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REVIEW PAPER

Simulation-based learning in nurse education: systematic review

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Abstract

Title. Simulation-based learning in nurse education: systematic review.

Aim. This paper is a report of a review of the quantitative evidence for medium to high fidelity simulation using manikins in nursing, in comparison to other educational strategies.

Background. Human simulation is an educational process that can replicate clinical practices in a safe environment. Although endorsed in nursing curricula, its effectiveness is largely unknown.

Review methods. A systematic review of quantitative studies published between 1999 and January 2009 was undertaken using the following databases: CINAHL Plus, ERIC, Embase, Medline, SCOPUS, ProQuest and ProQuest Dissertation and Theses Database. The primary search terms were 'simulation' and 'human simulation'. Reference lists from relevant papers and the websites of relevant nursing organizations were also searched. The quality of the included studies was appraised using the Critical Appraisal Skills Programme criteria.

Results. Twelve studies were included in the review. These used experimental or quasi-experimental designs. All reported simulation as a valid teaching/learning strategy. Six of the studies showed additional gains in knowledge, critical thinking ability, satisfaction or confidence compared with a control group (range 7–11%). The validity and reliability of the studies varied due to differences in design and assessment methods.

Conclusion. Medium and/or high fidelity simulation using manikins is an effective teaching and learning method when best practice guidelines are adhered to. Simulation may have some advantage over other teaching methods, depending on the context, topic and method. Further exploration is needed to determine the effect of team size on learning and to develop a universal method of outcome measurement.

Keywords: learning, literature review, nurse education, simulation, systematic review

Introduction

In practice-based healthcare professions, methods of teaching and learning focus on enabling students to assimilate clinical knowledge and skills. Nursing students need to learn how to apply classroom learning in the clinical context. Human simulation may well be an educational strategy for achievement of these outcomes as it uses active learning (Cioffi 2001) applicable to nursing (National Council of State Boards of Nursing 2005) and has been widely incorporated into international undergraduate nursing curricula (McKenna *et al.* 2007, Nursing and Midwifery Council UK and Council of Deans for Health 2007, Murray *et al.* 2008, Nehring 2008).

Human simulation aims to imitate reality whilst offering a skills-based clinical experience in a safe and secure environment (Fowler-Durham & Alden 2007). Hovancsek describes the aim of simulation as: 'to replicate some or nearly all of the essential aspects of a clinical situation so that the situation may be more readily understood and managed when it occurs for real in clinical practice' (Hovancsek 2007, p. 3). Furthermore, key aspects of simulation education are the ability to repeat practice to consolidate learning and develop competence (Issenberg *et al.* 2005, Hogg *et al.* 2006, Kardong-Edgren *et al.* 2008), using instructor feedback and video debriefing (Fanning & Gaba 2007, Kuiper *et al.* 2008). Kneebone (2005) suggests that simulation may be an effective method of learning because it implicates four key facets of education in nursing: developing technical proficiency through practice of psychomotor skills and repetition; assistance of experts which is tailored to students' needs; situated learning within context; and incorporation of the affective (emotional) component of learning. One outcome is the development of requisite competence in clinical reasoning (Simmons *et al.* 2003, Eva 2005, Banning 2008, Trede & Higgs 2008), as students learn to apply knowledge and skills during the analysis of current evidence to make a clinical judgment (Lasater 2007, Decker *et al.* 2008).

Simulation techniques used in teaching vary from low fidelity to high fidelity (Table 1), depending on the degree that they match reality. Low fidelity replication includes replica anatomical models and peer-to-peer learning using case studies or role play (Kinney & Henderson 2008). Two-dimensional virtual reality on a computer screen with interactive software may be used to solve problems in a cardiac clinical situation (Gomoll *et al.* 2008, Tsai *et al.* 2008). Full-scale or high fidelity computerized manikins attempt to replicate human anatomy and can be programmed to imitate vital signs (Hravnak *et al.* 2007) for skill and decision-making enhancement (Kuiper *et al.* 2008).

Simulation has been endorsed by nursing professional bodies (National Council of State Boards of Nursing 2005, Murray *et al.* 2008), educators (Hammond 2004, Henneman & Cunningham 2005, Haluck *et al.* 2007, Anderson & Leflore 2008, Hanberg 2008, McLaughlin *et al.* 2008) and students (Lasater 2007, Reilly & Spratt 2007, Gardner *et al.* 2008). There is evidence that it is an effective learning tool, particularly in medicine, where it has been used to train doctors in a wide range of clinical skills tasks from surgical procedures (Kneebone *et al.* 2002, Nackman *et al.* 2003, Dunkin *et al.* 2007, Sturm *et al.* 2008) to patient communication (Kneebone *et al.* 2006). Nursing studies suggest high levels of student satisfaction (Anderson 2007, Leighton 2007) but with the risk of anxiety or intimidation (Lasater 2007, Decarlo *et al.* 2008, Lundberg 2008), which may influence learning (Jeffries & Rizzolo 2006, Lundberg 2008).

The review

Aim

The aim of the study was to review the quantitative evidence for medium to high fidelity simulation (HFS) using manikins in nursing, in comparison to other educational strategies.

Table 1 A typology of fidelity elements in simulation-based education

Tool	Description
Partial task trainers (**low-tech simulators**)	Replica models or manikins used to learn, practice & gain competence in simple techniques and procedures
Peer to peer learning	Peer collaboration used to develop and master skills – such as basic health and physical assessment
Screen-based computer simulators	Programs used to acquire knowledge, to assess competency of knowledge attainment and to provide feedback related to clinical knowledge and critical-thinking skills.
Virtual reality	Combines a computer-generated environment with tactile, auditory and visual stimuli provided through sophisticated partial trainers to promote increased authenticity
Haptic systems	A simulator that combines real-world and virtual reality exercises into the environments
Standardized patients	Uses case studies and role-playing in the simulated learning experience; individuals, students or paid actors are taught to portray a patient in a realistic and consistent manner
Full-scale simulation (**medium to high fidelity**)	Simulation that incorporates a computerized full- body manikin that can be programmed to provide realistic physiologic response to practitioner actions; these simulation require a realistic environment and the use of actual medical equipment and supplies

Source: adapted from Decker, S., Sportsman, S., Puetz, L. & Billings, L. (2008) The evolution of simulation and its contribution to competency. *Journal of Continuing Education in Nursing* **39**(2), 78.

The following research question was addressed: How effective is simulation as a method of teaching and learning compared to other educational strategies?

Design

A systematic review was undertaken using guidelines for identification of quantitative data (Higgins & Green 2008). We set clear objectives, formulated selection criteria and defined a search strategy for identifying papers. We then analysed the selected studies and synthesized the results using published guides for assessing randomized controlled trials and case control studies (Public Health Resource Unit 2006a, 2006b).

Search methods

A systematic search was made for quantitative studies in English between 1999 and January 2009 that compared use of simulation with other methods of education in healthcare. The seven databases used were CINAHL Plus, ERIC, Embase, Medline, SCOPUS, ProQuest and ProQuest Dissertation and Theses Database. Reference lists from relevant papers and the websites of relevant nursing organizations were also searched.

The primary search terms were 'simulation' and 'human simulation' with no initial professional focus because earlier more focused search strategies (e.g. in Medline; CINAHL Plus) had either failed to narrow the search to particular levels of fidelity in studies of simulation in nursing or yielded no relevant results. Each database was searched using either these broad terms or MeSH terms with appropriate permutations: for example, for ProQuest: the terms 'higher education and simulation; 'health education and simulation'; 'education and simulation', 'simulation and nursing education' were exploded.

Search outcome

Of 2019 references located, those reporting quantitative studies of manikin-based medium to HFS in nursing were retained. Reports were excluded where the primary variable was electronic simulation, Web-based or virtual (computer) simulation, patient actors, role-play or case study. Both primary and secondary studies (such as theses and reports) were included if they met the selection criteria as it was considered important to review all relevant studies in nursing, even though some might not have been subject to independent review. As shown in Figure 1, the abstracts of studies that employed manikins were examined by the two authors, resulting in a full review of 32 papers and final inclusion of 12 papers.

Quality appraisal

The studies represented pre-test post-test experiments or quasi-experiments using medium to HFS as the education technique compared with a control group taught by other education methods. These were analysed and presented

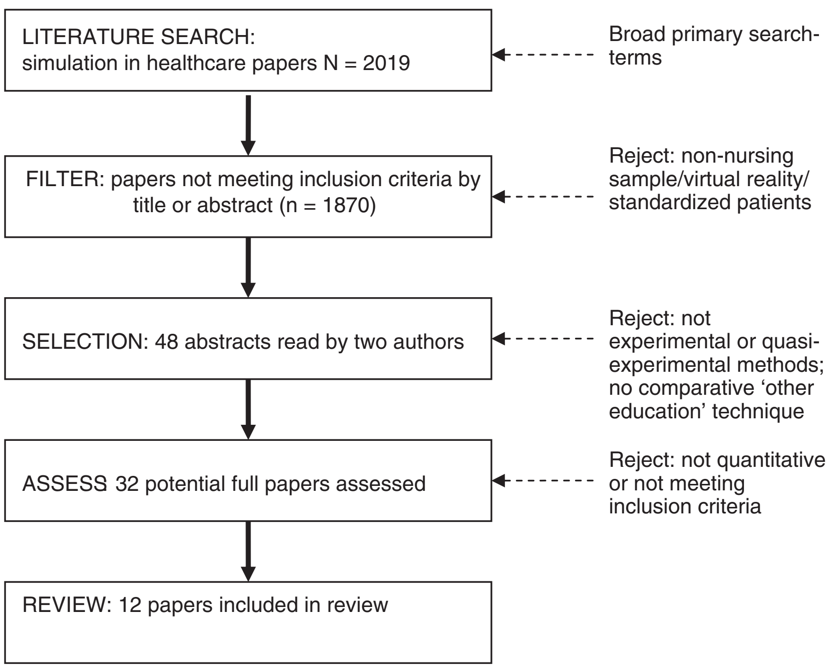

Figure 1 Flow diagram of the study selection process.

according to the quality criteria suggested for assessing randomized controlled trials and case control trials by the Critical Appraisal Skills Programme of the Public Health Resource Unit, England (2006a, 2006b). Of interest were the particular designs of the studies and whether description of each step of the research enabled assessment of the rigour of the data and statistical analysis. The quality indicators used to appraise each study are given in Table 2. Twelve studies met the inclusion criteria and were included in the review.

Data abstraction

A table was prepared using the criteria established for inclusion in the study (Table 3). Key to the review were results descriptors: the form of simulation delivered and the validity of measures of assessment for knowledge and/or skill, and the timing of assessment (whether immediate or extended after education).

Synthesis

In the included studies simulation was applied to various clinical themes, differing methods and interventions were used, and in the main non-probability samples from class enrolments were used. The findings are therefore summarized in a narrative manner rather than using direct comparison (such as meta-analysis).

Results

Characteristics of studies

The studies were published between 1999 and January 2009. Eleven had an experimental design, including one RCT and one using quasi-experimental methods. The selected studies were: six peer-reviewed journal papers (Alinier *et al.* 2006, Birch *et al.* 2007, Scherer *et al.* 2007, Shepherd *et al.* 2007, Brannan *et al.* 2008, Brown & Chronister 2009), five dissertations (Griggs 2003, Ravert 2004, Howard 2007, Linden 2008, Ruggenberg 2008) and one research report (Jeffries & Rizzolo 2006). Sample sizes ranged from 23 to 140 for the individual studies (mean n = 67) and 798 students in the one multi-site study. Participants included undergraduate nursing students or newly Registered Nurses (Shepherd *et al.* 2007), Registered Nurses (Scherer *et al.* 2007) and multi-professional groups of nursing and medical staff (Birch *et al.* 2007). All but one Australian study (Shepherd *et al.* 2007) reported on primary research in North America, with a range of clinical themes from postoperative care to core patient assessment skills (Table 3).

Educational interventions

The 12 studies involved a comparison of medium to HFS using manikins with various other strategies for teaching and learning, although the interventions varied in terms of administration, exposure and assessment. Nine studies compared simulation with the 'usual' method of teaching. Some researchers did not define the teaching methods, some named lecture, and six described their usual teaching method as student group interactions, case studies, structured clinical debriefing or tests. One study involved a self-learning package (see Table 2).

Assessment measures

Assessment measures varied (Table 3). The included assessments of knowledge and skill such as Objective Structured Clinical Examinations (OSCEs) and other indirect measures, such as participants' learning satisfaction or perceptions of their learning as indicators of ability to make clinical judgments. OSCEs are the most valid assessment measures as they examine students' performance of clinical nursing skills objectively using checklists or evaluation scales (Bartfay *et al.* 2004) One report stated that an OCSE was used (Alinier *et al.* 2006), in another 'skill stations' were used (Linden 2008) and in a third clinical competence was directly assessed using expert observation (Shepherd *et al.* 2007).

Seven of 12 studies included at least one validated assessment measure, but for other measures the reliability was unclear. As studies aimed to assess both knowledge and clinical skills, several applied a critical thinking scale (Ravert 2004, Howard 2007). Based on the notion that as self-efficacy increases, so does self-confidence (Bandura 1997), a self-confidence scale was often used as an indicator of ability to carry out a clinical behaviour. This concurred with the basic tenet that learning increases with development of self-confidence or comfort (Bremner *et al.* 2006, Lundberg 2008), and that low confidence is likely to be a barrier to learning (Lundberg 2008). It was apparent that researchers, where possible, had applied valid measurement scales to assess the field of learning (e.g. the Electrocardiogram Examination and Acute Myocardial Infarction Management Questionnaire) and supplemented these knowledge questionnaires with additional assessments aimed at assessing clinical preparedness.

Evidence of effectiveness

All 12 studies reported statistical improvements in knowledge/skill, critical thinking ability and/or confidence after the simulation education, indicating that simulation is an effec-

Table 2 Quality indicators of included studies

Study & origin	Design	Sample size	Focused research question	Selection/allocation to case or control groups	Power calculation/ analysis	Baseline comparability groups	Confounding factors considered
Alinier *et al.* (2006) (USA)	Pre-test post-test experiment: usual training vs. added HFS in scenarios	99	Yes	Volunteer undergraduate nursing students; random group allocation	Sample size adequate for effect 1·0. Analysis of means, *t*-tests	Yes: accounted for	Yes
Birch *et al.* (2007) (USA)	Pre-test post-test experiment: lecture vs. HFS or else combination of both	36	Not given	Random selection junior/senior medical/midwifery staff; multi-professional teams of six randomly allocated to method of education	Not adequate sample to achieve statistical significance. Analysis of means	Yes	How much simulation is required to train/ sustain?
Brown & Chronister (2009) (USA)	Experimental: comparative correlational design: HFS vs. didactic instruction	140	Yes	Recruited senior baccalaureate nursing students allocated by course selection	Power calculation not given. Two-sample *t*-tests, regression analysis	Yes	Yes
Brannan *et al.* (2008) (USA)	Pre-test post-test experi- ment HFS vs. lecture	107 (100%)	Yes	Sample: all enrolled undergraduate nursing students allocated to two groups	Power calculation not given. Multiple linear regression analyses	Yes	No difference in confidence results
Griggs (2003) (USA)	Pre-test post-test experiment HFS vs. managing actual patients	27 (93%)	Yes	Volunteer senior undergraduate nursing students randomly assigned: 12 in experimental group, 15 controls	Analysis of means. Independent samples *t*-test for confidence	Yes	Yes: post-test after further 12 clinical practice days
Howard (2007) (USA)	Pre-test post-test experiment HFS vs. usual teaching (video/case study/ group discussion)	49	Yes	Convenience sample of 50 nursing undergraduates, randomly assigned to groups by coin-toss	Sample size tested; adequate Analysis of means, ANCOVA, controlled for variance	Yes: variance accounted for	
Jeffries & Rizzolo (2006) (USA)	Pre-test post-test cross-over experiment: High vs. Low fidelity simulation vs. case study simulation	798	Yes	Convenience? sample of 798 nursing students from eight sites: randomized to controls (n = 398) and 403 to experi mental group	Power adequate. Analysis methods not given	Not given	
Linden (2008) (USA)	Pre-test post-test quasi- experiment HFS vs. usual teaching	97 (96%)	Yes	Volunteer undergraduate nursing students – randomly assigned by class	Power adequate. Analysis of variance (ANOVA)	Yes	
Ravert (2004) (USA)	Pre-test/post-test experiment HFS vs. usual teaching (case seminar and discussion)	25 (39%)	Yes	Convenience sample nursing undergraduates; random allocation to two groups by number draw	No power calculation given, although small sample recognized. Analysis: general linear model procedure	Yes	Yes

Table 2 (*Continued*)

Study & origin	Design	Sample size	Focused research question	Selection/allocation to case or control groups	Power calculation/ analysis	Baseline comparability groups	Confounding factors considered
Ruggenberg (2008) (USA)	Pre-test/post-test experiment HFS vs. usual teaching (video, written assignment)	58 (74%)	Yes	Convenience sample nursing undergraduates $N = 58$; random group allocation	No power calculation given. Multivariate analysis controlled for group differences	Yes: controlled for group differences	Yes
Scherer *et al.* (2007) (USA)	Pre-test/post-test quasi- experiment HFS vs. case study seminar	23	Yes	Convenience sample of Registered Nurses; randomly assigned to experimental group ($n = 13$) or control group ($n = 10$)	Equivalent groups One-way ANOVA and Tukey's test	Yes: by demography	A pilot study: little discussion of confounding factor such as small sample size
Shepherd *et al.* (2007) (Australia)	RCT – three groups: self-directed learning package vs. SDLP with scenario-based virtual workshops (on PC) vs. SDLP with low fidelity simulation	74	Yes	New graduate nurses: random group allocation. Rater blinded to method of education	Analysis of means and *t*-tests	Not given	

ANOVA, analysis of variance; ANCOVA, analysis of covariance; PC, personal computer; SDLP, self-direct learning package; RCT, randomized controlled trial; HFS, high fidelity simulation.

tive method of teaching and learning. Assessments to demonstrate statistically significant gains over and above the comparator learning method were mixed. Six of 12 studies demonstrated additional gains in knowledge, critical thinking ability, satisfaction or confidence compared with the control group. Tests for between-group differences quantified these gains as ranging from 7 to 11 percentage points (Table 3).

Knowledge

Of nine studies assessing the effect of simulation on knowledge, four showed statistically significantly higher means for the experimental vs. the control group. Alinier *et al.* (2006) reported a mean difference of +7% ($P < 0{\cdot}001$, 95% CI); Brannan *et al.* (2008) reported higher experimental group means (15·58 vs. 14·17: $P = 0{\cdot}002$); Howard (2007) reported case-adjusted scores of +10·5% and Linden (2008) reported statistically significantly greater knowledge improvement ($P \leq 0{\cdot}001$) for the simulation group. Birch *et al.* (2007), whilst reporting non-statistically significant gains in learning on initial postpartum haemorrhage education, reported sustained improvement in knowledge at 3 months for the HFS group, although this did not reach a statistical significance level.

Critical thinking

Eleven studies assessed critical thinking directly or via a proxy of self-reported confidence in ability to make clinical judgments. Of these, five (45%) reported statistically significantly greater scores for the experimental group vs. control group (Jeffries & Rizzolo 2006, Shepherd *et al.* 2007, Linden 2008, Ruggenberg 2008, Brown & Chronister 2009) (Table 3). Others that applied a critical thinking scale, such as the California Critical Thinking Disposition Inventory (Ravert 2004), found no difference in critical thinking between groups. Ravert (2004) also reported no difference for four learning styles compared with learning by clinical seminar. A single randomized trial (Shepherd *et al.* 2007) that directly assessed critical thinking via scored patient clinical assessments using HFS showed statistically significantly higher mean scores of +11% ($P < 0{\cdot}001$) for the simulation education vs. the control group (Table 3). Assessors were blinded to participants' method of education for this assessment.

Satisfaction with learning experience

A single trial with 798 students in multiple centres that assessed students' satisfaction with their learning experience (Jeffries & Rizzolo 2006) reported statistically significantly higher scores on satisfaction for the simulation vs. control group.

Table 3 Results and evidence of *effect* of simulation in nursing education

Study	Clinical theme	Intervention and exposure to simulation	Comparator	Assessment measures	Effect on knowledge	Effect on critical thinking or satisfaction or confidence
Alinier *et al.* (2006)	Pre- and postoperative care	6 hours of HFS over two sessions; four scenarios in groups of four working in pairs plus team debriefing using video & team observer role	Usual education	Valid OSCE on clinical knowledge, technical ability and communication skills	Statistically significant improvement 7% in mean *t*-test scores for experimental group (7·18% points vs. 14·18% points for experimental groups (95% CI): independent sample *t*-test d.f. = 97, $P < 0{\cdot}001$)	No statistically significant difference on stress or confidence working in technological environment
Birch *et al.* (2007)	Emergency obstetrics skills	1-day team training using repeated HFS with guided debriefing, or (group 2) half-day lecture with half-day HFS	Lecture-based teaching: 1 day	Altered valid questionnaire on postpartum haemorrhage	All teams improved in knowledge (non-statistically significant) but the HFS alone showed sustained improvement at 3 months	All teams improved in perceived confidence (non-statistically significant); the HFS showed most improvement
Brannan *et al.* (2008)	Acute myocardial infarction	2 hours: preparatory case vignettes with one HPS simulation experience in groups 8–10, plus debriefing	2-hour lecture	Valid AMI management (AMIQ) questionnaire plus 34-item Confidence Level Tool	Statistically significantly higher means for simulation group (AMIQ post-tests: Simulation $15{\cdot}58 \pm 2{\cdot}13$ vs. control $14{\cdot}17 \pm 1{\cdot}86$; $P = 0{\cdot}002$)	No difference in confidence results
Brown & Chronister (2009)	ECG rhythms	5·8 hours of didactic instruction and 2·5 hours of simulation (nine experiences) over 4 weeks	6·6 hours of didactic instruction over 4 weeks	Evolve Electrocardiogram Custom Exam (Elsevier) plus weighting via Health Education Predictions Model	Not tested	No difference in critical thinking scores between groups. Control group showed statistically significantly higher Confidence scores than the experimental group
Griggs (2003)	Medical-surgical skills	2+ hours of hands-on simulation plus simulation practice in labs over 4 hours in teams of 6–8	Usual teaching	Nursing Clinical Exam and Nursing Clinical Education Survey	No effect on knowledge	No effect on self-perceptions of nursing competence or decision-making (critical thinking) ability
Howard (2007)	Acute coronary syndrome and CVA	Individuals in teams of 3–5 briefed via slideshow & complete two simulation scenarios of 15 minutes & oral and written facilitated debriefing using video (total 2·5 hours)	2·5 hours usual teaching (case study plus group discussion)	Medical-surgical nursing knowledge and critical thinking via Simulation Evaluation Survey and Case Study Evaluation	Case adjusted scores for HFS +10·5% compared with case study group	Case adjusted scores statistically significantly different ($P = 0{\cdot}051$) but no effect shown

Table 3 *(Continued)*

Study	Clinical theme	Intervention and exposure to simulation	Comparator	Assessment measures	Effect on knowledge	Effect on critical thinking or satisfaction or confidence
Jeffries & Rizzolo (2006) (USA)	Postoperative patient care	Videotaped lecture and filmed simulation (40 minutes) plus one 20-minute HFS in groups of 4 – either (b) hands-on simulation with static manikin or (c) hands-on HFS [plus debriefing (20 minutes) using audiotape or videotape for all three groups]	Videotaped lecture and filmed simulation (40 minutes) plus written case study (group a)	Questionnaire on postoperative care, valid Educational Practices in Simulation Scale, Simulation Design Scale (experiences rating), Self Confidence Scale, and performance self-report	No difference between any group on knowledge scores	Statistically significant greater scores for simulation groups a,b, on confidence scores and sign. greater scores for HFS group alone on satisfaction with learning experience
Linden (2008)	Basic clinical skills	Traditional lecture & audiovisual plus skill stations plus multiple choice test plus simulation: teams of 8–10 in pairs complete two scenarios & multiple choice test	Traditional lecture & audiovisual plus skill stations then same test	Multiple choice examination on nursing knowledge and problem solving	(Measured together with critical thinking result- knowledge statistically significantly improved)	Statistically significantly greater increase in cognitive learning ($P < 0{\cdot}000$) for experimental (simulation) groups which were homogenous
Ravert 2004)	Clinical nursing skills	5x weekly 90-minute education sessions each including a scenario for HFS	5x 90-minute case seminar, discussion weekly	California Critical Thinking Disposition Inventory; Californian Critical Thinking Skills Test; Self-efficacy for nursing skills evaluation; written performance evaluation; evaluation of video scenarios	Both groups gained but no evidence of difference re cognitive variables	No statistically significant difference in gain in critical thinking between groups or by any of four learning styles. Simulation and clinical seminar had similar outcomes
Ruggenberg (2008)	Acute respiratory distress (asthma)	1 hour of simulation education in groups of 2–5 (20 minutes HFS scenario plus debriefing) plus usual teaching	1 hour usual teaching (case study, video, group discussion)	Knowledge acquisition and active learning	No difference re cognitive variables	Statistically significant difference ($P < 0{\cdot}01$) for active learning and engagement; higher mean scores for HFS group.
Scherer *et al.* (2007)	Cardiac event (atrial fibrillation)	1 hour slide presentation then one simulation scenario (20 minutes) and debriefing using video	Seminar: case study presentation and develop care plan	Knowledge and confidence tests before, after 1 week and after 1 month	No differences in pre-test and post-test 1 or post-test 2 for knowledge variables	No statistically significant difference between groups. Simulation and clinical seminar had similar outcomes
Shepherd *et al.* (2007)	Adult clinical assessment	Two simulation scenarios using low fidelity manikin (c)	Self- learning package (a) or same with virtual education (b)	Scored systematic patient assessment using a manikin	n/a	Mean test score for (c). Simulation group was statistically significant higher (135·52, $P < 0{\cdot}001$) than for (a). (107·42) or (b). (102·77) – scores approx 11% higher (180 points vs. 157; 163 points)

HFS, high fidelity simulation; OSCE, objective structured clinical examination.

Design and evaluation issues

Determining the effectiveness of simulation education compared with other methods of education in nursing (the research question) was complicated by lack of robust evidence in the nursing literature and few studies that could be directly compared due to various experimental designs delivering a range of intervention strategies.

Samples tended to be small (<100) and non-representative. For example, Scherer *et al.* (2007), in a study focusing on the management of cardiac events, compared a convenience sample of 13 Registered Nurses in a simulation group with 10 others in a case study group (controls). Furthermore, in many studies the control and experimental groups both experienced interactive teaching techniques. Scherer *et al.* (2007) reported that their experimental group attended a 60-minute slide presentation followed by a video-recorded 20-minute simulation scenario task followed by debriefing. The control group attended a case study seminar and prepared a care plan. Both groups completed 'knowledge' and 'confidence' pre-tests and post-tests 1 week and 1 month later. There were no statistically significant differences between the groups for the knowledge and confidence measures, indicating similar outcomes for both teaching methods. However, both groups experienced group discussion, worked together on a problem-solving care plan and had access to academic leadership, although the techniques differed. Given the small sample size ($n = 23$) and one exposure to simulation, it is unsurprising that HFS performance did not differ statistically significantly to the control. These and other design differences, such as the point at which knowledge/retention were measured, varied across all the studies.

Howard (2007), on the other hand, demonstrated that case-adjusted scores for a team-based simulation experimental group ($n = 24$) were 10·5 percentage points above the knowledge scores for a control group ($n = 25$). Results showed a positive (but non-statistically significant) trend in critical thinking for the simulation group. In this study of acute coronary syndrome and cerebral vascular accident management, between-group differences were demonstrated by analysis of covariance and there was an adequate sample and similar intervention exposure times.

In the largest study of 798 undergraduate nursing students, Jeffries and Rizzolo (2006) gave substantial data about simulation using various levels of fidelity and rigorous evaluation with validated instruments (see Table 3). Learning outcomes were compared for three intervention groups: case study, a static manikin group and a HFS manikin group. All groups gained knowledge but there was no difference between the groups. However, the HFS group were more satisfied and the HFS and static manikin groups reported statistically significantly greater confidence in their ability to care for a postoperative patient compared with the case study group.

Discussion

Although all studies showed that simulation techniques were a valid method of education, only half of those which compared simulation with a control group were able to show *additional* gains in knowledge, critical thinking, perceived clinical confidence or satisfaction ($n = 6$; 50%). These increases were statistically significant.

However, the lack of variation between simulation education and other similarly *interactive* comparator education strategies (such as clinical seminar, skill stations, videotaped simulation or case study presentation) may have reduced the comparative effect. Simulation education was, however, shown to be superior regarding its effect on knowledge compared with traditional lecture as the sole method of teaching in one study (Brannan *et al.* 2008).

In the 12 papers reviewed, the designs and methods varied considerably and there were differing levels of validity and reliability. Participant recruitment was predominantly by convenience and the characteristics of those who *did not* volunteer were unknown. There was variability in assessing education outcomes as in some studies learning was assessed prospectively (immediately after teaching) and in some retention was assessed 1 week or 1 month after the intervention. Thus, there was potential for bias. These variations limited our ability to draw inference or quantify the results from the review.

Some researchers had used validated assessment instruments such as an OSCE for clinical knowledge and technical ability. These are recognized as the best assessment option, even though there is some question about their validity in assessing overall competence (Watson *et al.* 2002). However, controversially, assessment measures were often indirect and self-reported, such as assessment of nurses' perceptions of their critical thinking using a proxy such as relative 'confidence' in decision-making (e.g. using the Self-confidence Scale). Whilst it is recognized that nurses' competence requires more than mere clinical knowledge and must extend to synthesis and knowledge application (Fowler-Durham & Alden 2007), use of these proxy measures introduces questions about the reliability of differences presented as valid indicators of learned skills. Further studies are needed which compare actual assessments of students' performance post-education, either using OSCEs or expert reassessment of simulation events.

What is already known about this topic

- Simulation is widely used in nursing education.
- Simulation may assist students to apply knowledge to clinical contexts, narrowing the 'know' vs. 'do' gap.
- Few researchers have directly compared simulation in nursing with other teaching/learning methods.

What this paper adds

- All included studies reported simulation as a valid teaching/learning strategy, and six showed additional gains in knowledge, critical thinking ability, satisfaction or confidence compared with a control group.
- Simulation may have some advantage over other teaching/learning methods.
- Additional well-designed studies are needed to quantify simulation education outcomes.

Implications for practice and/or policy

- Medium and/or high fidelity simulation using manikins is an effective teaching and learning method when best practice guidelines are adhered to.
- Further exploration is needed to determine the effect of team size on learning and to develop a universal method of outcome measurement.

Core components of successful simulation were apparent in this review and are presented in Table 4. These core components of simulation include briefing, simulation and debriefing exercises, but practices vary according to the context of the scenario. Role assignment, including that of leader, does not appear to have an influence on overall learning outcomes (Alinier *et al.* 2006, Jeffries & Rizzolo 2006, Howard 2007, Brannan *et al.* 2008, Linden 2008, Ruggenberg 2008), supporting the notion that *exposure* to the simulation experience is the operative variable. However, a greater number of simulations does not necessarily result in superior learning (Brown & Chronister 2009). Feedback is essential and is perhaps the most important factor influencing learning (Issenberg *et al.* 2005), because it allows students to self-assess their skills and then 'monitor their progress towards skill acquisition and maintenance' (p. 21). Feedback is achieved by a variety of means, including student observer and instructor feedback and from reflective review of video records (Seropian *et al.* 2004, Lasater 2007). HFS does require high staff:student ratios (Hovancsek 2007); however, successful learning has been achieved when students work in pairs in a single role or in a team of 8–10 (Alinier *et al.* 2006, Brannan *et al.* 2008).

Important components of simulation also include a need to match the simulation to clinical reality and the relevant curriculum, with provision of academic support for briefing and debriefing and scenario management in both individual and team-work settings. These findings concur with the four key facets of simulation education that assist learning listed earlier (Kneebone 2005).

Review limitations

Some limitations apply to this review. One study located had a high quality design (Level 11 evidence: an RCT) but the remainder were Level 111 evidence; pseudo-randomized controlled studies, comparative studies or lower (National Health and Medical Research Council 2000). Although most studies had experimental designs with random assignment to groups from particular student cohorts, the characteristics of non-participants were often unknown. Inadequate sample size was apparent in some studies and this limited the analyses. In some, but not all, studies group differences such as previous clinical experience or knowledge were controlled. Several studies may have been confounded by the limited exposure to a simulation experience, which ranged from one 15–20 minute session to weekly simulation sessions each of 90 minutes over 5 weeks. Finally, the use of indirect outcome measures such as self-perceived confidence may not be as reliable as clinical observations or other validated instruments in assessing learning, thus restricting statistical outcomes. These issues limit the generalizability of the review results. However, the strength of this review is that it brings together a collection of studies in an appraisal of the effectiveness of medium/HFS education in nursing education compared with other teaching and learning methods.

Table 4 Simulation components used by effective studies

Physical environment	Manikins in applicable clinical setting with equipment orientation
Curriculum-based scenarios	Clinical care scenarios based upon curricula, incorporating best practice guidelines
Academic support	Academic staff throughout the simulation
3-step simulation process	Stepped learning process based on (i) Briefing, (ii) Simulation and (iii) Debriefing
Exposure	Repeated simulation exposure in individual or team work settings

Conclusion

The available evidence supports the notion that medium and/or HFS using manikins is an effective teaching and learning method where best practice guidelines are adhered to. Simulation may also have some advantages over other teaching methods, depending on the context and subject method. Simulation enables nurses to develop, synthesize and apply their knowledge in a replica of real experience. Further exploration is needed to determine the effect of team size on learning and to develop a universal method of outcome measurement.

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Conflict of interest

The authors declare that they have no conflict of interest.

Author contributions

RC and SC were responsible for the study conception and design. RC collected the data and RC and SC performed the data analysis and drafted the manuscript. SC made critical revisions to the paper for important intellectual content.

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