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EVALUATING THE EFFICACY OF SIMULATION-BASED TRAINING ON CLINICAL COMPETENCY TRANSFER

Iurie SARATILA, Andrei ROMANCENCO, Larisa SPINEI

Nicolae Testemitanu State University of Medicine and Pharmacy, Chisinau, Republic of Moldova

Corresponding author: Iurie Saratila, e-mail: iurie.saratila@usmf.md

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Keywords: *simulation-based education, clinical competencies, Competency-Based Medical Education, learning transfer, parenteral administration, efficacy evaluation, students' satisfaction.*

Introduction. Efficient learning transfer is crucial for training specialists to ensure the provision of quality medical services. This study investigates the impact of simulation-based training on the transfer of medical students' clinical competencies in parenteral drug administration: subcutaneous (SC), intramuscular (IM), and intravenous (IV).

Material and methods. Using a quasi-experimental design, the research incorporates pre- and post-intervention testing, observational assessments, and a satisfaction survey to evaluate the educational impact.

Results. The results indicate significant improvements in theoretical knowledge and practical skills post-intervention, with notable score increases for all types of injections (SC: from 50% to 83.33%, IM: from 57.14% to 85.71%, IV: from 42.86% to 85.71%; p<0.001). Similarly, improved clinical performance was demonstrated, highlighting the transferability of the learned competencies to real settings. Student satisfaction recorded a score of 4.71 (95% CI 4.64; 4.79), reflecting strong acceptance and appreciation of the training.

Conclusions. The study emphasizes the crucial role of simulation in competency-based medical education, bridging the gap between theoretical knowledge and practical application, and advocates for the systematic integration of simulation into the medical curriculum, suggesting future research directions for optimizing the design and implementation of simulations.

Cuvinte-cheie: *instruire bazată pe simulare, competențe clinice, educație medicală bazată pe competențe, transferul învățării, administrare parenterală, evaluarea eficacității, satisfacția studenților.*

EVALUAREA EFICACITĂȚII FORMĂRII BAZATE PE SIMULARE ASUPRA TRANSFERULUI DE COMPETENȚE CLINICE

Introducere. Transferul eficient al învățării este esențial pentru formarea specialiștilor, în vederea asigurării serviciilor medicale de calitate. Acest studiu investighează impactul instruirii bazate pe simulare asupra transferului competențelor clinice ale studenților la medicină, în administrare parenterală a medicamentelor: subcutanată (ASC), intramusculară (AIM) și intravenoasă (AIV).

Material și metode. Folosind un design cvasi-experimental, cercetarea integrează testări pre și post-intervenție, evaluări observaționale și un sondaj de satisfacție, pentru a evalua impactul educațional.

Rezultate. Rezultatele indică îmbunătățiri semnificative în cunoștințele teoretice și abilitățile practice post-intervenție, cu creșterea scorurilor, în mod notabil, pentru toate tipurile de injecții (ASC: de la 50% la 83,33%, AIM: de la 57,14% la 85,71%, AIV: de la 42,86% la 85,71%; p<0,001). De asemenea, s-a demonstrat o performanță clinică îmbunătățită, evidențiind transferabilitatea competențelor achiziționate în condiții reale. Satisfacția studenților a înregistrat scorul de 4.71 (IÎ 95% 4,64; 4,79), reflectând o acceptare și apreciere puternică a instruirii.

Concluzii. Studiul subliniază rolul primodial al simulării în educația medicală bazată pe competențe, asigurând conexiunea între cunoștințele teoretice și aplicarea practică, și susține integrarea sistematică a simulării în curriculum medical, sugerând direcții viitoare de cercetare, pentru optimizarea designului și implementării simulărilor.

INTRODUCTION

Training future specialists with essential clinical competencies is fundamental, representing the core of Competency-Based Medical Education (CBME) (1). Increasingly, scientific evidence suggests that new teaching strategies have a positive impact on the efficiency of educational events (2). Simulation-based training has emerged as a vital component of CBME, bridging the gap between theoretical knowledge and the practical application of skills in a controlled, risk-free environment. However, it is still necessary to comprehensively evaluate how these simulated experiences translate into clinical competencies in the real work environment. This gap in research underscores the need not only to highlight the effectiveness of simulation-based training but also to outline the mechanisms through which these competencies are transferred and retained over time, contributing to the broader discourse on the evolution of pedagogies in medical education.

An increasing number of studies have shown that simulation-based training enhances learning outcomes, develops clinical skills, and boosts student confidence, ultimately leading to better patient care (3). Thus, Nuzzo and colleagues have demonstrated that medical students trained through simulation-based methods show significantly superior clinical competencies, evidenced by training outcomes including at objective structured clinical examinations (OSCE), compared to their peers who did not experience simulation (4). Comparative studies have shown that simulation-based learning is more effective than traditional lecture-based approaches, leading to greater knowledge retention and higher student motivation (5, 6, 7). Zendejas and colleagues have analyzed specialty studies regarding the influence of simulated training on patients cared for or assessed by physicians trained through this method and determined that there is evidence of a beneficial impact (8). This efficacy can be attributed to various features of the educational intervention design, such as deliberate practice, feedback, debriefing, high fidelity of the simulation, similarity of environments, etc., which are crucial for successful learning transfer (9, 10). Medical simulation helps learners understand that they can achieve good results when performing various procedures correctly. The confidence given is built on four main elements: personal experiences of success, observing the success of others, receiving encouragement from evaluators, and one's own physical reactions (11).

Trainees can acquire and retain clinical competencies using simulators but sometimes demonstrate a limited ability to transfer them to situations other than training settings (12). Despite the proven benefits of simulation-based training, there remains a gap in understanding how such training affects the transfer of clinical decision-making skills and the professional preparation of nurses, indicating a need for further research in this area (13). However, some interprofessional simulation experiences have shown prospects not only in improving short-term perceptions of competencies but also in facilitating the transfer of distance learning experiences to clinical environments, thus underlining the value of simulation in promoting collaborative practice among medical professionals (9, 14). This effect might be due to the fact that the transfer of knowledge and competencies to the practical environment is a complex process that depends on at least three categories of factors – the personal characteristics of the trainee, the design of the educational intervention, and factors related to the work environment (15). In other words, developing professional competencies through targeted specific interventions represents just one component of this complicated ensemble, but it is one of the most crucial.

The role of medical simulation extends beyond mere skill acquisition, providing learners with authentic scenarios that mirror real-life situations (16). This experiential learning environment not only increases the confidence of the learners but also minimizes the risk of medical errors in subsequent professional activities, contributing to safer patient care (17, 18). Various simulation techniques, such as the use of standardized patients and manikins, are crucial for the development of clinical competence and adherence to professional standards, fundamental in achieving accurate diagnosis and effective treatment (19, 20, 21). Simulation-based training has a significant impact on the development of technical skills (22, 23, 24), and it also aids in the formation of non-technical skills (23, 25, 26), which enhances the clinical performances of trained medical specialists. The incorporation of simulation into medical training has been associated with sustained

improvements in clinical competencies, highlighting the comprehensive nature of simulation training in addressing sets of competencies (17, 19, 22, 27, 28). Such findings advocate for the integration of simulation-based methodologies into medical curricular programs at all levels of professional medical training, to design more effective educational interventions.

Systematic evaluation of the impact of training programs is essential for determining their effectiveness, covering a wide spectrum from immediate reactions to long-term effects, according to the principles established by Kirkpatrick (29). For analysing clinical competencies and participant satisfaction, various methods have proven effective, including statistical analysis (30), online surveys (31), and the use of checklists (32). Additionally, assessing participant satisfaction and the impact of training on individual beliefs in performing clinical procedures aligns with Bandura's theory of self-efficacy, which suggests that confidence in one's abilities to succeed in specific situations can enhance performance (11).

Overall, simulation has been validated as a means to enhance the performance of medical students in clinical settings, with evidence indicating its efficacy, including in improving clinical competencies at OSCE stations (4, 33, 34). However, the effective integration of simulations into the medical education curriculum remains a challenge, given the need for significant resources, specialized equipment, and faculty training. Additionally, future research should explore ways to optimize the design and implementation of simulations to maximize learning transfer, including the use of emerging technologies such as virtual and augmented reality (35, 36, 37).

The aim of this study was to comprehensively evaluate the impact of a simulation-based educational intervention on the acquisition of transferable clinical competencies, using the example of parenteral medication administration skills (subcutaneous, intramuscular, and intravenous injections), which is in line with current methodologies in professional training. The specific objectives can be summarized as follows: (i) Evaluate the efficacy of a structured simulation-based educational intervention in improving medical students' knowledge retention in performing injections; (ii) Analyze the impact of the educational intervention on practical skills; (iii) Determine the transferability of skills acquired through simulation into clinical practice; (iv) Assess participant satisfaction with the training program and its impact on self-confidence in performing clinical procedures, which may suggest that confidence in the ability to succeed enhances performance in specific situations.

The article represents an extension and completion of the preliminary results of the study presented at the conference "Medical simulation – a look into the future" in 2021, published in the abstract collection of the same conference (38). While the previous publication provided an initial perspective on the research outcomes, this study deepens the analysis and includes a complete set of data, offering a more comprehensive picture and significant additional details that were not previously reported. Therefore, this article not only enhances the understanding of the effectiveness of simulation-based training but also highlights new findings that underscore the importance of our research in the field of knowledge and skill transfer, validating and expanding preliminary observations for further research and practical applications.

MATERIAL AND METHODS

The conducted study has a quasi-experimental design and comprised a structured educational method in four stages for learning a competency, using medical simulation. Participants involved were students (n=43) in their 3rd and 4th years of the Medicine program at Nicolae Testemițanu State University of Medicine and Pharmacy. None of them indicated having post-secondary medical education (college) and each enrolled in the participation list due to the lack of specialized and comprehensive training on parenteral medication administration techniques. Recruitment was based on a public call for participation, and inclusion criteria were: being a Medicine student and agreeing to voluntarily participate in the study. Conducted from February 10 to 14, 2020, the study took place at the University Center for Simulation in Medical Training for basic training, and at the University Clinical Center for Primary Medical Care for practicing maneuvers in a clinical environment. Participants were informed about the objectives and methodology of the study and ultimately, all voluntarily consented to be involved.

The training focused on the parenteral administration of medicinal preparations through three basic techniques – subcutaneous, intramuscular,

and intravenous, and was structured into two main components, a theoretical one followed by a practical one. The theoretical part of the training involved the distribution of educational materials and the theoretical study of the procedures to be performed, taking place in a single session in the form of a seminar. The practical part, in turn, consisted of two phases. The first phase included the use of task-training simulators combined with role-playing methods to replicate real conditions, where participants were trained through a four-step didactic process – demonstration, deconstruction, comprehension, and performance (39). The second phase took place in a controlled and safe clinical environment on a live person, a few hours later. As patients, the students themselves were involved, who had given their consent for subcutaneous, intramuscular, and intravenous injection procedures to be performed. It should be noted that at all stages of training, participants received feedback from the instructors.

Data collection was conducted through three measurement methods: A. Theoretical evaluations – an initial "pre-test" (TE no.1) and a final "post-test" (TE no.2), with the same set of questions; B. Observational evaluations – conducted at the end of the training, in the educational environment (OE no.1) and during practice in a real clinical setting (OE no.2), using the same checklist; C. Participant satisfaction evaluation (SE) was conducted with an anonymous Likert-type questionnaire with a 5-point scale, from "Strongly Disagree" (1 point) to "Strongly Agree" (5 points) (fig. 1). All research instruments (theoretical test, observational evaluation checklist, and questionnaire) were developed specifically for this intervention within the study. Data processing and analysis were performed using CAE LearningSpace®, Epi-InfoTM7, Microsoft Office Excel 2013, R Studio, and SPSS 26.

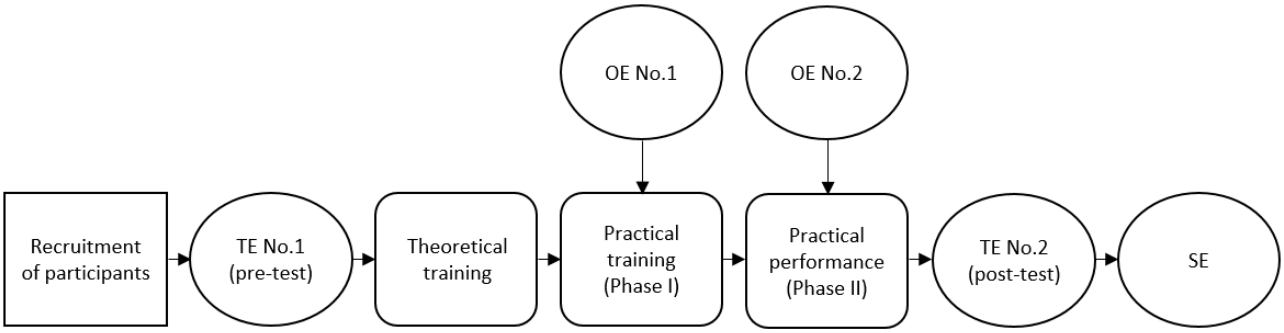

Figure 1. The design and stages of the study.

To demonstrate the positive effect of the educational intervention on the level of knowledge and skills, a significant difference is expected between the pre-/post-test evaluation scores (where TE no.1 < TE no.2) and satisfactory results ("good" and "very good" according to national and European grading systems) in the observational evaluation at the end of the training (OE no.1). Additionally, to establish the positive transfer of competencies acquired in the learning environment to the clinical work environment, the score recorded at the end of the training should be lower than that recorded in the clinical setting. Also, to assess the reaction and any suggestions regarding the intervention, participants were surveyed anonymously.

RESULTS

A. The results of the comparative theoretical evaluations pre-/post-test showed a statistically significant improvement in knowledge of injection administration for all three types studied. Specifically, competencies for administering subcutaneous injections recorded an average increase from 50% to 83.33% after the intervention, with a Wilcoxon signed-rank test indicating a significant difference (V_w=12.00; $p<0.001$) and an impressive effect size, estimated by the rank biserial correlation test (r=-0.97). The narrow confidence interval (CI 95% 0.99; 0.95) confirms the strong positive impact of the intervention (fig. 2).

Similarly, the IM administration skill demonstrated an average improvement from 57.14% to 85.71%, with statistical results highlighting a significant improvement (V_w= 0.00; $p<0.001$) (fig. 3).

A similar situation is observed in the case of IV ad

ministration. An increase in scores from 42.86% to 85.71% was noted, with an extremely significant improvement (Vw=0.00; p<0.001), highlighting a direct and strong impact of the training on the practitioners' knowledge (fig. 4).

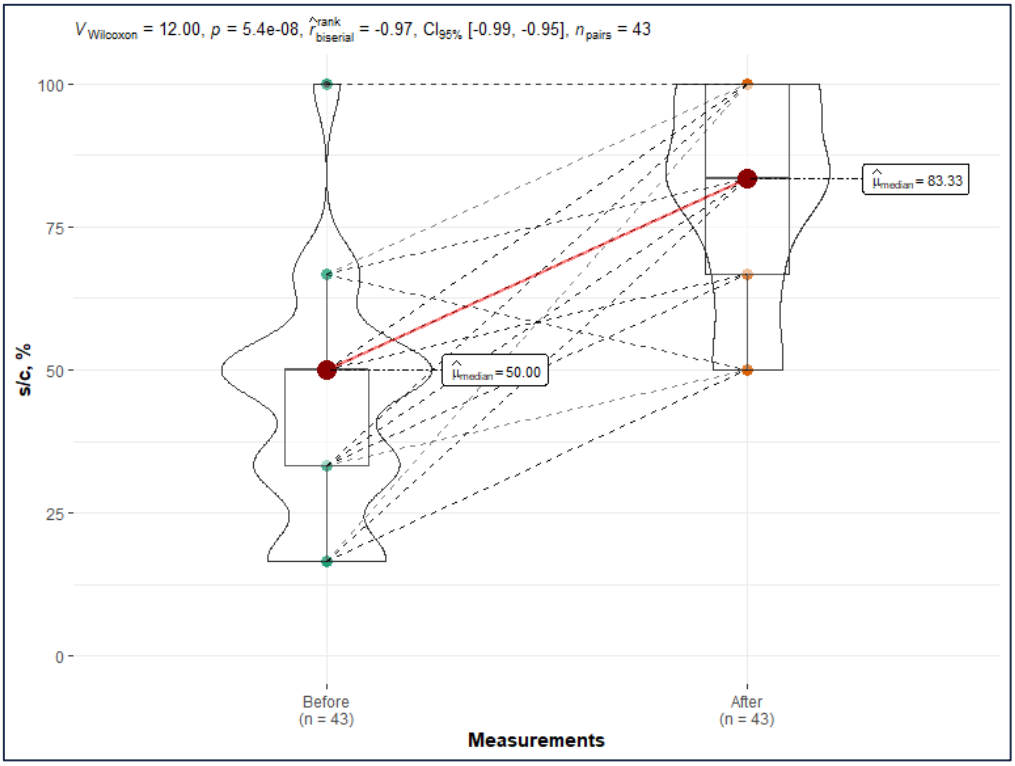

Figure 2. The comparative results of the theoretical evaluation (TE no.1 vs. TE no.2), for the SC administration skill.

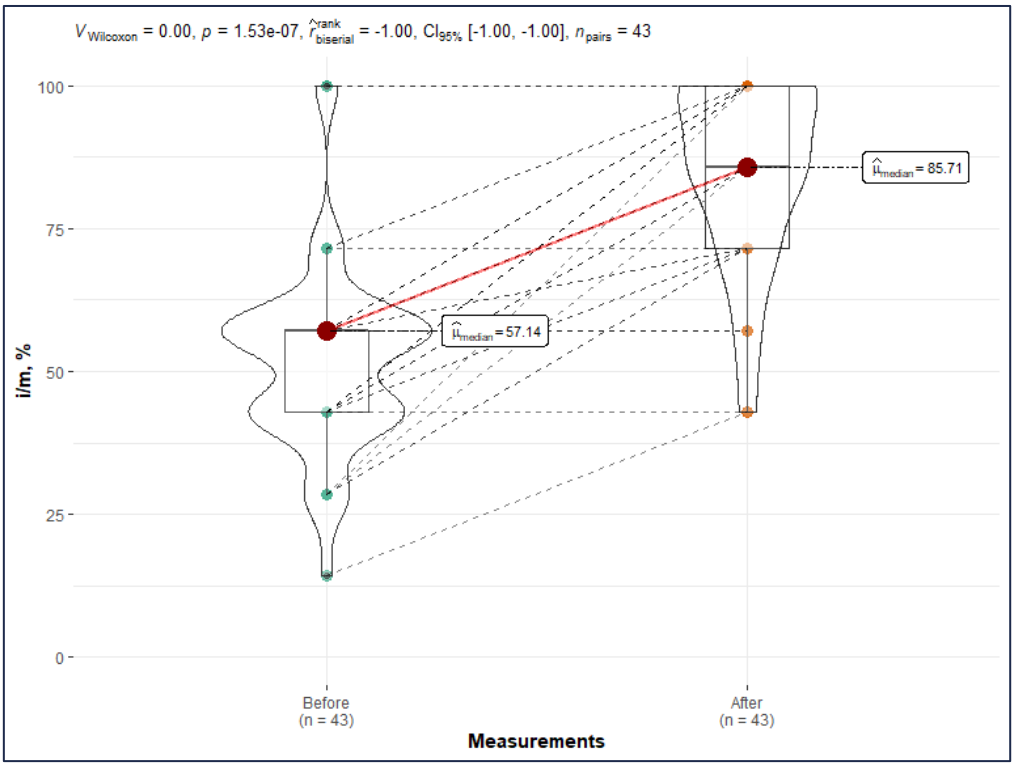

Figure 3. The comparative results of the theoretical evaluation (TE no.1 vs. TE no.2), for the IM administration skill.

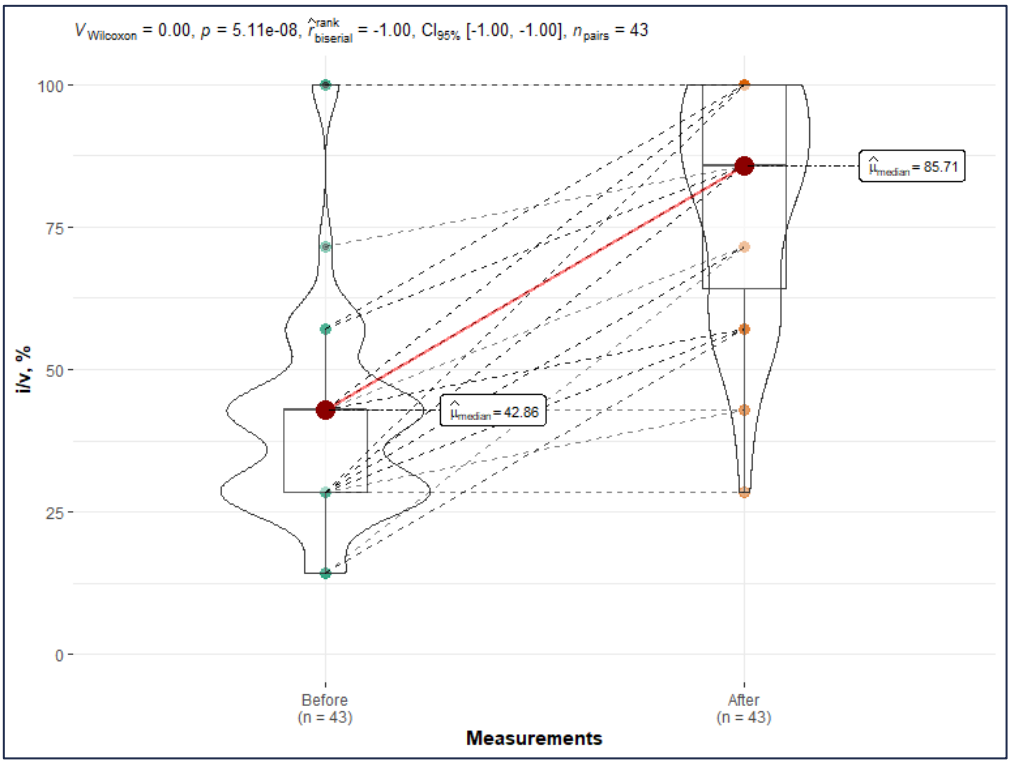

Figure 4. The comparative results of the theoretical evaluation (TE no.1 vs. TE no.2), for the IV administration skill.

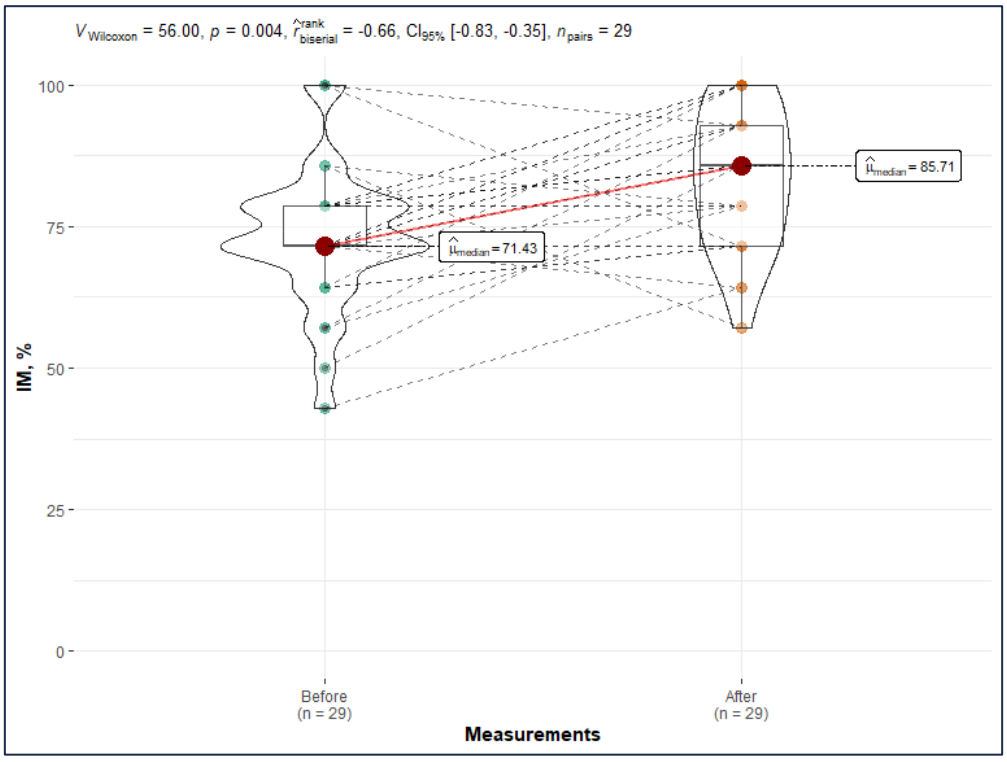

Figure 5. The comparative results of the observational evaluations (OE no.1 vs. OE no.2), for the IM administration skill.

B. The analysis of observational evaluations based on the checklist, immediately after the training phase (OE no.1), showed good performance results for all three learned skills.

Thus, the overall average score was: 81.09% (CI 95% 80.95; 81.22) for the SC administration maneuver, which corresponds to a grade of 8.5 or the range of 8.01-8.5, according to the national grading system (NGS) and a grade of B or "very good" as per the scale with grades recommended in the European Credit Transfer System (ECTS); 73.92% (CI 95% 73.8; 74.04), or 7.5 according to NGS or C/"good" according to ECTS, for the skill of performing intramuscular injections; and for the IV administration skill, similar to the first maneuver – 80.57% (CI 95% 80.46; 80.69), or a grade of 8.5 according to NGS and B/"very good" according to the ECTS system.

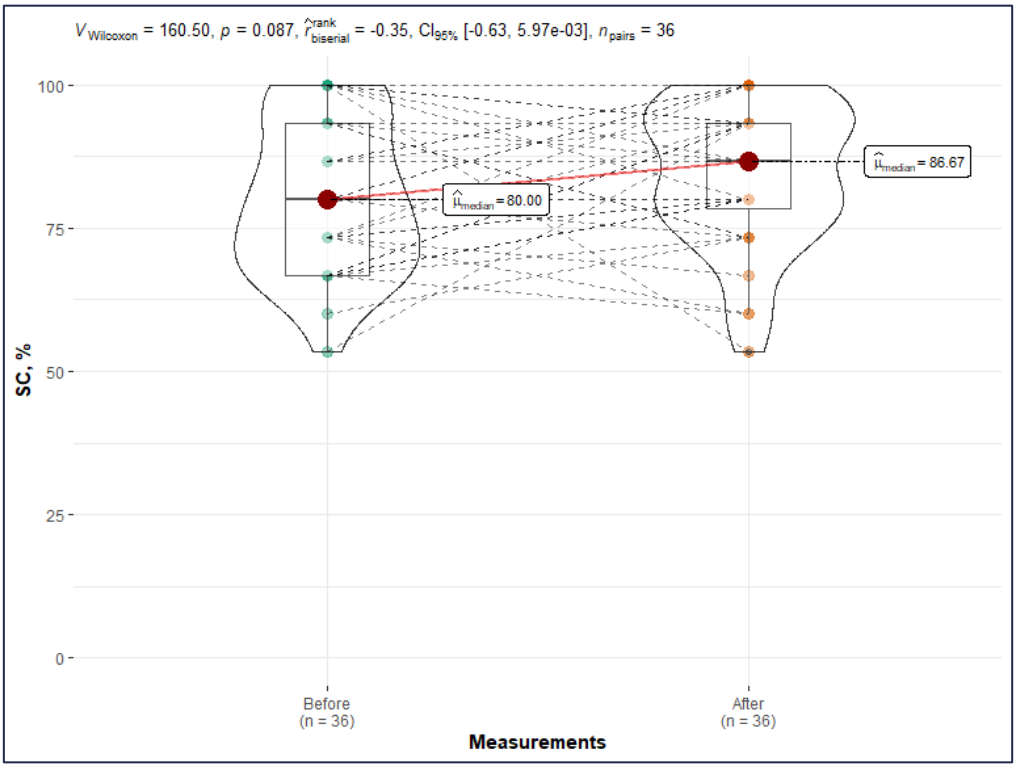

Figure 6. The comparative results of the observational evaluations (OE no.1 vs. OE no.2), for the SC administration skill.

The comparative analysis of the results of observational evaluations, immediately after the training phase (OE no.1) and during practice in a clinical setting (OE no.2), conducted based on the median scores, highlighted a significant improvement in the competencies for performing intramuscular injections from 71.43% post-training to 85.71% in the clinical setting (p=0.004). The effect size was estimated by the rank biserial correlation test (r=-0.66) (fig. 5).

For the other two skills, the comparative results proved to be more modest. For SC administration, an increase in median performance was observed from 80.00% in the educational setting to 86.67% in the clinical setting (p=0.087) with a medium effect size (r=-0.35) (fig. 6), and for IV administration, it increased from 82.35% post-training to 88.24% during clinical practice (p=0.1), with a medium effect size of the biserial correlation (r=- 0.33) (fig. 7).

The detailed comparative analysis (OE no.1 vs. OE no.2) for the SC administration skill revealed that for most criteria (C#) on the evaluation checklist, there were either improvements or no significant changes in the percentage outcomes. The most notable improvements were observed for items C8 (control aspiration), C11 (use of sharps disposal container), and C14 (cleaning the work area after the procedure), suggesting that the training had a positive effect on these specific criteria. It is worth noting that there was also a notable decrease in C9 (slow injection of the pharmaceutical) during the procedure in a clinical setting. The comparison of observational evaluation results for IM administration showed higher positive response rates in OE No.2 compared to OE No.1 for most items. The largest positive differences were recorded for C9 (rapid withdrawal of the needle

with application of a sterile pad at the injection site), C10 (use of sharps disposal container), C11 (securing the applied pad with adhesive tape), C13 (cleaning the work area after the procedure), C14 (hand hygiene at the end of the procedure). For items C2 (communication with the patient and explaining the procedure) and C5 (asking the patient to relax the muscles in the injection region), a decrease in the rate of positive ratings was noted. In the case of the IV administration maneuver, the data shows improvements in certain criteria following the educational intervention, such as C7 (inserting the needle at a 35-degree angle), C8 (inserting the needle into the vein 3-5 mm with the syringe and needle position secured), with the most significant improvements observed for C6 (stabilizing the vein by longitudinal traction of the skin) and C10 (loosening of the venous tourniquet). However, some areas showed a decrease in scores after the intervention in a real clinical setting, such as C17 (hand hygiene after the procedure).

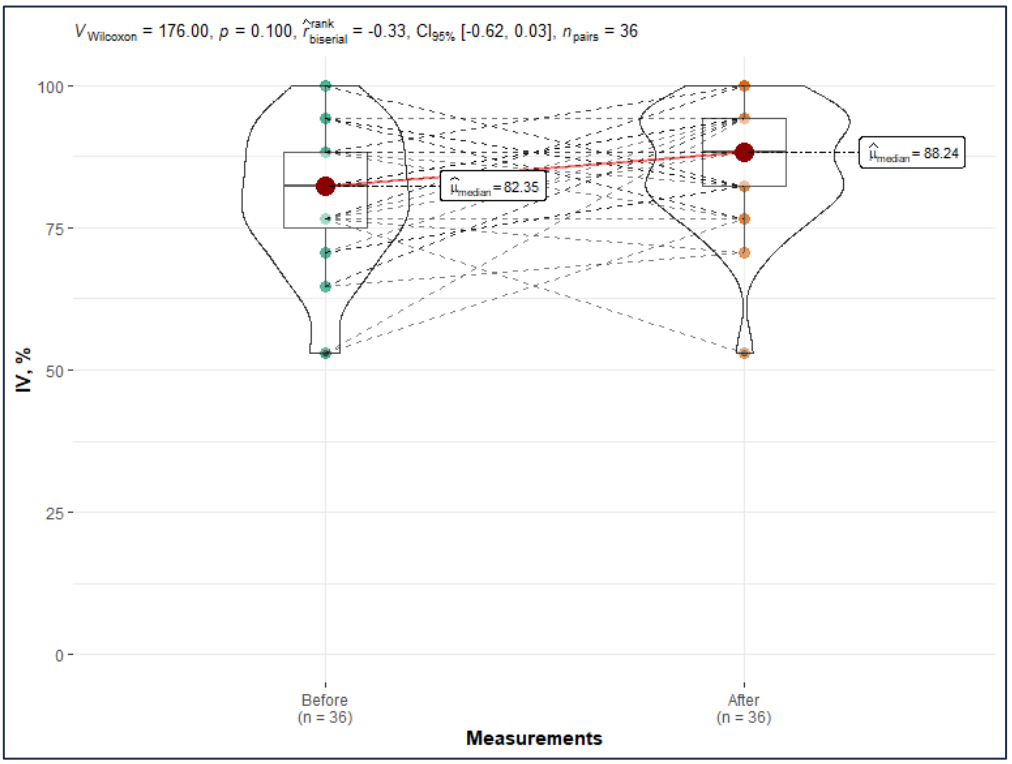

Figure 7. The comparative results of the observational evaluations (OE no.1 vs. OE no.2), for the IV administration skill.

The analysis of participant satisfaction in the study, conducted using a Likert-type questionnaire, reflected a high level of overall satisfaction. The simulation-based training method was particularly appreciated, with an average score close to the maximum possible of 4.71 points (CI 95% 4.64; 4.79), indicating strong acceptance and appreciation of this educational intervention. The total average score obtained by participants was 56.53 points out of a maximum of 60.00 points (CI 95% 55.65; 57.42), highlighting a high degree of satisfaction, which validates the reliability and consistency of the results obtained. The per-question analysis of the satisfaction questionnaire demonstrated that all evaluation criteria recorded significant scores, ranging from 4.33 (minimum score) to 4.98 (maximum score) out of a possible 5.00, which corresponds to the rating of "Strongly Agree" (4.30–5.00). Notably, the items with the highest scores stood out, especially: "Q5. Medical training through simulation deserves to be promoted and recommended" with a score of 4.98 (CI 95% 4.93; 5.02), followed by "Q6. I would opt for other courses using the method of medical training through simulation in the future" – 4.95 (CI 95% 4.89; 5.02) and "Q2. The method of training through simulation motivates me to develop professionally" – 4.93 (CI 95% 4.85; 5.01). The lowest scores were recorded for "Q10. The number of repetitions of practical maneuvers during

training was sufficient to master the respective competency" – 4.33 (CI 95% 4.10; 4.55) and "Q12. I believe that after completing this course I will possess the necessary practical skills to correctly perform the medical interventions taught", scoring 4.33 (CI 95% 4.08; 4.57).

DISCUSSIONS

The specialized literature emphasizes the crucial role of simulation methods in ensuring the transfer of learning in medical education. Simulations not only improve clinical competencies and students' self-confidence but also facilitate the application of theoretical knowledge in practical contexts. The study is quasi-experimental in order to investigate the effectiveness of simulation-based training regarding the transfer of clinical skills among medical students. However, there are some potential limitations related to the study design, such as the lack of a control group or potential biases in observational evaluations.

The data obtained clearly show a substantial improvement in the theoretical knowledge of medical students regarding injection techniques after the educational intervention. The significant statistical value and large effect size underscore the effectiveness of the "four-step" teaching approach based on simulation methods. The increase in the median score at the theoretical evaluations by over 30 percentage points, together with the very narrow confidence interval for the effect size, provide solid evidence that the intervention was highly effective. These results suggest that such educational interventions, which combine theoretical and practical training with simulation, are highly beneficial in improving the theoretical knowledge of medical students in this field. Additionally, the post-training observational evaluations indicated good performances in administering subcutaneous, intramuscular, and intravenous injections, with average scores reflecting solid competencies. The scores ranged from "good" to "very good" according to national and European grading systems, highlighting the effectiveness of the training in developing the targeted practical skills.

A key aspect addressed in this article is the impact of the educational intervention on the application of practical skills in a real clinical context. Repeated observational evaluations in the clinical setting (OE no.2) aimed to determine whether and how the skills learned in the training environment are transferred and applied in actual practice. Anticipating the outcomes of the measurements, we could hypothetically assume a range of possibilities. They might be modest, remain unchanged or insignificantly changed, or could be improved compared to the results obtained at the end of the training (OE no.1). In the first scenario, when the clinical environment observations indicate inferior performances, this suggests that the competencies developed in the training environment are too narrow and specific, inadequate for more varied contexts and not transferable, or that external factors, such as working conditions (including stress, material resources, work environment conditions), may hinder the effective transfer of skills (40). However, this assumption was contradicted by the findings of our study. At the opposite end of the spectrum is the case where clinical performances exceed the results achieved at the conclusion of the initial training, as in the case of the intramuscular administration competency in our study, where the increase in the median score at OE no.2 exceeded by approximately 14 percentage points (p=0.004), with an effect size of -0.66. In this context, it can be deduced that certain competencies significantly benefit from the specific educational intervention through simulation, not only reaching the desired performance level but also enhancing the skill transfer effect. This effect can also be attributed to repeated practice, a principle supported by research in the field (41). There are cases where clinical performance is similar or only slightly different from that in the training environment, as seen for subcutaneous and intravenous administration competencies. At first analysis, it might be misinterpreted that the training had no effect. However, this finding actually indicates that the acquired skills are transferable and applicable in real contexts. That is, the good results verified at the evaluations at the end of the training are maintained in the evaluations conducted in the real clinical environment, demonstrating the effectiveness and positive outcomes of the educational intervention. This suggests that the learned competencies are well generalized and can be effectively implemented in clinical practice (42). Nevertheless, a detailed analysis of the results of observational evaluations might suggest increasing attention to certain aspects of practical training, such as effective communication with the patient and proper management of post-injection procedures, through an adjusted or additional pedagogical approach to maximize the efficiency of training and ensure positive transfer.

The analysis of participant satisfaction in the study reflected a high level of overall satisfaction (score = 4.71 points), with an average close to the maximum possible score (5.00 points), indicating strong acceptance and appreciation of this component of the course. The average total score of 56.53 (CI 95% 55.65; 57.42) out of a maximum of 60 points underscores a high degree of satisfaction, and the narrow confidence interval validates the reliability and consistency of the data obtained. These results reinforce Bandura's (1977) theory on self-efficacy (11), demonstrating that confidence in one's own abilities can be significantly improved through deliberate practice in a controlled, risk-free environment, which facilitates learning and the transfer of skills in real clinical contexts (6, 8).

In line with previous studies that have highlighted the ability of simulation to improve clinical competencies and facilitate the transfer of learning, this study adds concrete evidence regarding the effectiveness of simulation in training for injection administration. Considering the significant improvements in performance and the substantial impact indicated by the effect size, it is clear that this educational strategy deserves to be implemented widely in professional training programs. Additionally, our study demonstrates enhanced effectiveness of simulation training methods when combined with role-playing and the "four-step" teaching approach to a skill, highlighting the applicability and importance of this strategy in the context of contemporary medical education. There is a clear need for deliberate integration of simulations into medical educational programs, not only to enhance technical skills but also to strengthen confidence and non-technical competencies, vital for ensuring high-quality and safe clinical practice (27, 28).

Although the widespread implementation of simulation-based training in the medical curriculum can face some difficulties, such as the need for substantial resources, specialized equipment, and appropriate teacher training, the findings of the study underscore its importance in cultivating clinical competencies in future health professionals. Further research should aim to identify the most effective strategies to optimize the implementation of simulations, to facilitate the transfer of knowledge and clinical competencies into the real-world environment.

CONCLUSIONS

1. The study results showed statistically significant improvements in theoretical knowledge, demonstrating the strong positive impact of the educational intervention.
2. Post-training observational evaluations indicated good performances in administering subcutaneous, intramuscular, and intravenous injections, with average scores reflecting solid competencies.
3. The analysis highlighted that the competencies acquired through simulation were transferable and applicable in the real clinical environment.
4. Student satisfaction with the educational intervention was high, reflecting strong acceptance and appreciation of simulation-based training, with a positive impact on self-confidence and motivation for professional development.

CONFLICT OF INTEREST

The authors of the article deny the existence of any conflict of interest in the publication of this material.

ETHICAL APPROVAL

The research has been approved by the Research Ethics Committee, no. 59, April 2, 2018, at *Nicolae Testemitanu* State University of Medicine and Pharmacy, Republic of Moldova. All participants were informed about the objectives and methodology of the study and voluntarily consented to participate by signing.

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Iurie SARATILA, Web of Science Researcher ID ACX-0567-2022, SCOPUS Author ID 57215603262
Andrei ROMANCENCO, Web of Science Researcher ID JZC-7634-2024
Larisa SPINEI, SCOPUS Author ID 7801524516