Effectiveness of using high-fidelity simulation on learning outcomes in undergraduate nursing education: systematic review and meta-analysis

S.I. TONAPA[1], M. MULYADI[2], K.H.M. HO[3], F. EFENDI[4,5]

[1]College of Nursing, Kaohsiung Medical University, Kaohsiung, Taiwan
[2]School of Nursing, Faculty of Medicine, Universitas Sam Ratulangi, Manado, Indonesia
[3]The Nethersole School of Nursing, The Chinese University of Hong Kong, Hong Kong
[4]Faculty of Nursing, Universitas Airlangga, Surabaya, Indonesia
[5]School of Nursing and Midwifery, La Trobe University, Melbourne, Australia

Abstract. – OBJECTIVE: **High-fidelity simulation-based learning, which mimics situation, environmental, and psychological exposure in the clinical setting, potentially helps nursing students acquire knowledge, confidence, and skills in learning clinical skills during the transition from pre-clinical to clinical practice. However, inconsistent evidence on its effect on learning outcomes was presented across the studies. The aim of our study was to review and analyze the effectiveness of high-fidelity simulation on learning outcomes in undergraduate nursing education.**

MATERIALS AND METHODS: **This study was a systematic review and meta-analysis of experimental studies. A literature search was conducted in four databases (CINAHL, SocINDEX, PubMed, and Web of Science) until July 2021. The Cochrane Risk of Bias Tool was used to appraise the studies' quality. The random-effect model was used to conduct a meta-analysis.**

RESULTS: **Fourteen studies were eligible for quantitative synthesis. The pooled effect indicated high-fidelity simulation-based learning significantly increased nursing students' knowledge acquisition (standardized mean difference [SMD]: 1.73, $p < 0.001$), self-confidence (SMD: 0.56, $p = 0.019$) and skills performance (SMD: 1.71, $p = 0.006$).**

CONCLUSIONS: **Stakeholders within the academic institution may consider enculturating the involvement of high-fidelity simulation as part of an innovative teaching strategy in nursing curricula. Therefore, when graduates enter the workforce, they can function quickly and practice confidently in clinical settings without bringing potential harm.**

Key Words:
High-fidelity simulation, Learning outcomes, Meta-analysis, Nursing students, Nursing education, Education research.

Introduction

In the current situation, nursing education is challenged to link theoretical knowledge and practical experience[1]. This gap needs to be bridged because nursing students will transition from pre-clinical to clinical practice as registered nurses. With regard to the COVID-19 pandemic, a large proportion of clinical nursing practicum has been suspended worldwide[2,3]. This makes student nurses at the undergraduate level vulnerable when transitioning from pre-clinical to clinical practice, as the reality of clinical practice bears little resemblance to their experiences as students[4]. The use of simulation in nursing education allows nurse educators to replicate what happens in real environments and enable students to experience experiential learning[5,6]. Simulators employed in clinical nursing education include anatomical or mechanical models, computer-based simulations, high-fidelity simulators, virtual-reality simulators, and simulated patients[7]. In particulars, high-fidelity simulation has been utilized mainly because nursing education should ideally be oriented toward real-world situations in clinical settings[4,8]. While there are few reviews[9,10] on simulation in nursing education, to our knowledge, none have review and quantify the meta-effects of high-fidelity simulations in nursing education. As high-fidelity simulations in nursing education will potentially be standard during the pandemic and thereafter[1,2], this systematic review fills a critical gap on the effectiveness of high-fidelity simulations.

Nursing education is demanded to prepare students by providing scientific and innovative

Corresponding Author: Ferry Efendi, Ph.D, MSc, RN; e-mail: ferry-e@fkp.unair.ac.id

teaching methods that meet student expectations and respond to current demands in clinical settings[11]. A high-fidelity simulation is thought to be the solution for nursing education to fulfill these demands. High-fidelity simulation is the creation of an event, situation, or environment that accurately reflects a clinical setting where the centerpiece of the environment is an interactive manikin simulator or standardized patient with the ability to respond to physiological parameters[12]. The utilization of high-fidelity simulation in the hospital is recognized as a vital part of the staff development curricula and the best practice for the education or orientation of nursing personnel[13]. Although simulation-based learning is not comparable to practicum in the clinical setting because actual patients have complex responses[14], a high-fidelity simulation provides a safe environment that enables students to practice and learn. In addition, high-fidelity simulations have several advantages over low-fidelity simulations. For instance, previous studies[15,16] reported that students who trained with high-fidelity simulations showed a more positive attitude, increased critical thinking, and better performance with real patients than those who trained with low fidelity simulations.

In the context of nursing education, some of the evidence for the application of high-fidelity simulations has shown mixed findings on students' learning outcomes. For example, some studies[17,18] have found no differences between high-fidelity simulation and control groups in nursing students' knowledge, satisfaction, and self-confidence. Also, a large-scale nationwide study conducted under the auspices of the National Council of State Boards of Nursing (NCSBN), which compared educational outcomes of students participating in 10 percent, 25 percent, and 50 percent of high-fidelity simulations indicated there were no significant differences in clinical competency, nursing knowledge assessments, or NCLEX-RN® pass rates[19]. However, these findings were not in line with previous original studies[20-23] among nursing students who reported that high-fidelity simulations improve motivation and clinical judgment, knowledge acquisition, confidence, and core nursing competencies[24]. As such, the benefits of high-fidelity simulations are inconclusive, which warrants a synthesis of findings to confirm the effects of high-fidelity simulations in nursing education.

A previous systematic review[25] covering studies from 2007-2017 reported that high-fidelity simulations could reduce anxiety and increase self-confidence among nursing students. However, this study did not quantify the meta-effect of high-fidelity simulations. Another meta-analysis by Kim et al[13] reported that high-fidelity simulation-based training had the largest effect on learning outcomes among students and nurse practitioners compared to other levels of fidelity. Considering the different levels of educational attainment and clinical learning outcomes among undergraduate and postgraduate student groups[26], it is necessary to examine the effects of high-fidelity simulation-based learning specifically on undergraduate nursing students. Additionally, investigation of the effectiveness of high-fidelity simulation is warranted because the implementation of such simulation was often costly for nursing education institution. Therefore, this study aims to review and analyze the effectiveness of high-fidelity simulation on learning outcomes for undergraduate nursing students.

Materials and Methods

Design

This is a systematic review and meta-analysis of experimental studies. This review was reported under the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines[27]. In addition, the review protocol of this study was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42021260731).

Search Strategy

A systematic search for articles published through December 2021 was conducted in CINAHL, Embase, SocINDEX, PubMed, and Web of Science with the help of an experienced medical librarian. The search involved the use of the controlled vocabulary Medical Subject Headings (MeSH) terms "nursing students," "undergraduate students," "high fidelity simulation," "experimental study," and "randomized controlled trial." In addition, these keywords were combined with Boolean operators ("AND," "OR").

Eligibility Criteria

The inclusion criteria for articles were determined according to the population, intervention, comparison, outcome, and study design (PICOS) framework[28] (Table I). The inclusion criteria were as follows: participants were undergradu-

Table I. PICO(S) framework.

PICO(S)	Description of detail
Population	Undergraduate nursing student
Intervention	Teaching with high-fidelity simulation
Comparison	Usual teaching method with traditional lecture, clinical rotation, and laboratory practicum with mannequin
Outcome	Learning outcomes expressed as knowledge acquisition, self-confidence, and skills performance
Study Design	Experimental study

ate nursing students who received high-fidelity simulation-based learning as the main intervention; the comparison was teaching that applied conventional or traditional lecture; study outcomes were learning experience that expressed as self-confidence and knowledge acquisition. The study design included in this review was a randomized controlled trial (RCT) or a quasi-experimental study. Studies were excluded if they were not published in English, were not peer-reviewed, did not implement a high-fidelity simulation, did not measure learning outcomes, were not experimental in nature, and did not provide sufficient data.

Screening and Selection of Studies

All retrieved studies were imported into EndNote X9 to exclude duplicate studies. Next, two reviewers independently screened the remaining studies' titles and abstract to assess their eligibility. A third reviewer was invited if there was a difference in opinion between the two reviewers. Finally, the full text was screened and evaluated for eligibility.

Data Extraction

One reviewer extracted data (author name, publication year, country, study design, population/study degree, simulation session, debriefing, simulation modality, interventions and comparisons, outcomes, and tool measurement) from the included studies and discussed it with a second reviewer if further clarification was needed.

Quality Appraisal

The quality of each RCT included in this study was assessed independently by two reviewers using Cochrane Collaboration's risk of bias for randomized trials (RoB-2)[29]. Assessment items on the RoB-2 address bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in selecting the reported result. Items are measured as "low risk of bias," "some concerns," or "high risk of bias."

The intervention studies without randomization were assessed using a modified risk of bias in non-randomized studies of interventions (ROBINS)[30]. ROBINS focuses on the aspect of bias due to confounding, bias in the selection of participants, bias in the classification of interventions, bias due to deviations from intended interventions, bias due to missing data, bias in the measurement of outcomes, and bias in the selection of the reported result. Risk of bias is measured as "low risk," "moderate risk," "serious risk" or "critical risk." If the assessment was not unanimous for each item, the supervisor of the review team was invited to resolve the conflict.

Statistical Analysis

The extracted data from each study were transformed into a pre-calculated effect size with Campbell Collaboration, which uses an equation that considers the mean gain scores, pre- and post-intervention standard deviation (SD), and the correlation coefficient (r) between the pre- and post-intervention results. A conservative estimated value ($r = 0.5$) was applied because most studies[31] did not report the r values between the pre- and post-intervention scores.

As various knowledge acquisition and confidence scales were used in the reviewed studies, standardized mean difference (SMD) was used to estimate the effect size of each study. The effect size was interpreted as small (0.2), medium (0.5), or large (0.8). The SMD with a 95% confidence interval (95% CI) was used to calculate the pooled effect size using Comprehensive Meta-Analysis® Version 3.0 (Biostat, Englewood, NJ, USA). The significance level of pooled effect size was set at $p < 0.05$. Additionally, heterogeneity was estimated using Cochran's Q ($p < 0.01$ was considered significant), Tau-squared (τ^2), and the I-squared (I^2) indicated the percentage of observed variance explained by the heterogeneity. When heterogeneity was present, the random-effects model was applied to avoid underestimating the heterogeneity between treatments[31].

A sensitivity analysis was performed using the "remove one study" method, where each study's impact on the stability of overall effect size is assessed. Finally, we tested the possibility of publication bias *via* Egger's regression intercept and the Begg and Mazumdar Rank test; publication bias was identified when $p < 0.05$[32].

Results

Identification of Studies and Study Selection

From the four databases, we initially identified 281 articles. Of these, 72 were duplicates. The titles and abstracts of the remaining 209 studies were screened, and 169 studies were deemed ineligible because they did not meet the PICOS criteria for the following reasons: participants were not nursing students (n = 18), the intervention did not involve a high-fidelity simulation (n = 143), the study was a review (n = 7), and the article was an editorial (n = 1). A total of 40 studies were screened in full to assess eligibility. Of these, 28 studies were excluded: 14 did not utilize high-fidelity simulation, 12 did not meet outcomes, one was a qualitative study, and two did not provide mean and SD scores. A total of 12 studies met the selection criteria and included two studies from another review. Thus, 14 studies were included in the meta-analysis (Figure 1).

The Methodological Quality of Reviewed Studies

The overall risk of bias and risk of bias for each study are shown in Figure 2. Various degrees of risk of bias from low to moderate were found in the included studies. For example, two of the six RCTs had a risk of bias due to deviations from the intended intervention[33,34]. For the non-randomized studies, two of the eight studies had a mod-

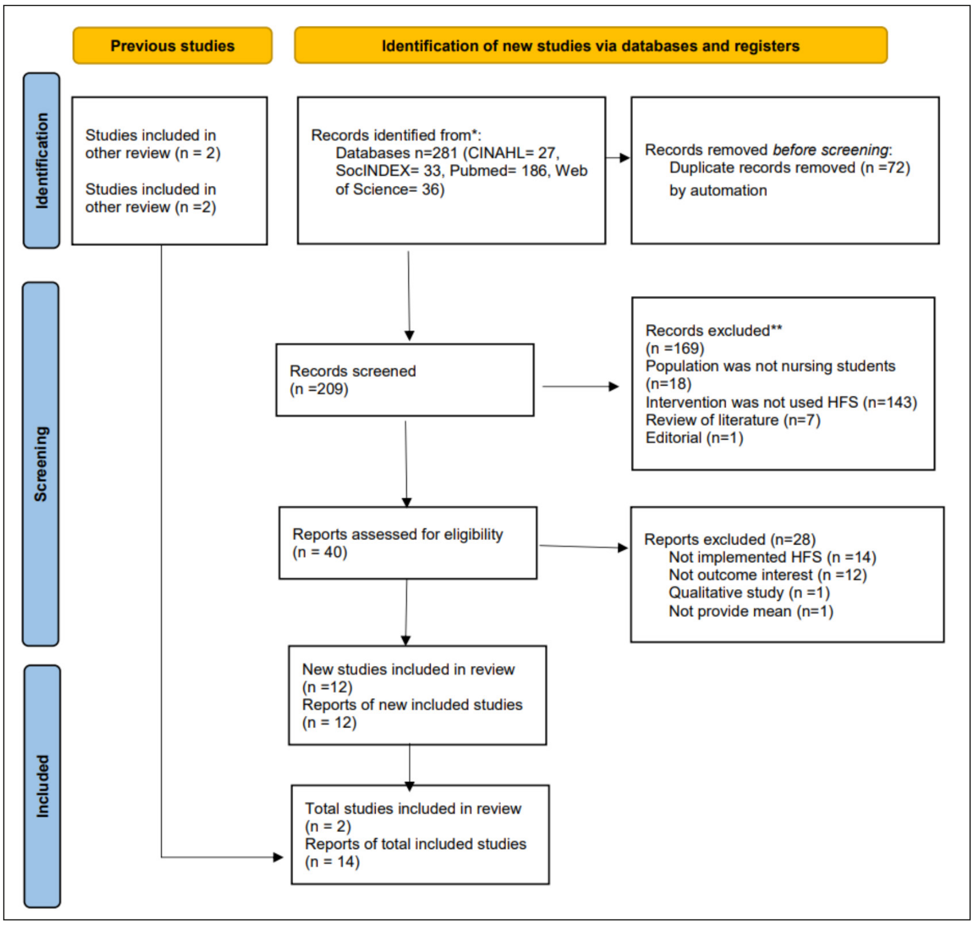


Figure 1. PRISMA Diagram – the process of study selection.

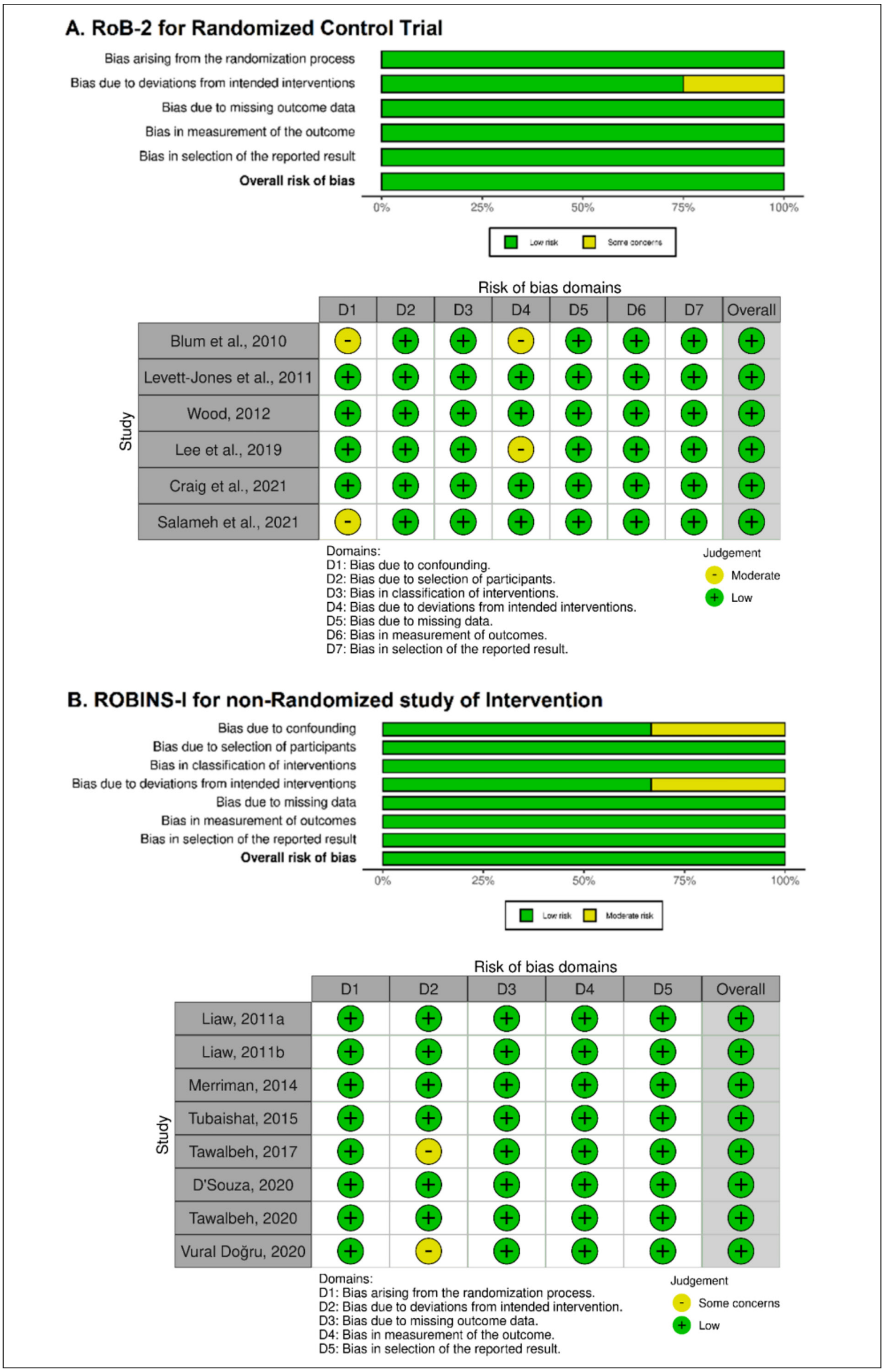


Figure 2. Overall risk of bias and risk of bias among included studies.

erate risk of confounding bias[35,36], and two of the eight studies had a moderate risk of performance bias[35,37]. In sum, the overall risk of bias in the 14 studies was low.

Study Characteristics

Detailed characteristics of the included studies are shown in Table II. Of the 14 studies that were reviewed, six were RCTs, and eight were quasi-experimental. Five of the reviewed studies were conducted in the USA[35,38-41], three in Jordan[33,42,43] and one each in Australia[18], United Kingdom[44], Taiwan[37], Turkey[34], Canada[23], and Palestine[36].

A total of 1,094 undergraduate nursing students were included in the 14 studies. Of them, 545 were in an intervention group, while 549 were in a control group. In the present study, nursing students in the intervention groups received high-fidelity simulation-based learning, while those in the control groups received typical learning methods such as regular lectures, skills labs with a static mannequin, and clinical practicums. Three studies[18,23,33] included a single session, six had multiple sessions[36-38,40-42], and five did not report the number of sessions[34,35,39,43,44]. Regarding intervention modality, all the studies used manikin simulator technology. In addition, all reviewed studies conducted debriefing sessions after the simulation(s).

Eight of the 14 studies examined learning outcomes by measuring nursing students' knowledge acquisition in various contexts, including knowledge about managing patients with life-threatening and critical conditions[18,37,43], cardiovascular, respiratory, and neurological systems[42], and performing nursing care plans such as cardiac auscultation, medication administration, and how to measure and monitor vital parameters[34,36,38]. All of the studies utilized validated instruments, either previously developed or newly self-developed instruments. Six studies[18,22,34,36,41,43] measured knowledge acquisition with self-developed multiple-choice questions (MCQ), one study[38] used the Medication Safety Knowledge Assessment (MSKA), and one study[37] used the Simulation-Based Learning Evaluation Scale (SBLES).

Five of the 14 studies examined learning outcomes by measuring nursing students' self-confidence in performing various tasks, such as in the management of cardiovascular, respiratory, and neurological health problems[42]; management of diabetes ketoacidosis[23]; management of respiratory emergency[33]; and medication administration[35]. All the studies utilized validated instruments, either previously developed or newly self-developed instruments. Three studies[33,35,41] measured students' confidence with a self-developed questionnaire, and one used the student satisfaction and self-confidence in learning (SSSCL) scale.

Among the 14 studies, four studies[39-41,44] examined learning outcomes by measuring nursing students' skills performance in performing the management patients with clinical deterioration condition. All the studies utilized validated instruments, either previously developed or newly self-developed instruments. Two studies[18,40] measured students' skills performance with a Rescuing a Patient in Deteriorating Situation Tool (RAPIDS-Tool), one used critical assessment competency examination, and one used the objective structured clinical examination (OSCE) checklist.

Effects of High-Fidelity Simulation-Based Learning on Students' Knowledge Acquisition

In the eight studies that involved 682 students, we analyzed the effect of high-fidelity simulation on students' knowledge acquisition. The pooled SMD using a random-effects model was 1.73 (95% CI: 0.99-2.47, $p < 0.001$), with considerable heterogeneity ($\tau^2 = 0.83$, $Q = 57.19$, df = 7, $I^2 = 87.76\%$) (Figure 3). These results suggest that teaching with high-fidelity simulation had a statistically significant effect on students' knowledge acquisition compared with usual teaching methods.

Effects of High-Fidelity Simulation-Based Learning on Students' Self-Confidence

Five studies involved 327 students; we analyzed the effect of high-fidelity simulation on students' self-confidence. The pooled SMD using a random-effects model was 0.56 (95% CI: 0.05-1.08, $p = 0.019$), with considerable heterogeneity ($\tau^2 = 0.25$, $Q = 17.91$, df = 4, $I^2 = 77.67\%$) (Figure 3). These results suggest that teaching with high-fidelity simulation had a statistically significant effect on students' self-confidence compared with usual teaching methods.

Effects of High-Fidelity Simulation-Based Learning on Students' Skills Performance

Four studies involved 181 students; we analyzed the effect of high-fidelity simulation on students' skills performance. The pooled SMD

Table II. Characteristics of the included studies.

Author, year, country	Study design	Participants	Intervention group: Nursing Context	Intervention group: Description of simulation	Intervention group: Debriefing	Intervention group: Number of simulation sessions	Intervention group: Modality	Control group	Outcomes and measurements tools
Blum et al[35], 2010, USA	Quasi-experimental	53 nursing students (junior year)	Health assessment and skills course	Used an HFS to demonstrate skill competency	Yes	Unknown	Manikins simulator	Practiced skill competency with task trainers and student volunteers	Confidence: student responses
Liaw et al[40], 2011[a], USA	Randomized controlled trial eporting of	31 third-year nursing using a students	Assessing, managing and reporting of patients with physiological deterioration	Simulation laboratory Sim-Man patient simulator	Yes	Four session simulator	Manikins activities	Laboratory performance:	Skills performance: RAPIDS-Tool
Liaw et al[41], 2011[b], USA	RCT	31 nursing students (third year)	Assessment of deteriorating conditions	Role play as a staff nurse to perform appropriate nursing assessment and interventions for the clinical deterioration event	Yes	Four session	Manikins simulator	Traditional lecture	Knowledge: validated multiple choice questions (MCQ) Confidence: Self-confidence scale (C-Scale)
Levett-Jones et al[18], 2011, Australia	Quasi-experimental	84 nursing students (third year)	Clinical deterioration in an elderly	Used an HFS to practice response to clinical deterioration in an older adult	Yes	One session	Manikins simulator	Practiced responses using full-body mannequin	Knowledge: self-developed MCQ
Wood and Toronto[39], 2012, USA	Quasi-experimental	85 nursing students (second year)	Critical assessment competency skills	Used an HFS to practice assessment competency skills	Yes	Unknown	Manikins simulator	Traditional practicum for ritical cassessment skills	Skills performance: Critical assessment competency examination

Continued

Table II ***(Continued).*** Characteristics of the included studies.

Author, year, country	Study design	Participants	Intervention group					Control group	Outcomes and measurements tools
			Nursing Context	Description of simulation	Debriefing	Number of simulation sessions	Modality		
Merriman et al[44], 2014, United Kingdom	RCT	34 nursing students (first-year)	Assessing and managing a deteriorating patient	Used an HFS to practice relation to assessing and managing a deteriorating patient	No	Unknown	Manikins simulator	Classroom based teaching	Skills performance: The objective structured clinical examination (OSCE) checklist Confidence: general perceived self efficacy and self-reported competency scores (GPSEC)
Tubaishat & Tawalbeh[43], 2015, Jordan	RCT	91 nursing students (fourth year)	Interpretation and management of cardiac arrhythmias	Used an HFS of cardiac arrhythmia	Yes	Unknown	Manikins simulator	Received a traditional lecture	Knowledge: self-developed structured questionnaire
Tawalbeh[33], 2017, Jordan	RCT	69 nursing students	Cardiopulmonary assessment skills	Received traditional theoretical education Used an HFS of a respiratory emergency	Yes	One session	Manikins simulator	Received traditional theoretical education and took part in traditional laboratory activities	Confidence: validated instruments
Lee et al[37], 2019, Taiwan	Pretest-posttest comparison	100 nursing students (second year)	Course of advanced acute care in adult	Used an HFS of a patient in the intensive care unit	Yes	Four sessions	Manikins simulator	Took part in traditional courses and case studies modified from the simulation scenario discussions	Knowledge: SBLES

Continued

Table II ***(Continued).*** Characteristics of the included studies.

Author, year, country	Study design	Participants	Intervention group: Nursing Context	Intervention group: Description of simulation	Intervention group: Debriefing	Intervention group: Number of simulation sessions	Intervention group: Modality	Control group	Outcomes and measurements tools
D'Souza et al[23], 2020, Canada	RCT	140 nursing students	Diabetes ketoacidosis in critical care	Reviewed clinical lab skills Used and HFS of a diabetes ketoacidosis simulation	Yes	One session	Manikins simulator	Attended clinical practice in the acute medical unit	Confidence: the SSSCL
Tawalbeh[22], 2020, Jordan	RCT	76 nursing students	Performing critical care intervention	Theoretical lectures Used HFSs about cardiovascular, respiratory, and neurological health problems	Yes	Nine sessions	Manikins simulator	Attended theoretical lectures and clinical training in-hospital	Knowledge: validated MCQ
Vural Doğru & Zengin Aydın[34], 2020, Turkey	RCT	72 nursing students (first year)	Cardiac auscultation	Cardiac auscultation training using an HFS	Yes	Unknown	Manikins simulator	Received traditional teaching with laboratory work using a static manikin	Knowledge: self-developed MCQ
Craig et al[38], 2021, USA	Quasi-experimental	77 nursing students (third year)	Safe medication administration	Used an HFS about medication administration Attended a clinical rotation on clinical units	Yes	Three sessions	Manikins simulator	Received standard training skills labs and continued to the clinical unit	Knowledge: the MSKA
Salameh, et al[36] 2021, Palestine	Quasi-experimental	151 nursing students (fourth year)	Simulation on mechanical ventilation	Regular course work for the advanced nursing course used an HFS about performing nursing care plans such as measuring and monitoring vital parameters	Yes	Six sessions	Manikins simulator	Took part in regular course work for the advanced nursing course	Knowledge: self-developed MCQ

RCT: Randomized controlled trial, HFS: high-fidelity simulation, RAPIDS-Tool: Rescuing a Patient in Deteriorating Situation Tool, SBLES: Simulation-Based Learning Evaluation Scale, MSKA: Medication Safety Knowledge Assessment, SSSCL: Student Satisfaction and Self Confidence in Learning, MCQ: Multiple Choice Questions.

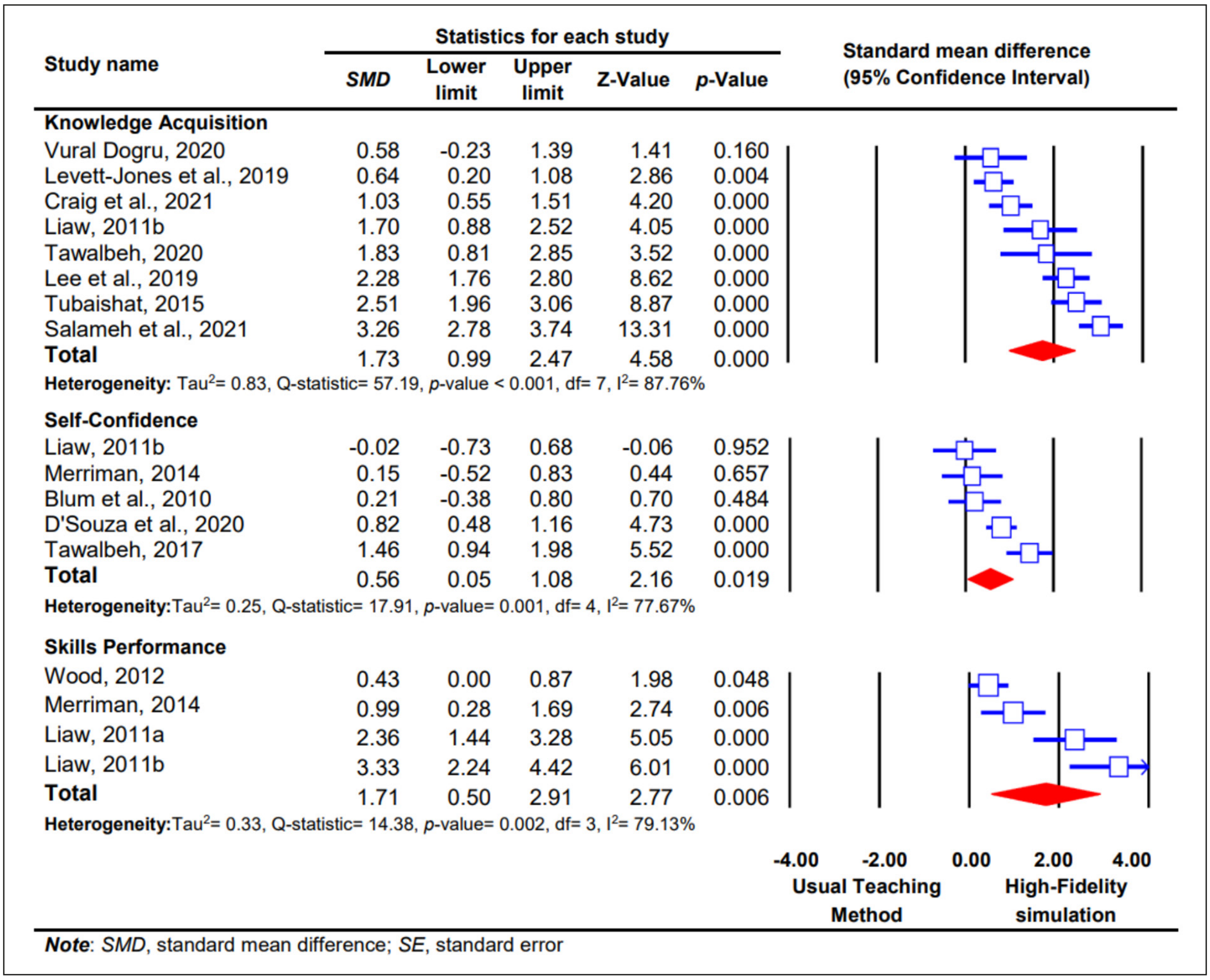


Figure 3. The effects of high-fidelity simulations on students' knowledge acquisition, self-confidence, and skills performance.

using a random-effects model was 1.71 (95% CI: 0.50-2.91, p = 0.006), with considerable heterogeneity (τ^2= 0.33, Q = 14.38, df = 3, I^2 = 79.13%) (Figure 3). These results suggest that teaching with high-fidelity simulation had a statistically significant effect on students' skills performance compared with usual teaching methods.

Publication Bias

The results of the publication bias analysis are provided in Table III. Indication for publication bias ($p > 0.05$) was not found with Egger's regression or the Begg and Mazumdar Rank test, which suggests potential considerable publication bias relatively small.

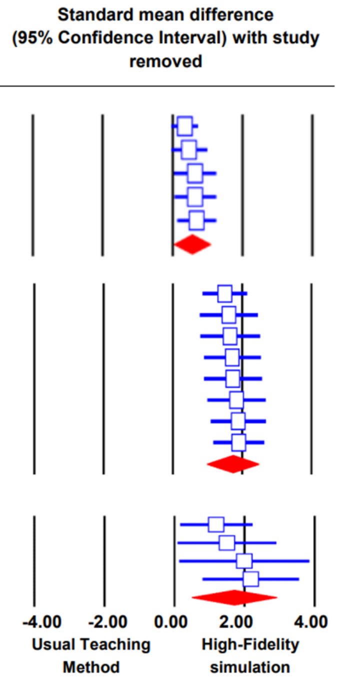
Sensitivity Analysis

The "leave-one study" results are shown in Figure 4. The sensitivity analysis indicated no significant change in SMD, and heterogeneity was still present after removing studies with the heaviest weight[18,23,39].

Table III. Publication bias.

Outcome	Begg and Mazumdar Rank			Egger's Regression		
	Tau	Z-value	*p*-value	Intercept	*t*-value	*p*-value
Knowledge acquisition	0.178	0.618	0.536	-3.710	1.146	0.334
Self-confidence	-0.500	1.224	0.220	-3.710	1.146	0.334
Skills performance	0.500	1.019	0.308	5.840	2.399	0.138

Study name	Statistics with study removed				
	Weight	*SMD*	Lower limit	Upper limit	*p*-Value
Self-Confidence					
Tawalbeh, 2017	20.85	0.36	0.00	0.80	0.05
D'Souza et al., 2020	23.74	0.47	0.00	1.20	0.05
Blum et al., 2010	19.65	0.65	0.05	1.25	0.03
Merriman, 2014	18.11	0.65	0.07	1.24	0.03
Liaw, 2011b	17.66	0.69	0.15	1.24	0.01
Total		0.56	0.05	1.08	0.03
Knowledge Acquisition					
Salameh et al., 2021	11.62	1.43	0.89	1.98	0.00
Tubaishat, 2015	11.39	1.54	0.82	2.26	0.00
Lee et al., 2019	11.50	1.57	0.83	2.31	0.00
Tawalbeh, 2020	9.60	1.63	0.91	2.35	0.00
Liaw, 2011b	10.41	1.64	0.91	2.37	0.00
Craig et al., 2021	11.62	1.73	0.98	2.48	0.00
Vural Dogru, 2020	10.46	1.77	1.07	2.48	0.00
Levett-Jones et al., 2019	11.74	1.78	1.10	2.47	0.00
Total		1.73	0.99	2.47	0.00
Skills Perfomance					
Liaw, 2011b	19.75	1.19	0.17	2.22	0.02
Liaw, 2011a	19.75	1.50	0.11	2.90	0.03
Merriman, 2014	23.57	1.99	0.15	3.84	0.03
Wood, 2012	28.66	2.18	0.81	3.55	0.00
Total		1.71	0.50	2.92	0.01



Note: *SMD*, standard mean difference

Figure 4. Sensitivity analysis.

Discussion

High-fidelity simulations address the gap between theoretical knowledge and performance in various practice contexts[23,37,38]. We analyzed 14 studies about the effectiveness of high-fidelity simulation-based learning in undergraduate nursing education. The present review highlighted high-fidelity simulation relatively moved on to incorporating emerging technology such as interactive manikins' simulators. The use of technology is essential to meet students' preferences, which promotes effective learning[45]. High-fidelity simulation in this review was characterized by the involvement of scenario and debriefing sessions as the essential part of the simulation. The main findings from the meta-analysis confirm that high-fidelity simulation-based learning is correlated with improved knowledge acquisition, self-confidence, and skills performance among undergraduate nursing students. For students, being confident, well-comprehending, and proficient with specific clinical skills will allow more autonomous practice and ultimately contribute to nurses' and patients' satisfaction[46]. In addition, nursing students gaining self-confidence, skills, and knowledge before graduation enables them to achieve satisfaction in their professional lives[46,47]. These results can guide educators to prepare graduates' by connecting education and clinical practice through the high-fidelity simulation method, which can complement conventional learning. Nevertheless, literature about high-fidelity simulation in the present review remained in its infancy because it mainly focused on students' knowledge acquisition, confidence, and skills, while little is known about its acceptability to faculty and learners alike.

Findings from the present study confirmed that high-fidelity simulation-based learning improves students' knowledge acquisition among nursing students. This is in line with a recent meta-analysis by Mulyadi et al[6], which reported that simulation technology-based learning, which involves high-fidelity simulation technology, effectively improves knowledge acquisition among undergraduate nursing students. Students exposed to high-fidelity simulations experience more complicated scenarios that are similar to those encountered in the real world[48], so they usually experience stronger emotional connections, visualizations, and learning associations that occur during hands-on experiences[49]. The improvement of knowledge acquisition may also be attributed to the debriefing sessions commonly found in the reviewed studies. Debriefing is a valuable element in simulation, in which students can receive direct feedback or corrections from instructors following the simulations[50]. Debriefing allows students to consolidate and systematize their new knowledge, memorize information, reflect, and organize their thoughts[51,52]. Thus, incorporating high-fidelity simulations into the curriculum can be beneficial to students because it allows for repetitive practice and encourages debriefing sessions and feedback, which can help students develop the ability to provide professional nursing care.

The pooled effect size from four studies indicated that high-fidelity simulation-based learning is correlated with increased self-confidence among undergraduate nursing students. This finding fills a gap in previous studies[17], which have reported inconsistent findings regarding the effects of high-fidelity simulation on nursing students' confidence. Increased self-confidence may have been found because high-fidelity simulations provide an environment very close to what they expect in the clinical situation. The increased self-confidence may also be because most of the studies included multiple simulation sessions. High-fidelity simulations with multiple scenarios may enrich students' knowledge and learning experiences by helping them consider human interactions and complex diseases[48]. The correlation between high-fidelity simulations and increased self-confidence is particularly noteworthy because maintaining and promoting self-confidence is essential to preparing nursing students for clinical practice. Thus, their simulation experience can be helpful in preparing them to provide professional nursing care after graduation[4,53]. Furthermore, from the graduate perspective, evidence shows that they have felt the high-fidelity simulation program contributed to their readiness in clinical practice and reduced challenges during the transition period[54,55].

Limitations

Several limitations of the current study should be considered. First, a limited number of studies met the inclusion criteria. Second, the context of high-fidelity simulation in the present study was quite broad (heterogeneous). It was shown that each study we analyzed did not share a typical effect size. Due to only a few included studies, we could not perform meta-regression or moderator analyses to explore the source of heterogeneity in the present study. Third, we only included studies published in English, which might have excluded important data from papers published in other languages. Finally, the literature included mainly focused on students' knowledge acquisition and confidence. Future research should further investigate other aspects of high-fidelity simulation, including its acceptability to faculty and learners alike.

This study has implications for nursing policy in educational sector. The integration of simulation in nursing education curricula had been advocated by the National League of Nursing and the National Council of State Boards of Nursing, however, no high-quality evidence supports this reccomendation[56]. With results from the present study, this finding can be used as evidence-based for stakeholders within the academic institution to consider utilizing high-fidelity simulation in nursing education.

Conclusions

The cumulative evidence is conclusive that the utilization of high-fidelity simulation is a more beneficial teaching method to students than usual learning methods. When nursing students enter the workforce, they are expected to provide professional nursing care. The high-fidelity simulation replicates what nurse educators think might happen in clinical practice. It can be used as a teaching method to improve undergraduate nursing students' knowledge acquisition, self-confidence, and skills performance. Suggesting educators may consider using high-fidelity simulations to prepare them to transition from pre-clinical to clinical practice. Integrating high-fidelity simulation as part of teaching strategy allows educators to provide students an overview of clinical practice by learning in a safe and realistic environment. As an implication for nursing education, educators can build high-fidelity simulation experiences based on what industry or clinical practice demands, this may allow students to experience and put into practice what is expected. Therefore, when graduates enter the workforce, they can function quickly and practice confidently in clinical settings without bringing potential harm.

Conflict of Interest
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this work.

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None.

Authors' Contribution
F. Efendi was the principal investigator in the study. S.I. Tonapa, M. Mulyadi, F. Efendi, K. H. Man Ho designed the study. SIT, M. Mulyadi, F. Efendi performed data collection. S.I. Tonapa carried out data analysis. All authors have contributed to, written, revised, and approved the final manuscript.

ORCID ID
Santo Imanuel Tonapa: 0000-0002-9730-1939; Mulyadi Mulyadi: 0000-0003-0632-3452; Ken Hok Man Ho: 0000-0003-4934-2450; Ferry Efendi: 0000-0001-7988-9196.

Ethics Committee and Informed Consent
Not applicable.

Data Availability
All data generated or analyzed during this study are included in this published article.

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