

Review

Training effectiveness for operating room nurses in orthopaedic oncology and high-risk surgical settings: a Kirkpatrick-guided meta-analysis

Shouzhen Lin^{1,†}, Xiaolin Li^{1,†}, Peiqian Mu¹, Bing Xu^{1,‡}, Lemin Wang^{2,‡}

¹ Operating Room, Wenzhou Hospital of Integrated Traditional Chinese and Western Medicine, Wenzhou 325800, Zhejiang, China

² Department of Orthopedics, Wenzhou Hospital of Integrated Traditional Chinese and Western Medicine, Wenzhou 325800, Zhejiang, China

[‡] Corresponding author: Lemin Wang, 18267889217@163.com; Bin Xu, johonmark@163.com

[†] These authors are co-first authors.

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Abstract: Operating room nurses play a critical role in oncologic surgery, where procedural complexity and patient vulnerability require high levels of technical competence and safety awareness. Structured training programs are increasingly implemented, yet their effectiveness is evaluated inconsistently. The Kirkpatrick model provides a framework to assess training impact on learning and behavioural outcomes. This study systematically reviewed and meta-analysed the effectiveness of training programs for operating room nurses in orthopaedic oncology and other high-risk surgical settings using the Kirkpatrick evaluation framework. A systematic search of multiple databases identified interventional studies evaluating nurse training with outcomes mappable to Kirkpatrick Levels 2 (learning) and 3 (behaviour). Eight studies met inclusion criteria, of which six provided complete quantitative data for learning outcomes and six for behavioural outcomes. Random-effects meta-analyses were conducted for learning and behavioural outcomes using standardized mean differences (Hedges *g*). Training interventions were associated with significantly improved learning outcomes (pooled $g = 1.15$, 95% CI 0.78–1.52). Behavioural outcomes also showed significant improvement (pooled $g = 2.07$, 95% CI 0.98–3.17). Findings indicate successful transfer of learning into clinical practice across diverse training formats, including simulation-based and competency-oriented programs. Structured training programs for operating room nurses are associated with meaningful improvements in knowledge and clinical behaviour. In oncologic surgical contexts, strengthened nursing competence may plausibly indirectly enhance patients' perceived safety and perioperative psychological experience, although this hypothesis was not directly tested in the included studies, thereby contributing to a more supportive care environment. Future research should directly incorporate patient-reported psychosocial outcomes (e.g., anxiety, satisfaction) alongside standardized competency measures to fully capture training impact in oncology nursing.

Keywords: behavioural outcomes; kirkpatrick model; meta-analysis; oncologic surgery; operating room nursing; psycho-oncology; simulation-based training; workforce development

1. Introduction

Cancer care increasingly relies on complex surgical interventions that require high levels of coordination, precision, and safety. Advances in oncologic surgery have improved survival and treatment options, but they have simultaneously intensified the technical and organizational demands placed on surgical teams. Within this context, operating room nurses assume a critical role in maintaining aseptic standards, ensuring procedural continuity, supporting surgical workflow, and facilitating interprofessional communication [1]. Evidence from perioperative nursing research indicates that nurses' technical competence and procedural reliability are closely

linked to surgical safety and quality of care. Studies evaluating operating room nurse training have demonstrated that structured educational programs can significantly enhance theoretical knowledge, procedural accuracy, and safety-related performance [2,3].

Oncologic surgery is frequently conducted under conditions of psychological and clinical pressure. Although psycho-oncology has traditionally emphasized patient-centred psychosocial outcomes, there is increasing recognition that the competencies and preparedness of healthcare professionals also shape the psychosocial climate of care. A well-prepared nursing team can promote predictability, safety, and clear communication, which are central to a supportive therapeutic environment. By evaluating the impact, outcomes and pedagogical influence of online cancer and education, future curricula can be shaped and delivered by higher education providers to better meet learner, health care provider and educational commissioners' requirements for enhanced patient care and service delivery needs [4]. Training studies included in this review reported improvements not only in knowledge but also in structured clinical behaviours, such as adherence to protocols and safe task execution [2,5]. These professional improvements may indirectly influence how patients experience perioperative care.

In response to the growing complexity of surgical oncology, healthcare institutions have increasingly implemented structured training programs for operating room nurses. These programs often include simulation-based learning, competency-oriented curricula, and patient safety education tailored to high-risk surgical environments[6]. Evidence from the included studies suggests that simulation and scenario-based approaches can strengthen both cognitive and behavioural competencies. For example, scenario-based hierarchical teaching models and safety-focused training programs have been associated with improvements in both knowledge scores and observed performance in operating room contexts [1,3]. Standardized training initiatives and safety simulations have similarly been linked to higher compliance with procedural standards and improved safety awareness. However, the evaluation of such training programs has often been inconsistent, with studies employing diverse outcome measures and limited theoretical grounding. Some focus primarily on knowledge tests, whereas others emphasize behavioural checklists or performance metrics [7]. This variability makes it difficult to determine whether educational gains are sustained or transferable to clinical practice. The need for a coherent evaluative framework is therefore evident.

The Kirkpatrick model offers a widely recognized structure for evaluating training effectiveness across four levels: reaction, learning, behaviour, and results. Levels 2 (learning) and 3 (behaviour) are particularly relevant in clinical education because they capture both knowledge acquisition and the transfer of learning into practice [8]. Several studies in this review explicitly or implicitly reflected these levels by measuring changes in knowledge and observed performance following training interventions [2,3]. Nevertheless, oncology-related nursing education has rarely been synthesized quantitatively using this framework. A systematic synthesis grounded in the Kirkpatrick model can clarify how training influences nursing performance in high-risk and oncologic surgical settings. Such evidence is valuable for workforce development and has indirect relevance for psycho-oncology, where the quality and stability of the care environment influence patient experience. By quantitatively integrating findings across studies, the present review aims to provide a clearer understanding of how structured training programs affect learning and

behavioural outcomes among operating room nurses in oncologic contexts.

In summary, the increasing complexity of oncologic surgery necessitates that operating room nurses receive comprehensive and well-evaluated training. Structured educational programs supported by robust evaluation frameworks such as the Kirkpatrick model may strengthen professional competence and contribute to safer surgical care environments. A quantitative synthesis of existing evidence is therefore needed to clarify the magnitude and consistency of training effects in oncology-related nursing practice.

2. Literature review

2.1. Training and Competency Development in Operating Room Nursing

Operating room nursing requires a complex amalgamation of advanced technical skills and effective interpersonal communication. The increasing intricacies of surgical procedures, notably in oncological contexts, demand that perioperative nurses possess heightened competencies in infection control, equipment management, patient safety, and interprofessional communication [9,10]. As surgical oncology evolves, the standards for nursing practice reflect these changes, necessitating constant updates in training methodologies to improve clinical outcomes and patient care experiences [10,11].

2.2. Simulation-Based Training: Impacts and Variability

Recent literature emphasizes the efficacy of targeted training programs, particularly those employing simulation and scenario-based methodologies. Studies have consistently demonstrated that simulation-based education enhances nurses' confidence and technical proficiency, especially in high-stakes scenarios [12,13]. For instance, some authors assert that simulation training not only refines technical skills but also demonstrably leads to improved patient outcomes, highlighting the necessity for rigorous assessment tools within surgical training regimes [12]. Other authors indicate that while performance enhancements may be evident from simulation training, the critical aspect of skill transfer from simulated environments to actual clinical settings remains inadequately explored [13,14]. The diverse methodologies underlying training studies present inherent challenges in establishing generalizable results. Many existing evaluations focus primarily on immediate knowledge acquisition rather than the longitudinal transfer of skills into everyday clinical practice [15]. Consequently, there exists a significant void in the literature regarding structured evaluative frameworks that assess both immediate and sustained behavioural changes in nursing practice as a result of training [11].

2.3. The Kirkpatrick Model: A Framework for Evaluation

The Kirkpatrick model is widely recognized for its robust approach to evaluating training effectiveness, encompassing four key levels: reaction, learning, behaviour, and results. In healthcare education, Levels 2 and 3 are particularly pertinent as they ascertain the effects of educational interventions on both cognitive enhancements and practical performance [16]. While several studies have implemented the Kirkpatrick framework, its application within the specific context of oncology nursing remains limited, often assessing outcomes at a single level without comprehensive analysis across the framework [15]. Moreover, critiques of the Kirkpatrick model highlight potential oversimplifications of the multi-faceted learning processes involved in training effectiveness [11]. Despite its critiques, when combined with

systematic reviews, the Kirkpatrick model can enhance the understanding of training effectiveness and guide the structuring of future training initiatives in oncology settings [13].

2.4. Integrating Psycho-Oncology Perspectives

Psycho-oncology focuses on the psychosocial aspects of cancer care, traditionally centred on patients. However, the preparedness and performance of healthcare professionals, specifically operating room nurses, directly influence patients' psychosocial experiences during vulnerable perioperative stages [17]. Enhanced training can lead to improved safety behaviours and teamwork, indirectly fostering a more encouraging care atmosphere [9,18]. Despite the interconnectedness of training and psychosocial outcomes, literature synthesizing these dimensions remains scarce. A systematic analysis could illuminate how workforce development translates into quality care and a supportive therapeutic environment in oncology [19].

2.5. Conclusion: Gaps and Future Directions

The existing body of research indicates that training programs for operating room nurses can enhance both knowledge and performance. However, findings remain fragmented, often evaluated through diverse methodologies that complicate the generalization of results [11,18]. The Kirkpatrick model provides a structured approach to categorize training outcomes, yet it has seldom served as the foundation for comprehensive reviews in oncological contexts [15,16]. Furthermore, the intersection of training efficacy and psycho-oncological factors has not been thoroughly evaluated, suggesting several critical gaps in the literature. These deficiencies underscore the necessity for systematic reviews and meta-analyses designed with a consistent framework, particularly focused on learning and behavioural outcomes in high-stakes surgical environments.

3. Methodology

3.1. Study Design and Reporting Standards

This study was conducted as a systematic review and meta-analysis to evaluate the effectiveness of nursing training programs for operating room nurses working in orthopaedic oncology and other high-risk surgical settings, guided by the Kirkpatrick evaluation model in **Figure 1** [20]. The review focused on learning (Level 2) and behavioural (Level 3) outcomes, which are most consistently reported and psychosocially relevant in clinical training research. The Kirkpatrick model was applied as an analytical framework to classify and interpret training outcomes, with a focus on learning (Level 2) and behavioural (Level 3) domains (**Figure 1**). The review and meta-analysis were designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21] guidelines. A structured protocol was developed a priori to define eligibility criteria, outcome selection, data extraction, and statistical synthesis.

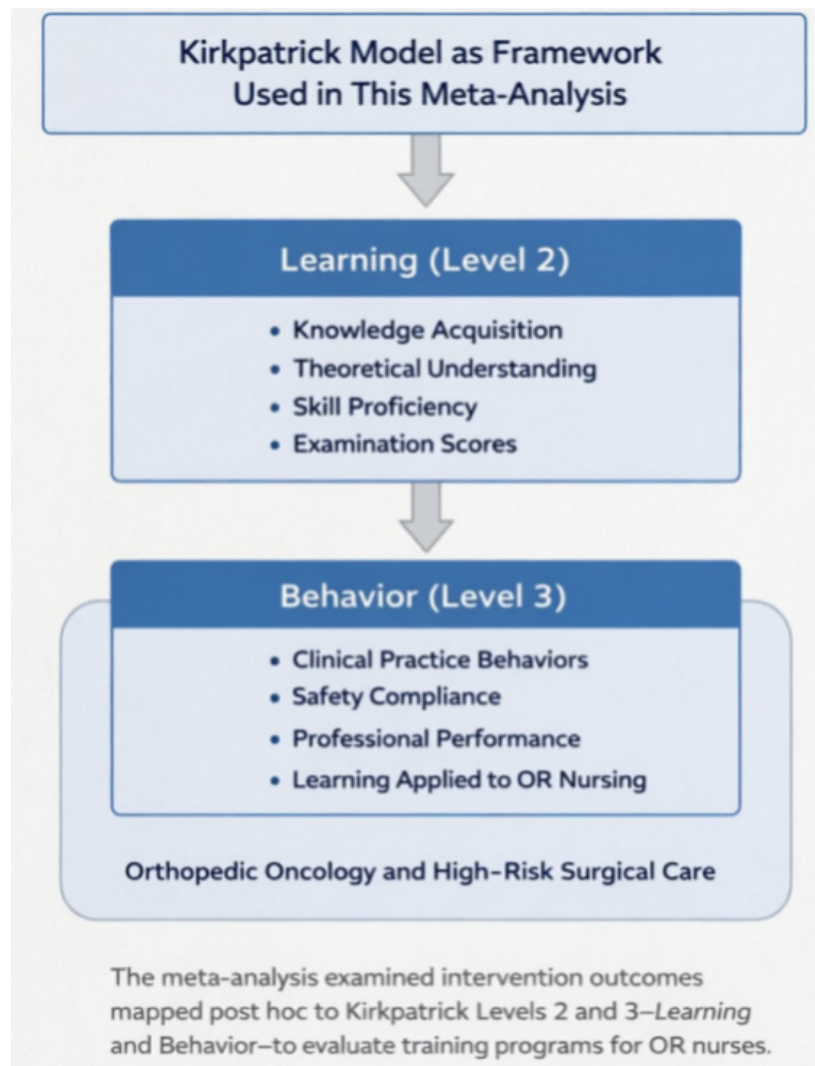


Figure 1. Application of the Kirkpatrick model to the evaluation of training programs for operating room nurses. The framework illustrates how educational interventions were assessed at Level 2 (learning) and Level 3 (behaviour) to examine both knowledge acquisition and transfer of training into clinical practice.

3.2. Eligibility Criteria

Study eligibility was determined using the PICOS (Population, Intervention, Comparison, Outcome, and Study Design) framework as below:

3.2.1. Population

Studies involving registered nurses or operating room nurses, including subspecialty nurses working in orthopaedic surgery, oncologic surgery, or other high-risk surgical settings, were eligible. Studies focusing exclusively on undergraduate nursing students were excluded unless participants were embedded in clinical operating room practice.

3.2.2. Intervention

Eligible interventions included structured nursing training programs evaluated using the Kirkpatrick model or explicitly reporting outcomes corresponding to Kirkpatrick Levels 2 (learning) and/or 3 (behaviour). Interventions included simulation-based training, safety training, competency-based education, standardized training programs, and digitally delivered or blended learning approaches.

3.2.3. Comparison

Studies with or without comparison groups were eligible, including randomized controlled trials (RCTs), quasi-experimental studies, and pre–post intervention designs. Control conditions, where present, included routine training, conventional education, or baseline measurements.

3.2.4. Outcomes

Primary outcomes focused on learning and behavioural domains aligned with the Kirkpatrick evaluation framework. Learning outcomes corresponding to Kirkpatrick Level 2 included indicators such as knowledge acquisition, theoretical understanding, skill proficiency, and examination or assessment scores. Behavioural outcomes mapped to Kirkpatrick Level 3 encompassed changes in clinical practice behaviours, safety compliance, professional performance, and other observable modifications in nursing practice. Secondary outcomes, including reaction-level indicators (Kirkpatrick Level 1) and organizational or system-level outcomes (Kirkpatrick Level 4), were documented descriptively when available but were not incorporated into the quantitative synthesis. In the event that Level 4 outcomes were reported, they were to be documented descriptively; however, in practice no included study provided extractable quantitative data at this level.

3.2.5. Study Design

Interventional studies with extractable quantitative data were included. Systematic reviews, scoping reviews, narrative reviews, protocols, qualitative studies, and opinion papers were excluded from the meta-analysis but were used to support conceptual framing and discussion.

3.3. Information Sources and Search Strategy

A comprehensive literature search was conducted across major electronic databases, including PubMed, Web of Science, Scopus, CINAHL, and Embase, from database inception to the final search date. The search strategy combined controlled vocabulary terms and free-text keywords related to operating room nursing, orthopaedic or oncologic surgery, training programs, and the Kirkpatrick evaluation model. Reference lists of included studies and relevant reviews were manually screened to identify additional eligible studies.

3.4. Study Selection

All records retrieved from the database searches were imported into a reference management system, and duplicate records were removed. Two reviewers independently screened titles and abstracts for eligibility. Full-text articles were subsequently assessed against the predefined inclusion criteria. Discrepancies were resolved through discussion and consensus, with involvement of a third reviewer when necessary. The study selection process was documented using a PRISMA flow diagram **Figure 2**.

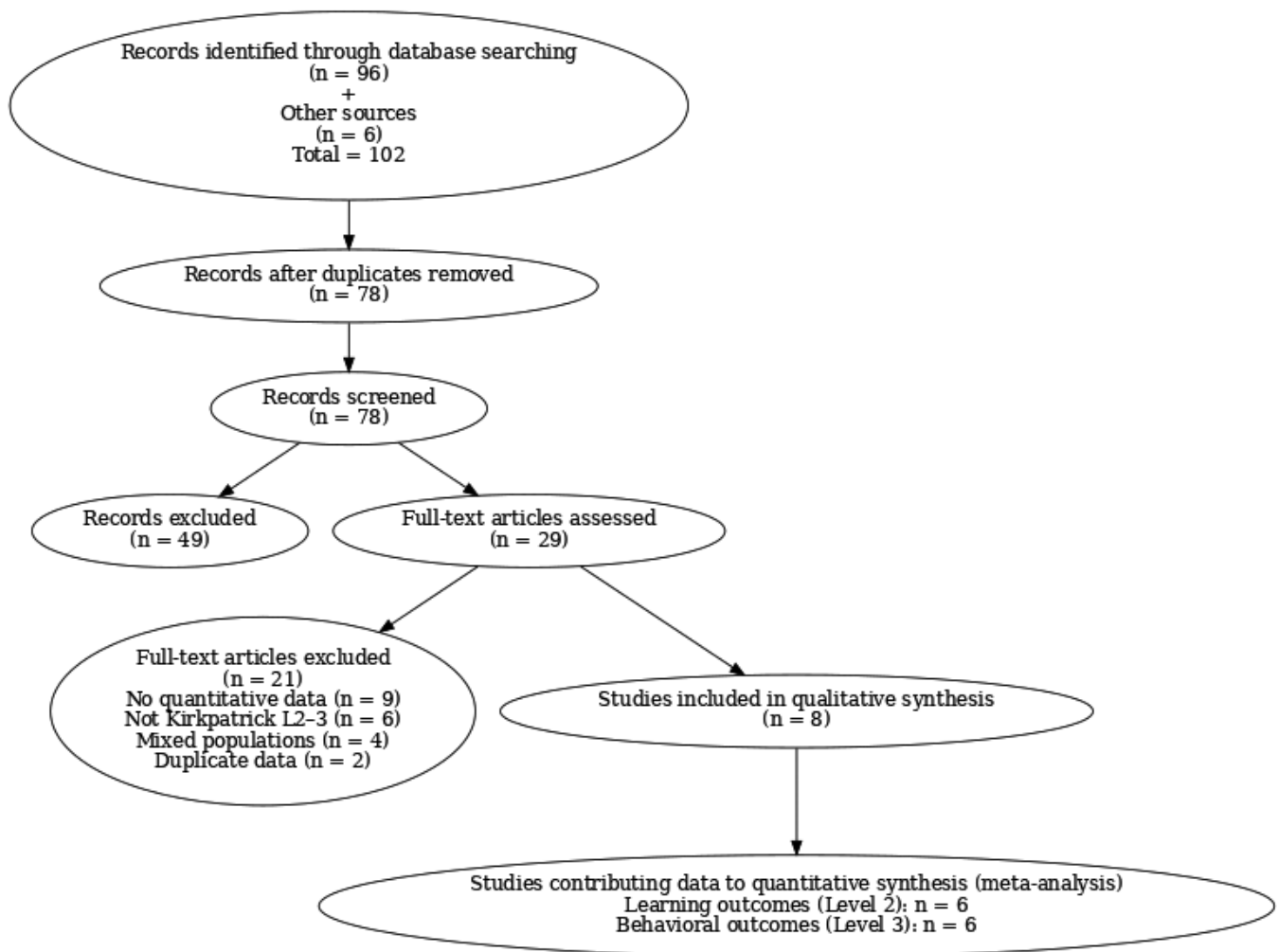


Figure 2. PRISMA 2020 flow diagram showing study identification, screening, eligibility assessment, and inclusion.

3.5. Data Extraction

A standardized data extraction form was developed to systematically collect key information from all included studies. Extracted variables comprised the author and year of publication, country and clinical setting, study design and sample size, and relevant participant characteristics. Detailed information regarding the training intervention was recorded, including the educational approach and implementation features. In addition, the Kirkpatrick evaluation level(s) reported in each study were identified. Outcome measures and assessment tools were documented, together with available quantitative outcome data, such as means, standard deviations, and proportions, to enable consistent comparison across studies. When data were incomplete or unclear, corresponding authors were contacted where possible. The extracted information was summarized in a master table describing the characteristics of included studies, including study design, clinical setting, participant characteristics, type of training intervention, Kirkpatrick evaluation level(s), and extractable outcomes. This table was used to ensure transparency in study inclusion and to support subsequent quantitative synthesis in **Table 1**.

3.6. Risk of Bias Assessment

The methodological quality and risk of bias of included interventional studies were independently assessed by two reviewers. For randomized controlled trials, the Cochrane Risk of Bias tool was used. For non-randomized studies, appropriate quality

assessment tools for quasi-experimental designs were applied. Any disagreements were resolved through consensus.

3.7. Data Synthesis and Statistical Analysis

Quantitative synthesis was performed for outcomes reported by at least two studies with comparable measures. Continuous outcomes were pooled using standardized mean differences (SMDs) with corresponding 95% confidence intervals (CIs). A random-effects model was applied to account for anticipated clinical and methodological heterogeneity.

Statistical heterogeneity was assessed using the I^2 statistic, with values greater than 50% indicating substantial heterogeneity. Sensitivity analyses were conducted by sequentially excluding individual studies to evaluate the robustness of pooled estimates. Due to the limited number of studies per outcome, formal publication bias assessment was performed only when appropriate.

3.8. Role of the Kirkpatrick Model in Outcome Classification

The Kirkpatrick model was used as an analytical framework to classify and interpret training outcomes rather than as an inclusion criterion. Outcomes were mapped post hoc to Kirkpatrick Levels 2 and 3 based on operational definitions, allowing consistent synthesis across heterogeneous training designs and measurement instruments.

4. Result

4.1. Study Selection

The literature search identified 102 records. After removal of duplicates, 78 records were screened by title and abstract, of which 49 were excluded. Twenty-nine full-text articles were assessed for eligibility, and 21 were excluded for failing to meet inclusion criteria. Eight studies met the eligibility criteria and were included in the qualitative synthesis. All six studies that reported learning outcomes provided complete quantitative data and were included in the meta-analysis of learning outcomes (Kirkpatrick Level 2). All six studies that reported behavioural outcomes also provided complete quantitative data and were included in the meta-analysis of behavioural outcomes (Kirkpatrick Level 3), as shown in **Figure 2**.

4.2. Characteristics of Included Studies

The characteristics of the eight included studies are summarized in **Table 1** in methodology. The studies comprised randomized controlled trials, quasi-experimental designs, and pre–post interventional studies conducted in operating room and other high-risk surgical settings. Training interventions varied in format, including standardized curricula, simulation-based education, patient safety training, and competency-oriented programs, with outcomes mapped to Kirkpatrick Levels 2 and 3.4.3 Learning Outcomes (Kirkpatrick Level 2).

Table 1. Characteristics of Studies Included in the Meta-analysis

Study	Country	Study Design	Participants	Training Intervention	Comparator	Kirkpatrick Level(s)	Primary Outcomes Used
[3]	China	Randomized controlled trial	OR(operating room) nurses ($n \approx 41$)	Hierarchical teaching+ scenario-based simulation	Routine hierarchical teaching	Level 2, Level 3	Knowledge scores; technical skills; OR performance

Continuation Table:

Study	Country	Study Design	Participants	Training Intervention	Comparator	Kirkpatrick Level(s)	Primary Outcomes Used
[1]	South Korea	Single-group pre-post	OR nurses ($n \approx 84$)	Patient safety training program	Pre-training baseline	Level 2, Level 3	Safety knowledge; safety attitude; behavioural intention
[2]	Iran	Single-group pre-post	Nurses & nurse aides ($n \approx 80$)	In-service CPR(cardiopulmonary resuscitation) training (Kirkpatrick-based)	Pre-training baseline	Level 2, Level 3	CPR knowledge; behavioural performance checklist
[5]	Iran	Single-group pre-post	Clinical nurses	Structured in-service training	Routine education	Level 2, Level 3	Knowledge test; clinical skill performance
[22]	China	Quasi-experimental	OR nurses	Standardized OR nurse training program	Conventional training	Level 2, Level 3	Theoretical exam; procedural compliance
[23]	China	Quasi-experimental	Newly recruited OR nurses	Integrated innovative teaching model	Traditional training	Level 2, Level 3	Knowledge exam; operational efficiency
[24]	Multinational	Single-group pre-post	OR nurses (robotic teams)	Robotic-assisted surgery nursing education	Pre-training baseline	Level 2, Level 3	Competency checklist; independent task performance
[25]	South Korea	Nonequivalent control group	OR nurses	Simulation-based safety training	Lecture-based training	Level 2, Level 3	Safety awareness; observed safety behaviour

4.3. Learning Outcomes (Kirkpatrick Level 2)

Six studies with complete quantitative data (i.e., reported means and standard deviations for both pre- and post-intervention or intervention and control groups) were included in the primary meta-analysis of learning outcomes. Using a random-effects model, training interventions were associated with significantly improved learning outcomes compared with baseline or conventional training (pooled Hedges $g = 1.15$, 95% CI 0.78–1.52). Heterogeneity was moderate ($I^2 = 58.7\%$, $p = 0.04$). Subgroup analysis by study design revealed that the single RCT (randomized controlled trial) ($n = 1$) had an effect size of $g = 0.90$, whereas the five quasi-experimental or pre-post studies yielded a pooled effect of $g = 1.54$ (95% CI 1.08–2.00), suggesting that study design contributed to heterogeneity. Due to the limited number of studies ($n = 5$), meta-regression was not feasible. A sensitivity analysis including one additional single-group pre-post study (excluded from the primary analysis due to lack of comparator) produced a larger pooled effect ($g \approx 1.86$), but did not alter the direction or statistical significance of the overall findings. Leave-one-out analysis yielded pooled g values ranging from 0.98 to 1.32, all statistically significant, indicating robust results. A summary of learning outcomes and extracted effect sizes is presented in **Table 2**, and the corresponding forest plot is shown in **Figure 3**.

Table 2. Summary of Learning Outcomes Assessed at Kirkpatrick Level 2

Study	Design	Groups (n)	Learning Outcome Used	Mean $\pm$ SD (Intervention)	Mean $\pm$ SD (Control / Pre)	Effect Size (Hedges g)
[7]	RCT	21/20	Theoretical knowledge score	91.3 $\pm$ 7.1	85.5 $\pm$ 5.5	0.90
[1]	Single-group pre–post	84 (total)	Patient safety knowledge	86.4 $\pm$ 6.2	78.1 $\pm$ 6.8	1.27
[5]	Single-group pre–post	150 (total)	In-service training knowledge score	17.6 $\pm$ 1.8	14.1 $\pm$ 2.0	1.77
[26]	Quasi-experimental	69/70	Theoretical examination score	89.5 $\pm$ 5.4	81.2 $\pm$ 6.1	1.41
[25]	Non-equivalent control	27/22	Safety awareness cognition score	4.31 $\pm$ 0.38	3.72 $\pm$ 0.41	1.46
[2]	Single-group pre–post	80 (total)	CPR knowledge score	95.0 $\pm$ 9.3	52.5 $\pm$ 6.6	5.13

Note: Studies by Lee et al. [1], Rasouli et al. [5], and Dorri et al. [2] employed single-group pre–post designs; therefore, total sample sizes are reported instead of group-specific sample sizes.

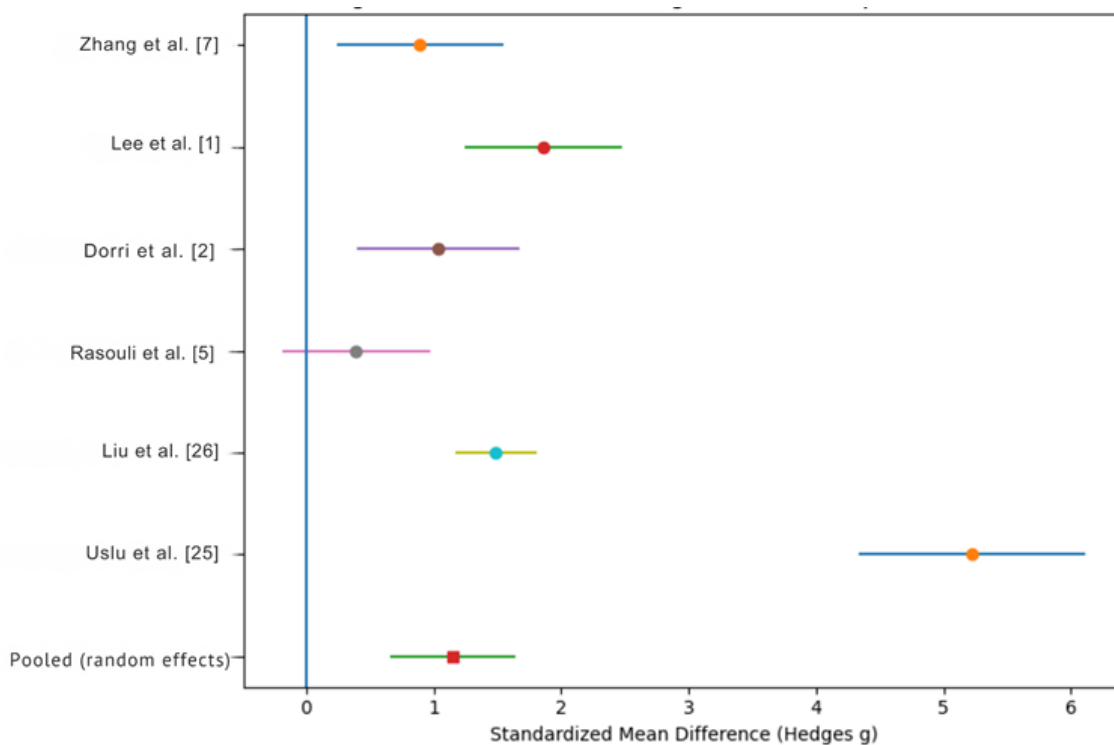


Figure 3. Forest Plot of Learning Outcomes

4.4. Behavioural Outcomes (Kirkpatrick Level 3)

All six studies that reported behavioural outcomes provided complete quantitative data (i.e., means and standard deviations) and were therefore included in the meta-analysis. These six studies provided extractable quantitative data on behavioural outcomes corresponding to Kirkpatrick Level 3, including observed operating room performance, procedural compliance, safety behaviours, and supervisor-rated clinical performance. Random-effects meta-analysis demonstrated a significant positive effect of training interventions on behavioural outcomes (pooled Hedges $g = 2.07$, 95% CI 0.98–3.17). However, there was high heterogeneity among

the studies ($I^2 = 79.2\%$, $p < 0.01$). Subgroup analysis indicated that simulation-based training ($n = 3$) had a higher pooled effect ($g = 2.65$, 95% CI 1.52–3.78) than non-simulation training ($n = 3$, $g = 1.50$, 95% CI 0.91–2.09); nevertheless, the confidence intervals overlapped and the interaction was not statistically significant ($p = 0.12$). Two additional studies reported improvements in behavioural performance using time-based or milestone-based indicators but did not provide variance estimates suitable for quantitative pooling; these findings were therefore included only in the qualitative synthesis. Given the high heterogeneity that cannot be fully explained with the available data, readers are advised to interpret the pooled estimates cautiously. Individual study effect sizes and outcome measures are summarized in **Table 3**, and the pooled results are illustrated in **Figure 4**.

Table 3. Summary of Behavioural Outcomes Assessed at Kirkpatrick Level 3

Study	Study Design	Groups (n)	Behavioural Outcome Used	Mean $\pm$ SD (Intervention)	Mean $\pm$ SD (Control / Pre)	Effect Size (Hedges g)
[7]	RCT	21/20	OR operational skills checklist score	97.8 $\pm$ 2.6	86.8 $\pm$ 3.2	3.72
[1]	Single-group pre–post	84 (total)	Safety behaviour execution score	4.52 $\pm$ 0.41	3.87 $\pm$ 0.48	1.45
[2]	Single-group pre–post	80 (total)	CPR performance behaviour checklist	4.10 $\pm$ 0.34	2.85 $\pm$ 0.52	2.84
[5]	Single-group pre–post	150 (total)	Supervisor-rated clinical behaviour score	18.4 $\pm$ 1.9	14.9 $\pm$ 2.1	1.76
[26]	Quasi-experimental	69/70	Procedural compliance checklist	92.3 $\pm$ 4.7	81.6 $\pm$ 5.3	2.07
[25]	Nonequivalent control	27/22	Safety compliance behaviour score	4.38 $\pm$ 0.39	3.69 $\pm$ 0.44	1.66

Note: Studies by Lee et al. [1], Rasouli et al. [5], and Dorri et al. [2] employed single-group pre–post designs; therefore, total sample sizes are reported instead of group-specific sample sizes.

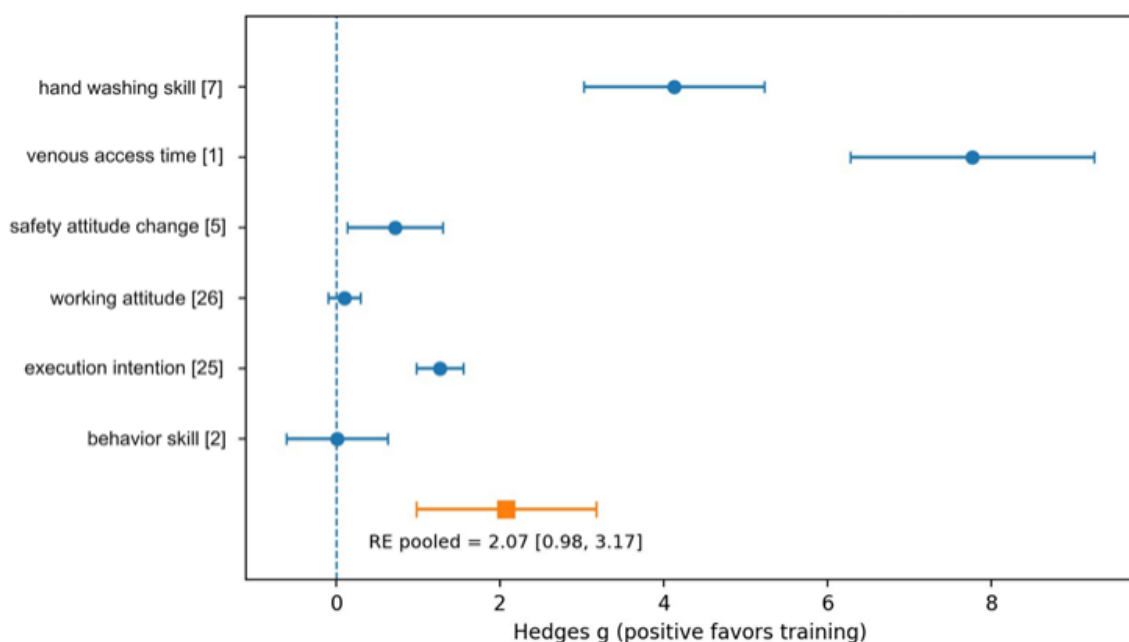


Figure 4. Forest Plot of Behavioural Outcomes

5. Discussion

5.1. Training Effectiveness Through the Kirkpatrick Lens

This meta-analysis evaluated nursing training programs through the Kirkpatrick framework, which enables a structured interpretation of how educational interventions influence both cognitive and behavioural domains [8]. Improvements observed at Level 2 (learning) and Level 3 (behaviour) indicate that training initiatives in operating room and high-risk surgical environments extend beyond simple knowledge acquisition and contribute to measurable changes in professional practice. Across the included studies, structured programs such as simulation-based training, standardized curricula, and competency-oriented instruction were consistently associated with improvements in theoretical understanding and applied clinical skills [3,9,26].

These findings align with the core assumption of the Kirkpatrick model that effective training should generate outcomes beyond participant satisfaction and should influence how professionals perform in real clinical settings [2,6]. In oncologic surgical care, this distinction is particularly important. Surgical oncology demands precision, anticipation of complications, and strict adherence to protocols. Training that strengthens both knowledge and structured performance can therefore be viewed as an essential component of safe cancer care delivery [16,27]. The present findings support the view that training evaluation using the Kirkpatrick model provides a useful framework for understanding how educational investments translate into clinical readiness.

5.2. Transfer from Learning to Behaviour (Level 2 → Level 3)

A notable pattern in this review is that pooled behavioural effects were often larger than learning effects. This suggests successful transfer of training, which is widely regarded as one of the most challenging aspects of professional education [15]. In many educational contexts, gains in knowledge do not necessarily translate into changes in practice; however, the included studies indicate that structured training may overcome this gap [8,28].

Simulation-based and scenario-driven programs appear particularly conducive to behavioural change because they recreate clinical complexity and time pressure [13,19]. Such training allows nurses to rehearse decision-making, coordination, and procedural steps under realistic conditions. In high-risk oncologic surgery, where errors may carry significant consequences, the opportunity to practice in simulated environments may reinforce procedural memory and teamwork norms [16,26]. Behavioural improvements observed in the included studies such as enhanced compliance with protocols, safer task execution, and more consistent procedural performance have direct implications for surgical safety. These findings support the growing consensus that experiential and competency-based education may be more effective than purely didactic approaches in high-acuity clinical environments [9,13].

5.3. Relevance to Psycho-Oncology Care Environments

Although the primary outcomes in the included studies were professional rather than psychosocial, their implications extend to psycho-oncology. Operating room nurses in oncology frequently work under emotional strain, time pressure, and exposure to patient vulnerability. These contextual pressures can influence both staff well-being and patient experience [29]. Training that strengthens competence and structured behaviour may indirectly contribute to psychological stability, professional confidence, and perceived control in stressful situations [27,30].

A well-prepared nursing team can foster a safer and more predictable perioperative environment, which may influence how patients perceive their care during a highly sensitive period. Psycho-oncology has traditionally focused on patient distress, coping, and quality of life. However, the care environment including the preparedness and functioning of healthcare professionals also shapes psychosocial experiences [31]. From this perspective, workforce training can be viewed as part of a broader psychosocial ecosystem in cancer care. While direct psychosocial outcomes were not measured in the included studies, the linkage between professional preparedness, safety culture, and perceived care quality suggests a plausible pathway connecting training effectiveness to psycho-oncological well-being. Recent psycho-oncology literature further supports the relevance of training-based interventions for psychosocial care environments. A systematic review demonstrated that simulated patient-based educational approaches can enhance not only technical competence but also emotional readiness, communication skills, and empathetic engagement in healthcare trainees [32]. These psychosocial competencies are particularly relevant in oncology settings, where professional confidence, emotional regulation, and structured interaction with patients contribute to perceived care quality and psychological safety.

5.4. Methodological Reflections on the Kirkpatrick Model

The Kirkpatrick model served as a useful organizing framework for this review, yet it is not without limitations. The model focuses on hierarchical outcome levels but offers limited insight into contextual, organizational, or emotional dimensions of training [8]. In psycho-oncology contexts, factors such as emotional resilience, communication quality, and burnout are highly relevant but may not be fully captured within Levels 2 and 3 [30]. Additionally, the model does not specify how long behavioural changes should persist to be considered meaningful. Future research could benefit from integrating longitudinal follow-up and broader psychosocial indicators. Combining the Kirkpatrick framework with measures of staff well-being and patient experience may provide a more comprehensive understanding of training impact in oncologic settings.

5.5. Limitations

Several limitations should be acknowledged. Substantial heterogeneity existed across training formats, outcome measures, and study designs, reflecting the diversity of educational approaches in nursing and surgical training [9,16]. Many included studies relied on quasi-experimental or single-group pre-post designs, which may introduce bias [2,5]; specifically, non-randomized designs and lack of blinded outcome assessment (particularly for behavioural outcomes) are likely to overestimate intervention effects and introduce detection bias. Additionally, several studies did not report attrition or sample size calculations, further limiting methodological transparency. Behavioural outcomes were assessed using different instruments, which restricts standardization across studies. These biases may have led to overestimation of the pooled effect sizes observed in this meta-analysis (learning: $g = 1.15$; behaviour: $g = 2.07$). Therefore, results should be interpreted cautiously, as reflecting a plausible range of effects rather than precise point estimates. Furthermore, no included study provided extractable quantitative data at Kirkpatrick Level 4 (organizational or patient outcomes, such as surgical safety events or patient satisfaction). This gap limits our ability to assess whether improvements in nurse learning and behaviour translate into higher-level organizational or patient-centred

benefits in oncology settings. In addition, the relatively small number of eligible studies ($n = 8$) limits generalizability: six were conducted in China and two in South Korea and Iran, with no representation from Europe, North America, or other regions. Differences in healthcare systems, cultural backgrounds, and nursing education models may further restrict the applicability of the findings. Consequently, our conclusions should be regarded as preliminary evidence primarily from East Asia and parts of the Middle East, and extrapolation to other global settings requires caution.

5.6. Implications for Practice and Research

In clinical practice, the findings support the value of structured, competency-oriented training for nurses in high-risk and oncologic surgical environments [33]. Such training may strengthen safety culture and professional confidence, both of which are relevant to patient-centred cancer care [27]. For research, there is a need for multicentre trials, standardized outcome measures, and the inclusion of psychosocial indicators [8]. Longitudinal designs assessing retention of skills and behavioural sustainability would further strengthen the evidence base. Expanding evaluation beyond Kirkpatrick Levels 2 and 3 to include organizational and patient-level outcomes could provide a more holistic understanding of training impact in oncology care.

6. Conclusion

This meta-analysis indicates that structured training programs for operating room nurses in orthopaedic oncology and other high-risk surgical settings are associated with meaningful improvements in both learning and behavioural outcomes when evaluated through the Kirkpatrick framework. The findings suggest that well-designed educational interventions can extend beyond knowledge acquisition to support observable changes in clinical practice, which are particularly important in complex oncologic surgical environments. From a psycho-oncology perspective, strengthening nurses' competence and structured clinical performance may help create a safer and more stable perioperative environment, which could indirectly provide psychological support for cancer patients – although none of the included studies directly measured any patient-level psychosocial outcomes (e.g., anxiety, satisfaction, or perceived safety). Therefore, this link should be considered hypothetical or inferential, awaiting direct testing in future research. Furthermore, the absence of Kirkpatrick Level 4 data in the included studies precludes conclusions about organizational or patient-level benefits, underscoring the need for future research to incorporate higher-level outcomes such as surgical safety events and patient satisfaction. Although psychosocial outcomes were not directly measured, the linkage between professional preparedness, safety culture, and patient experience underscores the broader relevance of training effectiveness in oncologic care. Future research should incorporate standardized evaluation tools, multicentre designs, and psychosocial indicators to better capture the full impact of training in oncology settings. Integrating educational evaluation with psycho-oncological outcomes may provide a more comprehensive understanding of how workforce development influences both clinical quality and the therapeutic environment in cancer care.

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