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Performance Effect of Simulation Training for Medical Students – A Systematic Review

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Abstract

Objective: Simulation based medical education (SBME) is fast becoming embedded into undergraduate medical curricula with many publications now describing its various modes and student self-reported impacts. This systematic review synthesizes the available literature for evidence of performance effect of SBME as an adjunct within traditional teaching programmes.

Methods: A narrative systematic review was conducted according to PRISMA guidelines using Ovid MEDLINE, EMBASE, and PubMed databases for studies, published in English, reporting on general medical and surgical undergraduate SBME between 2010 to 2020. Two reviewers independently assessed potential studies for inclusion. Methods and topics of simulation with their assessments were evaluated. Descriptive statistics were used to describe pooled student cohorts.

Results: 3074 articles were initially identified using the search criteria with 92 full-text articles then screened for eligibility. Nineteen articles, including nine randomised trials, concerning 2459 students (median 79/study), were selected for review. Cardiac scenarios were commonest (n=6) with three studies including surgical topics. Nine studies used mannequin simulators (median time/session 17.5minutes) versus standardised patients in seven (median time/session=82 minutes). Educational impact was measured by written (n=10), checklist (n=5) and OSCEs (n=3) assessment either alone or in combination (n=1, OSCE/written assessment). All articles reported a positive effect of SBME on knowledge including improved knowledge retention in three.

Conclusion: As an adjunct to existing curricula SBME, , improves knowledge-based performance of medical students at least in the short-term. Future studies should broaden its topics, assess longer term impacts and cost-effectiveness while also considering potential areas of traditional undergraduate learning it could replace.

Keywords: Undergraduate medical education, simulation, medicine, surgery, performance, knowledge.

Introduction

Medical education largely still follows traditional structures [1,2]. Students undergo didactic lecture-based learning throughout their studies but especially in their early years [3]. Once on clinical sites, they learn by engaging with clinical teams and real patients. Although proven sufficient over time, the acquisition of medical knowledge and skills in this way has a number of potential pitfalls. Students are expected to learn from and practice recently acquired knowledge and skills on actual patients. This interaction may be complicated both ways– medical students can be nervous and patients, a vulnerable cohort, can be fearful. Furthermore, the clinical experience may be variable between teams and over time and much of the interaction happens without direct observation by academic faculty. The heterogeneity and inconsistency of clinical exposure coupled with lack of assessment-relevant feedback before examinations is suboptimal and may undermine fairness in competitive assessments and standards in future medical practice. Additionally, the COVID-19 pandemic has greatly challenged medical undergraduate programmes and students by the withdrawal of ward-based placements.

To improve their skills in both history taking and physical examinations, students have long practiced individually and with their peers. This provides a safe, comfortable environment for them to hone their skills and enables iterative improvement by doing, although these methods lack senior supervision and standardisation and may not challenge students. Simulation is fast becoming a formal component of undergraduate and postgraduate medical education [4-6]. Simulation training providing a "device that presents a simulated patient (or part of a patient) that interacts appropriately with the actions taken by the simulation participant" allows users to learn in a safe, controlled and standardised environment, so that skills and knowledge can be applied and practiced [7]. Recent technological advances have increased the capability to realistically mimic actual patients and real-life clinical scenarios [8,9].

Postgraduate simulation has been studied extensively in the literature, which has detailed it's proven benefits including greater patient safety, improved teamwork and enhanced confidence [10-16]. Although many previous studies have detailed the self-reported effects of simulation training on medical students [10,17,18], objectively assessed impacts need to be established prior to its broad implementation most particularly to justify the necessary expenditure, but also especially if it's to replace other existing curricular components, either by design or necessity, such as due to public health emergencies. Crucial to any education innovation is assurance of benefit. The primary metric of performance in medical education are assessment scores. The purpose of this review is to synthesise the available evidence on the performance effect of simulation based medical education (SBME) for undergraduate medical students in general medicine and surgery.

Methods

Search database

This systematic review was conducted using the Preferred Reporting Items for Systematic Review & Meta-Analyses (PRISMA) guidelines. The searches were performed independently in duplicate (NM, FK) using OVID, EMBASE and PubMed databases from 2010 to 2020 inclusive. The final search was completed in January 2021. All eligible records were screened independently (NM, FK) for relevance.

Search terms

The following Medical Subject Headings terms and keywords were used: "medical education" OR " medical students" OR medical student AND simulation training OR high fidelity simulation training OR mannequin OR manikins OR SimMan or simulation. Boolean AND/OR operators were used to combine MeSH and terms and keywords. Following the search, titles and abstracts were screened. Full text of potentially eligible articles were reviewed by two authors (NM, FK) independently and eligible studies selected. Reference lists of full-text studies were checked for additional relevant articles.

Inclusion/exclusion criteria

Our inclusion criteria required all articles to be in English, to be research-based and to include objective investigation of the efficacy of a simulation-based training programme for undergraduate medical students in general medical and surgical clinical learning stages regarding clinical performance. Studies which assessed history taking, physical examination, and clinical practice either separately or together were included regardless of method of simulation (including use of mannequins or simulated patients) and assessment (i.e. written, Objective Structured Clinical Examination (OSCE) or tutor assessment). Objective Structured Clinical Examinations in the included studies followed the traditional format described by Harden (19). Studies assessing procedural protocols (including basic life support (BLS), advanced cardiac life support (ACLS) and advanced trauma life support (ATLS)) and surgical skills were excluded as were those using only subjective assessment methodology. Studies assessing subspecialty domains such as obstetric, paediatric, anaesthetic and psychiatric simulation were excluded.

Data Collection

The following data was extracted from each included publication: first author, publication year, country, study design, number and stage of students, simulation method, assessment method, performance levels pre and post simulation, effects on knowledge retention, students' confidence and authors' conclusion (Figure 1).

Results

Study Characteristics

Figure 1 shows the PRISMA flowchart of search and selection process. Table 1 summarizes the nineteen included studies comprising 2459 students ranging from first to final year medical students. Studies from eleven countries were included with three focusing on first (n=2) or second year (n=1) students and the remainder on students in years three to six. There were nine randomised control trials [20,21,23,28,29,31,34,35,37], six prospective cohort studies [22,25-27,30,33], two crossover studies [32,36], one retrospective analysis [24], and one case-control study [38]. The median number of patients per study was 79 (20-615 patients). Due to heterogeneity of study type including the variety of tools used for assessing multiple skills, meta-analysis was prohibited. Table 2 summarizes the results from each study.

Specialities

Medical scenarios were the most common topics for simulation with fourteen groups [22,2435-38,26-28,30-34] conducting simulation training based around common medical pathologies. Of these, six groups simulated cardiac scenarios with four of these assessing auscultation skills [20,25,31,36] and two simulating acute cardiac presentation scenarios [30,35]. Surgical topics were simulated in two groups [20,25] while one group [29] used both medical and surgical scenarios for their simulation sessions.

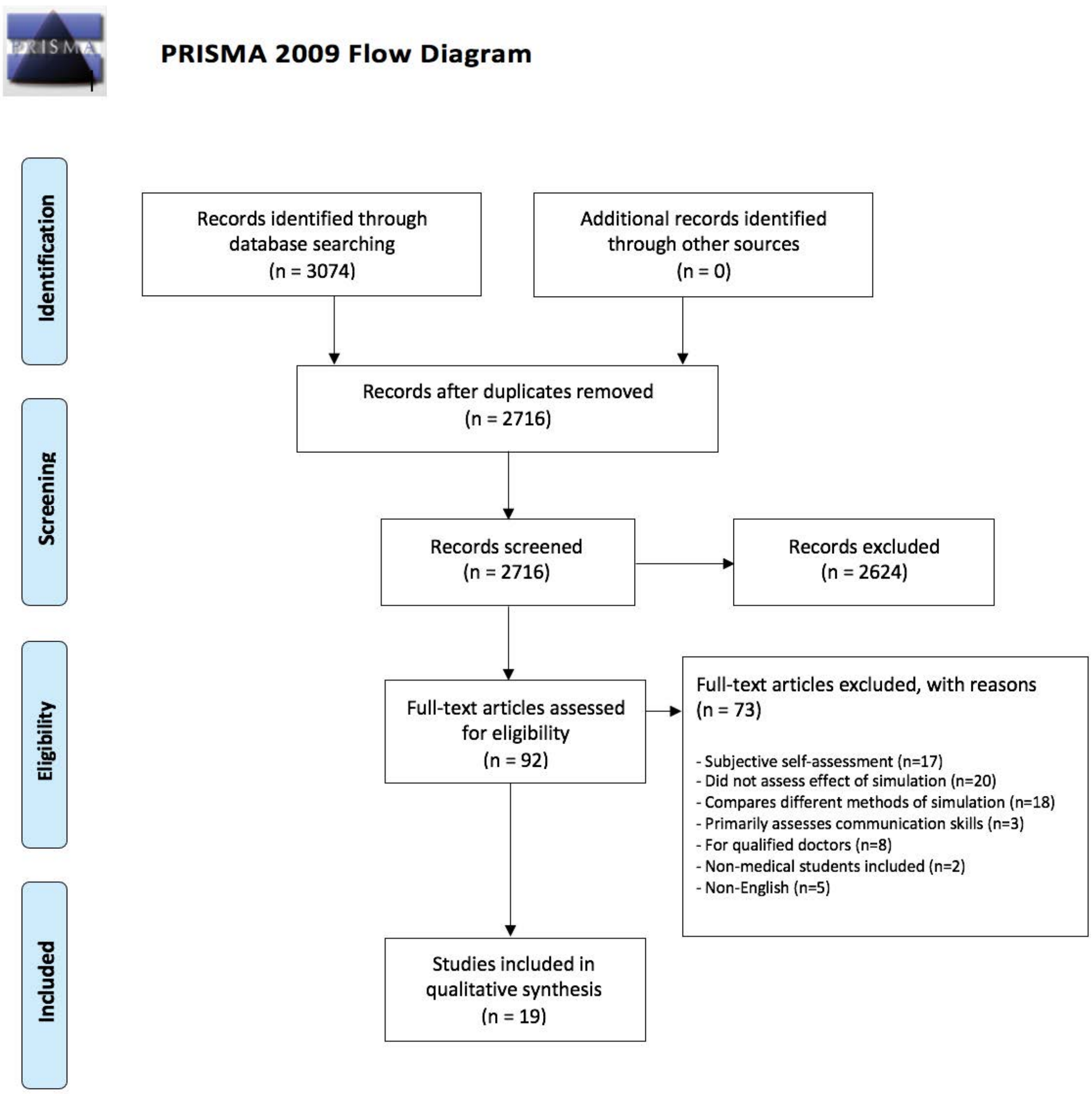

Figure 1: PRISMA flowchart of the search and selection process.

Methods of Simulation

A range of patient simulators were used with the majority (n=12) using artificial patient models in scenarios to mimic the medical setting lasting a median of 17.5 minutes (range 15-30 mins) [22,23,37,38,24,26-28,31-33,36]. SimMan™ (Laerdal) was the most commonly used simulator (n=6) [24,26,31,32,36,37]. The other simulators used included Harvey (n=2) [33,38], METI (n=1) [28] and Kyota kagaku (n=1) along with a heart-sound simulator (n=1). SimMan is a wireless, life-sized advanced patient simulator, that can display physiological changes that the 'patient' undergoes in real-time on a monitor, under the control of the simulation facilitator [39]. In all six groups who used SimMan, general medical scenarios involved students taking a history and performing a physical examination [24,26,31,32,36,37]. In these, the SimMan displayed abnormal cardiovascular and respiratory signs based on the simulated scenario. In two studies [26,37], students were given a short orientation (15-30 minute) to clinical practice using a SimMan.

Standardized patients were used in seven studies [20,21,25,29,30,34,35], three of which focussed on assisting clinical examination practice 24,29). Standardized patients methods ranged from actors [20,24,35] or academic staff mimicking learned symptoms to expert patients and focused on standardised patient histories [34] and ward rounds [20] with supplementary material such as drugs charts, patients' vital parameters and end of bed notes being made available to students in all studies. The median time for simulation with standardized patients was 82.5 minutes (15-180 minutes). In one study [25], students cumulatively spent 21 hours over the course of one semester simulating encounters with standardized patients.

Methods of Assessment

A range of assessment methods were used to evaluate the performance effect of simulation training. Written assessment was the most common (n=10) [22,25,36,27,28,30-35], predominantly comprising of an multiple choice question MCQ examination. In four studies [20,24,26,37] a checklist assessment was completed during or after the simulation scenario. In three studies [21,29,38] students were assessed using objective structure clinical examinations (OSCE) alone and one study [23] used a combination of OSCE and written assessment.

Effect on Performance

All groups reported a performance benefit to students associated with simulation training. Simulation training was shown to have a positive effect when used across a broad range of medical and surgical specialities, in acute and non-acute scenarios.

Auscultation Simulation

In one study [36] improved results on a knowledge based questionnaire were reported following clinical chest examination training with SimMan™ compared to examining their student colleagues. These results were confirmed later using a larger cohort [32]. There was also improvement noted in the simulation group's self-perceived confidence [36]. In a cross-over trial, at the mid-test point, the group who performed examinations on mannequins performed significantly higher in knowledge assessment than those who performed peer examinations (mean 9.3 vs 7.2, p<0.001). A second study, demonstrated the impact of simulation training on knowledge retention focusing on cardiac auscultation [33]. After three years, a subgroup of students who did not receive further exposure to the Harvey simulation were reassessed, and were found to have maintained their acquired capability (68.4% vs 73.1%, baseline 12.1; p<0.001) [33]. In a different study [27], a positive effect of simulation on acquired capability was seen, with a comparison of students' pre- and post-test scores indicated a 16% performance improvement when simulation training on cardiac auscultation was added to the existing curriculum. Improvement in cardiac auscultation skills when practiced on a simulator was also demonstrated in another study (aortic stenosis 84.5 vs 77.6, p = 0.03, mitral regurgitation 89.7 vs 71.4, p = 0.02) however no improvements were identified in respiratory auscultation between the simulation and control group [33]. In a study where a cardiac auscultation programme was implemented [38] students who received simulation training using the Harvey simulator, along with the standard curriculum were compared to students who received the standard curriculum alone, with both groups facilitated by the same faculty to control for variation in teaching.. Five weeks after their respective training sessions, students were assessed in a multi-station OSCE Students who had received simulation training performed significantly better in the respective assessed cardiac skills than the control group who received only the standard curriculum (see table two for results).

Breast Examination Simulation

One study [21] used a hybrid simulation model of breast examination where a standardized patient wearing a silicone breast simulator jacket was examined. This group was compared to students who examined a standardized tabletop breast model. Following this intervention, both groups were assessed in an OSCE. Students who participated in hybrid simulation training were significantly better at lesion reporting (p < 0.001), identification of malignant features (p < 0.001), and accurate location identification (p < 0.001), compared to the group who received traditional teaching. A different study [23] also evaluated the effect of simulation training on students' clinical breast examinations. Students were taught using a simulation and multimedia-based curriculum, which was compared to the traditional didactic lecture and clinic based teaching. Both groups were assessed using written and OSCE assessments. The group who completed the simulation based training were significantly better at all aspects of the breast examination (including inspection, position, palpation, pressure, axillary exam and providing justifications for performing a breast exam) (p < 0.00001). Additionally, students who underwent simulation training were significantly more confident than their peers who were taught with traditional methods. Simulation was also used to teach pre-clinical medical students, and assessed the effect in a randomised, controlled cross-over study finding that both simulation and didactic lectures improved student knowledge when assessed on an MCQ (p=0.036) [28]. When assessing delayed test scores, thus evaluating retention of knowledge, students who completed simulation training demonstrated greater improvement (p<0.001), than those who were taught didactically (p =0.882).

Simulation of Emergency Scenarios

One study [24] assessed sixth year medical students' knowledge and confidence in septic shock resuscitation. Significant improvements were reported in knowledge and resuscitation skills among students who received simulation training whilst also improving their confidence in assessing patients in septic shock (pre-simulation 5.64+/-13.1, p<0.001 vs post-simulation 68.1%+/-12.2%). Another study [31] looked at the area of critical medicine, comparing simulation based teaching to traditional didactic teaching. Final year students were evaluated using a MCQ - at baseline, post-teaching and a two week follow up. Although there was a significant improvement following simulation compared to the didactic lecture group (6.8 (21.1 - 14.3) vs. 4.5 (21.5 - 17), p = 0.0387) baseline scores were higher in the didactic lecture group. In a third study [37] performed a cross-over study, particularly focusing on assessing critically unwell patients with myocardial infarction or anaphylaxis. Simulation training was compared to traditional didactic lectures. Students' performance was evaluated in real-time during the simulation. Almost all (96%) students performed better when trained with simulation. Overall, simulation training resulted in a 22% absolute increase in scores (95% CI 18-26%). Components of the assessment

Table 1: Table summary of included publication study characteristics.

Author	Year	Origin	Population	Speciality	Sample Size	Simulation method	Assessment method
Grunewald etal., [20]	2019	Germany	4th year	Surgery	27	Standardized patients	Checklist
Nassif et al., [21]	2019	Lebanon	3rd year	Breast surgery	82	Standardized patients and a breast model	OSCE
Bernardi et al., [22]	2019	Italy	5th year	Cardiology	107	Kyota kagaku simulator	Written
Angarita et al., [23]	2019	Canada	4th year	Breast surgery	120	Simulated breast model	OSCE and written assessment
Vattanavanit et al., [24]	2016	Thailand	6th year	Medicine	79	SimMan	Checklist
Giblett et al., [25]	2017	UK	3rd year	Surgery	104	Standardized patient	Written
Sanchez-Ledesma et al., [26]	2016	Spain	4th year	Medicine	300	SimMan	Checklist
Pereira et al., [27]	2016	Portugal	3rd and 4th years	Cardiology	117	Heart sounds simulator	Written
Alluri et al., [28]	2016	USA	2nd year	Medicine	20	METI simulator	Written
Zhang et al., [29]	2015	China	5th year	Medicine and Surgery	203	Standardised patient	OSCE
Williams et al., [30]	2015	UK	5th year	Cardiology	24	Standardised patient	Written
Solymos et al., [31]	2015	Ireland	5th year	Medicine	41	SimMan	Written
Swamy et al., [32]	2014	UK	1st year	Medicine	79	SimMan	Written
Perlini et al., [33]	2014	Italy	3rd and 4th year	Cardiology	615	Harvey simulator	Written
Fisher et al., [34]	2014	UK	3rd year	Medicine	74	Standardized patient	Written
DeWaay et al., [35]	2014	USA	4th year	Cardiology	291	Standardized patient	Written
Swamy et al., [36]	2013	UK	1st year	Medicine	24	SimMan	Written
McCoy et al., [37]	2011	Canada	4th year	Medicine	28	SimMan	Checklist
Kern et al., [38]	2011	USA	3rd year	Cardiology	124	Harvey simulator	OSCE

Table 2: Tabulated summary of authors, assessment methods, non-simulation and simulation group scores, effect on performance, self-perceived confidence and knowledge.

Author	Assessment method	Non-simulation group scores	Simulation group scores	Effect on performance	Self-perceived confidence	Knowledge retention
Grunewald(20)	Checklist	n = 11 Difference in pre and post intervention scores -1.2 +/-11.1	n = 16 Difference in pre and post intervention scores 6.9+/-10.3	Difference of 8 points on SWAT assessment between groups p = 0.061	Confidence at conducting surgical ward round following intervention: Control group: 0.7+/-0.4 (p = 0.088) Intervention group: 4.8+/- 0.4 (p<0.001)	
Nassif(21)	OSCE	n = 26 CBE completeness score: 16.83 Visual inspection score: 4.83 Palpation score: 11.67 Lesion identification grade: 1 Reporting a lesion: 0.5 Malignant features of the lesion: 0.00 Accurate location of the lesion: 0.33 Falsely reporting a lesion: 0.00 Detecting lymph nodes: 1.0 Falsely reporting lymph nodes: 0.00	n = 56 CBE completeness score: 16.58 Visual inspection score: 5 Palpation score: 11.5 Lesion identification grade: 3 Reporting a lesion: 1 Malignant features of the lesion: 0.67 Accurate location of the lesion: 1.33 Falsely reporting a lesion: 0.00 Detecting lymph nodes: 1.0 Falsely reporting lymph nodes: 0.00	Simulation group were significantly better at lesion identification, identification of malignant features, and accurate location identification (p < 0.001	11.11% of simulation group feel more prepared for their upcoming examination compared to 3.85% of the control group (p=0.418)	

Bernardi(22)	Written	Cardiac auscultation Aortic stenosis: 77.6% Mitral regurgitation: 71.4% Split heart sounds: 79.6% Respiratory auscultation Wheeze: 91.7% Fine crackles: 58.3% Coarse crackles: 66.7%	Cardiac auscultation Aortic stenosis: 84.5% Mitral regurgitation: 89.7% Split heart sounds: 89.7% Respiratory auscultation Wheeze: 91.4% Fine crackles: 63% Coarse crackles: 70.7%	Training with a patient simulator improved students' cardiac auscultation skills, in particular auscultating for aortic stenosis ($p = 0.36$), mitral regurgitation ($p = 0.02$) and split heart sounds ($p = 0.15$) Training with a patient simulator did not significantly improve students' lung auscultation skills.		Performances of the same experimental students between year three and year five, there were no changes in the heart auscultation results, whereas they significantly improved over time in lung auscultation.
Angarita(23)	OSCE and written assessment	n =58 Percentage of students who adequately completed all 13 items: 28.2%	n = 62 Percentage of students who adequately completed all 13 items: 88.2%	Students in simulation group adequately completed all 13 items was significantly higher than the control group ($p < 0.00001$)	Students who underwent simulation training were "very confident" more frequently than traditionally trained students (97.1% vs 9.6%, $p = 0.00001$)	
Vattanavanit(24)	Checklist		Pre & post-test analysis Mean test score significantly improved following simulation training (66.83% +/-19.7% vs 47.59%+/-19.7%, $p<0.001$)		Student confidence in the management of septic shock significantly better following simulation training (68.10%+/-12.2% vs 51.64+/-13.1%, $p<0.001$).	
Giblett(25)	Written	n = 50 Median score = 17 (43%) Ranger 5-29 (13-74%)	n = 39 Median score = 29 (74%) Range 16-35 (41-90%)	$p < 0.001$	Confidence improvement in all domains of evaluated (including acute abdomen, assessing breast lumps, assessing peripheral vascular disease. ($p < 0.001$).	
Sanchez-Ledesma(26)	Checklist		Pre-test scores 2014: 5 2015: 10 Post-test scores 2014: 12 2015: 28	Statistically significant difference found between pre-test and post-test groups ($p<0.05$)		
Pereira(27)	Written	Pre-test scores Normal: 40.17% Pathology unspecified: 14.02% Mitral regurgitation: 7.18% Aortic regurgitation: 5.47% Aortic stenosis: 4.1% Pulmonic stenosis: 6.32% VSD: 5.47%	Post test scores Normal: 56.92% Pathology unspecified: 31.28% Mitral regurgitation: 10.26% Aortic regurgitation: 7.52% Aortic stenosis: 4.96% Pulmonic stenosis: 4.27% VSD: 2.05%	Significant improvement (+16%) in the differentiation between normal and pathological cases.		

Alluri(28)	Written	n = 20 Pre-intervention: 41.17+/-20.42% Post-test: 66.67+/-19.49% Delayed post-test: 67.71+/-22.33%	n = 20 Pre-intervention: 40.00+/- 21.89% Post-test: 55.00+/- 18.02% Delayed post-test: 79.17+/-18.76%	Average individual student improvement from post-test to delayed post-test significantly improved in simulation group compared to lecture (p=0.036)		When assessing delayed test scores, thus evaluating retention of knowledge, students who completed simulation training demonstrated improvement, those who were taught didactically did not.
Zhang(29)	OSCE	2013: n = 36 69.91+/-1.24 2014: n = 27 73.58+/-1.34	2013: n=73 80.95 +/- 0.61 2014: n=67 86.12+/- 0.56	p = 0.0114 p = 0.006		
Williams(30)	Written		n = 24 Pre-simulation:25/43 Immediately post-simulation:34/43 >1 week post simulation:35/43 p < 0.001	Improvement in all domains assessed, including management of MI, LV failure, fast AF, medical emergencies and starting as an FY1 doctor. p < 0.001		
Solymos(31)	Written	Baseline MCQ score: 17+/-3 Post didactic lecture MCQ score: 21.5+/-3.1	Baseline MCQ score: 14.3+/-2.2 Post-simulation MCQ score: 21.1+/-1.8	Significant difference in the improvement from baseline and post teaching MCQ in the simulation group compared to lecture 6.8 (21.1 - 14.3) vs. 4.5 (21.5 - 17), p = 0.0387		2-week follow up MCQ were lower in both groups than post teaching results. Smaller margin in the simulation group 1.3 (19.8-21.1) vs. 3.6 (17.9 - 21.5), but not statistically significant (p = 0.167).
Swamy(32)	Written	Pre-test score: 6.5 Mid-test score: 7.2	Pre-test score: 6.7 Mid-test score: 9.3	The group who simulated examinations on a mannikin performed significantly better than the group who performed peer examinations in the mid-test.	Confidence in examining patients improved significantly in the simulation group compared to the control group.	
Perlini(33)	Written	Pre-simulation training percentage of correct diagnoses: 11%	Post-simulation training percentage of correct diagnoses: 72%	Improved capability of correctly recognising cardiac diagnoses (p <0.001)		After three years without any further simulation training, retention remained high (68.4%, p<0.001)
Fisher (34)	Written	Elder abuse management: 20% Falls management: 25% Delirium management: 20%	Elder abuse management: 36% Falls management: 40% Delirium management:52%	p = 0.002 p = 0.001 p < 0.001	>95% of students felt better equiped to deal with geriatric scenarios	
DeWaay (35)	Written	n = 80 Overall performance score: 47.9+/-9.8%	n = 147 Overall performance score: 53.5 +/-8.9%	Overall performance was significantly better with simulation training versus the control group (p <0.001)		

Swamy (36)	Written	n = 12 Mean mid-test score: 5.66	n = 12 Mean mid-test score: 6.75	Mid-test knowledge scores increased significantly between both groups ($p < 0.001$), and the group who performed examinations on SimMan™ performed better than the control group No significant difference in post-test scores after crossing over, which demonstrates equal knowledge improvement after performing examinations on SimMan™	Both groups felt more confident differentiating between normal and abnormal signs after practicing on SimMan™	
McCoy(37)	Checklist	Mean overall score: 71%	Mean overall score: 93%	Significant improvement in student performance for those trained with simulation compared with those trained with traditional didactic lecture ($p<0.0001$)		
Kern(38)	OSCE	Evaluation of point of maximal impulse: 64% Anterior auscultation of four cardiac areas: 71% Left lateral cardiac auscultation: 41% Inspection for lower extremity edema: 52% Inspection for jugular venous distention: 41% Respiratory Chest expansion: 89% Percussion: 89% Auscultation:99%	Evaluation of point of maximal impulse: 74% Anterior auscultation of four cardiac areas: 85% Left lateral cardiac auscultation: 52% Inspection for lower extremity edema: 71% Inspection for jugular venous Distention: 56% Respiratory Chest expansion: 83% Percussion: 82% Auscultation 97%	Students who trained using cardiopulmonary simulator (SimSPLE) performed significantly better than the controls in all five cardiac exam skills: (a) evaluation of point of maximal impulse ($p = 0.045$), (b) anterior auscultation of four cardiac areas ($p = 0.003$), (c) left lateral cardiac auscultation ($p = 0.037$), and inspection for (d) lower extremity edema ($p \leq 0.001$), and (e) jugular venous dis- tention ($p = 0.004$). No statistically significant difference in pulmonary examination skills between the groups.		

were higher in the simulation group compared to the lecture only group with increases in absolute score for history taking (27%), physical examinations (26%) and patient management (16%). One study used three arms to investigate differences between fourth year medical student performance in students who received simulation training compared to a control group that did not receive anintervention) and to a group who received didactic lectures [27]. Simulation training was reported to significantly improve overall performance with simulated trained students scoring 53.5+/-8.9% correct answers, compared to 47.9 +/- 9% in the didactic teaching group and 47.9 +/- 9.8% in the control group ($p<0.001$) [27]. Another study [30] also simulated cardiac emergencies, but this time using real patients with a cardiac history taking the simulated patient role. Students were assessed using knowledge based short answer questions. Mean scores increased (25/43 to 34/43) post-intervention. A sustained effect was seen at one week post intervention, with scores of 35/43. Students' self-perceived confidence was also improved post- intervention. One study [26] focused on the use of simulation training in the management of neurological emergencies. The simulation instructor evaluated students' during the simulation session. where statistically significant differences were found between pre (2014: 5, 2015: 10) and post-test (2014: 12, 2015: 28) groups.

Simulation in Non-emergent Scenarios

Another study [34] developed and delivered a simulation programme dealing with common geriatric issues, including delirium, falls and elder abuse. Mannequins and simulated patients were both incorporated into the scenarios. Students were assessed pre, post and one month post-simulation. Test scores were compared to those who underwent traditional didactic teaching with post simulation test scores being better than pre-simulation test scores. For all scenarios, there was a statistically significant difference between the simulation and control group ($p<0.005$). Students in Zhang et al's [29] study were pre-selected into a simulation and didactic lecture group by virtue of variants in facility across their clinical sites. Students simulated both medical and surgical scenarios. Across two year groups, the mean score for 16 OSCE stations was significantly better in those who had undergone simulation training. The mean score in 2013 for the simulation was 80.95+/-0.61 versus 69.91+/-1.24 for the didactic lecture group (p=0.0114), and 86.12+/-0.56 versus 73.58+/-1.34 in 2014 (p=0.006).

Simulation in Surgical Education

Two studies specifically examined simulation in surgery. one study [25] randomised two groups of medical students in their first year of clinical attachments. In the first semester, one group received traditional didactic lecture based education while the other group received simulation training, broadly covering the surgical curriculum. Using independent t-test analysis, a significant performance benefit in a knowledge based assessment was seen amongst the group who received simulation training (p <0.001). Additionally, the simulation group had higher self-reported confidence and understanding of surgical principles. These students also showed substantially improved confidence in acute surgical assessments, particularly in abdominal (p < 0.001), vascular (p < 0.001) and breast examinations (p < 0.001). Another study [20] used an objective surgical ward round assessment tool to evaluate students' performance. The control group did not receive simulation training. Competence in the intervention group improved from 62.6 to 69.6 points (p = 0.0169). In contrast, there was no improvement in the control group (pre: 62.6 vs post 69.6 points (p= 0.72)).

Discussion

There is increasing interest in the use of SBME in undergraduate medical training programmes. This is related in part to the COVID-19 pandemic pressurising clinical placements access with added emphasis on graduating competent doctors in a timely fashion or indeed even early. The primary outcome of this study was to examine the performance effect of simulation training on medical student performance through a synthesis of the published literature including summarising the methods used to provide simulation training and the tools used to assess efficacy. Overall, this review shows that simulation training in tandem with the traditional curriculum improves medical students' performance and knowledge retention as well as self-perceived confidence when compared to didactic teaching and learning through observation. These benefits were seen across a number of required skills, including core components such as history taking and physical examinations including those, of an intimate nature, such as a breast examination which can be otherwise challenging for students to learn and across various specialities in both emergency and elective general medical and surgical situations. Evidence exists that as students learn best when they are actively involved [40], and it was unsurprising that students who experienced simulation training were found to be more satisfied with their teaching [25]. While medical training has traditionally utilised the adage "see one, do one, teach one", simulation-based education provides the opportunity to 'do one' repeatedly, safely and under supervision to improve future practice.

The use of SBME requires some investment in terms of teaching personnel, equipment and space meaning that objective proof of its usefulness is very important to justify the expenditure. Additionally nuance exists. Hamstra [41] detailed some of the key components to effectively run simulation scenarios Learner engagement and suspension of disbelief enhance the learning environment for medical students [41]. By presenting students with scenarios and an environment that mimics real life, a realistic educational experience can be obtained. Also, some studies have suggested that improved student confidence may be a negative finding [42], specifically when students are overconfident and unaware of their limitations, indicating that further work needs to be done in this specific area. Furthermore, while simulation training as been shown to improve cardiac auscultation skills, it seems to have no effect on respiratory auscultation skills [22,27,33,38]. Bernardi [22] hypothesised that this difference is related to the different teaching methods employed for each and that using graphic representation of the lung sounds heard may offset this. Further, additional 'real-world' validity can be added when constructing the scenarios. For example, Williams simulated cardiac emergencies with real patients who had recovered following a previous emergency cardiac presentation including intermittent interruption of the students to simulate a real life "on call scenario" as doctors are often required to multi-task, manage their time efficiently and remain calm under pressure [28].

Simulation training facilitates the standardization of medical education, in allowing all students access similar clinical experiences and can also provide a useful means of contributing to student summative assessment in a manner that is reproducible and objective. To date, written examinations in conjunction with observed clinical examination and skills assessment have traditionally been major components of medical students' assessment [43,44]. Of note, in two recent studies it was noted that a simulation-based assessment may be appropriate for assessing clinical competence [45,46]. In addition, the healthcare educator's primary function is to produce competent and proficient doctors and physical and mental wellbeing of students is increasingly recognised as essential given the rising rates of burnout and mental health issues reported amongst medical students [47,48]. A consensus statement on medical student wellbeing from the Australia and New Zealand [49] recommends "curricula that promote peer support and progressive levels of challenge to students and to employ strategies to promote positive outcomes from stress and to help others in need". These strategies are already components of SBME and further aspects such as resilience training can be readily incorporated. Future research could also investigate if enhancements in confidence gained from simulation experiences can help ease the transition from medical student to junior doctor.

This systematic review studies heterogenous groups consisting of various methods of simulation and assessment. As such meta-analysis was prohibited.

In conclusion, this systematic review provides evidence that SBME can improve medical students' performance in history taking, physical examination, knowledge retention and self-perceived confidence in a variety of domains and specialities that validates its use as an adjunct to the traditional didactic lecture-based curriculum. For the purposes of ensuring optimal education of medical students, further studies could investigate the best methodologies for SBME by comparison and whether simulation is best employed as an adjunct or replacement to the traditional lecture based curriculum. It is important also to examine cost-effectiveness especially the role of lower cost set-ups versus more expensive systems. Ultimately too it is important to correlate the performance effect of simulation training directly to competence. By building up such an evidence-base we will best evolve the curriculum for the purpose of producing better doctors, and most importantly, better patient outcomes.

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