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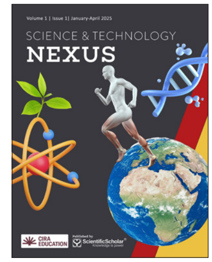

Original Article

High-Fidelity versus Low-Fidelity Simulation Training on Medication-Related Emergencies for Pharmacy Students

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ABSTRACT

Objective: Medication-related problems can cause serious adverse drug events, which may contribute to hospital admissions. In response, the role of pharmacists in managing these high-risk situations requires training in medication therapy consultation and emergency response. To adapt the pharmacy curriculum for clinical emergency practice, we developed an immersive simulation-based training course focused on medication-related emergencies and Advanced Cardiac Life Support (ACLS) to evaluate and train pharmacy students' consultation and emergency response skills.

Material and Methods: This randomised pre-post educational study involved 39 pharmacy students (both sexes, aged 22–33) in their 8th semester at Heinrich Heine University in Düsseldorf, Germany. Students were recruited through an introductory seminar within a two weeks period. The study was conducted as part of the clinical pharmacy course between November and December 2024. Before and after the respective training, each student went through a simulated emergency case scenario either with High-Fidelity Simulation (HFS) or with Low-Fidelity Simulation (LFS) with paper-based cases and completed a self-assessment questionnaire and a knowledge multiple-choice exam.

Results: Pharmacy students in both the High-Fidelity Simulation (HFS) and Low-Fidelity Simulation (LFS) groups showed significant improvements in knowledge and self-assessment scores from pre- to post-training. However, there was no significant difference in post-training knowledge exam scores between the two groups. Post-training self-assessment scores in both adult and pediatric simulation scenarios were significantly higher in the HFS group compared to the LFS group.

Conclusion: These findings suggest that the HFS approach may be more effective in enhancing students' self-assessment, supporting its use in simulation emergency training.

Keywords: Advanced cardiac life support, High-fidelity simulation, Medication-related emergencies, Pharmacy education

1. INTRODUCTION

Medication-related problems are important and preventable healthcare challenges,[1] representing 5–7% of hospital admissions worldwide, with around 25% of hospitalisations linked to medication misuse or overuse,[2] and 5% in Germany specifically attributed to adverse drug effects.[3] These issues place a burden on healthcare systems and can contribute to clinical deterioration, requiring the activation of medical emergency teams.[4] Pharmacists play a vital role in emergency departments by ensuring appropriate drug selection and performing medication reviews.[4,5]

Despite their positive impact in optimising medication therapy, particularly through managing medication-related problems in Germany, their integration into hospital emergency departments has yet to be fully realised.[6] Advanced Cardiac Life Support (ACLS) is an evidence-based method for managing life-threatening cardiac emergencies and has become an important part of healthcare education.[7] Healthcare simulation methods for ACLS, such as high-fidelity simulation (HFS) and low-fidelity simulation (LFS), are incorporated into medical education programs,[8,9] that enable students to improve their knowledge and practical patient assessment skills.[10] Upon reviewing the literature, previous studies found that HFS offers more benefits than LFS in ACLS training, including enhanced satisfaction and confidence in resuscitation.[11,12] Additionally, there is a lack of RCTs evaluating the impact of high-fidelity and low-fidelity ACLS simulations on pharmacy students.[13,14] In addition to the different results in comparing the benefits of HFS versus LFS in ACLS emergencies and the lack of a standardised method for ACLS training in pharmacy education.[11,15] No studies were found on ACLS-based medication-related emergency simulations for pharmacy students at German universities, particularly those assessing the effectiveness of HFS training versus the traditional LFS method. In this study, the hypothesis is to investigate whether HFS training, using full-body simulators, will result in a greater change in pharmacy participants' pre- and post-training scores on a multiple-choice exam and self-assessment questionnaire in terms of medication-related emergencies and basic ACLS skills, compared to LFS training with paper-based cases and a basic cardiopulmonary resuscitation (CPR) simulator. The primary objective of this study is to develop a simulation-based training course for medication-related emergencies using high-fidelity patient simulators of different age groups, with the aim of training pharmacy students in emergency care scenarios for both adults and pediatrics, as well as the application of basic ACLS skills.

2. MATERIAL & METHODS

2.1. Study design

This randomised pre-post educational study was conducted with pharmacy students to investigate the impact of high-fidelity simulation training on ACLS-based medication-related emergencies using adult and pediatric simulators, compared to low-fidelity simulation training. We evaluated and compared baseline knowledge and self-assessment performance using multiple-choice exam and a self-assessment questionnaire before training with post-training results using a pre–post design [refer to Supplementary Materials, Section 1]. The study was conducted in the German language from November to December 2024 as part of the clinical pharmacy course at Heinrich Heine University in Duesseldorf, following the approval of this study by the responsible ethics committee (Nr. 2024-3041). The sample size of participants represents all fourth-year pharmacy students enrolled in the 8th semester. In Germany, the 8th semester is part of the 4th year of a five-year pharmacy program, which includes four years of academic study followed by a one-year practical training. Students must pass three state examinations (at the 4th, 8th, and 10th semesters) to become licensed pharmacists. Therefore, the participants in this study, who are in their 8th semester, are nearing the end of their academic years but are not yet eligible for licensure. The inclusion criteria required participants to be enrolled in the 8th semester, which is the final academic semester of the pharmacy program at the university, and to provide voluntary consent to participate in the study and data collection process. Exclusion criteria included students who did not provide consent to participate in the study or who withheld data protection consent. The sample size calculation was performed using the Wilcoxon-Mann-Whitney test in G*Power software[16] to estimate the number of participants required to compare the impact of HFS versus LFS on students' performance. The following parameters were applied: $\alpha = 0.05$, power = 0.8, and effect size = 0.7, resulting in a target sample size of 56 participants. However, due to the limited number of students enrolled during the semester ($n = 39$), the study included all available students who met the inclusion criteria. After completing the procedure for participation (refer to Supplementary Materials, Section 2.1), the pharmacy participants were randomly assigned using Microsoft Excel 365 (Version 2403) into high-fidelity simulation groups and low-fidelity simulation groups as shown in Figure 1. Participant characteristics for both HFS and LFS groups were collected. Detailed descriptions are provided in Supplementary Materials, Section 2.2.

2.2. Pre- and post-training simulations

In the pre- and post-training simulations, pharmacy students were required to individually simulate medication consultation and emergency response skills to evaluate any differences between HFS and LFS approaches. Four emergency cases for adult and pediatric were prepared and reviewed by faculty members. The cases were simulated using adult HAL® S1000 and pediatric S3005 Gaumard simulators [refer to Supplementary Materials, Section 2.3]. The cases covered emergencies in both adult and pediatric simulations, including opioid overdose, diuretic overdose-induced hypokalemia, Reye's syndrome, and Stevens-Johnson syndrome. The pre- and post-training simulation cases followed the same pattern, where a patient was initially admitted for consultation due to an acute illness, and the

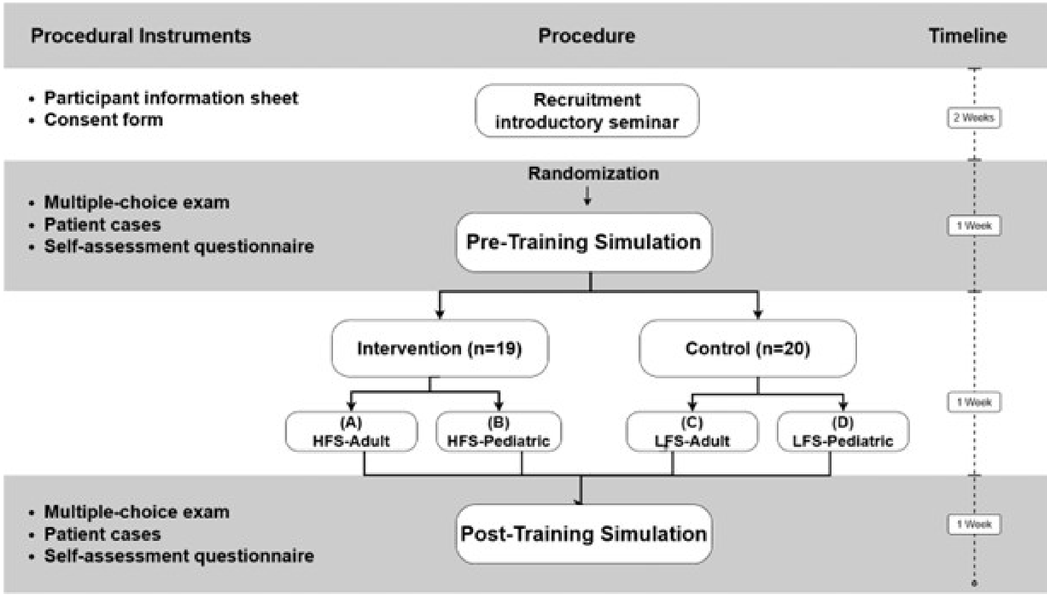

Figure 1: Flowchart of the study. HFS: High-fidelity simulation. LFS: Low-fidelity simulation.

case then escalated into a life-threatening cardiac emergency. Furthermore, all cases were prepared using a consistent checklist format that was the same in terms of structure but with content tailored to each case [refer to the simulation case checklist in the supplementary materials, Section 2.4]. Training sessions for both study groups followed pre- and post-simulation. Detailed descriptions are provided in Supplementary Materials, Section 2.5.

2.3. Statistical methods

For statistical analysis, G*Power software was used[16] and a comparison of pre- and post-training simulation was performed in the HFS as well as LFS groups using a non-parametric statistical test, i.e., a one-sided paired Wilcoxon signed-rank test, with a significance level of alpha = 0.05 in each investigation. Additionally, a one-sided Mann–Whitney test with a significance level of alpha = 0.05 was applied to measure the effect of simulation training for the respective groups. For data calculations, Microsoft Excel 365 was used and for statistical analysis Origin Pro Version 2021 was used. Notably, it has been demonstrated that there is a potential for effect overestimation when participants answer self-assessment questionnaires in pediatric simulation scenarios [refer to Supplementary Materials, Section 1], [Table 1] and [Supplementary section 3.1]. Therefore, pre- and post-training scores of both groups were analysed separately to ensure an unbiased comparison with the respective training situation.[17,18] As well as The self-assessment questionnaire results were presented as overall cumulative self-assessment scores for the HFS and LFS groups for adult and pediatric in pre- and post-training.

3. RESULTS AND DISCUSSION

3.1. Multiple-Choice Exam

3.1.1. Multiple-choice exam scores results for HFS and LFS groups – adult):

At baseline, there was no significant difference between the control (LFS) and intervention (HFS) groups (p = 0.174). After the training, both the LFS and HFS groups showed significant improvements in their exam scores (intervention group: $p < 0.001$; control group: $p = 0.002$). However, the overall exam score difference of the intervention group did not differ significantly from that of the control group (p = 0.212). The pre- and post-training simulation multiple-choice exam scores are presented in the Supplementary materials, Section 3.2 Table 5.

3.1.2. Multiple-choice exam scores for HFS and LFS – pediatric):

At baseline, no statistical difference was observed between the LFS and HFS groups ($p = 0.457$). Both groups demonstrated significant improvements in their performance after the study training (intervention group: $p = 0.001$; control group: p = 0.003). However, no significant difference was found in the overall exam score between the intervention and control groups ($p = 0.294$).

3.2. Self-assessment questionnaire

3.2.1. Intervention (HFS) and control (LFS) adult groups

At baseline pre-training simulation, no significant differences were observed between the intervention and control groups

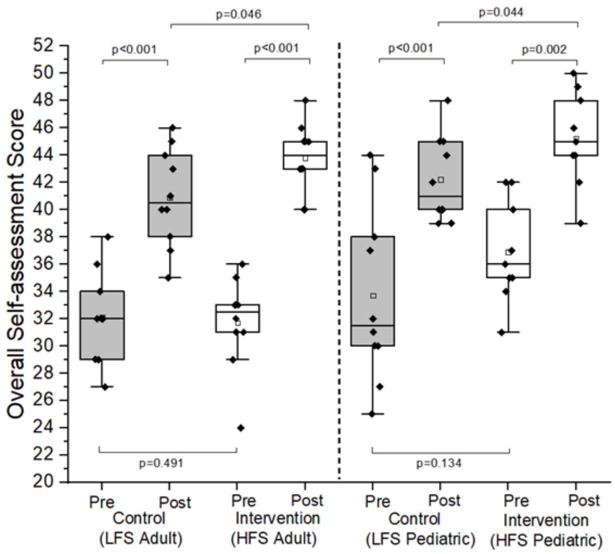

Figure 2: Box plot of overall cumulative Self-assessment scores between the intervention (HFS-adult/HFS-pediatric) and control groups (LFS-adult/LFS-pediatric). A one-sided Wilcoxon signed-rank with a significance level of alpha = 0.05 was used to compare pre- and post-simulation overall self-assessment scores of participants within each group. A one-sided Mann–Whitney test with a significance level of alpha = 0.05 was used to compare pre- and post-simulation overall self-assessment scores between participants in each group. The hollow blocks (□) represent the mean of pre and post overall self-assessment score for each group. The black diamonds (♦) indicate individual participants' overall pre- and post-self-assessment scores. HFS: High-fidelity simulation; LFS: Low-fidelity simulation. Figure 2 is related to Section 3.3. Results (3.2 Self-Assessment Questionnaire) in the main manuscript.

(p =0.491) [Figure 2], with median self-assessment scores of 32.5 in the HFS group and 32 in the LFS group. Additionally, both control and intervention groups showed significant improvement in their overall self-assessment scores after the post-training simulation (intervention group: $p < 0.001$; control group: $p < 0.001$) [Figure 2], with median post-training scores of 44 in the HFS group and 40.5 in the LFS group. Moreover, there was a significant difference (p=0.046) in the overall post self-assessment scores of the intervention compared to the control group [Figure 2].

3.2.2. Intervention (HFS) and control (LFS) pediatric groups

At baseline, there was no significant difference in self-assessment scores between the intervention and control groups (p = 0.134) [Figure 2], with median self-assessment scores of 36 in the HFS group and 31.5 in the LFS group. After the post-training simulation, both the intervention and control groups demonstrated a significant improvement in their overall self-assessment scores (intervention group: p = 0.002; control group: $p < 0.001$) [Figure 2], with median post-training scores of 45 in the HFS group and 41 in the LFS group. Additionally, there was a significant difference (p =0.044) in the overall post self-assessment scores of the intervention compared to the control group [Figure 2].

3.2.3. Overestimation proportion across HFS and LFS groups

This section presents the proportion of overestimation across the HFS and LFS groups for both adult and pediatric cases. It includes the total number of students in each group, the median self-assessment score (calculated as the median of all students' self-assessment scores, representing those who rated themselves above 3 on the self-assessment questionnaire), and the median multiple-choice exam score (calculated as the median of all students' exam scores, representing those who scored below 4 on the multiple-choice exam). Students who met both criteria — self-assessment score > 3 and multiple-choice exam score < 4 — were classified as overestimated students. The overestimation proportion was then calculated as the percentage of students in each group who overestimated their performance; a detailed definition and analysis are provided in Supplementary Materials, Section 3.1.

3.3. Discussion

In this study, HFS training for medication-related emergencies resulted in a greater increase in pharmacy students' post-self-assessment scores compared to LFS, particularly in adult and pediatric simulations. Both groups showed improvements pre- to post-training, reflecting positive perceptions of

Table 1: Overview of the overestimation proportion across HFS and LFS groups.

Group	Total participants	Median self-assessment score	Median multiple-choice exam score	Overestimated participants	Overestimation proportion (%)
HFS -Adult (Intervention)	10	4	4	2	20%
LFS- Adult (Control)	10	3,5	3	3	30%
HFS -Pediatric (Intervention)	9	3.5	3	5	55.55%
LFS -Pediatric (Control)	10	3,5	3	7	70%

HFS: High-fidelity simulation, LFS: Low-fidelity simulation

simulation-based learning. The lack of significant difference in exam scores between groups suggests that the method of simulation may influence confidence more than knowledge. These results align with studies that showed there is no significant difference in theoretical knowledge between the simulation groups.[19] Multiple-choice exam scores in HFS and LFS demonstrated a significant difference between pre- and post-trainings. Likewise, other studies demonstrated significant improvements in written examination scores related to emergency resuscitation between pre- and post-simulation training.[7] Studies such as those reported by Qin Zeng *et al*. and several RCTs have demonstrated significant improvements with HFS over LFS.[11] In the current study, pharmacy students who received LFS training showed a significant increase in overall self-assessment from pre- to post-simulation. However, their overall post-self-assessment scores did not show as much improvement as those of students who received HFS training in adult and pediatric emergency cases. The results of this study support the findings of several studies that reported improved self-assessment and confidence in healthcare students following HFS training.[13] Furthermore, participants in our study had limited exposure to medication-related emergencies during their pharmacy education. As a result, certain participants with high self-assessment scores were not fully aligned with their actual knowledge. To address this, studies suggest incorporating more practical experiences that reflect real-world clinical scenarios into the pharmacy curriculum.[18] Therefore, integrating HFS-based emergency simulation training could be beneficial, as it enables students to manage emergency care scenarios effectively compared to LFS, and reduce errors in actual patient care.[20] The potential overestimation effect observed in the HFS and LFS pediatric groups may be attributed to the students' limited practical experience in managing pediatric medication-related emergencies,[17,21] as reflected in their characteristics data [see Supplementary Materials, Section 2.2; Table 3]. This interpretation is further supported by the mismatch between participants' self-assessment scores and their actual performance on the multiple-choice exam, indicating that high self-confidence did not consistently reflect actual knowledge. In addition, the didactic nature of traditional clinical pharmacy education in Germany may contribute to this overestimation by limiting students' exposure to hands-on pediatric cases.[21] This was supported by another study that showed high self-assessment did not always align with exam performance.[18] Our study has several limitations that need to be acknowledged. Firstly, the training was conducted without the participation of other healthcare disciplines such as medicine, due to scheduling conflicts during student recruitment, which hindered our initial collaborative approach. Despite these challenges, most students' self-assessment responses showed confidence in collaborating with other healthcare disciplines. These findings provide a basis for future studies to further evaluate pharmacy students' ability to work in interprofessional emergency simulations. Lastly, the small sample size may affect the generalizability of the findings. Therefore, further studies with a larger number of participants are recommended to provide more insight into students' knowledge and performance across different age groups.

4. CONCLUSION

This study showed that HFS training improved pharmacy students' post-self-assessment scores for medication-related emergencies compared to LFS, with both methods exhibiting significant pre-to-post training improvements. However, multiple-choice exam scores showed no significant differences between the study groups, suggesting that knowledge acquisition may be comparable between the two simulation methods. These findings support the incorporation of HFS into pharmacy curricula to enhance student confidence in emergency care. Future studies should focus on longitudinal outcomes and the impact of interprofessional simulation training.

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Ethical approval: he study was approved by the Institutional Review Board of the Ethics Committee at the Medical Faculty of Heinrich Heine University Düsseldorf (Approval No. 2024-3041, dated 02 December 2024).

Declaration of patient consent: The authors certify that they have obtained all appropriate participant consent.

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