Physical Realism of Simulation Training for Health Care in Low- and Middle-Income Countries—A Systematic Review

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Abstract: This systematic review was conducted, according to PRISMA standards, to examine the impact of the level of physical realism of simulation training on clinical, educational, and procedural outcomes in low- and middle-income countries (LMICs) as defined by the World Bank. A search from January 1, 2011 to January 24, 2023 identified 2311 studies that met the inclusion criteria including 9 randomized (n = 627) and 2 case-controlled studies (n = 159). Due to the high risk of bias and inconsistency, the certainty of evidence was very low, and heterogeneity prevented any metaanalysis. We observed limited evidence for desirable effects in participant satisfaction and confidence, but no significant difference in skills acquisition and performance in the clinical practice environment. When considering the equivocal evidence and cost implications, we recommend the use of lower physical realism simulation training in LMIC settings. It is important to standardize outcomes and conduct more studies in lower income settings.
(*Sim Healthcare* 19:S41–S49, 2024)

Key Words: Simulation, health care professionals, education, low-income settings, medium-income settings.

Training in the health professions has benefited greatly from integrating simulation as a training tool. Simulation has supported the acquisition of skills for procedures that are high-risk and infrequent through exercises that mimic patients and environments without compromising patient safety. In addition, it has been shown to improve trainees' skills, knowledge, and behavior,[1] which are essential attributes of health care. Simulation can be successfully used to train multidisciplinary teams in complex scenarios and to assess clinical skills.[2]

Technological advances have enhanced simulation in health education by introducing simulators with a high degree of realism. Physical realism includes "factors such as environment, equipment, and related tools."[3] It is recognized that physical realism occurs on a continuum from high (ie, extremely realistic, complex, interactive experiences) to low (ie, simplistic, low-tech, not requiring programming). As such, we sought to include studies where high/low may be a comparison of 2 closely related or vastly different simulation modalities. High physical realism simulators are reported to produce better results than low physical realism simulators.[1,4]

The World Bank uses a categorization framework to evaluate and classify nations into 4 distinct income strata contingent on their gross national income per capita.[5] These encompass low-income (<$1135), lower middle-income ($1136–$4465), upper middle-income ($4466–$13,845), and high-income nations (>$13,845). The first 3 strata are defined cumulatively as low- and middle-income countries (LMICs).

In LMIC settings with relatively few skilled health care providers, simulation-based training could have a remarkable impact.[6] However in such locales, the capital and ongoing maintenance costs of high-fidelity systems are generally unaffordable at the scale that would be needed.[7] The LMICs face many constraints that hinder their ability to acquire high-fidelity manikins for medical training effectively. Although establishing advanced simulation centers is crucial for promoting enduring progress in medical and surgical training, it is imperative to recognize that this undertaking is characterized by demanding financial resources and time investments. A review of the strengths and limitations of surgical simulation initiatives based on an international survey encompassing 42 simulation centers prioritized the need for robust public funding allocations, dedicated simulation technicians, and unwavering endorsement and support from institutional leadership.[8] Moreover, it is noteworthy that using high-fidelity models in this context in all settings has yet to conclusively demonstrate a

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Funding: This systematic review, including the services of Danielle Gerberi (information specialist), was funded by the Society for Simulation in Healthcare.

This systematic review was part of the Society for Simulation in Healthcare guideline development process. A.L. is president of Resuscitation Council UK and a member of the International Liaison Committee on Resuscitation Education, Implementation and Teams task force. A.D. is a member of the International Liaison Committee on Resuscitation Education, Implementation and Teams task force. The other authors declare no conflict of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.simulationinhealthcare.com).

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DOI: 10.1097/SIH.0000000000000761

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substantial advantage over their low-fidelity counterparts in pedagogical outcomes.[9]

There are few reports comparing high and low physical realism simulation specifically in LMICs. Therefore, this systematic review examined whether the level of physical realism of simulators/task trainers makes a difference in clinical, educational, and procedural outcomes in these settings.

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METHODS

The Society for Simulation in Healthcare commissioned this review as part of an effort to establish practice guidelines. The review was meticulously planned, executed, and reported in strict accordance with the quality standards set forth by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for reporting metaanalyses (see Table, Supplemental Digital Content 1, http://links.lww.com/SIH/A988, which presents the completed PRISMA checklist).[10] Although a study protocol had not been publicly disclosed before this review, an a priori protocol was created and diligently followed (see Table, Supplemental Digital Content 2, http://links.lww.com/SIH/A989, which presents the review protocol). Because this was a systematic review of previously published studies, there was no need for ethical approval or patient consent.

Research Question

The PICO format (Population, Intervention, Control, Outcomes)[11] was used to formulate the research question: In health care providers and/or health care trainees/students engaging in simulation training in LMICs (P), does a higher physical realism simulator or task trainer approach (I), as opposed to a lower physical realism simulator or task trainer approach (C), affect educational outcomes (immediate and retention): participant satisfaction, knowledge, skills, and attitudes; clinical outcomes: changes in health care practitioner behaviors and patient outcomes; and process outcomes: cost (O).

Study Eligibility

We included all comparative prospective and retrospective randomized and observational studies that have been published since 2011 to ensure the relevance of the evidence. We aimed to include publications in all languages, provided they had an available English abstract. Excluded from consideration were studies involving unpublished findings, trial protocols, commentaries, editorials, and review articles.

Data Sources

With the assistance of an information specialist, we devised search strategies using a blend of keywords and standardized index terms focused on assessing the level of physical realism in simulation settings within LMICs, involving comparative analyses (see Table, Supplemental Digital Content 3, http://links.lww.com/SIH/A990, which presents the search strategy). These searches were initially executed on January 29, 2022, across CINAHL via EBSCO (1963+), Ovid Embase (1974+), and Ovid Medline (1946+ encompassing epub ahead of print, in-process, and other nonindexed citations). We limited the search to commence from 2011, and ineligible studies were removed from consideration. An update of these searches was conducted on January 24, 2023.

Study Selection

The titles and abstracts of all potentially eligible studies underwent a dual and independent screening for inclusion. Subsequently, the selected studies underwent a more comprehensive, duplicate screening for eligibility, in accordance with predefined inclusion and exclusion criteria. In cases where discrepancies arose between the reviewers, resolution was achieved through discussion. In addition, the included articles were thoroughly examined for any supplementary citations.

Data Collection

Each reviewer independently extracted data from every study, and any discrepancies were addressed through discussion until a consensus was reached. The data included study design, country, World Bank classification, study population, study duration, description of intervention and control, and outcomes measured.

Analysis

Given the significant heterogeneity in clinical and methodological aspects among the identified studies in our search, conducting a metaanalysis was considered impractical. Instead, we opted for a narrative summary. To evaluate the risk of bias, we conducted independent and duplicate assessments using the revised Cochrane risk-of-bias tool (RoB2)[12] for randomized trials and the ROBINS-I tool[13] for nonrandomized studies. In addition, we assessed the certainty of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.[14]

RESULTS

Study Selection

The search identified 2311 articles after removal of duplicates. Of these, 2198 were excluded leaving 113 full-text articles to be screened for eligibility (see Fig. 1). In total, 11 studies were identified for inclusion.[15–25]

Study Characteristics

Nine randomized controlled studies with 627 participants[15–23] and 2 case-controlled studies with 159 participants[24,25] were conducted between 2006 and 2022 (Table 1). Most of the studies[15–22,25] were conducted in upper middle-income countries, as designated by the World Bank classification.[5] One study was conducted in a lower middle-income country[24] and 1 was conducted in a low-income country.[23] Participants included students and residents from both nursing and medicine. Higher physical realism was compared with lower physical realism training for a broad range of educational interventions including basic surgical skills, intramuscular injection skills, nurse training, life support awareness and skills, clinical examination skills, and more complex medical interventions (fiber optic bronchoscopy). Outcomes identified in the studies included participant satisfaction, participant confidence, skills acquisition, and performance in a clinical environment.

Risk of Bias Within Studies and Certainty of Evidence

The risk-of-bias assessments are summarized in Tables 2 and 3. There were no studies that were assessed to be low risk of bias. The main issues identified with the studies related to inadequate blinding of participants and assessors, inadequate randomization, and unclear selection processes. The certainty

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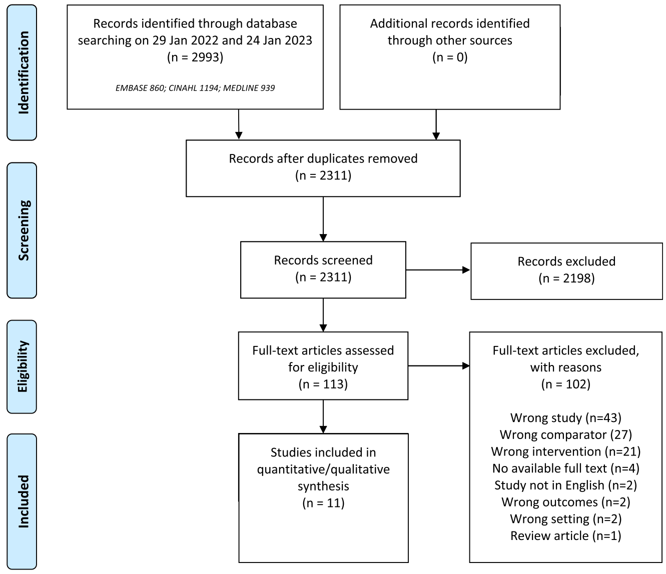

FIGURE 1. Flow chart of inclusion of articles.

of evidence was judged to be very low for all outcomes, downgraded for very serious risk of bias and inconsistency.

Outcomes

Participant Satisfaction

One randomized controlled study (n = 45) compared higher physical realism with lower physical realism mannequins for Advanced Trauma Life Support training. Although the higher physical realism mannequin performed better than lower physical realism mannequin in most procedures, students and instructors found that both were acceptable for teaching and learning Advanced Trauma Life Support surgical skills.[20] Data were presented graphically for this study and not in tabulated format, meaning that absolute numbers for each group are unclear.

Two case-controlled studies[24,25] (n = 159) showed mixed levels of satisfaction between higher and lower physical realism models. When used for teaching an Advanced Life Support protocol, the high physical realism group gave higher satisfaction scores on all items except the one about the variety of learning materials and activities used during simulation.[24] With regard to nursing education, the students' satisfaction scores were high in both groups. The satisfaction score in the control group (mean [SD], 4.50 [0.35]) was significantly higher than that in the intervention group (4.23 [0.33]), $t = 3.048$, $P = 0.003$.[25]

Participant Confidence

Four randomized controlled studies (n = 182) showed higher confidence levels for higher levels of physical realism.[17–19,21] Three studies from the same center involved the use of didactic training only (control), ethylene-vinyl acetate bench model (low physical realism), or animal bench model (high physical realism) to teach medical students a variety of suturing skills. In the study addressing basic suturing skills, students felt more confident ($P = 0.00$) to perform both types of sutures after training [simple suturing: control 1.67 ± 0.65, low 3.17 ± 0.72, high 3.25 ± 0.75; subdermal suturing: control 1.33 ± 0.49, low 2.83 ± 0.72, high 2.92 ± 0.67].[17] With regard to elliptical suture skills, students felt more confident to perform the skill in both simulation groups (control: 2.5 ± 0.52; low: 4.25 ± 0.73 and 4.13 ± 0.64; high: 4.13 ± 0.64 and 4.25 ± 0.71; $P = 0.00$).[18] For rhomboid flap skills, both simulation groups showed similar confidence rates and superior to the didactic training group (control: 1.75 ± 0.75; low: 3.17 ± 0.83 and 3.25 ± 0.62; high: 3.68 ± 0.67 and 3.33 ± 0.78; $P < 0.05$ between intervention groups; $P > 0.05$ intervention vs. control).[19] Finally, a study comparing a virtual reality mannequin with a standard mannequin for fiber optic bronchoscopy showed that participants' confidence increased after training but did not differ significantly between groups.[21]

Two case-controlled studies (n = 159) showed mixed results for confidence between higher and lower physical realism models.[24,25] The high physical realism group teaching Advanced Life Support awareness showed greater confidence in all parameters except the one about the resourcefulness of the techniques in learning simulation.[24] For nursing education, the mean self-confidence score in the control group (4.08 [0.38]) was significantly higher than that in the intervention group (3.79 [0.34]), $t = 3.120$, $P = 0.003$.[25]

Skills Acquisition

Six randomized controlled studies (n = 469) examined skills acquisition, including self-efficacy scoring. There were no differences in skills acquisition between higher and lower physical realism models for intramuscular injections, suturing, fiber optic intubation, and breast examination.[16–19,21,23] One study addressing teaching of intramuscular injection skills showed that the hybrid simulation model (intervention) group had better total General Self-Efficacy Scale scores than the standard (control) model group (91.1 ± 14.98 vs. 85.23 ± 12.05, $P < 0.05$). The mean score of the intervention group in the State-Trait Anxiety Inventory was lower than that of the control group (32.02 ± 8.81 vs. 35.12 ± 7.82, $P < 0.05$). The mean score of the intervention group was higher in the Guide to Performing Intramuscular Injections compared with the control group (28.02 ± 5.36 vs. 21.86 ± 2.85, $P < 0.05$)[16] One study using higher versus lower physical realism of bench models for simple and subdermal suturing training showed

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TABLE 1. Study Characteristics

Study	Design	Setting/Date	Participants	Research Question	Intervention	Control	Outcomes	Conclusion	Limitations
Akdemir 2014	RCT	Türkiye (UMIC) January 2012–June 2013	60 Gynecology residents	To investigate whether a virtual reality simulator (LapSim) and traditional box trainer are effective tools for the acquisition of basic laparoscopic skills	LapSim and box trainer	Standard surgical education	Performance	Novice residents who trained on a LapSim or box trainer performed similarly. Both groups performed better live laparoscopies than residents who trained via standard clinical surgical education.	• single center • convenience sample • participants and investigators were not blinded • sample size was too small to obtain generalizable results.
Amanak 2020	RCT	Türkiye (UMIC) May 2–25, 2018	73 Midwifery students	To compare low-fidelity simulation/model and hybrid simulation techniques for teaching how to perform intramuscular injections.	Hybrid simulation model	Standard model	Skill	Students using a hybrid simulation method had better levels of self-efficacy and skill compared with those trained on the conventional method.	• single center • participants and investigators not blinded • dataset was based on self-reported results • possibility of bias cannot be excluded.
Denadai 2012	RCT	Brazil (UMIC) 1 d (date not specified)	36 Novice medical students	To evaluate whether bench model fidelity interferes with the acquisition of suture skills by novice medical students.	Animal bench model (high-fidelity); organic bench model (low-fidelity)	Didactic materials	Confidence Skill	The acquisition of suture skills on the low-fidelity bench model was similar to that of the high-fidelity bench model	• single center • assessed only 1 basic surgical skill (suturing); caution should be exercised in generalizing the results to other technical skills. • No assessment of retention • both the pretests and posttests were conducted on an inanimate table model.
Denadai & Oshiiwa 2014	RCT	Brazil (UMIC) 1 d (date not specified)	40 Novice medical students	To evaluate if the bench model fidelity interferes with the acquisition of elliptical excision skills by novice medical students.	Animal bench model – 2 groups (high-fidelity); organic bench model – 2 groups (low-fidelity)	Didactic materials	Confidence Skill	The acquisition of elliptical excision skills on the low-fidelity bench model was similar to that of the high-fidelity bench model	• single center • convenience sample • assessed only 1 basic skin surgery skill (elliptical excision training), which does not meet all the needs of medical students in training.
Denadai & Saad-Hossne 2014	RCT	Brazil (UMIC) 1 d (date not specified)	60 Novice medical students	To assess if the bench model fidelity interferes with the acquisition of rhomboid flap skills by medical students.	Animal bench model – 2 groups (high-fidelity); organic bench model – 2 groups (low-fidelity)	Didactic materials	Confidence Skill	The acquisition of rhomboid flap skills on the low-fidelity bench model was similar to that of the high-fidelity bench model	• single center • convenience sample • only investigated a single surgery procedure (rhomboid flap)

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Garcia 2019	RCT	Brazil (UMIC) 1 d (date not specified)	36 Physician candidates and 9 instructors; ATLS	To determine whether the SurgeMan model would have equivalent learner and instructor satisfaction compared with TraumaMan and animal models for the surgical procedures of the ATLS course. Secondary objective was to evaluate the students' and instructors' opinions on artificial models as substitutes for animal models.	High-fidelity manikin (TraumaMan) and low-fidelity manikin (SurgeMan)	Animal model	Satisfaction	SurgeMan should be an approved model to teach ATLS skills. It should particularly be considered in areas where cost is a significant concern	• single center • convenience sampling • allocation not concealed • investigators and participants were not blinded • dataset was based on self-report, so bias cannot be ruled out • level of specialization of the participants was not balanced because the instructors were general surgeons, and 70% of the students had training in general surgery
Jiang 2018	RCT	China (UMIC) 1 d (date not specified)	46 Anesthesia residents	To compare the efficacy and efficiency of virtual reality simulation (VRS) with high-fidelity manikins in the simulation-based training of fiber optic bronchoscope manipulation in novices.	Virtual reality simulation	Standard mannikin	Confidence Skill	Intervention more efficient than control on simulation-based flexible fiber optic manipulation in novices, but similar effects can be achieved in both modalities after adequate training.	• single center • convenience sample • participants and investigators were not blinded • sample size was too small to obtain generalizable results • study did not follow up on the residents' performance in clinical practice, so learning may not have the same impact in the long term
Labuschagne 2022	RCT	South Africa (UMIC) 1 d (date not specified)	53 Final-year medical students	To compare the effectiveness of CPR compression training of final-year undergraduate medical students using electronic feedback QCPR manikins and training using conventional manikins.	QCPR manikin	Standard manikin	Performance	Efficacy of CPR training was comparable. CPR training in low-resource settings can be just as effective on conventional manikins.	• single center • sample size was too small to obtain generalizable results • researchers and participants were not blinded • entire dataset was based on self-report, so the possibility of bias cannot be excluded • study did not assess the transfer and retention of skills • participants' previous knowledge or basic training in CPR could have introduced bias

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TABLE 1. *(Continued)*

Study	Design	Setting/Date	Participants	Research Question	Intervention	Control	Outcomes	Conclusion	Limitations
Murthy 2020	RCT	Rwanda (LIC) July 2014–March 2015	214 Medical students and residents	To determine whether learning clinical breast examination (CBE) on a low-fidelity (LF) simulation model conferred similar skill acquisition as training on a high-fidelity (HF) breast model and to evaluate the overall improvement in technical skills of trainees before and after delivery of a simulation-based session designed to teach CBE in a resource-poor setting.	HF model	LF model	Skill	Mean difference in examination scores were not significantly different between participants trained with HF vs. LF models. The LF models can be used as cost-effective teaching tools for CBE skill acquisition in resource-poor areas.	• single center • convenience sample • participants and investigators were not blinded • sample size was too small to obtain generalizable results • the same investigator designed and conducted the study. He was also the lecturer, the video recorder, and the evaluator of the video study
Rishipathak 2020	Cross-sectional study	India (LowMIC) 2 d (date not specified)	100 Postgraduate emergency medicine students	To compare self-efficacy reported by EMS students after ACLS protocol on cardiac arrest algorithm using high-fidelity vs. low-fidelity simulation.	High-fidelity manikin	Part task trainer	Satisfaction Confidence	Intervention has a positive impact on confidence and satisfaction and a boost for self-efficacy for EMS students	• single center • participants and investigators were not blinded • sample size was too small to obtain generalizable results • investigators and participants were not blinded • dataset was based on self-report, so the possibility of bias cannot be excluded
Wang 2013	Cross-sectional study	China (UMIC) 16 wk (date not specified)	59 Nursing students	To explore differences in the outcomes related to use of 2 levels of simulation fidelity for nurse education.	High-fidelity (SimMan)	Moderate fidelity (MicroSim)	Satisfaction Confidence	Satisfaction and confidence scores high in both groups, with higher scores for both in control group.	• single center • convenience sample • sample size was too small to obtain generalizable results • investigators and participants were not blinded • dataset was based on self-report. Therefore, the possibility of bias cannot be excluded

ACLS, advanced cardiac life support; ATLS, advanced trauma life support; World Bank classification: EMS, emergency medical service; LIC, lower income country; LowMIC, lower middle-income country; UMIC, upper middle-income country.

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TABLE 2. Risk-of-Bias Assessment Using ROB2 for Randomized Controlled Studies

Study	Total (N)	Population	Allocation Generation	Allocation Concealment	Blinding Participants	Blinding Assessors	Outcome Complete	Outcome Selective	Other Bias	Overall
Denadai 2012	36	Medical students	Some concerns	Low	Low	Low	Low	Low	Low	Some concerns
Akdemir 2014	60	Gynecology residents	Low	Low	High	High	Low	Low	Low	High
Denadai & Oschiiwa 2014	40	Medical students	Some concerns	Low	Low	Low	Low	Low	Low	Some concerns
Denadai & Saad-Hosne 2014	60	Medical students	Some concerns	Low	Low	Low	Low	Low	Low	Some concerns
Jiang 2018	46	Anesthesia residents	Low	Low	Low	High	Low	Low	Low	High
Garcia 2019	36	ATLS candidates	High	High	High	High	Low	Low	Low	High
Amanak 2020	73	Midwifery students	Low	High	High	High	Low	Low	Low	High
Murthy 2020	214	Medical students & residents	Low	Low	High	High	Low	Low	Low	High
Labuschagne 2022	53	Medical students	Some concerns	Low	Low	Low	Low	Low	Low	Some concerns

ATLS, advanced trauma life support.

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that animal and organic bench model groups demonstrated similar performance. These in turn were both better in the Global Rating Scale evaluation ($P = 0.00$) compared with the didactic-only (control) [simple suturing mean difference (MD): control 3.27, low 14.56, high 14.77; subdermal suturing MD: control 1.63, low 13.17, high 14.00].[17] One study that looked at elliptical suture training showed no significant difference between groups (Mean difference for low physical realism groups: 14.57 and 14.75, high physical realism groups 15.13 and 15.00; $P > 0.05$).[18] Both high and low physical realism groups of rhomboid flap skills had similar posttraining results and were better than didactic-only (control: 13.82 ± 1.11; low: 24.42 ± 1.11 and 24.58 ± 1.24; high: 24.42 ± 1.50 and 24.5 ± 1.24; $P < 0.05$ between intervention groups; $P > 0.05$ intervention vs. control).[19]

One study looking at virtual reality versus standard mannequin training for fiber optic intubation showed that plateaus in the learning curves were achieved more swiftly after 19 (95% confidence interval, 15–26) practice sessions in the intervention group as opposed to 24 (95% confidence interval, 20–32) in the control group. No significant difference was found between the groups in procedure time [13.7 (6.6) vs. 11.9 (4.1) secs, t =1.101, P = 0.278] or global rating scale [3.9 (0.4) vs. 3.8 (0.4), $t = 0.791$, $P = 0.433$].[21] Finally, another study using higher versus lower physical realism to teach clinical breast examination skills showed that the mean difference in examination scores were not significantly different [postlecture MD 0.86 ± 0.69, $P = 0.16$; postlecture and sim MD 0.03 ± 0.38, $P = 0.66$; crossover examination MD 0.1 ± 0.37, $P = 0.29$][23]

Performance in Clinical Environment

Two randomized controlled studies (n = 113) measured provider performance in a clinical environment. There was no difference in provider performance between higher and lower physical realism models of laparoscopic surgery and cardiopulmonary resuscitation (CPR).[15,22] A study comparing a higher with a lower physical realism simulation trainer for laparoscopic surgery showed that the median (range) total score of the general skills part of the objective structured assessment in laparoscopic surgery rating scale was 17 (15–19) points in the higher physical realism group, 17 (16–18) points in the lower physical realism group, and 11.5 (10–14) points in the control group (senior residents with previous laparoscopic experience). The median operation time to complete the procedure was 340 (260–400) seconds in the higher physical realism group, 340 (270–430) seconds in the lower physical realism group, and 425 (320–530) seconds in the control group. There were no differences between the higher and lower physical realism groups[15] One study comparing higher with lower physical realism mannequins for CPR training showed that the median flow fraction for the higher physical realism group was 78.0% (interquartile range [IQR], 63–89) and for the lower physical realism group 80.0% (IQR, 74–85). The median number of compressions for the higher physical realism group was 104 (IQR, 101–109) and for the lower physical realism group 107 (IQR, 79–124). Both groups achieved a 100% compression rate with adequate depth. The maximum total effectiveness of both groups was 99%. No statistically significant difference was seen for the overall percentage of compression effectiveness between the groups[22]

DISCUSSION

The findings of this review suggest that lower as opposed to higher physical realism simulators/task trainers should be used for health care simulation training in LMICs. The lack of evidence for any clear benefit or desirable effects of higher physical realism combined with its higher cost argue against recommending its use in most LMIC settings.

In addition to cost-effectiveness, the impact of resources required and equity are counterintuitive to higher physical realism training. In any setting it is critical to consider the feasibility, sustainability, and scalability of implementation, which in LMIC settings favor lower physical/low-cost realism in the implementation of simulation-based programs. If low-cost higher physical realism training equipment were to become available, then this would impact the principle of feasibility, but further directed research is needed to identify such a solution.

TABLE 3. Risk-of-Bias Assessment Using ROBINS-I for Nonrandomized Studies

Study	Year	Total (N)	Population	Eligibility Criteria	Exposure/Outcome	Confounding	Follow-Up	Overall
Wang	2013	59	Nursing students	Moderate	Serious	Low	Low	Serious
Rishipathak	2020	100	Medical students	Moderate	Serious	Low	Low	Serious

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Our review confirmed that simulation-based medical education is an effective methodology in LMICs compared with no simulation. We found that simulation is effective in acquisition and retention of suturing, CPR, and other surgical/procedural skills. Unfortunately, implementation is often prohibited by the human resources and financial cost required.

There was limited evidence in this review for desirable effects in participant satisfaction[20] and confidence.[17–19,21] The remaining studies presented mixed results for these outcomes.[24,25] Four studies demonstrated no difference in skills acquisition between higher versus lower physical realism models,[17–19,23] and 2 studies found that hybrid physical realism or higher physical realism models were better than the lower physical realism models.[16,21] Two studies examined learner performance with simulated laparoscopic skills and quality of CPR skills, which showed no difference between higher and lower physical realism models.[15,22]

Given the gaps in opportunities present in LMIC settings, it is important to consider the value of training equity over physical realism. The associated resources and costs may prohibit high physical realism simulation training in some LMIC settings.[26,27] If implementation of high physical realism simulation was to be prioritized in these settings, it would likely come at the expense of other important health care educational interventions in these low-resource settings. This should be balanced against the benefits of improving patient outcomes with potentially little cost and lower resources if low physical realism models are used. It is also notable that significant inequity already exists within health care and medical education in LMIC settings due to constraints in resource allocation and variable support from local government and nongovernmental entities and ministries of health.[28] Although physical realism does play a role in learner and stakeholder acceptability, the high comparative cost may not be acceptable to stakeholders. Health ministries and nongovernmental organizations must inevitably consider factors of scalability and logistics of implementation of simulation in addition to cost. Most levels of health care trainees, from the viewpoint of learners as stakeholders, perceive acceptability of any form of simulation to be an acceptable benefit.[29] Due to high cost, feasibility of program implementation and sustainability for high physical realism simulation will inevitably be negatively impacted. This is frequently amplified by the lack of trained individuals for repair and maintenance of equipment in LMIC settings, creating issues with dissemination and sustainability of high-technology equipment.

Limitations and Future Research

Our review was limited by the number of studies comparing lower physical realism with higher physical realism in LMICs. In addition, most studies were conducted in upper middle-income settings, highlighting the need for more scrutiny of low- and lower middle-income settings. The paucity of evidence precluded any meaningful subgroup comparisons between LMIC settings.

All studies examined had significant issues with multiple confounding factors, methodological validity, and significant heterogeneity of learner populations, ranging from medical students to midwifery students to practicing surgeons. The definitions of higher versus lower physical realism were heterogeneous. Generalizability was low due to metrics used to assess main study outcomes. Most of these studies did not directly compare high versus low physical realism mannequins, and those that did failed to show significant differences between the 2 groups. Studies with outcomes of skill acquisition and performance in clinical practice were downgraded for risk of bias and inconsistency, resulting in very low certainty of evidence.

The overall balance of effects does not favor higher versus lower physical realism simulation in LMICs, but it is important to consider that there are major gaps in simulation research in LMICs. None of the studies examined patient outcomes, making the pragmatic value of study outcomes more limited in clinical practice applications. None of the studies discussed previously examined cost efficacy, resulting in our inference that equivocal efficacy combined with large financial and human resource costs undermines current implementation strategies for high physical realism simulation training in LMICs.

CONCLUSION

Our systematic review suggests that lower as opposed to higher physical realism simulators/task trainers should be used for health care simulation training of individuals in LMICs. Further research is needed to identify a solution that considers physical realism balanced with cost, equity, impact of resources, sustainability, and scalability. Future studies in LMICs should focus on appropriate study populations and interventions and be adequately powered to address relevant study outcomes. In addition, it will be important for future studies to use consistent and standardized definitions of "high" and "low" physical realism and to conduct robust comparative studies between the 2 modalities, given the paucity of high-quality literature currently available to address this research question.

ACKNOWLEDGMENT

The authors would like to thank Danielle Gerberi (information specialist) for her help with this review. We would also like to thank the leadership team from the Society for Simulation in Healthcare (Dimitrios Stefanidis, Sharon Decker, Sharon Muret-Wagstaff, David Cook, Mohammad Kalantar, Mohammed Ansari, Kathryn Adams, and Kristyn Gadlage) for their support and guidance in this process.

REFERENCES

1. Cheng A, Lang TR, Starr SR, Pusic M, Cook DA. Technology-enhanced simulation and pediatric education: a meta-analysis. *Pediatrics* 2014; 133(5):e1313–e1323.
2. Aggarwal R, Mytton OT, Derbrew M, et al. Training and simulation for patient safety. *BMJ Qual Saf* 2010;19(Suppl 2):i34–i43.
3. Lioce L, Loprieato J, Downing D, et al, the Terminology and Concepts Working Group. *Healthcare Simulation Dictionary (2nd Ed)*. Rockville, MD: Agency for Healthcare Research and Quality; 2020.
4. La Cerra C, Dante A, Caponnetto V, et al. Effects of high-fidelity simulation based on life-threatening clinical condition scenarios on learning outcomes of undergraduate and postgraduate nursing students: a systematic review and meta-analysis. *BMJ Open* 2019;9(2):e025306.
5. Fantom NJ, Serajuddin U. The World Bank's classification of countries by income. *World Bank Policy Research Working Paper* 2016;7528.
6. Puri L, Das J, Pai M, et al. Enhancing quality of medical care in low income and middle income countries through simulation-based initiatives: recommendations of the Simnovate Global Health Domain Group. *BMJ Stel* 2017;3:S15–S22.
7. Campain NJ, Kailavasan M, Chalwe M, et al. An evaluation of the role of simulation training for teaching surgical skills in sub-Saharan Africa. *World J Surg* 2018;42:923–929.

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8. Qayumi K, Pachev G, Zheng B, et al. Status of simulation in health care education: an international survey. *Adv Med Educ Pract* 2014;5:457–467.

9. Lefor AK, Harada K, Kawahira H, Mitsuishi M. The effect of simulator fidelity on procedure skill training: a literature review. *Int J Med Educ* 2020; 11:97–106.

10. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev* 2021;10(1):89.

11. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. *ACP J Club* 1995; 123(3):A12–A13.

12. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019;366:l4898.

13. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016;355: i4919.

14. Schünemann H. *The GRADE Handbook*. Cochrane Collaboration; 2013.

15. Akdemir A, Şendağ F, Öztekin MK. Laparoscopic virtual reality simulator and box trainer in gynecology. *Int J Gynaecol Obstet* 2014;125(2):181–185.

16. Amanak K. Comparing low fidelity simulation/model and hybrid simulation techniques for teaching how to perform intramuscular injections: a case control study. *J Pak Med Assoc* 2020;70(10):1698–1705.

17. Denadai R, Oshiiwa M, Saad-Hossne R. Does bench model fidelity interfere in the acquisition of suture skills by novice medical students? *Rev Assoc Med Bras* 2012;58:600–606.

18. Denadai R, Oshiiwa M, Saad-Hossne R. Teaching elliptical excision skills to novice medical students: a randomized controlled study comparing low-and high-fidelity bench models. *Indian J Dermatol* 2014;59(2): 169–175.

19. Denadai R, Saad-Hossne R, Raposo-Amaral CE. Simulation-based rhomboid flap skills training during medical education: comparing low-and high-fidelity bench models. *J Craniofac Surg* 2014;25(6): 2134–2138.

20. Garcia DFV, Domingues CA, Collet E Silva FS, et al. Efficacy of a novel surgical manikin for simulating emergency surgical procedures. *Am Surg* 2019;85(12):1318–1326.

21. Jiang B, Ju H, Zhao Y, Yao L, Feng Y. Comparison of the efficacy and efficiency of the use of virtual reality simulation with high-fidelity mannequins for simulation-based training of fiberoptic bronchoscope manipulation. *Simul Healthc* 2018;13(2):83–87.

22. Labuschagne MJ, Arbee A, de Klerk C, et al. A comparison of the effectiveness of QCPR and conventional CPR training in final-year medical students at a South African university. *Afr J Emerg Med* 2022;12(2): 106–111.

23. Murthy SS, Ntakiyiruta G, Ntirenganya F, et al. A randomized cross-over trial focused on clinical breast exam skill acquisition using high fidelity versus low fidelity simulation models in Rwanda. *J Surg Educ* 2020;77(5): 1161–1168.

24. Rishipathak P, Hinduja A, Sengupta N. A comparative analysis of self-efficacy in low fidelity vs high fidelity simulation post advanced cardiac life support (ACLS) sessions on cardiac arrest algorithm amongst EMS students of Pune, India. *Indian J Public Health Res Dev* 2020;11:415–419.

25. Wang AL, Fitzpatrick JJ, Petrini MA. Comparison of two simulation methods on Chinese BSN students' learning. *Clin Simul Nurs* 2013;9(6): e207–e212.

26. Ayaz O, Ismail FW. Healthcare simulation: a key to the future of medical education—a review. *Adv Med Educ Pract* 2022;13:301–308.

27. Yin Mar O, Nataraja RM. The application of simulation-based medical education in low- and middle-income countries; the Myanmar experience. *Semin Pediatr Surg* 2020;29(2):150910.

28. Kruk ME, Gage AD, Arsenault C, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. *Lancet Glob Health* 2018;6(11):e1196–e1252.

29. Najjuma JN, Bajunirwe F, Twine M, et al. Stakeholder perceptions about the establishment of medical simulation-based learning at a university in a low resource setting: a qualitative study in Uganda. *BMC Med Educ* 2020;20(1):379.

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