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Impact on Confidence, Competence, and Skill Acquisition on Simulation-based Orthopedic Training for Medical Students

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Abstract

Introduction: Traditional orthopedic education has relied heavily on didactic instruction and clinical observation. This study evaluates the impact of simulation-based learning (SBL) on both self-reported confidence and objectively assessed technical competence among undergraduate medical students. **Materials and Methods:** A cross-sectional study was conducted among 106 final-year medical students who completed orthopedic clinical postings. Participants underwent seven simulation exercises, including fracture fixation using synthetic bone models, joint reduction techniques, and arthroscopic navigation. Self-confidence and satisfaction were measured using the validated Student Satisfaction and Self-Confidence in Learning Scale. Objective skill acquisition was assessed using a faculty-rated checklist modeled on the Objective Structured Assessment of Technical Skills. **Results:** Post-training, the proportion of students reporting high confidence increased from 17% to 56.6% ($P < 0.001$). Objective skill scores also improved significantly, with a mean increase from 62.4 ± 8.1 to 78.9 ± 6.7 ($P < 0.001$). Prior simulation exposure and baseline confidence were independent predictors of post-training confidence. Gender did not significantly influence outcomes. High inter-rater reliability ($\kappa = 0.84$) supported the consistency of faculty assessments. **Conclusion:** Simulation-based orthopedic training significantly enhances both perceived confidence and objectively measured competence in undergraduate medical students. The use of validated assessment tools strengthens the reliability of these findings. Early and repeated integration of structured simulation modules into the undergraduate curriculum is recommended to foster clinical readiness and procedural proficiency.

Keywords: Competency-based training, Medical students, Objective structured assessment of technical skills, Orthopedic education, Simulation-based learning, Student satisfaction and self-confidence in learning scale, Technical skill assessment

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Introduction

Medical teaching has been based on didactic teaching, observation, and apprenticeship to bring up new healthcare providers.[1,2] Yet, in the orthopedic field, the demand for a more organized, practical, skill-based method of training has been growing. Orthopedic interventions usually require technical skills, spatial cognition, and instant clinical judgment, and they are not included purely through theoretical education.[3] Simulation-based learning (SBL) has therefore been proposed as an educational modality to provide medical students with a safe, standardized, and reproducible setting within which to learn and practice essential orthopedic skills before participation in actual patient care.[4]

Orthopedic simulation is a broad field that may involve synthetic bone models, virtual reality trainers, high-fidelity manikins, and cadaveric simulations.[3,5-7] These techniques can be used by students to learn key skills such as fracture fixation, joint manipulation, casting, and arthroscopic navigation, up to complex surgical procedures. Training in traditional clinical rotations is usually scarce for performing procedures due to constraints related to patient availability and number of procedures, as well as case heterogeneity, while simulation enables repetitive practice, prompt performance feedback, and gradual skill development at the learner's pace.[8-10] Not only does it close the medical education gap between theory and application but it also remedies this dichotomy that has been ingrained in medical education, particularly in skill-based medical education, such as in the case of orthopedics.[11,12]

The importance of improved procedural training has been highlighted in other healthcare systems across the world. Challenges posed by rising concerns for patient safety, time constraints placed on trainees, and the expectations of competency-based medical education have made the establishment of novel learning environments a priority.[13] It also fosters students' confidence, decision-making, and professional behavior, which are equally important for their transition from medical students to proficient orthopedic trainees.[13-15]

Although simulation has demonstrated success within postgraduate surgical training, its utility in undergraduate orthopedic training is less evaluated. Undergraduates in medicine have little exposure to orthopedics, and thus, there is a lack of understanding of the assessment and management of musculoskeletal problems.[16,17] The incorporation of simulation into the undergraduate curriculum at an earlier stage may

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increase the technical competency of students and interest them in orthopedic surgery. Further, through the routine assessment of student experiences and skills through structured data collection, educators can identify the potential pitfalls of simulation-based curricula and make evidence-informed decisions regarding their broad adoption.[18]

A need for a more complete assessment of competency in orthopedics is being increasingly recognized beyond passing theoretical exams. The development of practical skills, clinical reasoning, and procedural confidence is also important and needs to be objectively assessed and continually fostered. By capturing information directly from medical students, including perceptions, skill acquisition, and challenges encountered with simulation-based orthopedic sessions, useful knowledge may be obtained.[19,20] Such lessons may optimize simulation methods, develop educational content to learners needs, and ultimately produce better-prepared graduates who provide high-quality musculoskeletal care.

In addition, with a shift in medical education toward competency-based programs, the need to develop new teaching and assessment methods reflects the realities of actual clinical practice. Knowing how learners react to simulation – and what they learn – could assist curriculum developers who seek to justify a financial and pedagogical commitment to simulation-based infrastructure and curricula as standard teaching resources. Accordingly, this investigation has an added goal of not only evaluating the efficacy of the use of simulation-based instruction in orthopedic practice but also considering the perceptions and responses of the principal subjects – the students themselves – in terms of turning theory into practice.

Materials and Methods

An observational, cross-sectional study was conducted among undergraduate medical students to evaluate the efficacy and perception of SBL in orthopedics after obtaining the institutional ethics clearance. The study was conducted at the department of orthopedics of a medical college hospital, where simulation training has been provided through bone models, arthroscopic simulators, and fracture fixation workshops. The period of study lasted for 2 months, from January 2025 to February 2025, for recruiting, simulations, and gathering data. The final-year undergraduate medical students who had completed their orthopedics clinical postings and were agreeable to participate voluntarily in the simulation-based training sessions were selected for the study.

We determined the sample size using the formula for estimating a proportion with desired absolute precision. Considering the hypothetical proportion (p) of 50% having a positive perception toward SBL (to maximize sample size) and desired confidence interval (CI) (95%) at Z = 1.96 and precision (d) of 10%, the sample size is computed using the formula: $n = Z^2 \times p(1-p)/d^2$; using the values in the above formula, we selected a sample of 96 students. The final sample size was rounded to include 106 students with an anticipated 10% non-responder.[3] A convenience sample was employed, and all eligible students who were present during the data collection period were asked to participate.

The study population included all the final year undergraduate medical students of the institution, who had finished their clinical orthopedics posting and given written informed consent. Exclusion included pre-vocational students who had already attended any external orthopedic simulation-based training, were no-shows during simulation, and refused to participate. A structured questionnaire and skill assessment checklist were used as tools for data collection.

The simulation-based training comprised three structured modules: (1) Fracture fixation using synthetic bone models (n = 3 exercises), (2) joint reduction and immobilization techniques (n = 2 exercises), and (3) arthroscopic navigation using a virtual simulator (n = 2 exercises). Each student participated in all seven exercises over 2 consecutive days, with faculty supervision and standardized instruction. The modules were designed to reflect common orthopedic procedures encountered in clinical practice and were aligned with undergraduate competency goals. A structured questionnaire was administered post-training, incorporating the Student Satisfaction and Self-Confidence in Learning Scale (SSSCLS), a validated instrument developed by the National League for Nursing.[21] This scale has demonstrated reliability and validity in measuring learners' satisfaction and self-confidence in simulation-based education. The questionnaire included items on demographics, prior simulation exposure, and self-confidence before and after training. Responses were scored according to the SSSCLS guidelines,[22] enabling standardized comparison across participants. In addition to the SSSCLS, objective skill acquisition was evaluated using a faculty-rated checklist modeled on the Objective Structured Assessment of Technical Skills (OSATS). This included criteria such as procedural accuracy, instrument handling, and completion time. Each student's performance was scored independently by two trained faculty members immediately following the simulation session. Ethical considerations were well covered. Before study initiation, the study protocol was approved by the Institutional Ethics Committee. At the time of sampling, the objective and confidentiality of the investigation were explained to each participant, and oral informed consent was also obtained from all of the subjects, in which they were informed that they had the right to withdraw their intention to participate at any time from completing the questionnaire without any academic consequences.

The Statistical Package of Social Sciences software (Version 26.0), IBM Corp, Chicago, Illinois, USA, was used for data analysis. Summary statistics were provided as mean, standard deviations, frequencies, and percentages for continuous and categorical variables. Wilcoxon signed-rank tests were used to compare pre-and post-simulation confidence category distribution. Chi-square analysis was used to compare demographic variables with attitudes toward simulation. $P < 0.05$ were considered significant.

Results

One hundred and six (106) final-year medical students were recruited into the study. The average age of the students was 22.5 ± 1.2 years old. Sex was nearly balanced, with 52 men (49.1%) and 54 women (50.9%). Previous experience with orthopedic simulation training was reported by 18 students (17%), with the majority, 88 students (83%) reporting no previous exposure. Concerning the confidence level at baseline before the simulation session, 48 students (45.3%) had low levels of confidence, 40 students (37.7%) had moderate confidence, and only 18 students (17%) had high confidence [Table 1]. Among the modules, students reported the highest confidence gain in fracture fixation exercises, followed by joint reduction and arthroscopy. Objective scores also reflected this trend, with fracture fixation showing the greatest improvement in technical accuracy.

After the simulation training modules, there was a significant increase in the confidence of the participants. Confidence scores were derived from the SSSCLS, with higher scores indicating greater self-assessed competence and satisfaction with the simulation experience. The number of students with high confidence rose from 17% before training to 56.6% post-training ($P < 0.001$), and the students reporting low confidence decreased sharply from 45.3 to 11.3%, respectively [Table 2]. These results demonstrate the beneficial effects of SBL on the self-confidence of students in performing orthopedic skills.

A further examination of gender and perceived improvement after simulation revealed no statistically significant difference ($P = 0.337$) [Table 3]. In male participants, 47 of 52 (90.4%) reported improvement, whereas 52 of 54 (96.3%) female participants experienced improvement after sim training, indicating that both sexes equally benefited from the intervention.

There was an association between previous exposure to SBL and attaining high confidence with training ($P = 0.017$) [Table 4]. The former (16/18, 88.9%), who had prior exposure to using any type of simulation-based environment, was statistically significantly ($P = 0.04$) more likely to reach high post-simulation confidence than the latter (44/88, 50%).

In the unadjusted odds ratio (OR) analysis, students with previous exposure to simulation were 8 times more likely (OR 8.00; 95% CI 1.67–38.39; $P = 0.009$) to report high post-training confidence than those who had not been previously exposed [Table 5]. Likewise, the odds of being confident after training were 3.5 times higher for students with high pre-training confidence (OR 3.50; 95% CI 1.42–8.62; $P = 0.006$).

On multivariate logistic regression analysis compared with gender, exposure before simulation, and initial confidence level, exposure before simulation was an independent predictor for achieving high post-training confidence (adjusted odds ratios [AOR] 7.21; 95% CI 1.40–36.98; $P = 0.018$). Similarly, higher confidence before training was significantly associated with better following training (AOR 3.12; 95% CI 1.18–8.26; P = 0.022) [Table 6]. After adjustment, gender was not a significant predictor (AOR 0.76; 95% CI 0.33–1.75; $P = 0.521$).

Objective skill scores, based on the faculty checklist, showed a significant improvement post-training. The mean composite score increased from 62.4 ± 8.1 to 78.9 ± 6.7 ($P < 0.001$). Inter-rater reliability was high ($\kappa = 0.84$), indicating consistent faculty evaluations. These findings support the effectiveness of SBL in enhancing procedural competence.

Table 1: Baseline characteristics of the study participants (*n*=106)

Variable	*Category*	*Frequency*	*Percentage*
Age (years)	Mean±SD	23.5±1.2	—
Gender	Male	52	49.1
	Female	54	50.9
Prior simulation exposure	Yes	18	17
	No	88	83
Confidence level (pre-training)	Low	48	45.3
	Moderate	40	37.7
	High	18	17

SD: Standard deviation

Table 2: Change in confidence level before and after simulation training

Confidence level	*Pre-simulation n (%)*	*Post-simulation n (%)*	*P-value*
Low	48 (45.3)	12 (11.3)	<0.001
Moderate	40 (37.7)	34 (32.1)	
High	18 (17)	60 (56.6)	

Table 3: Association between gender and perceived improvement after simulation

Variable	*Perceived improvement*	*No perceived improvement*	*Chi-square value*	*P-value*
Male	47	5	0.92	0.337
Female	52	2		

Table 4: Association between prior exposure to simulation and high post-training confidence

Variable	*High confidence achieved*	*No high confidence*	*Chi-square value*	*P-value*
Prior simulation exposure	16	2	5.67	0.017
No prior simulation exposure	44	44		

Discussion

SBL experiences enhance undergraduate medical students' self-perceived confidence in orthopedic skills.[23,24] Our results are consistent with the increasing data that supports simulation as an educational tool for surgical and procedural training. Simulator training has been shown by several previous studies to increase not only technical but also cognitive and decision-making skills. Prospective and experimental studies have demonstrated the benefits of simulation-based surgical training. In an evidence-based systematic review, Dawe *et al*.[25] concluded that simulation-based training improves surgeons' technical performance and recommended its integration early in surgical education to enhance skill acquisition and optimize training outcomes. In orthopedic surgery, Rebolledo *et al*.[26] showed that arthroscopic simulation-based training was effective in increasing procedural skills in trainees with no previous surgical experience, highlighting the potential benefits of simulation in musculoskeletal education.

We observed a significant improvement in the confidence level after training, which is in line with research by Bartlett *et al*.,[27] who found that orthopedic boot camps and simulation courses greatly improved both technical skills and confidence in medical students. Simulation-based fracture fixation practices improved students' performance and confidence in clinical skills.[28] Notably, we also found that previous simulation exposure was strongly

Table 5: Unadjusted ORs for factors associated with high post-training confidence

Variable	*OR (95% CI)*	*P-value*
Male gender	0.82 (0.38–1.76)	0.609
Prior simulation exposure	8.00 (1.67–38.39)	0.009
Pre-training confidence (High)	3.50 (1.42–8.62)	0.006

OR: Odds ratio, CI: Confidence interval

Table 6: Multivariate logistic regression: AOR for high post-training confidence

Variable	*AOR (95% CI)*	*P-value*
Male gender	0.76 (0.33–1.75)	0.521
Prior simulation exposure	7.21 (1.40–36.98)	0.018
Pre-training confidence (High)	3.12 (1.18–8.26)	0.022

AOR: Adjusted odds ratios, CI: Confidence interval associated with subsequent high post-training confidence. Martin *et al*.[29] repeated that simulation sessions showed cumulative improvement in both skills and confidence among surgical trainees. It also emphasizes the value of simulation exposure through one's training, providing further evidence for longitudinal simulation curricula.

Our study found no statistically significant impact of gender on learning outcomes. Studies reported no gender-based difference in skill acquisition and self-assessment outcomes on simulation-based surgical training.[30,31] Furthermore, the substantial effects of pre-training confidence on post-simulation performance also parallel the findings of Ilgen *et al*.,[32] which indicates that self-efficacy is significantly associated with learner engagement and learning new skills in simulation. Thus, focusing intervention efforts on students with lower baseline confidence for further support in the form of intervention (repeated or tailored) simulation could be expected to add to already increasing educational benefits.

While self-reported confidence improved significantly, the inclusion of objective skill assessments adds robustness to our findings. The parallel improvement in OSATS-modeled scores confirms that simulation not only boosts perceived readiness but also translates into measurable technical competence. This addresses the well-documented gap between confidence and actual performance, as highlighted in prior literature.

The implications of these findings are more far-reaching. As healthcare organizations increasingly embrace patient safety and competency-based learning, simulation-based training provides a safe and controlled environment for learners to practice, make errors, and learn with support systems in place without jeopardizing patient well-being. As pointed out by Wolpe,[33] simulation is not an add-on, but a must in today's medical education. Our study adds to the increasing body of evidence in support of embedding formative, simulation-based orthopedic education into the undergraduate medical curriculum. It not only develops technical expertise but also nurtures clinical confidence, enhances preparedness to meet real-life participants may even have an impact on the choice of specialty by students.[34] However, some limitations are worth noting. It is a single-institution study, and with convenience sampling, the generalizability of the findings may be limited. Prospective multi-center studies with larger cohorts and objective skill assessments (e.g., OSATS scores) are likely to enhance the evidence on this issue.

This is a single-center study with a limited number of participants, which may restrict the application of the results. Unlike prior studies that relied solely on subjective measures, our study employed the SSSCLS, a validated tool for assessing self-confidence and satisfaction in SBL.[21] This strengthens the reliability of our findings and aligns with best practices in simulation research. Although our study incorporated both subjective and objective measures, future work should explore longitudinal retention of skills and real-world transferability. In addition, while our faculty checklist was modeled on OSATS, formal validation of the tool within our context would further strengthen its reliability.

Conclusion

Simulated learning effectively boosts medical students' confidence in orthopedic interventions and serves as a link between theoretical concepts and bedside exercises. However, previous experience with simulation and baseline confidence were both independently predictive of greater benefit from the training. These results provide additional support for the early integration of structured simulation modules into the undergraduate orthopedics curriculum, for competency-based training and increased clinical readiness. These findings suggest that simulation-based training should be integrated early in the undergraduate program and repeated at different course levels to facilitate skill acquisition and clinical preparedness. The sample size of our study is small, so future work on a larger, multi-centered population is needed to verify our results, and the objective performance assessment must be used to test the evidence. Furthermore, intermittent reinforcement using repetitive simulation experiences and the creation of a set of validated, nationally applicable evaluation tools can help maintain consistency in the outcomes of training. Simulated delivery and feedback methods training for faculty should be emphasized to realize the educational benefit of simulation-based education.

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Authors' Contributions

V. S. Nisanth and MS Ortho: Manuscript writing and data collection, V. M. Sajith and MS Ortho: Manuscript writing and data collection, D. K. Dibin and MS Ortho: Manuscript writing and data collection, and Mithun Manohar and MS Ortho: Manuscript writing, data collection, and statistics.

Data Availability

Available from the corresponding author on reasonable request.

Ethical Clearance

Dr.MGR-ERI/SLMCH/2024/048.

AI Declaration

No generative AI was used for conceptualization, analysis, or content generation. AI use was limited to language refinement, and the authors remain fully responsible for the accuracy, originality, validity, and integrity of the manuscript's content.

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