

Exploring Optimal Group Sizes for Learning in Medical Simulation: A Systematic Review

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ABSTRACT

OBJECTIVES: Simulation is an effective teaching method that improves learner competence and confidence. Optimizing group size balances efficiency without sacrificing efficacy. While simulation technology is widely used in medical education, no standard for learner group size exists. This study investigates the optimal group size for simulation, aiming to identify best practices that maximize efficiency and efficacy in learning environments.

METHODS: This systematic review adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. A team of emergency medicine educators screened citations and reviewed relevant full-text articles. Inclusion criteria focused on group sizes with the best outcomes. Quality assessment employed the Medical Education Research Study Quality Instrument approach to evaluate evidence.

RESULTS: Thirty-four articles were identified; 17 were deemed relevant for full-text review. The studies varied in methods, including prospective and retrospective reviews, mixed methods, and randomized controlled trials. Smaller groups improved outcomes, with an ideal size dependent on learning objectives. Five studies suggested groups of up to 4 learners were optimal, with mixed results on the exact number. One study identified 6 as the ideal group size. Debriefing was effective in larger groups, while procedural skills were best taught in groups of 2 to 4 learners.

CONCLUSION: This review suggests smaller group sizes are more effective for efficiency, knowledge, and confidence. For procedural skills, groups of 2 to 4 are most effective, and effectiveness declines with more than 6 participants. Smaller groups allow for more hands-on learning and cognitive engagement. While clinical skills can be taught in larger groups, learners favor smaller groups for debriefing and complex scenarios. Effective curriculum planning should account for available resources, the type of simulation, and the material being taught, with group sizes adjusted to optimize learning outcomes.

KEYWORDS: medical simulation, group size, medical education

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Introduction

Simulation is defined as an array of structured activities that represent actual or potential situations in education and practice. These activities allow participants to develop or enhance their knowledge, skills, and attitudes, or to analyze and respond to realistic situations in a simulated and safe environment. Resources required for a simulation include instructors and manikins, task trainers, standardized patients, or a combination of these. Manikins can be classified as “high-fidelity” or “low-fidelity,” depending on the extent to which they simulate a live patient or scenario. Simulation technology has become a popular method for training in medical education at both the undergraduate and graduate levels. It allows learners to practice both skill-based competencies and clinical scenarios in a realistic, safe, and controlled environment.^{1–4} Not only do learners find simulation enjoyable, but studies have shown simulation to be a valuable and effective teaching method, demonstrating improvements in learner competence and confidence.^{5–11} Many studies have shown it to be superior to traditional

training methods such as didactics or test-based methods.^{5,12–14} The ethical imperative to “first do no harm” also supports high-fidelity simulation as a way for learners to gain practice prior to performing in real-life clinical situations.^{2,15–18}

Although simulation offers numerous benefits, it also presents limitations, notably financial constraints, spatial requirements, and time restrictions affecting both faculty and learners.^{19,20} Limitations often relate to cost; however, cost analysis of simulation practices can be difficult to measure. While up-front costs of the simulation center and the costs of designing the simulation scenario and attaining the necessary equipment are fixed, the downstream effects can be measured at any number of time points. Benefits can be measured as a rubric-defined evaluation of technical skill, or as behavioral changes that lead to improved patient outcomes.^{19–22} An ideal environment for simulation learning should be sought to balance these difficult-to-measure costs and benefits.

Simulation can be performed individually or in groups. Traditional thinking has suggested that smaller group size



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and lower instructor-to-learner ratios are optimal. However, some studies have shown benefits of larger group size, particularly with skills-based training in dyads, compared to individuals.^{23,24} Additionally, the ability to lead simulation in larger groups can theoretically increase efficiency while minimizing the costs of simulation.

Despite the widespread use of simulation technology and its popularity as a method for training in medical education, there are no standard practice guidelines describing optimal group sizes for simulation. Further, ideal group size can vary depending on the type of simulation, as procedural simulations (eg, technical skills like intubation or central line placement) and clinical simulations (eg, teamwork in code situations or patient communication scenarios) have different educational objectives, learner dynamics, and resource demands.

Optimizing group size involves balancing the efficiency of educational delivery with the efficacy of skill development, ensuring that learners receive the intended educational benefit without overburdening resources or compromising individual participation. Educators must carefully consider these factors to design an effective and impactful curriculum. We aim to conduct a systematic review to identify best practices regarding group size in medical education simulation, examining how different types of simulation influence what constitutes an optimal group size and to provide evidence-based recommendations.

Methods

This is a systematic review addressing the ideal group size for learners in medical-based simulation. The review was conducted in adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.²⁵ It was performed in accordance with best practice guidelines. Being a systematic review, it was not necessary to obtain institutional ethics approval.

Study selection

We conducted a comprehensive search of MEDLINE, Embase, Cochrane, PubMed, Web of Science, MedEd Portal, and Google Scholar databases for articles published from inception until September 28, 2022 to identify articles discussing simulation and group size within medical education. Studies that investigated group size for simulation-based education were included in the final analysis. This included research that directly evaluated how group size influenced educational outcomes, learner engagement, performance, or skill acquisition in simulation settings. Additionally, all references from relevant articles were reviewed to identify any potential missed studies.

Inclusion and exclusion criteria

Each article identified was screened by 2 researchers and included for final review if it described best outcomes for learners with regards to group size in simulation. For studies that

met this criterion, the group of investigators collected additional details including type of simulation (procedural or clinical), study design, population, group sizes and outcomes. No study design restrictions were imposed. Exclusion criteria consisted of articles not in English, nonhuman studies, nonmedical-related studies, and abstracts without manuscripts. Abstracts, opinion pieces or editorials, and literature reviews were excluded from the review.

Data extraction and analysis

Papers that met the inclusion criteria were analyzed by 2 reviewers independently and then data was extracted onto a standardized form. The following information was abstracted and examined: study's first author, title, year published, type of trial, country where the study took place, whether single versus multicenter, training level of study participants, take-away, group sizes, whether clinical or procedural skill, and usage of manikins, task trainers, virtual reality (VR) trainers, or human actors. While there is no definition of "small" or "large," for the purpose of this study we are considering groups of 2 to 6 as a smaller group size.

The analysis primarily relied on a narrative approach due to the limited number of relevant studies found. Conducting a meta-analysis was not feasible due to insufficient data availability as well as the heterogeneity of study designs and data.

Quality assessment

Two independent reviewers independently assessed the risk of bias in the included studies using the Medical Education Research Study Quality Instrument (MERSQI), an instrument with 10 items (18 maximum points) that enables the evaluation of the methodological rigor of articles, which has previously been demonstrated to have good interrater reliability.^{26,27} MERSQI items reflect 6 domains: study design, sampling, type of data, validity of evaluation instrument, data analysis, and outcomes. MERSQI adopts the Kirkpatrick 4-level model to approach the effectiveness construct. All disagreements were resolved by discussion and consensus.

Results

Search results

A total of 281 records were retrieved. After removing duplicate studies and those that did not meet inclusion criteria, 34 studies were assessed for eligibility and underwent initial title and abstract screening. Of these studies, 17 were determined to be relevant in describing simulation and group size; these underwent full-text screening and standardized data extraction (see Figure 1).

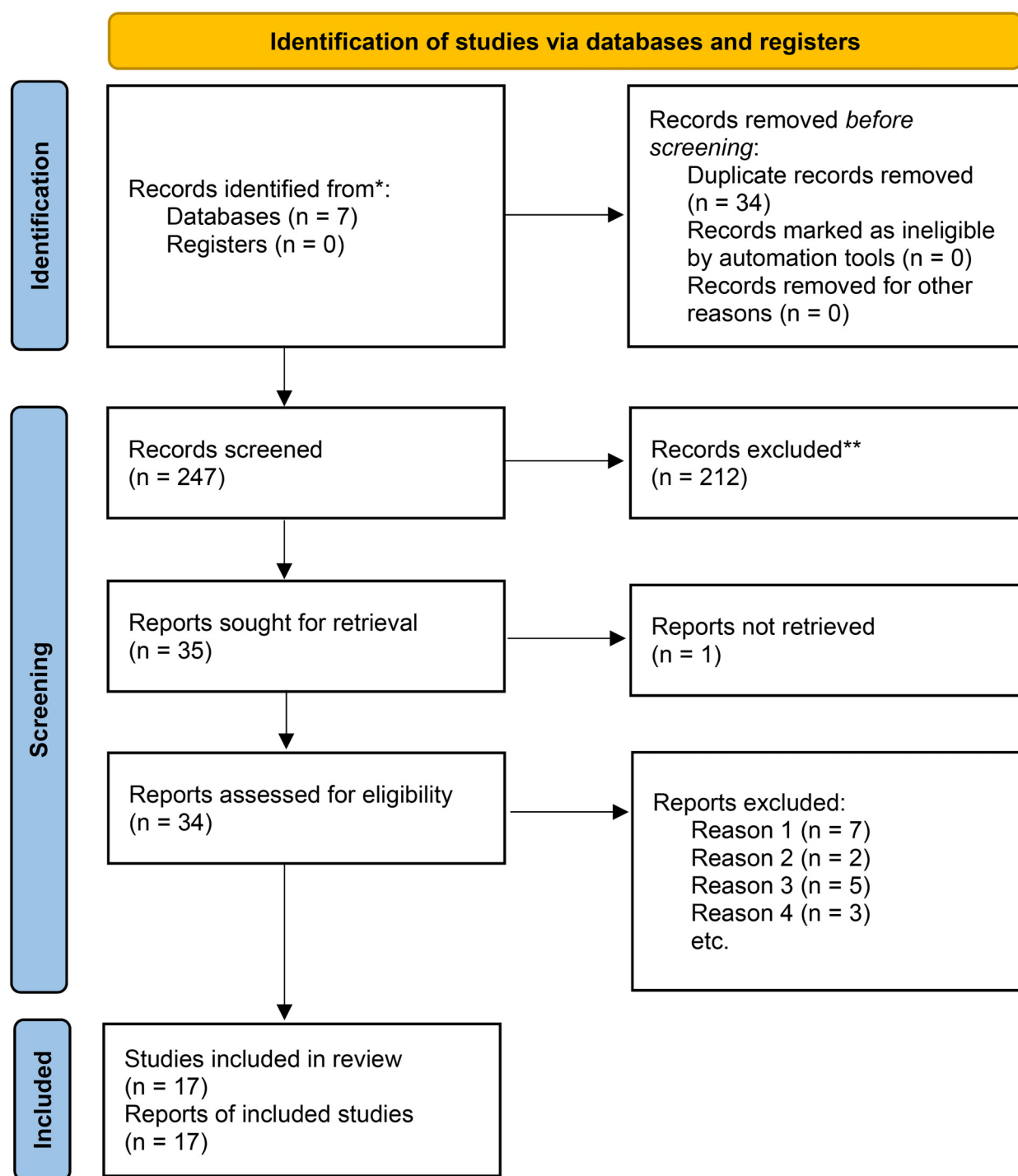


Figure 1. PRISMA flow diagram.
PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

Study characteristics and quality

Characteristics of included studies are summarized in Table 1. Studies were published between 2002 and 2022 and conducted in the United States, Australia, Switzerland, Denmark, Germany, Canada, and South Korea. All were single institution studies; 11 were conducted in undergraduate medical education, 2 in graduate medical education, 1 in nursing education, 2 in interprofessional groups, and 1 in interprofessional instructors.

Ten of the studies utilized manikin-based (2 specifically used ultrasound manikin trainers), 3 utilized task trainers, 2 utilized VR trainers, and 2 utilized human actors. Ten studies were classified as procedural skills, 6 were classified as clinical skills, and 1 study did not fit into either category but rather assessed the teachers' ability to recognize students' procedural errors.

Among the studies there were 12 randomized controlled trials, 1 prospective review study, 1 retrospective review study, and 3

Table 1. Characteristics of included studies.

FIRST AUTHOR	TITLE	TRIAL TYPE	COUNTRY	BRIEF DESIGN	SIMULATION TYPE	MODALITY	OUTCOMES
Nabecker	Effective group size for teaching CPR	Randomized control trial	Switzerland	Assessed instructors' ability to correct errors based on group size	Teaching skills	Manikin	Increasing group size worsened instructors' ability to correct performance errors
Rezmer	Impact of group size on the effectiveness of a resuscitation simulation curriculum for medical students	Randomized control trial	USA	Posttraining learner survey	Clinical skills	Manikin	Varying group size had no effect on student's experience or exam performance
Lim	Team size impact on assessment of teamwork in simulation-based trauma team training	Nonrandomized 2 groups	USA	Teamwork scores were recorded by participants and nonparticipants	Clinical skills	Manikin	Larger teams perform less well than smaller teams
Hensel*	The effects of group size on outcomes in high-risk, maternal–newborn simulations	Nonrandomized 2 groups	USA	Posttraining learner survey	Clinical skills	Manikin	Good outcomes noted in all size groups studied
Noerholk	Does group size matter during collaborative skills learning? A randomized study	Randomized control trial	Denmark	Pre, post, and transfer (retention) test	Procedural skills	Manikin	Group size upto 4 did not impair skills transfer
Mahling	Basic life support is effectively taught in groups of 3, 5, and 8 medical students: a prospective, randomized study	Randomized control trial	Germany	Pre and posttest	Procedural skills	Manikin	Scores and pass rates were comparable in size group studied although smaller groups had advantages in teaching interventions and hands-on time
Brim	Long-term educational impact of a simulator curriculum on medical student education in an internal medicine clerkship	Single group cross-sectional or observational	USA	Pre and postsimulation curricular study survey	Clinical skills	Manikin	Smaller group size improves simulation experience
Owen	Improving learning of a clinical skill: the first year's experience of teaching endotracheal intubation in a clinical simulation facility	Nonrandomized 2 groups	Australia	Descriptive poststudent evaluation, posttraining assessment	Procedural skills	Manikin	Groups of 2 were the most effective, groups of 3 to 5 found too much time between receiving feedback and reattempting the procedure
Glatts	Student perspectives of interprofessional group debriefing: use of the national league for nursing guide for teaching thinking	Single group cross-sectional or observational	Canada	Posttraining learner survey	Clinical skills	Standardized patients	Group size matters for debriefing groups, smaller groups preferred
Borges	Optimizing multidisciplinary simulation in medical school for larger groups: role assignment by lottery and guided learning	Nonrandomized 2 groups	USA	Posttraining learner survey	Clinical skills	Manikin	Successful educational outcomes with larger groups, upto 19 students
Cho	The effect of peer-group size on	Randomized controlled trial	South Korea	Posttest	Procedural skills	Manikin	Group size less than 6 did not affect test

(continued)

Table 1. Continued.

FIRST AUTHOR	TITLE	TRIAL TYPE	COUNTRY	BRIEF DESIGN	SIMULATION TYPE	MODALITY	OUTCOMES
	the delivery of feedback in basic life support refresher training: a cluster randomized controlled trial						score however allowed more participation during peer feedback
Dubrowski	Randomised, controlled study investigating the optimal instructor: student ratios for teaching suturing skills.	Randomized control trial	Canada	Pre, post, and transfer (retention) test	Procedural skills	Task trainers	The optimal instructor to student ratio was 1:4, higher ratios or lower ratios resulted in less learning
Shanks	Use of simulator-based medical procedural curriculum: the learner's perspective	Single group cross-sectional or observational	Canada	Posttest and postsurvey	Procedural skills	Task trainer	Instructor to learning ratio 1:3 to 4 is ideal
Shanks	Are 2 heads better than 1? Comparing dyad and self-regulated learning in simulation training	Randomized controlled trial	Canada	Pre, post, and transfer (retention) test	Procedural skills	Task trainer	Learning in pairs as effective as independent self-regulated learning
Tolsgaard	The effect of dyad versus individual simulation-based ultrasound training on skills transfer	Randomized controlled trial	Denmark	Pre, post, and transfer (retention) test	Procedural skills	Manikin	Pair practice improves efficiency of simulation-based training and noninferior to individual practice
Rader	A study of the effect of dyad practice versus that of individual practice on simulation-based complex skills learning and of students' perceptions of how and why dyad practice contributes to learning	Randomized controlled trial	Denmark	Transfer (retention) and postsurvey	Procedural skills	VR simulator	Pair learner practice is more efficient, may not apply to clinical training
Bjerrum	Dyad practice is efficient practice: a randomized bronchoscopy simulation study	Randomized controlled trial	Denmark	Pre, post, and transfer (retention) test	Procedural skills	VR simulator	Pair learner practice equally effective as individual practice however more efficient for resource utilization

VR, virtual reality.

*Dissertation.

mixed methods or qualitative descriptive design studies. Many of the studies utilized pre- and postsurveys to answer questions in their studies. The mean MERSQI for included studies was 12.03.

Synthesis

A summary of each study's main findings can be found in Table 1. Ten studies focused on procedural skills using a manikin, VR trainer, or task trainer.^{23,24,28–35} Dubrowski

et al compared 3 different group sizes of students participating in a suturing course using a randomized instructor-to-student ratio (1:2, 1:4, or 1:12) and found that outcomes with a ratio of 1:4 was better than 1:12; decreasing the ratio to 1:2 did not improve outcomes.³³ Noerhalk et al studied individuals, dyads, triads, and tetrads during an obstetric ultrasound training and found no difference between 1 and 4 learners per group.³¹ Owen et al studied group sizes between 1 and 5 students for endotracheal intubation and found that dyads were

most effective, postulating 1:1 training did not allow for recovery and having 3 or more students led to loss of feedback between attempts.³² Mahling et al studied groups of 3, 5, and 8 in Basic Life Support (BLS) training, reporting similar test scores among the differing group sizes, however, it was found that smaller groups had better engagement, while larger groups asked fewer questions and had less hands-on training.²⁹ Similarly, Cho et al compared groups of 3 to 5 students to groups of 7 to 10 students for BLS training and noted that although test scores were similar, students preferred smaller groups.²⁸ Shanks et al studied group sizes of 2 to 8 learners for various procedures; learners preferred instructor ratios of 1:3 or 1:4.³⁰

Four studies compared individual learners to dyads: Shanks et al studied medical residents participating in lumbar puncture training, Tolsgaard et al studied medical students participating in gynecologic ultrasound training, Räder et al studied medical students learning coronary angiography skills, and Bjerrum et al studied medical students learning bronchoscopy.^{23,24,34,35} Each study found that individuals versus dyads did not differ in terms of effectiveness, and thus found dyads were more efficient.^{23,24,34,35}

The 6 studies that were focused on clinical teaching and learning had mixed results regarding group size.^{28–30,36–40} Lim et al compared small groups of 5 to 7 and large groups of 8 to 9 learners and reported increased effectiveness in small groups.³⁷ Brim et al noted that faculty agreed group sizes of 3 to 4 were better but did not directly compare to larger group sizes.³⁸ Glatts et al focused on debriefing and reported group sizes of 16 to 25 were too large.⁴⁰ Borges et al had group sizes of 8 to 19 where groups of 12 or higher rated worse than smaller groups.³⁹ Reznier et al had groups of 2 to 4 and found no significant differences in performance on the postsimulation exam as a function of group size.⁴¹ Hensel et al found equivalent outcomes with student perception (satisfaction and self-confidence) with groups ranging from 5 to 10 learners.⁴²

Nabecker et al differed in study design in that it specifically evaluated the instructor's ability to teach BLS to various group sizes ranging from 3 to 10.³⁶ In this study, student actors intentionally made errors; instructors' ability to recognize and correct errors decreased as group sizes included greater than 6 learners.³⁶

Discussion

The use of simulation in medical education has become increasingly popular to teach both procedural and nonprocedural skills. Despite its widespread use, there are no guidelines regarding ideal group size to learn and practice these various skills in medical education simulation. Effectiveness in simulation education requires well-trained instructors and sufficient resources, both of which require financial support. Although smaller groups may enhance learning outcomes, practical factors, such as scheduling and time availability, may influence group sizes; larger groups may be needed when sessions are costly, time

restricted, or when there is a lack of instructor availability. This study examines optimal group size for various medical education simulations, aiming to improve the understanding and implementation of simulation-based learning strategies in medical training.

Despite a somewhat limited number of robust studies, direct comparisons of group sizes have been explored which generally agree that smaller group sizes are ideal.³⁷ The results of this review highlight the advantages of smaller group sizes during simulation-based learning for procedural skills, where groups of 2 to 6 learners are most effective and offer greater hands-on opportunities.^{32,33,40}

For procedural skill training, many studies identified a 1:4 instructor-to-student ratio as ideal for effective learning, notably with no significant differences in knowledge assessment between group sizes of 2 to 4 learners, while other studies showed that groups of up to 6 learners were effective.^{29,31,33,41} For procedural tasks, as group size increased, there was a shift from active to more passive learning as smaller group sizes allow for more hands-on training time per individual.^{29,32} Students' confidence and knowledge significantly increased with smaller group sizes compared to larger groups. These studies highlighted the advantages of smaller groups, including more effective teaching interventions and increased hands-on time.^{29,41} Thus, learners achieve better outcomes with group sizes of between 2 and 4 for procedural skills, while larger groups reduced the active learning opportunities.

Several studies compared individuals to dyads, including studies using VR trainers, task trainers, and ultrasound manikins. Each of these simulation modalities found that dyads are as effective as independent learning.²⁴ Because the use of dyads improves both efficiency and cost-effectiveness without negatively impacting education, dyad groups are preferred over individuals.

Notably, the study assessing teacher effectiveness and instructors' ability to identify errors during simulations found that larger group sizes hindered error correction. This underscores the importance of selecting optimal group sizes in simulation-based learning to ensure effective feedback and performance improvement.³⁶

Knowledge acquisition appears less affected by larger group sizes for simulations focusing on clinical skills. This may be because nonprocedural group activities in simulation require a higher cognitive level of thinking and more discussion, so the learner can effectively learn the material with less hands-on training.^{31,42} However, smaller groups were often preferred by students for reasons including fostering more active participation, having more individual instructor attention, and having fewer distractions.^{29,31,40} Additionally, students preferred smaller group sizes during debriefing and in more complex simulation scenarios, supporting the idea that such settings benefit from smaller groups.

This systematic review indicates that smaller group sizes offer advantages over larger groups, particularly in simulations focused on teaching procedural skills compared to those focused on clinical skills. For procedural skills, group sizes can range from 2 to 6, with decreasing effectiveness in groups larger than 6. It is important to note, though, that when simulating procedural skills, hands-on learning is required and smaller groups of 2 to 4 may have increased benefits. Although clinical skills can be effectively taught in large groups, learners preferred smaller groups for debriefing sessions and complex scenarios. When planning simulations, it is essential to consider available resources, the type of simulation (procedural vs. clinical skills), and the material being taught. Group sizes should be adjusted accordingly as part of effective curriculum planning.

Limitations

The studies included measured various learning outcomes, so direct comparison of learning outcomes between multiple studies and direct comparison of group size was limited. Results also differed depending on the type of simulation, whether procedural or nonprocedural. Lastly, publication and selection biases can influence any systematic review. To minimize publication bias, an extensive search strategy was implemented, drawing from multiple primary literature databases without restrictions. Additionally, all the included studies took place in countries that are classified as high-income countries, which likely reflect the resources and educational structures available in these settings, where simulation technology and training resources are more accessible. Funding for advanced simulation tools and smaller learner-to-instructor ratios may not be as feasible in lower-income settings. This can limit the generalizability of the study's recommendations to countries with fewer resources.

Conclusion

This systematic review highlights the benefits of smaller group sizes in simulations, particularly for teaching procedural skills, where groups of 2 to 4 are most effective, and effectiveness declines with more than 6 participants. While clinical skills can be taught in larger groups, learners favor smaller groups for debriefing and complex scenarios. Effective curriculum planning should account for available resources, the type of simulation, and the material being taught, with group sizes adjusted to optimize learning outcomes.

Authors contributions

Study design: JLC, CNM, SJ, and JEF; data collection and analysis: JLC, CNM, SJ, JEF, and TR; manuscript preparation: JLC, CNM, SJ, JEF, and TR.

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Appendix

Search methods: eligibility criteria and search strategy.

CATEGORY	INCLUSION	EXCLUSION
Search terms	"Simulation" + "medical education" + "group size"	
Language	Full text in English	Abstract only, non-English language
Publication date		After September 28, 2022
Publication status	Published in peer-reviewed journals	Unpublished papers
Study design	Randomized control trials Controlled pre- posttrials Observational studies	Editorial and opinions Commentaries Abstracts
Populations	Medical students, graduate medical learners, nursing students, EMT students	Learners in nonhuman medical training

SEARCH ENGINE	DATE SEARCH PERFORMED	PAPERS CONSIDERED FOR INCLUSION
MEDLINE	September 28, 2022	All
EMBASE	September 28, 2022	All
Cochrane	September 28, 2022	All
PubMed	September 28, 2022	All
Web of Science	September 28, 2022	All
Med Ed Portal	September 28, 2022	All
Google Scholar	September 28, 2022	Top 200 results