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).


### 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>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
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<tbody>
<tr>
<td>Partial task trainers (low-tech simulators)</td>
<td>Replica models or manikins used to learn, practice &amp; gain competence in simple techniques and procedures</td>
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<td>Peer to peer learning</td>
<td>Peer collaboration used to develop and master skills – such as basic health and physical assessment</td>
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<tr>
<td>Screen-based computer simulators</td>
<td>Programs used to acquire knowledge, to assess competency of knowledge attainment and to provide feedback related to clinical knowledge and critical-thinking skills.</td>
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<td>Virtual reality</td>
<td>Combines a computer-generated environment with tactile, auditory and visual stimuli provided through sophisticated partial trainers to promote increased authenticity</td>
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<td>Haptic systems</td>
<td>A simulator that combines real-world and virtual reality exercises into the environments</td>
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<td>Standardized patients</td>
<td>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</td>
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<td>Full-scale simulation (medium to high fidelity)</td>
<td>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</td>
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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
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>
<thead>
<tr>
<th>Study &amp; origin</th>
<th>Design</th>
<th>Sample size</th>
<th>Sample size</th>
<th>Focused research question</th>
<th>Selection/allocation to case or control groups</th>
<th>Power calculation/analysis</th>
<th>Baseline comparability groups</th>
<th>Confounding factors considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alinier et al. (2006) (USA)</td>
<td>Pre-test post-test experiment: usual training vs. added HFS in scenarios</td>
<td>99</td>
<td>Yes</td>
<td>Volunteer undergraduate nursing students; random group allocation</td>
<td>Sample size adequate for effect 1:0. Analysis of means, t-tests</td>
<td>Yes: accounted for</td>
<td>Yes</td>
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</tr>
<tr>
<td>Birch et al. (2007) (USA)</td>
<td>Pre-test post-test experiment: lecture vs. HFS or else combination of both</td>
<td>36</td>
<td>Not given</td>
<td>Random selection junior/senior medical/midwifery staff; multi-professional teams of six randomly allocated to method of education</td>
<td>Not adequate sample to achieve statistical significance. Analysis of means</td>
<td>Yes</td>
<td>How much simulation is required to train/sustain?</td>
<td></td>
</tr>
<tr>
<td>Brown &amp; Chronister (2009) (USA)</td>
<td>Experimental; comparative correlational design; HFS vs. didactic instruction</td>
<td>140</td>
<td>Yes</td>
<td>Recruited senior baccalaureate nursing students allocated by course selection</td>
<td>Power calculation not given. Two-sample t-tests, regression analysis</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Brannan et al. (2008) (USA)</td>
<td>Pre-test post-test experiment HFS vs. lecture</td>
<td>107 (100%)</td>
<td>Yes</td>
<td>Sample: all enrolled undergraduate nursing students allocated to two groups</td>
<td>Power calculation not given. Multiple linear regression analyses</td>
<td>Yes</td>
<td>No difference in confidence results</td>
<td></td>
</tr>
<tr>
<td>Griggs (2003) (USA)</td>
<td>Pre-test post-test experiment HFS vs. managing actual patients</td>
<td>27 (93%)</td>
<td>Yes</td>
<td>Volunteer senior undergraduate nursing students randomly assigned: 12 in experimental group, 15 controls</td>
<td>Analysis of means. Independent samples t-test for confidence</td>
<td>Yes</td>
<td>Yes: post-test after further 12 clinical practice days</td>
<td></td>
</tr>
<tr>
<td>Howard (2007) (USA)</td>
<td>Pre-test post-test experiment HFS vs. usual teaching (video/case study/group discussion)</td>
<td>49</td>
<td>Yes</td>
<td>Convenience sample of 50 nursing undergraduates, randomly assigned to groups by coin-toss</td>
<td>Sample size tested; adequate Analysis of means, ANCOVA, controlled for variance</td>
<td>Yes: variance accounted for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jeffries &amp; Rizzolo (2006) (USA)</td>
<td>Pre-test post-test cross-over experiment: High vs. Low fidelity simulation vs. case study simulation</td>
<td>798</td>
<td>Yes</td>
<td>Convenience? sample of 798 nursing students from eight sites: randomized to controls (n = 398) and 403 to experimental group</td>
<td>Power adequate. Analysis methods not given</td>
<td>Not given</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linden (2008) (USA)</td>
<td>Pre-test post-test quasi-experiment HFS vs. usual teaching</td>
<td>97 (96%)</td>
<td>Yes</td>
<td>Volunteer undergraduate nursing students – randomly assigned by class</td>
<td>Power adequate. Analysis of variance (ANOVA)</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Ravert (2004) (USA)</td>
<td>Pre-test/post-test experiment HFS vs. usual teaching (case seminar and discussion)</td>
<td>25 (39%)</td>
<td>Yes</td>
<td>Convenience sample nursing undergraduates; random allocation to two groups by number draw</td>
<td>No power calculation given, although small sample recognized. Analysis: general linear model procedure</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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</tbody>
</table>
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% ($P < 0.001$, 95% CI); Brannan et al. (2008) reported higher experimental group means (15.58 vs. 14.17: $P = 0.002$); Howard (2007) reported statistically significantly greater knowledge improvement ($P \leq 0.001$) 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% ($P < 0.001$) 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

<table>
<thead>
<tr>
<th>Study</th>
<th>Clinical theme</th>
<th>Intervention and exposure to simulation</th>
<th>Comparator</th>
<th>Assessment measures</th>
<th>Effect on knowledge</th>
<th>Effect on critical thinking or satisfaction or confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alinier et al. (2006)</td>
<td>Pre- and postoperative care</td>
<td>6 hours of HFS over two sessions; four scenarios in groups of four working in pairs plus team debriefing using video &amp; team observer role</td>
<td>Usual education</td>
<td>Valid OSCE on clinical knowledge, technical ability and communication skills</td>
<td>Statistically significant improvement 7% in mean t-test scores for experimental group (718% points vs. 1418% points for experimental groups (95% CI): independent sample t-test d.f. = 97, ( P &lt; 0.001 ))</td>
<td>No statistically significant difference on stress or confidence working in technological environment</td>
</tr>
<tr>
<td>Birch et al. (2007)</td>
<td>Emergency obstetrics skills</td>
<td>1-day team training using repeated HFS with guided debriefing, or (group 2) half-day lecture with half-day HFS</td>
<td>Lecture-based teaching: 1 day</td>
<td>Altered valid questionnaire on postpartum haemorrhage</td>
<td>All teams improved in knowledge (non-statistically significant) but the HFS alone showed sustained improvement at 3 months</td>
<td>All teams improved in perceived confidence (non-statistically significant); the HFS showed most improvement</td>
</tr>
<tr>
<td>Brannan et al. (2008)</td>
<td>Acute myocardial infarction</td>
<td>2 hours: preparatory case vignettes with one HFS simulation experience in groups 8–10, plus debriefing</td>
<td>2-hour lecture</td>
<td>Valid AMI management (AMIQ) questionnaire plus 34-item Confidence Level Tool</td>
<td>Statistically significantly higher means for simulation group (AMIQ post-tests: Simulation 15.58 ± 2.13 vs. control 14.17 ± 1.86; ( P = 0.002 ))</td>
<td>No difference in confidence results</td>
</tr>
<tr>
<td>Brown &amp; Chronister (2009)</td>
<td>ECG rhythms</td>
<td>5-8 hours of didactic instruction and 2-5 hours of simulation (nine experiences) over 4 weeks</td>
<td>6-6 hours of didactic instruction over 4 weeks</td>
<td>Evolve Electrocardiogram Custom Exam (Elsevier) plus weighting via Health Education Predictions Model</td>
<td>Case adjusted scores for HFS +10.5% compared with case study group</td>
<td>No difference in critical thinking scores between groups. Control group showed statistically significantly higher Confidence scores than the experimental group</td>
</tr>
<tr>
<td>Griggs (2003)</td>
<td>Medical-surgical skills</td>
<td>2+ hours of hands-on simulation plus simulation practice in labs over 4 hours in teams of 6–8</td>
<td>Usual teaching</td>
<td>Nursing Clinical Exam and Nursing Clinical Education Survey</td>
<td>No effect on knowledge</td>
<td>No effect on self-perceptions of nursing competence or decision-making (critical thinking) ability</td>
</tr>
<tr>
<td>Howard (2007)</td>
<td>Acute coronary syndrome and CVA</td>
<td>Individuals in teams of 3–5 briefed via slideshow &amp; complete two simulation scenarios of 15 minutes &amp; oral and written facilitated debriefing using video (total 2.5 hours)</td>
<td>2.5 hours usual teaching (case study plus group discussion)</td>
<td>Medical-surgical nursing knowledge and critical thinking via Simulation Evaluation Survey and Case Study Evaluation</td>
<td>Case adjusted scores for HFS +10.5% compared with case study group</td>
<td>Case adjusted scores statistically significantly different (( P = 0.051 )) but no effect shown</td>
</tr>
<tr>
<td>Study</td>
<td>Clinical theme</td>
<td>Intervention and exposure to simulation</td>
<td>Comparator</td>
<td>Assessment measures</td>
<td>Effect on knowledge</td>
<td>Effect on critical thinking or satisfaction or confidence</td>
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<tr>
<td>Jeffries &amp; Rizzolo (2006) (USA)</td>
<td>Postoperative patient care</td>
<td>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)</td>
<td>Videotaped lecture and filmed simulation (40 minutes) plus written case study (group a)</td>
<td>Questionnaire on postoperative care, valid Educational Practices in Simulation Scale, Simulation Design Scale (experiences rating), Self Confidence Scale, and performance self-report</td>
<td>No difference between any group on knowledge scores</td>
<td>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</td>
</tr>
<tr>
<td>Linden (2008)</td>
<td>Basic clinical skills</td>
<td>Traditional lecture &amp; audiovisual plus skill stations plus multiple choice test plus simulation: teams of 8–10 in pairs complete two scenarios &amp; multiple choice test</td>
<td>Traditional lecture &amp; audiovisual plus skill stations then same test</td>
<td>Multiple choice examination on nursing knowledge and problem solving</td>
<td>(Measured together with critical thinking result-knowledge statistically significantly improved)</td>
<td>Statistically significantly greater increase in cognitive learning ($P &lt; 0.000$) for experimental (simulation) groups which were homogenous</td>
</tr>
<tr>
<td>Ravert (2004)</td>
<td>Clinical nursing skills</td>
<td>5x weekly 90-minute education sessions each including a scenario for HFS</td>
<td>5x 90-minute case seminar, discussion weekly</td>
<td>California Critical Thinking Disposition Inventory; Californian Critical Thinking Skills Test; Self-efficacy for nursing skills evaluation; written performance evaluation; evaluation of video scenarios</td>
<td>Both groups gained but no evidence of difference re cognitive variables</td>
<td>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</td>
</tr>
<tr>
<td>Ruggenberg (2008)</td>
<td>Acute respiratory distress (asthma)</td>
<td>1 hour of simulation education in groups of 2–5 (20 minutes HFS scenario plus debriefing) plus usual teaching</td>
<td>1 hour usual teaching (case study, video, group discussion)</td>
<td>Knowledge acquisition and active learning</td>
<td>No difference re cognitive variables</td>
<td>Statistically significant difference ($P &lt; 0.01$) for active learning and engagement; higher mean scores for HFS group. No statistically significant difference between groups. Simulation and clinical seminar had similar outcomes</td>
</tr>
<tr>
<td>Scherer et al. (2007)</td>
<td>Cardiac event (atrial fibrillation)</td>
<td>1 hour slide presentation then one simulation scenario (20 minutes) and debriefing using video</td>
<td>Seminar: case study presentation and develop care plan</td>
<td>Knowledge and confidence tests before, after 1 week and after 1 month</td>
<td>No differences in pre-test and post-test 1 or post-test 2 for knowledge variables n/a</td>
<td>Mean test score for (c). Simulation group was statistically significant higher (135.52, $P &lt; 0.001$) than for (a), (107.42) or (b), (102.77) – scores approx 11% higher (180 points vs. 157; 163 points)</td>
</tr>
<tr>
<td>Shepherd et al. (2007)</td>
<td>Adult clinical assessment</td>
<td>Two simulation scenarios using low fidelity manikin (c)</td>
<td>Self-learning package (a) or same with virtual education (b)</td>
<td>Scored systematic patient assessment using a manikin</td>
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</table>

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, 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 1 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

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