-based training to administer medication to an 81-year-old patient. The control group did not receive any simulation-based training based on the simulation method and was only provided with traditional medication administration practices in a classroom-like environment. Using a pretest–posttest design, the results indicated the effectiveness of the clinical simulation method on nursing students' medication administration competence.

In research conducted by Sanko *et al*.[34] and Dubovi *et al*.,[2] the control and intervention groups were not from the same semester, which may have slightly affected the results.

In another study, the designed scenarios primarily focused on the patient nursing process instead of medication issues. For example, students had to focus on femoral joint bleeding and take bleeding control measures, including coordination with other medical staff, which could adversely affect their focus on medication administration.[10]

Research conducted by Motycka *et al*.[33] is one of the few studies investigating the effect of collective clinical simulation on the medication administration competence of nursing, medical, and pharmacy students in each group. The scenarios designed by the researchers deviated slightly from the application of teamwork, although it was the primary objective of this study. For example, the students only had to stop the medication in one of the scenarios because the patient had an anaphylactic shock caused by the injection of penicillin. In other scenarios, the students had to deal with children aged four and eighteen months.

Kuo *et al*.[35] compared the effects of simulation training and problem-based scenarios on medication errors of graduating nursing students using control and intervention groups. The intervention group received both a problem-based scenario and medication administration simulation training, while the control group received problem-based scenarios alone. Scenario training based on medication errors could affect the results of both groups.

Although the above studies reached positive results, the interventions were implemented in laboratory settings instead of the actual clinical environment. However, as emphasized by Lee *et al*.,[41] laboratory simulation experiences never replace real-world clinical experiences. Similarly, Hutton *et al*. (2010) compared the computer and clinical simulation methods and found that the latter could more effectively assess skills and knowledge.[42] However, this review study showed that the simulation teaching method is highly effective in enhancing the medication safety of nursing students.

Among the limitations of the present study is its focus only on English and Persian articles, excluding articles published in other languages. Additionally, articles without full text available or not in electronic format were excluded from the research. Despite these limitations, the findings suggest that simulation as a teaching method is highly effective in enhancing medication safety among nursing students.

In light of our findings, simulation is a method whereby the characteristics of real-world situations are depicted by providing feedback, minimizing distractions, and conducting controlled exercises in clinical laboratories. It is a widely used and recognized method in nursing education that can be employed to train students, novice nurses, and experienced practitioners in various scenarios. The present review study demonstrates the positive impact of this model on improving medication safety for students. Considering the significant advantages of simulation training, the researchers of this study suggest that its impact on other aspects of nursing, such as the nursing process, should also be evaluated.

## Conclusion

The results indicate that the clinical simulation method enhanced medication safety and safety knowledge among nursing students, while also improving their competence in medication administration within simulated clinical environments. Therefore, it is advisable for educational administrators at universities to prioritize clinical simulation as a key component of their planning before students transition to real clinical settings. By doing so, they can effectively bolster patient safety through the enhancement of students' medication safety skills.

## Acknowledgments

The authors extend their gratitude to all the researchers whose articles and findings contributed to this review study.

## Financial support and sponsorship

Nil.

## Conflicts of interest

Nothing to declare.



## References

1. Brazil V, Purdy E, Bajaj K. Simulation as an Improvement Technique. Elements of Improving Quality and Safety in Healthcare. Cambridge University Press; 2023.
2. Dubovi I, Levy ST, Dagan E. Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. Comput Educ 2017;113:16-27.
3. Koukourikos K, Tsaloglidou A, Kourkouta L, Papathanasiou IV, Iliadis C, Fratzana A, *et al*. Simulation in Clinical Nursing Education. Acta informatica medica : AIM: journal of the Society for Medical Informatics of Bosnia & Herzegovina : casopis Drustva za medicinsku informatiku BiH. 2021;29:15-20.
4. Lee J, Son HK. Effects of simulation problem-based learning based on Peplau's interpersonal relationship model for cesarean section maternity nursing on communication skills, communication attitudes and team efficacy. Nurse Educ Today 2022;113:105373.
5. Ford DG, Seybert AL, Smithburger PL, Kobulinsky LR, Samosky JT, Kane-Gill SL. Impact of simulation-based learning on medication error rates in critically ill patients. Intensive Care Med 2010;36:1526-31.
6. Bliss M, Aitken LM. Does simulation enhance nurses' ability to assess deteriorating patients? Nurse Educ Pract 2018;28:20-6.
7. Sapiano AB, Sammut R, Trapani J. The effectiveness of virtual simulation in improving student nurses' knowledge and performance during patient deterioration: A pre and post test design. Nurse Educ Today 2018;62:128-33.
8. Yuan HB, Williams BA, Fang JB, Ye QH. A systematic review of selected evidence on improving knowledge and skills through high-fidelity simulation. Nurse Educ Today 2012;32:294-8.
9. Fernandez R, tenHam-Baloyi W, Mathew E, Secginli S, Bahar Z, Jans C, *et al*. Predicting behavioural intentions towards medication safety among student and new graduate nurses across four countries. J Clin Nurs 2023;32:789-98.
10. Mariani B, Ross JG, Paparella S, Allen LR. Medication safety simulation to assess student knowledge and competence. Clin Simul Nurs 2017;13:210-6.
11. Panagioti M, Hodkinson A, Planner C, Dhingra N, Gupta N. Global Burden of Preventable Medication-related Harm in Health Care: A Systematic Review. World Health Organization; 2024.
12. Raghavendran M, Bhattarcharjee T, Revathi R. A descriptive study to assess the knowledge level regarding prevention of medication error among students in selected nursing college, Kanpur. Int J Pharm Investig 2021;11:324-6.
13. Isaacs AN, Ch'ng K, Delhiwale N, Taylor K, Kent B, Raymond A. Hospital medication errors: A cross-sectional study. Int J Qual Health Care 2021;33:mzaa136.
14. Cheraghi MA, Nikbakhat Nasabadi AR, Mohammad Nejad E, Salari A, Ehsani Kouhi Kheyli SR. Medication errors among nurses in intensive care units (ICU). J Mazandaran Univ Med Sci 2011;20:115-9.
15. Ebrahimpour F, Shahrokhi A, Ghodousi A. Patients' safety and nurses' medication administration errors. Iran J Forensic Med 2014;20:401-8.
16. Zarea K, Mohammadi A, Beiranvand S, Hassani F, Baraz S. Iranian nurses' medication errors: A survey of the types, the causes, and the related factors. Int J Afr Nurs Sci 2018;8:112-6.
17. Abdulmutalib I, Safwat A. Nursing strategies for reducing medication errors. Egyptian J Nurs Health Sci 2020;1:77-98.
18. Choo J, Hutchinson A, Bucknall T. Nurses' role in medication safety. J Nurs Manag 2010;18:853-61.
19. Chan R, Booth R, Strudwick G, Sinclair B. Nursing students' perceived self-efficacy and the generation of medication errors with the use of an electronic medication administration record (eMAR) in clinical simulation. Int J Nurs Educ Scholarsh 2019;16:20190014.
20. Craig SJ, Kastello JC, Cieslowski BJ, Rovnyak V. Simulation strategies to increase nursing student clinical competence in safe medication administration practices: A quasi-experimental study. Nurse Educ Today 2021;96:104605.
21. Simonsen BO, Daehlin GK, Johansson I, Farup PG. Differences in medication knowledge and risk of errors between graduating nursing students and working registered nurses: Comparative study. BMC Health Serv Res 2014;14:580.
22. Hewitt J, Tower M, Latimer S. An education intervention to improve nursing students' understanding of medication safety. Nurse Educ Prac 2015;15:17-21.
23. Wolf ZR, Hicks R, Serembus JF. Characteristics of medication errors made by students during the administration phase: A descriptive study. J Prof Nurs 2006;22:39-51.
24. Jarvill M. Nursing student medication administration performance: A longitudinal assessment. Nurse Educ 2021;46:59-62.
25. Zohar E. Quantum simulation of lattice gauge theories in more than one space dimension—requirements, challenges and methods. Philos Trans A Math Phys Eng Sci 2022;380:20210069.
26. Jarvill M, Jenkins S, Akman O, Astroth KS, Pohl C, Jacobs PJ. Effect of simulation on nursing students' medication administration competence. Clin Simul Nurs 2018;14:3-7.
27. Shin S, Park J-H, Kim J-H. Effectiveness of patient simulation in nursing education: Meta-analysis. Nurse Educ Today 2015;35:176-82.
28. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. J Pharmacol Pharmacother 2010;1:100-7.
29. Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, *et al*. The mixed methods appraisal tool (MMAT) version 2018 for information professionals and researchers. Educ Inform 2018;34:285-91.
30. Barker TH, Habibi N, Aromataris E, Stone JC, Leonardi-Bee J, Sears K, *et al*. The revised JBI critical appraisal tool for the assessment of risk of bias for quasi-experimental studies. JBI Evidence Synthesis 2024;22:378-88.
31. Pol-Castañeda S, Carrero-Planells A, Moreno-Mulet C. Use of simulation to improve nursing students' medication administration competence: A mixed-method study. BMC Nurs 2022;21:117.
32. Molloy J. Reinforcing medication administration through student-directed simulation. Teach Learn Nurs 2017;12:307-8.
33. Motycka C, Egelund EF, Gannon J, Genuardi F, Gautam S, Stittsworth S, *et al*. Using interprofessional medication management simulations to impact student attitudes toward teamwork to prevent medication errors. Curr Pharm Teach Learn

2018;10:982-9.

34. Sanko JS, Mckay M. Impact of simulation-enhanced pharmacology education in prelicensure nursing education. Nurse Educ 2017;42:S32-7.
35. Kuo S-Y, Wu J-C, Chen H-W, Chen C-J, Hu SH. Comparison of the effects of simulation training and problem-based scenarios on the improvement of graduating nursing students to speak up about medication errors: A quasi-experimental study. Nurse Educa Today 2020;87:104359.
36. Saastamoinen T, Härkänen M, Vehviläinen-Julkunen K, Näslindh-Ylispangar A. Impact of 3D simulation game as a method to learn medication administration process: Intervention research for nursing students. Clin Simul Nurs 2022;66:25-43.
37. Kinney S, Henderson D. Comparison of low fidelity simulation learning strategy with traditional lecture. Clin Simul Nurs 2008;4:e15-8.
38. Rad M, Fallahi Khoshknab M, Arsalani N, et al. Challenges of Simulation Training in Nursing Student Education and Proposing Effective Approaches: A Systematic Review Study. ijsr. 2022;2:53-63.
39. Eyikara E, Baykara ZG. The importance of simulation in nursing education. World J Educ Technol Curr Issues 2017;9:2-7.
40. Adib-Hajbaghery M, Sharifi N. Effect of simulation training on the development of nurses and nursing students' critical thinking: A systematic literature review. Nurse Educ Today 2017;50:17-24.
41. Lee B-O, Liang H-F, Chu T-P, Hung C-C. Effects of simulation-based learning on nursing student competences and clinical performance. Nurse Educ Pract 2019;41:102646.
42. Hutton M, Coben D, Hall C, et al. Numeracy for nursing, report of a pilot study to compare outcomes of two practical simulation toolsAn online medication dosage assessment and practical assessment in the style of objective structured clinical examination. Nurse Education Today. 2010;30:608-614.