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The effectiveness of improving healthcare teams' human factor skills using simulation-based training: a systematic review

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Abstract

Background: Simulation-based training used to train healthcare teams' skills and improve clinical practice has evolved in recent decades. While it is evident that technical skills training is beneficial, the potential of human factor training has not been described to the same extent. Research on human factor training has been limited to marginal and acute care scenarios and often to validate instruments. This systematic review aimed to investigate the effectiveness of simulation-based training in improving in-hospital qualified healthcare teams' human factor skills.

Method: A review protocol outlining the study was registered in PROSPERO. Using the PRISMA guidelines, the systematic search was conducted on September 28th, 2021, in eight major scientific databases. Three independent reviewers assessed title and abstract screening; full texts were evaluated by one reviewer. Content analysis was used to evaluate the evidence from the included studies.

Results: The search yielded 19,767 studies, of which 72 were included. The included studies were published between 2004 and 2021 and covered research from seven different in-hospital medical specialisms. Studies applied a wide range of assessment tools, which made it challenging to compare the effectiveness of human factor skills training across studies. The content analysis identified evidence for the effectiveness. Four recurring themes were identified: (1) Training human factor skills in qualified healthcare teams; (2) assessment of human factor skills; (3) combined teaching methods, and (4) retention and transfer of human factor skills. Unfortunately, the human factor skills assessments are variable in the literature, affecting the power of the result.

Conclusion: Simulation-based training is a successful learning tool to improve qualified healthcare teams' human factor skills. Human factor skills are not innate and appear to be trainable similar to technical skills, based on the findings of this review. Moreover, research on retention and transfer is insufficient. Further, research on the retention and transfer of human factor skills from simulation-based training to clinical practice is essential to gain knowledge of the effect on patient safety.

Keywords: Systematic review, Simulation-based training, Medical simulation, Human factor skills, Non-technical skills (NTS), Adverse events, Teamwork, Crisis resource management (CRM), Qualified healthcare team, In-hospital

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Background

Adverse events¹ are common in hospitals all over the world. They cause higher mortality and morbidity, along with more pain and increased healthcare costs [1]. Since 2004, the number of reported adverse events in Denmark has increased and has stabilised at a relatively high level [2]. The Danish Patient Safety Strategy [3] has an organisational approach that addresses adverse events by providing knowledge through guidelines, e-learning, and newsletters [4, 5]. Providing knowledge implies that adverse events might be avoided through enhanced guidelines and safety procedures. However, several studies find that adverse events often occur in non-routine, complex environments due to interactions between humans and the systems in which they work. These interactions are modifiable due to learning skills (e.g. leadership-followership, decision-making and coordination) rather than lack of knowledge [6–9]. The medical simulation and patient safety literature most often refer to these aspects as non-technical skills, crisis resource management or interpersonal relations [9–14]. These common concepts are too limited, however, since they specifically define competence in terms of what is lacking (non-technical skills), what it is for (crises resource management) or interaction between people (interpersonal relations). The comprehensive concept of human factors includes broader aspects of human interaction, including social skills, cognitive skills and decision-making. It emphasises how the environment, the organisation and human psychology interact [15, 16]. Based on this reflection, this article will use human factors skills (HFS) as the terminology for the skills in focus. Patient safety reports and root cause analysis indicate that adverse events occur in interactions between technology, organisation and human factors, and adverse events are about understanding the interactions among humans and other elements of a system, including social and cognitive structures [1, 2, 17]. An example is the relocation of healthcare personnel from their everyday work to COVID-19 units [18]. This challenged even highly competent personnel and might have caused an increased number of human errors. Personnel had to adapt to unfamiliar technical and cognitive procedures and new surroundings, complications, colleagues and workflows. The Danish Patient Safety Database shows a 32% increase in reported adverse events in 2020 [19], with a peak at the beginning of the COVID-19 pandemic.

¹ Adverse events: an event that results in injury or risk of injury during health professional activity. The incident is unintentional and includes known and unknown events and errors that are not due to the patient's illness and that are either harmful or could have been harmful (near-accident).

Research indicates that simulation-based training (SBT) is a safe and effective tool to develop and increase competencies in healthcare [20]. However, existing reviews focus on technical skills (TS), self-confidence, self-efficacy and the effectiveness of SBT for unqualified healthcare students [21–24] and develop unqualified healthcare students' HFS [25, 26]. SBT has been found to refine qualified healthcare teams' TS, self-efficacy and confidence [24, 27]. Existing studies of qualified healthcare teams' HFS focus on developing curricula, specific settings or situations or testing new evaluation or rating instruments [28–32]. Buljac-Samardzic et al. [33] explored interventions that improved team effectiveness and concluded that SBT enhances teamwork, though interventions studies were limited to specific situations, settings and outcomes. As mentioned, HFS are crucial to reducing adverse events [34], but evidence concerning the effectiveness of SBT to refine qualified healthcare teams' use of HFS is sparse. There is a need for additional knowledge about the effectiveness of developing HFS in qualified healthcare teams with SBT.

Aim

This systematic review aimed to investigate the effectiveness of in-hospital simulation-based training as a learning and teaching method to develop qualified healthcare teams' human factor skills.

Methods

The AMSTAR 2-criteria (A Measurement Tool to Assess systematic Reviews) were used to prepare the review [35]. The review report follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [36]. Details of the protocol were registered in the International Prospective Register of Systematic Reviews (PROSPERO) [37] (record ID: CRD42021118670).

Search strategy

SPICE (Setting, Perspective/population, Intervention, Comparison and Evaluation) [38], an alternative to the qualitative conceptualising model PICO [39], provided a framework for the formulation of questions, keywords and the search process. The SPICE elements were outlined: Setting = in-hospital healthcare specialisms and units; Population = all authorised qualified clinical healthcare personnel, apart from dentists and pharmacologists; Intervention = using SBT to teach HFS; Comparison = SBT compared to classroom teaching or no training; and Evaluation = improvements in the personnel's HFS.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Studies of qualified healthcare professionals. The population covers post-graduate clinical healthcare personnel, all seniorities and competency levels, for instance midwives, nurses, physicians and respiratory therapists.	Studies were the teams consists of non-qualified healthcare providers. Pre-graduate, students (midwives, nurses, physician etc.), roleplaying staff, dentists or pharmacologist.
Studies of simulation-based training with human patients (artificial, human or combination) focusing on improving HFS, regardless of location (centre or in situ) or group of personnel.	Studies of simulation-based training focusing on technical skills, confidence, self-efficacy, satisfaction, and/or communication with patients or relatives.
Studies of mono- or multidisciplinary teams. A team have four attributes: two or more members with assigned and clear roles, who perform independent task with a common goal.	Studies of team training without simulation-based training, with virtual reality or teams with roleplaying personnel.
Studies investigating the effect of training human factors using simulation-based training.	Studies of test or validation of tools, development of curricula, studies without empirical data, reviews, editorial letters, books.

Boolean operators were used, combining keywords and blocks. Furthermore, the databases' unique thesauri, truncation, phrase searches and proximity searches were included. An experienced information specialist (author TFF) optimised the search. Publications in English, Danish, Norwegian and Swedish were deemed eligible.

The following databases were searched: CINAHL (EBSCO), Cochrane Library, EMBASE™ (OVID), ERIC (EBSCO), MEDLINE® (OVID), PsycINFO (OVID), SCOPUS and Teacher Reference Centre (EBSCO), September 28th, 2021. Search histories are available in [Supplement A](#).

Study selection and critical appraisal

Covidence [40], a screening and data extraction tool, was used in the study selection process. Except for reviews, research protocols and conference abstracts, all study design and publication types were included. Authors LA, MLH and ABN individually performed the title and abstract screening using a standardised pre-piloted guide of inclusion and exclusion criteria (Table 1). Communication with patients or relatives and virtual reality were excluded as the focus was on the performance of qualified healthcare teams. Studies using role-play were excluded because some team members role-play it does not resemble the everyday practice where every team member interacts due to the situation and competencies. The role-playing personnel has a role and a script and therefore only acts if given a significant task.

Conflicts were resolved through dialogue. LA subsequently selected eligible studies for inclusion by full-text reading, and, in cases of doubt, the consensus was achieved by consulting the authors MLH, ABN, LH and SVS. Each study was scrutinised for validity, reliability, generalisability and replicability of the results using the

Critical Appraisal Skills Programme checklists (CASP) [41], Mixed Methods Appraisal Tool (MMAT) [42] or Critical Appraisal of a Survey [43]. The studies were labelled with either a high, medium or low-reliability rating for use in the analysis of effectiveness.

The analysis process

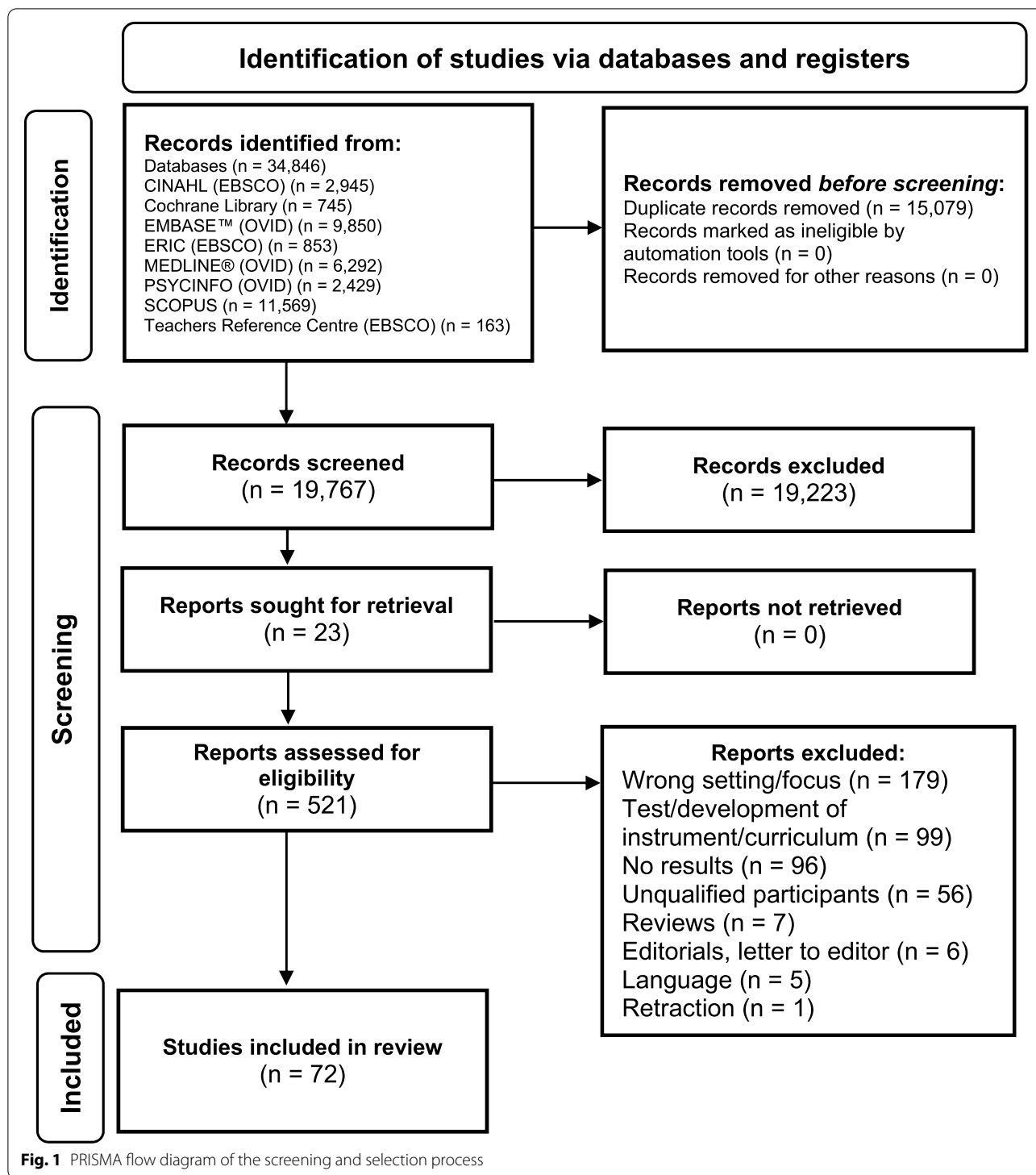
Content analysis [44, 45] was used to assess the effectiveness. Content analysis is a systematic and objective research method that enables qualitative and quantitative content analysis. Stemler's inductive technique was used to analyse the content. From open coding to creating themes and abstraction [44]. The following topics framed the content analysis: *characteristics, target population, HFS focus, intervention type and content, type of assessment, outcome, results and limitations, summaries of intervention effects* for each study. Due to the variation of the included study types, all assessments and methods were analysed and categorised. Every theme was verified and, where necessary, revised or split into two.

Ethical consideration

Ethical approval was not deemed necessary because data was from previously published studies, but the study meet(s) the claims of the Helsinki Declaration [46].

Results

The initial search identified 34,846 publications, representing 19,767 unique studies, after removing duplicates. After title and abstract screening, 521 studies were identified for full-text screening, of which 72 were included for data extraction and synthesis. This process is shown in the PRISMA flow diagram (Fig. 1).



Result of quality assessment of included studies

The included studies were of varying quality, as shown in Table 2. The assessment included factors, such as unsuitable assessments methods, unclear selection methods, and

uneven weighting of HFS and TS, favouring TS in assessing effectiveness. No studies were excluded following the quality assessment; however, it was used as an indicator of validity and reliability of the effectiveness of HFS training.

Table 2 Quality assessment of 72 studies included in a systematic review of The effectiveness of improving healthcare teams’ human factor skills using simulation-based training. Green = Yes, Red = No, Grey = Can’t tell, Yellow = Not relevant, Q = Question

ID	Clay-Williams et al.	Dedy et al.	Fernandez et al.	Fransen et al.	Jonsson et al.	Rubic-Gurung et al.	Skelton et al.	Yule et al.	Barra et al.	Mahramus et al.	Marko et al.	AbdelFattah et al.	Colman et al.	George & Quatrara	Jaffri et al.	Rao et al.	Rosqvist et al.	Steinemann et al.	Birch et al.	Burden et al.	Bursiek et al.	Chamberland et al.	Dounouras & Engels	Fregley et al.	Joshi et al.	Pena et al.	Shapiro et al.	Siassakos et al.	Sudkoff, Overy & Shapiro	Andreatta et al.	Colman et al.	Kumar et al.	van der Boer-Boon et al.											
Tool	CASP-RCT								CASP-RCT				CASP-COHORT								CASP-CASECONTROL								MMAT															
Design	RCT								N-RCT				COHORT								CASECONTROL								MIXED METHOD															
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Q8																																												
Q9																																												
Q10																																												
Q11																																												
Q12																																												

ID	Figueroa et al.	Gardner et al.	Armstrong et al.	Arora et al.	Blum et al. (2005)	Burtscher et al.	Caicagno et al.	Caskey et al.	Gilfoyle et al.	Lee et al.	Lemke	Miller et al.	Rice et al.	Undre et al.	Weiler et al.	Yee et al.	Auerbach et al.	Hazwani et al.	Pascual et al.	Beamman et al.	Burke et al.	Capella et al.	Gum, Greenhill & Dix	Mariker, Mohr & Ostergaard	Blum et al. (2004)	Colachio et al.	Cordero et al.	Cory et al.	De Bernardo et al.	Ermani et al.	Kenaschuk et al.	Meeker et al.	Mekta et al.	Palmer et al.	Paull et al.	Roberts et al.	Rochlen et al.	Ross et al.	Sawyer et al.				
Tool	CEBMa		CASP-CASECONTROL														CASP-COHORT				CASP-QUALITATIVE				CEBMa																		
Design	SURVEY		CASESTUDY														CASESTUDY				CASESTUDY																						
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Study characteristics

Included studies were published between 2004 and 2021 and were conducted mostly ($n = 70$) in Western countries. The 72 studies used 51 different assessment methods to measure the outcome of the team training interventions, including pre-tests, peri-tests and post-tests, (un)blinded ratings, self-assessments, surveys and interviews. The methods were validated ($n = 30$), non-validated or no information about validation ($n = 14$) and modified versions of validated ($n = 9$) instrument. The studies reported SBT settings such as simulation centres ($n = 36$), in-situ training ($n = 24$) and the use of both centre and in-situ training ($n = 7$). A broad variation was seen in the size and range of the studies ($n = 7$ to 675 participants) and represented SBT within seven different in-hospital medical specialisms: anaesthesiology ($n = 7$), emergency medicine ($n = 20$), intensive care ($n = 9$), internal medicine ($n = 2$), obstetrics ($n = 12$), paediatrics ($n = 6$) and surgery ($n = 15$). A range of teaching methods were used: SBT ($n = 30$); SBT and didactics ($n = 34$); SBT, didactics and workshops ($n = 6$); and SBT and workshops ($n = 1$).

The courses in the included studies were mostly stand-alone ($n = 51$), meaning not part of formal educational ($n = 18$) progress. The participants were either voluntary ($n = 35$), mandatory ($n = 16$), randomly selected participants ($n = 9$) or not stated ($n = 12$). Participants trained one or more HFS: communication, coordination, decision-making, followership, leadership, situational awareness, task management or teamwork.

Team size varied from two to twenty members, typically training in teams of two to five members. Two-thirds of the studies were of multidisciplinary teams ($n = 47$). Midwives, nurses and physicians were the most common participants, but 13 different disciplines participated. Mono-disciplinary SBT was seen in 20 studies; physicians ($n = 18$) were primarily trained separately from other qualified personnel. An extracted summary of included studies is shown in Table 3, and the whole summary is available in Supplement B.

Content analysis

The content analysis identified four recurring themes: (1) Training HFS in qualified teams, (2) assessment of

Table 3 Extracted summary of studies included in a systematic review of The effectiveness of improving healthcare teams' human factor skills using simulation-based training. The full summary of included studies is available in [Supplement B](#)

ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Mono)disciplinary (MO) /Multidisciplinary (MU)	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Clay-Williams 2013 Australia	RCT	N=60 Obstetrics (MU)	C / U / A	S (HFS) / L - S (HFS) / L (HFS)	SA teamwork P= 0.009 R teamwork P= 0.027	Hi/Lo	I = A) No interventions B) Class room C) Simulation D) Class room + simulation No positive changes in teamwork attitudes were found associated with classroom or simulation training. Positive changes were found in knowledge, self-assessed teamwork behaviour and independently observed teamwork behaviour
Dedy 2016 Canada	RCT	N=11 Surgery (MO)	C / F / A	L - S (HFS)	SA TeamSTEPS P= 0.008 R Teamwork P=0.008 R NOTSS P=0.012 R OSANTS P=0.012	Me/Me	I = Conventional training / NTS simulation Effectiveness of structured training on HFS Participants in the intervention group scored significantly higher on the knowledge
Fernandez 2020 America	RCT	N=60 Emergency Medicine (MO)	C / U / A	L - S (HFS)	R Leadership P<0.01	Hi/Me	I = No training / Simulation Leadership training Significant difference in post-training leadership behaviors. Leadership training resulted in the transfer of complex skills to the clinical environment and may have an indirect effect on patient care through better team leadership. Strong support for incorporation of more robust team leadership training into trauma education.
Fransen 2012 Netherlands	RCT	N=12 Obstetrics (MU)	Ch / U / A+U	S (HFS)	R Communication P=0.008 R Coordination P=0.118 R Decision making P=0.01 R Situational Awareness P=0.078 R Teamwork a=0.014	Hi/Hi	I = Simulation / No training Significant improvement in team performance and a significant increase in the use of new medical technical skills 8 months after obstetric, multiprofessional team training
Jonsson 2021 Sweden	RCT	N=75 Intensiv care (MU)	I / U / A	L - S (HFS)	R Overall teamwork 0.030 R Leadership P=0.003 R teamwork P=0.508 R task management P=0.030	Hi/Hi	I: online lecture, reflection session, simulation vs simulation only Education in situation awareness in the intervention group improved leadership, task management and TEAM total. No significant differences were observed in the SAGAT or the ABCDE checklist, shows that a 2-h education in situation awareness improved parts of team performance in an acute care situation. Team leadership and task management improved in the intervention group, which may indicate that the one or several of the components in situation awareness (perception, comprehension and projection) were improved
Rubio-Gurung 2014 United Kingdom	RCT	N=6 Obstetrics (MU)	I / U / U	S (HFS - TS)	R Task management P=0.01/0.004 R Teamwork P<0.001	Hi/Hi	I = Simulation / No training Significantly positive effect of in situ simulation training on multidisciplinary teams in both technical skills and teamwork.
Skelton 2016 Rwanda	RCT	N=20 Obstetrics (MU)	? / U / A	L - S (HFS)	R Overall HFS score P=0.335 R Decision making P=0.282 R Situational Awareness P=0.465 R Task management P=0.865 R Team work P=0.195	Me/Me	I = Simulation / No training Improvement in ANTS practice during cesarean delivery after 1 teaching session The ANTS score of the control group was 8, with a statistically significant difference (P = 0.002). Simulation participants showed statistically significant improvement in subcategories and in the overall ANTS score compared with ANTS score before simulation exposure.
Yule 2015 Northern Ireland	RCT	N=8 Surgery (MO)	C / F / A	S (HFS)	R Overall HFS score P=0.04	Hi/Me	I = Simulation + coaching / Simulation Improved residents' HFS in the simulated OR Deliberate practice in the form of non-technical skills coaching can improve critically important intraoperative behaviors and enhance patient safety.
ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Mono)disciplinary (MO) /Multidisciplinary (MU)	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Barra 2018 Italy	NRCT	N=15 Anesthesiology (MO)	C / F / A	L - S - W (HFS - TS)	R Overall HFS score P=0.0007	Hi/Hi	I = Simulation / Cohort control An intensive simulation-based program can be an effective way to acquire and develop basic skills, including HFS Residents significantly improved in all three evaluated areas cognitive, technical and behavioral.
Mahrinus 2016 America	NRCT	N=73 Emergency Medicine (MU)	C / U / A	L - S (HFS)	R Teamwork P<0.001 SA Teamwork P<0.001	Hi/Me	I = Simulation The simulation-based teamwork training improved measures of perceived teamwork from a multidisciplinary group who routinely respond to code events.
Marko 2019 America	NRCT	N=578 Obstetrics (MU)	I / F / A	L - S (HFS - TS)	T Knowledge P<0.0001 R Teamwork P<0.0001 R Teamwork +12 m P<0.0001	Hi/Hi	I = Simulation / 12 month audit No measurements exactly on HFS Multimodal simulation with an interprofessional educational approach improves the knowledge, skills, and safety culture attitudes Severe perineal laceration rates were reduced.
AbdelFattah 2018 America	Cohort	N=30 Emergency Medicine (MO)	C / F / A	S (HFS)	R Overall performance 2013 P<0.1 2014 P<0.1 2015 P<0.1 2015 cohort was statistically significantly better than both the 2013 and 2014	Me/Lo	I = Simulation / Cohort control Trauma-focused simulation improved performance in the clinical setting compared with previous cohorts with no such simulation experience.
Colman 2019 America	Cohort	N=128 Intensive Care - Pediatrics (MU)	I / U / A	S (HFS)	R Communication P=0.005 R Decision making P=0.017 R Leadership/followership P=0.002 R Situational awareness P=0.06 R Teamwork P=0.005 R Overall teamwork P<0.05 SA Overall Teamwork P=0.15	Hi/Hi	I = Simulation training / Teamperformance in real life Pre- and post-SBT intervention survey data demonstrated an improvement in the perception of teamwork Team performance skills such as communication, role assignment, role clarity, shared mental model, and situational awareness acquired during SBT can be applied to the management of emergency events
George 2018 America	Cohort	N=19 Emergency medicine (MU)	I / U / A	S (HFS)	SA Knowledge P<0.000 SA Teamwork P<0.05	Me/Me	I = Simulation Relatively short SBT is feasible and can increase perception of teamwork Significant improvements on both knowledge test and teamscores demonstrate the effectiveness of the intervention, and retention of the information gained and teamwork skills learned. Participants valued the intervention and recommended to increase the frequency of training.
Rao 2016 America	Cohort	N=15 Surgery (MO)	C / F / A	L - S (HFS - TS)	R Overall Teamwork P=0.010 R Communication P=0.002 R Decision Making P=0.029 R Leadership P=0.004 R Situational awareness P= 0.063 R Overall technical skills P=0.006	Me/Me	I = Simulation Significant improvement of HFS from before to after team task training, except for the situation awareness category, which showed improvement trending toward significance.
Steinmann 2011 America	Cohort	N=137 Emergency medicine (MU)	I / U / A	L - S (HFS)	R Overall Teamwork P<0.05 SA Overall Teamwork P<0.01	Hi/Me	I = Simulation SBT curriculum can improve the teamwork and clinical performance of multidisciplinary trauma teams that include surgical residents. This improvement was evidenced both in simulated and actual trauma settings, and across teams of varying composition.

Table 3 (continued)

ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Monodisciplinary (MO) /Multidisciplinary (MU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Birch 2007 United Kingdom	Case control	N=36 Obstetrics (MU)	I / N / A	L - S (HFS)	T Lecture & simulation 98 points T Simulation 74 points T Lecture 75 points SA Overall knowledge 100% SA Communication improved SA Teamwork improved	Me / Me	I = A) Theory B) Simulation C) Theory & simulation All teams improved in their performance and knowledge. The teams taught using simulation only (SBT) were the only group to demonstrate sustained improvement in clinical management of the case, confidence, communication skills and knowledge. Did not have enough power to reach statistical significance. A combination of lecture and simulation-based training appears to give the best short-term improvement in team performance.
Burden 2014 America	Case control	N=52 Internal medicine (MO)	C / F / A	L or S (HFS, TS)	T Communication P<0.001 T Leadership P<0.001	Hi / Hi	I = Simulation / +6 month re simulation Resulted in significantly improved team communication and cardiopulmonary arrest management. SBT with deliberate practice of HFS resulted in improved rare event and team management. Residents exposed to simulation communicated and completed HFS more effectively than those taught in a lecture format.
Bursiek 2020 America	Case control	N=14 Surgery (MU)	C / U / A	S (HFS)	SA Overall Teamwork P<0.001 SA decision making P<0.05 decrease in falls P=0.02	Me/Lo	I = Simulation / control + 2 and 6 month Only 57% and 50% of the included participated in the 2 and 6 month followup The current intervention seems to have led to significant improvement in nurse and physician perceptions of teamwork and the practice environment.
Chamberland 2018 Canada	Case control	N=29 Intensive care (MU)	C / U / A	S (HFS - TS)	R Communication P<0.001	ME/Me	I = A) Debriefing HFS, B) Debriefing TS Although information sharing improved for all teams, communication quality improved only for experimental teams. Increase in communication effectiveness. Increase of effect in both experimental and control, but mostly in experimental group. The retention of the communication decreases in both groups, but mostly in control group.
Doumouras 2017 Canada	Case control	N=9 Emergency medicine (MO)	C / F / A	L - S (HFS)	R Overall Teamwork P=0.001 R Communication P=0.01 R Coordination P=0.001 R Decision making P=0.01 R Leadership P=0.02 R Situational Awareness P=0.01	Hi/Hi	I = Simulation / Historical Beneficial effect and long-term retention after crisis nontechnical skill training.
Fregley 2011 Scotland	Case control	N=11 Surgery (MO)	C / U / A	L - S (HFS - TS)	R Overall Teamwork P<0.02 R Communication P<0.04 R Coordination P<0.02 R Leadership P<0.02	Hi/Hi	I = Simulation / Feedback SBT seems to be an effective teaching strategy The participants feedback was that the course was relevant, increased confidence of emergency events
Joshi 2018 America	Case control	N=46 Emergency medicine (MO)	C / U / A	S (HFS)	R Situational Awareness P<0.05 R Task management P<0.01 R Overall Teamwork P<0.05	Me/Me	I = Simulation stable team / Simulation dynamic team Simulation is an effective method for enhancing team competencies. Teamwork can improve across simulation scenarios regardless of team membership, whereas clinical effectiveness requires team stability to develop and improve. Less changes in improvements teams
Pena 2015 Australia	Case control	N=40 Surgery (MO)	I / U / A	L - S - W (HFS)	R Overall Teamwork P<0.001 R Communication P<0.001 R Decision making P<0.001 R Leadership P<0.001 R Situational awareness P=0.001	Hi/Me	I = Simulation / Simulation + HFS workshop HFS training is feasible and can impact positively participants' nontechnical performance in a simulated environment. The addition of a 1-day didactic workshop does not seem to provide additional benefit over simulation-based training as a sole strategy for nontechnical skills training.
ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Monodisciplinary (MO) /Multidisciplinary (MU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Shapiro 2004 America	Case control	N=16 Emergency medicine (MU)	C+ / U / A+U	L - S (HFS)	R Coordination P=0.12 R Teamwork P=0.07	Lo/Me	I = Simulation / No simulation There were no significant differences between experimental and comparison groups at baseline SBT appears to be a promising method for enhancing didactic teamwork training. Unclear how much simulator based training must augment didactic teamwork training for clinically meaningful differences to become apparent.
Siassakos 2009 United Kingdom	Case control	N=24 Obstetrics (MU)	C+ / U / A	S - W (HFS)	R Communication P=0.002	Lo/Me	I = HFS lecture + simulation / Simulation Teams that received additional teamwork training used more directed commands after training 'on-site' clinical drills can improve team communication in simulated emergencies, and additional teamwork training might improve this further.
Sudikoff 2009 America	Case control	N=16 Anesthesiology (MO)	C / F / A	L - S (HFS - TS)	R Communication P=0.36 R Coordination P=0.0004 R Decision making P<0.0001 R Leadership P=0.0008 R Task management P=0.011 R Teamwork P=0.0088	Me/Hi	I = Simulation + lecture + workshops / simulation Supports SBT for improving performance and teamwork skills. Showed significant relationship between the intervention and the performance. Behaviorally Anchored Rating Scale improved at each session though statistically unrelated to the intervention.
Andreatta 2011 America	Mixed method	N=228 Pediatrics (MO)	I / U / U	S (HFS - TS)	R Survival rates P=0.000 Audit 50 % increased survival rates	Me/Hi	I = Simulation Survival rates increased to approximately 50% correlating with the increased number of mock codes. Results are significantly above the average national pediatric CPA survival rates and held steady for 3 consecutive years, demonstrating the stability of the program's outcomes. SBT code program may significantly benefit pediatric patient CPA outcomes—applied clinical outcomes—not simply learner perceived value, increased confidence, or simulation-based outcomes.
Colman 2019 America	Mixed method	N=35 Intensive Care - Pediatrics (MU)	C+ / U / A	S (HFS)	R Overall Teamwork P=0.005 R Communication P=0.005 R Coordination P=0.007 R Decision making P=0.017 R Leadership P=0.002 R Situational Awareness P=0.06	Hi/Hi	I = Team performance in clinic after simulation Improvement in the perception of teamwork, most notable in the area of shared mental model and situational awareness following SBT Teamwork behaviors and skills acquired during SBT can translate into improved bedside performance Significant improvement in 12 out of 15 composite teamwork skills during real emergency events
Kumar 2018 Australia	Mixed method	N=237 Obstetrics (MU)	I / F / A	S (HFS - TS)	SA Communication 37% SA Leadership 31% SA Task management 33% SA Teamwork 20%	Lo/Lo	I = Simulation Change in the management of postpartum haemorrhage by early recognition and intervention. Participants reported a positive learning experience and increase in confidence Improvement of both clinical and non-technical skills highlighting principles of teamwork, communication, leadership and prioritisation in an emergency situation. No significant change was noted in clinical outcomes over a 2-year period
van den Bos- Boon 2021 Netherlands	Mixed method	N=71 Intensive Care - Pediatrics (MO)	C / U / A	L - S (HFS - TS)	SA Communication improved SA Teamwork improved R Communication improved R Teamwork improved R Task management improved	Me/Me	I = E-learning, lecture, simulation This study shows encouraging improvement of nurses' resuscitation and teamwork skills in a simulation setting following a proficiency check for resuscitation. We may not automatically assume that this effect can be translated to the real-life setting, and this should be explored in future research.
Figuerola 2013 America	Survey	N=37 Intensive care - Pediatrics (MU)	C / U / A	S (HFS - TS)	SA Communication P<0.05 SA Leadership P<0.05 SA Task management P<0.05 SA Teamwork P<0.05	Hi/Hi	I = Lectures + simulation Confidence and skill in the roles of team leader, advanced airway management, and cardioversion/defibrillation were increased significantly. A significant increase also was observed in the use of Team STEPPS concepts.

Table 3 (continued)

ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Monodisciplinary (MO) /Multidisciplinary (MeU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Gardner 2008 America	Survey	N=58 Obstetrics (MU)	C / U / A	S (HFS - TS)	SA Communication 92.5% SA Leadership 85% SA Teamwork 90%	Hi/Lo High number of withdrawals	I = Simulation Reported improved teamwork and communication in managing a critical obstetric event in the interval since taking the course. SBT HFS training can serve as a strategy for mitigating adverse perinatal events
Arora 2015 United Kingdom	Case study	N=385 Surgery (MO)	I / F / A	S (HFS - TS)	R Communication P=0.001 R Decision making P<0.001 R Leadership P=0.001 A significant improvement in the teams' communication, coordination, cooperation, leadership, situation awareness, and decision-making skills	Hi/Hi	I = Simulation Evidence for the efficacy of ward-based team training using simulation. Focus on the Technical outcome, HFS outcome described in 2 sentences
Armstrong 2020 New Zealand	Case study	N=15 Emergency Medicine (MU)	C+ / U / A	L - S (HFS - TS)	R Coordination P=0.006 R Communication P=0.1064 R Decision making P<0.0001 R Leadership P=0.0031 R Situational Awareness P=0.0008	Hi/Me	I = Lecture, simulation Simulation is an effective training tool for improving teamwork and senior nurse leadership skills in the novel setting of nurse and doctor shared leadership during CPR. Wider benefits of nurse empowerment and interdisciplinary training is ripe for further qualitative review.
Auerbach 2014 America	Case study	N=269 Emergency Medicine - Pediatrics (MU)	I / U / U	S (HFS - TS)	R Overall Teamwork P=0.002 R Task Management P=0.002 Statistically significant trends over time in (a) overall performance, (b) the teamwork component	Hi/Hi	I = Unannounced in situ simulation Improved validated trauma simulation assessment scores for overall performance, teamwork, and intubation Most valuable aspect of this simulation: Debriefing, High-acuity trauma training, Teamwork and communication training, Review of policies. In situ trauma simulation is a sustainable and effective method to reinforce teamwork and trauma skills
Bearman 2012 Australia	Case study	N=11 Surgery (MO)	C / U / A	L - S - W (HFS - TS)	SA Highly useful, better communication, teamwork SA 90 % would recommend SA 82 % better HFS + TS	Me/Me	I = Lectures, workshops and HF simulation SBT is feasible to teach competencies in communication, teamwork, leadership, and the encompassing professionalism to surgical trainees
Blum 2004 America	Case study	N=55 Anesthesiology (MO)	C / U / A	L - S (HFS)	SA Overall HFS I = 4.80 IV = 4.82 (1-5 scale) SA Communication P<0.035	Me/Me	I = Lecture, simulation, focus on CRM Improvement in their CRM non-technical skills. Indirect evidence supporting the contention that this type of training should be more widely promoted, although more definitive measures of improved outcomes are needed
Blum 2005 America	Case study	N=38 Anesthesiology (MU)	C / U / A	L - S (HFS)	R Communication (Probe placing) 56 % successful, 33 % overheard P=0.2	Lo/Mo	I = Simulation + lecture + simulation There was no statistical difference in "group sharing" from beginning to end of training, despite trainees' survey responses that the course would be useful for their education and practice.
Burke 2017 America	Case study	N=55 Emergency Medicine - Pediatrics (MU)	I / U / A	S (HFS)	SA Communication SA Coordination SA Leadership SA Teamwork	Me/Lo	I = Simulation / Focus group interview Valued the practice they received during trauma simulations and supported the continuation of the simulations to improve trauma activation teamwork and communication
ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Monodisciplinary (MO) /Multidisciplinary (MU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Burtscher 2011 Switzerland	Case study	N=30 Anesthesiology (MU)	I / U / A	S (HFS)	R Communication P=0.86 R Task management P=0.45 Participants spent an average of 35.22% of their time on coordination activities	Hi/Hi	I = Simulation Adaptation of coordination activities is related to improved team performance in healthcare
Calcagno 2018 America	Case study	N=12 Anesthesiology (MO)	? / U / A	S (HFS - TS)	R Communication P=0.38 R Decision-making P=0.91 R Leadership P=0.29 R Situational awareness P=0.08	Me/Lo	I = Simulation HFS Multidisciplinary simulation transcends the individual experience by allowing trainees to develop algorithms for crisis management and to improve on aspects of teamwork, leadership, and communication skills that can be applied throughout their careers Multidisciplinary learning has real-world practicality, enhances communication, and is linked to measurable improvements.
Capella 2010 America	Case study	N=73 Emergency medicine (MU)	I / U / A	L - S (HFS)	R Communication P=0.001 R Leadership P=0.003 R Situational awareness P=0.009 R Teamwork P=0.001 SA Communication P<0.01 SA Coordination P<0.01	Hi/Me	I = Simulation Significant improvement in all teamwork domain ratings and overall ratings from pretraining to posttraining
Caskey 2017 America	Case study	N=9 Surgery (MO)	? / F / A	L - S - W (HFS - TS)	R Overall Teamwork P<0.0001 R Communication P<0.0001 R Decision-making P<0.0001 R Leadership P=0.0001 R Situational awareness P<0.0001	Hi/Hi	I = HFS + TS lectures, workshops and HF simulation SBT HFS training for laparoscopic cholecystectomy (that was separate from technical skills training) led to a sustained increase in residents' HFS
Colacchio 2012 America	Case study	N=154 Intensive Care - Pediatrics (MU)	C / U / A	L - S (HFS)	SA Improvements in teamwork, leadership, situational awareness and communication on 0.62-0.88 points (5-point Likert scale)	Me/Me	I = HFS lecture + simulation Although participants had a positive perception of their teamwork skills pre-training, the majority still found the course useful and all sessions resulted in recommendations for improved teamwork made by participants
Cordero 2013 America	Case study	N=26 Pediatrics (MO)	C / U / A	L - S (HFS - TS)	R Overall Teamwork P=0.37 R Communication P=0.25 R Leadership P>0.99 R Task management P=0.25	Lq/Lo	I = Simulation Significant improvement in team communication was noted. Residents' improvements in self-confidence did not reflect gains in actual performance. The HFS simulation offers opportunities for NR and team skills training and assessment.
Cory 2020 America	Case study	N=72 Intensive Care - Pediatrics (MU)	I / U / A	S (HFS)	SA Communication P<0.05 SA Coordination P<0.05 SA Leadership P<0.05	Me/Lo	I = Simulation Multidisciplinary simulation-based team training in the pediatric cardiac intensive care unit improves knowledge of HFS principles in addition to improved perception of effective teamwork. Subgroup analysis demonstrated that the participants with less than five years of experience had a significant increase in the correct response rate on how to use closed-loop communication
De Bernardo 2016 Italy	Case study	N=23 Pediatrics (MU)	C / F + U / A	L - S - W (HFS - TS)	SA + R Improvements in HFS from 34 to 42 points (max point 45)	Me/Lo	I = Lecture - simulation / +2 month Limited impact on technical and non-technical skills of participants working in low level hospitals. Training programs should be tailored to the participants' professional background and to the more relevant sessions. Technical and nontechnical scores were significantly correlated

Table 3 (continued)

ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical specialty (Monodisciplinary (MO) /Multidisciplinary (MU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Emani 2018 America	Case study	N=23 Intensive Care - Pediatrics (MU)	I / U / A	L - S (HFS)	R Communication P=0.018 R Coordination P=0.026 SA Teamwork P=0.033	Me/Me	I = Lecture + Simulation Simulation training implemented in low-resource environments can result in significant improvements in communication Simulation fosters a culture of open communication and idea acceptance
Gillfoyle 2017 Canada	Case study	N=300 Pediatrics (MU)	C / U / A	L - S (HFS - TS)	R Overall Teamwork P<0.0001 R Communication P<0.0001 R Decision making P<0.0001 R Situational awareness P<0.0001	Hi/Hi	I = Lecture, simulation A positive correlation between clinical and teamwork performance suggests that effective teamwork improves clinical performance of resuscitation teams
Gum 2010 Australia	Case study	N=17 Obstetrics (MU)	? / ? / ?	L - S (HFS - TS)	SA Increase in personal role awareness, which included role definition, scope of practice and communicating roles.	Me/Lo	I = Simulation workshop / Interview + postworkshop Significance of interprofessional training, particularly through simulation learning in a team where rural clinicians are able to learn more about each other and gain role clarity, leadership skills and mutuality in a safe environment. It is argued that no 'single' teamwork training course can alter attitudes, and change in work culture can only be achieved through repetitive training
Hazwani 2020 Saudi Arabia	Case study	N=492 Pediatrics (MU)	I / F / U	S (HFS - TS)	R Overall Teamwork P=0.230 R Leadership P<0.0001 Improvements in communication	Me/Me	I = Simulation In situ code simulation is a helpful way to enhance team performance and improve the quality of cardiac resuscitation.
Jafri 2021 America	Case study	N=162 Emergency Medicine - Pediatrics (MU)	C / U / A	L - S (HFS - TS)	R Overall Task management P<0.001 R Overall Teamwork P<0.001 R Communication improved R Decision making improved R Situational Awareness improved	Hi/Me	I = Simulation, group discussions A interprofessional program in a community hospital site demonstrating that teaching CRM skills can improve simulated team performance in a diverse experienced cohort. Also moderate positive correlation between CTS and CPT among all 48 cases, pre and post combined.
Kenaszchuk 2011 Canada	Case study	N=154 Internal Medicine (MU)	C / U / A	L - S (HFS)	SA + R Attitudes toward teamwork did not exhibit linear growth SA + R Attitudes toward shared leadership had significant differences.	Hi/Lo	I = Lecture, simulation SBT shared leadership may provide the most leverage to improve interprofessional care. Attitudes toward healthcare teamwork likely did not exhibit linear growth in the six-week follow-up. These results may undermine confidence in the ability of simulation activities to substantially improve interprofessional attitudes in the long run.
Lee 2021 America	Case study	N=7 Emergency medicine - Pediatrics (MU)	I / U / A	S (HFS - TS)	SA Communication improved SA Teamwork improved	Lo/Lo	I = Simulation Teamwork and communication, as measured by the TeamSTEPS Team Performance Observation Tool, improved from the baseline to 12-month assessments for both scenarios, but scores did not change over the 12-month period.
Lemke 2020 America	Case study	N=81 Emergency medicine - Pediatrics (MC)	C / F / A	L - S (HFS - TS)	SA Communication improved SA Teamwork improved	Lo/Lo	I = Simulation, rapid cycle deliberate practice, coaching This technique was well received and provided positive feedback on the sessions. In particular, when asked if the course "improved my teamwork and leadership skills" they agreed with a mean score of 4.9 out of 5.
Marker 2019 Denmark	Case study	N=19 Emergency Medicin (MO)	C / F / A	L - S - W (HFS)	SA Structured communication SA Understanding the role of other team members SA Role as leader SA Plan and prepare SA Decision making SA Use of HFS in clinical practice was found to be helpful in meeting the medical expertise challenges.	Me/Me	I = Lecture, workshops, simulation SBT increasing their preparedness for clinical practice and handling the critically ill patient Concern was expressed related to staff willingness and preparedness in using these tools. Experienced an ability to transfer the use of algorithms and non-technical skills trained in the simulated environment to the clinical environment. The application of these skills was more difficult if these skills were unfamiliar to the surrounding clinical staff.
Meecker 2018 America	Case study	N=36 Obstetric (MU)	C + I / U / A	S (HFS - TS)	SA Communication P=0.03 SA Teamwork P=0.04 SA Follow-up (+3M) 90.9% perceived improved teamwork and communication	Me/Me	I = Simulation Participants experienced promoted enhanced communication and teamwork
Mehta 2013 United Kingdom	Case study	N=78 Surgery (MU)	I / U / A	S (HFS - TS)	SA + R Enhanced clinical knowledge SA + R Address non-technical skills	Hi/Hi	I = Simulation Improvement in clinical knowledge, teamwork, leadership and non-technical skills, as well as the mutual understanding and respect between related medical and non-medical team members Emphatically demonstrate the universal success of this multi-disciplinary training method for all team members, regardless of hierarchical position or background.
Miller 2012 America	Case study	N=80 Emergency Medicine (MU)	I / U / ?	L - S (HFS)	Simulation R Communication P= 0.003 R Coordination P=0.037 R Decision making P=0.015 R Leadership/Fellowship P=0.018 R Situational Awareness P=0.035 R Teamwork P=0.020 Transfer R Communication P=0.003 R Coordination P=0.069 R Decision making P=0.047 R Leadership/Fellowship P=0.050 R Situational Awareness P=0.066 R Teamwork P=0.059	Hi/Hi	I = Lecture, simulation / Simulation Teamwork and communication in the clinical setting were improved, this effect was not sustained after SBT were stopped. Only overall communication appeared significantly different Comparing the didactic phase to baseline, only closed-loop communication was significantly different. Comparing the ITS phase to baseline, nearly all of the communication component measures were significantly improved over baseline Transfer: yes, but not significant
Palmer 2019 America	Case study	N=23 Obstetrics (MO)	C / U / A	S (HFS)	SA Communication P=0.013 SA Leadership P=0.085 SA Situational Awareness P=0.008 SA Teamwork P=0.001	Me/Me	I = Simulation Supports the use of SBT to enhance team-based training, performance, and communication Participants identified debriefing and briefing as a valuable experience
Pasual 2011 America	Case study	N=12 Intensive care (MU)	C / F / A	S (HFS)	R Decision making P<0.01 R Situational Awareness P<0.05 R Teamwork P<0.01	Lo/Lo	I = Simulation, debriefing Leadership/ interpersonal skills scores improved significantly. SBT improves leadership, teamwork, and self-confidence skills in managing medical emergencies.
Pauli 2013 America	Case study	N=325 Surgery (MU)	C + I / F / A	L - S (HFS)	R Communication 16% R Decision making 18% R Leadership/Fellowship 18% R Situational Awareness 12% R Teamwork 19%	Hi/Hi	I = Simulation Teamwork and communication scores improved 14 of the 15 observed skills showed significant improvement that ranged from 15% to 23%. SBT improves teamwork and communication skills among interprofessional staff caring for postoperative patients.
Rice 2016 America	Case study	N=7 Emergency medicine (MO)	C / U / A	L - S (HFS)	Observed R Overall Communication P=0.001 R Overall Situational Awareness P=0.000 R Overall Teamwork P=0.000 Attitude SA Overall Communication P=0.001 SA Overall Teamwork P=0.041 Perception SA Overall Communication P=0.009 SA Overall Teamwork P=0.021	Hi/Hi	I = Simulation, lecture (between scenarios) Improved teamwork attitudes, perceptions, and performance. Team communication demonstrated significant improvement Team training increases communication and decreases patient errors. Combining simulation training with team training improves the function of teams.

Table 3 (continued)

ID 1st Author Year of publication Country of study	Study design	Participants (N=) Medical speciality (Monodisciplinary (MO) /Multidisciplinary (MeU))	Training type (In situ (I), Center (C) / (Un)Formal (U/F) / (Un)Announced (U/A))	Intervention (Lecture (L), Workshop (W), Simulation (S) (HFS /TS))	Improvement Self Assessed (SA) Rated (R) Test (T) Tool or Skill trained	Quality (Validity (Hi-Me- Lo), Reliability(Hi- Me-Lo))	Keyfindings
Roberts 2013 America	Case study	N=45 Surgery (MU)	I / U / A	L - S (HFS)	R Communication P=0.015 R Cooperation P=0.01 R Decision making P=NS R Leadership P=NS R Situational Awareness P=0.05	Hi/Me	I = Lecture, simulation Brief training exercises can change teamwork and communication behaviors on ad hoc trauma teams. Transfer after 3W – lost retention
Rochlen 2019 America	Case study	N=27 Surgery (MU)	I / U / A	S (HFS)	SA + R Team nontechnical skills improved from the first simulation to the second simulation during the intervention.	Me/Me	I = Simulation Improved team HFS scores when assessed following intervention. Participants found the intervention to be effective and beneficial to their learning. Transfer self-assessed
Rosqvist 2021 Finland	Case study	N=225 Emergency medicine (MU)	I / F / ?	S (HFS)	R Overall HF P<0.001	Me/Me	I = In situ simulation the non- technical skills of the participating trauma teams improved statistically significantly after the simulation training course when evaluated using the T- NOTECHS instrument.
Sawyer 2013 France	Case study	N=42 Pediatrics (MU)	? / U / A	L - S (HFS)	Observed R Communication P<0.001 R Leadership P<0.001 R Situational Awareness P<0.001 R Teamwork P<0.001 Attitude SA Overall Communication P<0.001 SA Overall Teamwork P<0.001	Hi/Hi	I = Lecture, simulation Significant improvements in teamwork skills - team structure, leadership, situation monitoring, mutual support and communication Challenges by nurses to a scripted medication order error doubled from 38% - 77%, a significant improvement
Undre 2007 United Kingdom	Case study	N=80 Surgery (MU)	C / U / A	S (HFS - TS)	R Communication P<0.001 R Decision Making P<0.05 R Leadership P<0.05 R Situational Awareness P<0.001 R Teamwork P<0.001	Me/Me	I = Simulation Multidisciplinary simulation-based team training is feasible and well received by surgical teams. HFS can be assessed alongside technical skills, and differences in performance indicate where there is a need for further training.
Wesler 2016 New Zealand	Case study	N=213 Surgery (MU)	C / U / A	S (HFS)	R Communication P<0.001 R Situational Awareness P<0.01 R Teamwork P<0.001	Me/Me	I = Observation, simulation, observation Improvement in scores for teamwork and communication in general surgical OR. Scores for teamwork and communication in the clinical environment improved by more than 20%
Wong 2016 America	Case study	N=72 Emergency medicine (MU)	C / U / A	L - S (HFS)	SA Communication P=0.107 SA Leadership P=0.029 SA Situational Awareness P=0.014 SA Teamwork P<0.0001 Patient safety measure R Communication P=0.548 R Teamwork P=0.035	Hi/Hi	I = Lecture, simulation Improving participant attitudes toward teamwork and components of patient safety culture related to teamwork and communication (transition P=0.024, organisational learning P=0.057)
Yee 2015 Canada	Case study	N=20 Anaesthesiology (MO)	C / U / A	L - S (HFS)	R Coordination P<0.05 R Decision Making P<0.05 R Situational Awareness P<0.05 R Task management P<0.05 R Teamwork P<0.05	Me/Me	I = Lecture, simulation A single exposure to anesthesia crises using a high-fidelity patient simulator can improve the nontechnical skills of anesthesia residents. Simulation based education is beneficial and can significantly improve the nontechnical skills ability of residents Impression from both teachers and participants is that simulation-based education is very useful.

HFS, (3) combined teaching methods and (4) retention and transfer of skills. These themes will be elaborated on below.

Training HFS in qualified healthcare teams

The vast majority (n = 65) of the studies concluded that SBT could develop qualified teams using HFS. In two-thirds of the studies, HFS as the sole focus of the training were seen and associated with enhanced effectiveness [13, 47–73]. These studies were mainly conducted in simulation centres, with smaller teams (n = 2–8 members), and the SBT-courses were announced. It is a significant result that HFS usually are trained together with TS, and when trained on its own, it is taught in centres rather than in situ and minor teams. Most of the 27 studies (n = 22) used validated assessment methods and performed debriefing (n = 24) immediately after every SBT scenario. Nevertheless, Emani et al. [60] and Jafri et al. [74] show a correlation between TS scores and HFS scores, which emphasises that the effect of SBT is evident when HFS is trained solely in combination with other competencies. Studies of multi-disciplinary training (n = 47) [13, 48, 53, 56, 58–64, 66–69, 71–102] were generally associated with greater effectiveness than mono-disciplinary training, perhaps because multi-disciplinary training better reflects everyday clinical practice.

Three studies showed potential effect [71, 93, 99], concluding that SBT is a promising tool to train HFS but

that more applicable assessment methods are needed. Only two studies did not show effect [85, 98]; they mention positive selection bias because high numbers of participants withdrew, along with methodological problems and lack of assessment methods as possible causes of the non-effect result.

The trainees were mainly personnel from acute or high-intensity medical departments, and nearly all the trained situations involved acute life and death situations. Only four studies [68, 74, 93, 100] trained HFS in day-to-day work, such as reducing falls, ethical issues, delirium, the busy ward and caring for older patients and relatives. A paediatric focus was found in 25 SBT studies, in anaesthesiology, intensive care and obstetrics [13, 56, 60, 61, 72, 74–77, 80, 81, 83, 86, 88, 90, 91, 98, 102–109]. In total, 3251 of the participants were trained in acute paediatric scenarios. HFS during resuscitation (n = 20) was the second most trained situation [10, 13, 49, 52, 53, 59, 61, 62, 65, 72, 76, 78, 87, 89–91, 101, 104–108, 110], involving 1887 personnel. This illustrates that acute and high-intensity situations are the main focus of SBT concerning teams’ HFS. Common to these training situations are available algorithms and checklists of the TS or HFS (e.g. acute caesarean, cardiopulmonary resuscitation, Crisis Resource Management), which facilitate a form of corrective actions. However, compliance with checklists and training algorithms does not cover the dynamics of HFS. Checklists and algorithms are task-oriented (check

of rhythm, request read-back) that differ from the nature of HFS, which are social and cognitive processes within environmental and organisational frames. These task-oriented approaches increase the risk of changing the focus from the all-around focus to the tasks themselves. This could be why the focus on TS overtakes the focus on HFS in some of the studies, for instance, in Arora et al. and Siassakos et al. [99, 111].

This demonstrates that SBT increases the HFS among qualified teams, but due to the lack of high-quality studies using similar assessment tools, the level of effectiveness was not established.

Assessment of HFS

The studies lack an adequate description of how HFS refinements should be assessed. Existing HFS assessment tools are insufficient, which was emphasised in 28 studies [49, 55, 58, 61, 64, 65, 68, 71, 75, 78, 80, 81, 84, 85, 87, 89, 95, 96, 98, 99, 103, 107, 111–115]. Assessment methods ($n = 51$) spanned quantitative, qualitative and mixed methods, validated and non-validated methods, rating behavioural markers, rating via checklists, interviews, self-assessments, passing probes of information, measuring time and evaluation of reported experiences. Even though the studies used different assessment methods, they concluded that HFS enhanced among the participants. In 68 studies, HFS was considered to have improved and a significant development in HFS as a result of SBT was shown in 33 studies [10, 47–49, 51–56, 59, 60, 62, 64, 65, 72–77, 79, 80, 83, 87, 90, 100, 101, 104, 107, 108, 114, 116]. In conclusion, SBT can refine HFS.

The primary challenge in assessing HFS was a lack of definitions for HFS and insufficient coverage of many different HFS. HFS were, as mentioned, undefined or broadly described in several studies, or the assessment was unfit for HFS, such as measuring the time from the outset of a procedure to a specific action or treatment [13, 51, 61, 83, 89]. For instance, the increased time could also be due to improvements in the TS and not the HFS. HFS training associated with specific behaviour markers were the most successful assessment [10, 49, 54, 59, 65, 72, 73, 79, 101, 102, 114]. Five tools generally inspired the methods used: crisis resource management [117, 118]; Kirkpatrick Model: Four Levels of Learning Evaluation [119]; Mayo High-Performance Teamwork Scale [120]; Ottawa Global Rating Scale [121]; and TeamSTEPS[®] [122].

The rating of markers was either blinded or unblinded by internal or external faculty or assessed by the participants themselves. Self-assessments were used in 31 studies. Self-assessment were used in combination with other methods in 18 studies [47, 53, 57, 60, 65, 67, 68, 72, 78, 81, 85, 88, 93, 95, 97, 98, 108, 116], whereas 13

studies used self-assessment as the only method [82–84, 87, 92, 94, 100, 102, 105, 107, 109, 110, 112]. There are inherent challenges in using rating and self-assessments because assessors must be congruent and unbiased, and participants tend to overrate their performance and therefore, the method has been proven unreliable [123, 124]. Some studies ($n = 21$) used video recording and blinded assessors [47, 48, 54, 58, 60, 61, 63, 66, 70, 71, 74, 76, 89, 91, 98, 99, 103, 106, 108, 111, 114], which increased the validity of the ratings; because the assessors' could rewind the video and review the situation multiple times. Other studies rated participants in real-time, which challenged the assessors' ability to simultaneously watch, listen and rate [10, 49–51, 53, 57, 59, 62–65, 67, 68, 72, 73, 75, 77–79, 81, 85, 93, 96, 101, 107, 115, 125].

The most frequently trained HFS were communication, leadership and teamwork. The specification of the trained HFS were described in various ways. Eleven studies [10, 13, 54, 69, 71, 98, 100, 101, 103, 114, 115] described HFS with behaviour markers, attitudes or as a definition of the chosen HFS, while others ($n = 15$) only mentioned the HFS in broad indefinite terms such as communication or teamwork [49, 57, 58, 63, 73, 76, 79, 85, 88, 89, 102, 106, 108, 109, 112]. Communication and teamwork were the two most trained HFS.

Communication and teamwork are both broad terms. Communication and teamwork are not isolated and unequivocal tasks; they depend on and influence each other, like most HFS. The purpose of outlining and dividing the tasks into behaviour markers is to simplify a complex clinical situation, i.e. highlight easily recognisable behaviour for the participants, making it easier to acquire and develop skills [118, 126]. The studies that described HFS using either behaviour markers or attitudes succeeded to a greater extent in assessing HFS and developments than those that described HFS in broad, indefinite terms. It is difficult to determine and report the effect of training when the focus is on general terms such as communication and teamwork without a definition or level of detail. It is not possible to distinguish between teamwork/communication and cognition. While communication and teamwork are often immediately recognisable and valid interpretations for training personnel, they are high-level concepts difficult to rate to assessors. Maybe because you know it when you experience it but not always when you see it. However, the studies that reflected on the use of high-level concepts and worked to specify these in behaviour markers achieved greater internal validity along with assessed facts, due to the increased transparency [10, 13, 47, 48, 50, 52–55, 65–67, 69–72, 74, 75, 77, 78, 96–98, 100, 101, 103, 107, 114, 116].

They combined teaching methods

Significant effects on HFS were observed in 32 studies that combined SBT with didactics and workshops, compared to 12 that just trained SBT. The impact on qualified teams' use of HFS was evident, regardless of whether SBT was combined with didactics and workshops or training HFS on their own or in combination with TS. HFS training was combined with TS training in 30 of the studies, of which 19 showed a significant effect on one or more HFS, equalling 48 of all the included studies. Thus, it appears that the studies in which HFS training was separate from TS training resulted in the most significant improvements in the teams' use of HFS.

The studies that combined HFS and TS training tended to focus more on TS. For instance, Burden et al. and Siasakos et al. covered the results of HFS training with only a few sentences [99, 125], and Hazwani et al. asserted that a refined time to first medicine infusion in cardiopulmonary resuscitation training was because of an enhancement in teamwork [13].

Retention and transfer of skills

Retention or transfer of HFS was explored in 21 of the studies. The retention of HFS were measured from participants' knowledge, self-assessment, audits and patient outcome. Transfer of enhanced HFS are identified in 20 studies, but in two of these [79, 104], the authors identify transfer due to developed TS. The researchers argue that improved TS and time decrease in accomplishing the procedure are due to an increase in HFS skills. Roberts et al. find a transfer of HFS, but with low retention over time [66]. The transfer of HFS was measured as a decrease in adverse events and improved patient outcomes in six studies [49, 59, 79, 95, 97, 104].

Discussion

This systematic review demonstrates that SBT is a successful learning tool to improve HFS in-hospital healthcare settings. Unfortunately, we were unable to show the effect level due to the use of all the different assessment tools. More research is required to increase knowledge about the transfer of competencies to daily clinical practice, examining why many studies use non-validated assessment strategies and the barriers to training HFS. While HFS are widely taught, there are gaps in the literature regarding efficacy assessment. There is a need for more long-term studies and studies about how we translate assessment of skills to clinical work. However, there is a lack of knowledge about the transfer and retention of the HFS developed, from SBT to actual competencies in clinical practice. The culture of viewing HFS as innate and complicated to train could be one of the obstacles.

Although this review revealed support for training HFS in the clinical setting using SBT, there is a lack of agreement on which tools are best to assess HFS. There are gaps in the literature regarding the assessment of the HFS. More research and consensus on how we assess HFS is needed before the level of effectiveness can be estimated. All assessment methods in SBT should be supported by valid evidence. Several instruments are designed to evaluate the effect of HFS skills through SBT. Still, this review shows that the existing assessment methods are not solid enough to establish consensus on the way HFS are assessed. Although tools exist to assess HFS, methods to study communication and other team-related processes are far from being standardised, making comparison challenging. This raises new questions about training HFS and future directions for research.

Cognition is an emergent property of the situation and environment. Knowledge, perceived facts, understanding and predictions within each team member's mind interact with displayed information, cues and devices in the environment to affect decision-making and situational awareness. Recurrent exposure to these factors can lead to personal, team and institutional learning. Furthermore, the environment can be modified and redesigned to support the team's improved performance and safety. Cognition is thus an individual and shared mental process within the team in all situations [127–129]. Therefore, it is essential to add social, cognitive, environmental and technology markers to the teaching/learning situations if the goal is to enhance the teams' HFS or redesign the environment to increase patient safety. Nevertheless, 43% of the studies show significant effectiveness in refining HFS using SBT, and 92% show some effectiveness. This means that, regardless of multiple assessment methods, this review offers a significant or improved effect of HFS using SBT, and the outcome was relatively homogeneous—HFS improves using SBT. A meta-analysis by Salas et al. concludes that team training is a useful intervention with a moderate, positive effect on team processes [130]. This adds to the reliability of the present review. Therefore, the differences among the methods in the included studies are not a weakness of the research but rather a strength for the results. On the other hand, it makes the results inconsistent because of the lack of comparability. More research and effort towards a consensus on assessing human factor skills in the medical simulation society are requested.

The review also demonstrates that studies in which HFS was trained alone had a more significant effect than those focused on both HFS and TS. However, although the increase of HFS was lower in combined TS and HFS training, HFS was still enhanced in most studies. In SBT research, HFS are often relegated to an add-on to develop procedures, algorithms and associated

TS in specific settings. This may be for several reasons: everyday clinical situations involve both HFS and TS, trained together, or it is easier to measure technical outcomes. HFS often play a minor role in the conclusions drawn. In this way, TS “steal” the focus, and the focus is on solving the medical problem at hand (e.g. bleeding or anaphylaxis) rather than improving HFS, which generally are the cause of most adverse events [34]. HFS are unfortunately often understood as innate skills and not skills that can be trained and refined. HFS are not innate; they are generic and essential in reducing adverse events within healthcare and need to be qualified and trained just as seriously as technical skills and clinical procedures.

The high amount of studies from acute and high-intensity situations and the paediatric speciality shows that there is awareness of the need for training qualified personnel, that SBT is not only for the students and novices. The training mostly around algorithms is unclear and could be an exciting focus in future research. Nevertheless, the results also show that qualified teams mostly train situations where life is at stake. However, adverse events not only happens in highly acute situations but also in slow situations such as medication administration [131], receiving and transferring patients [132, 133] and development of sepsis [134]—all situations where teams interact. If healthcare teams are trained in everyday care, it might reflect everyday clinical practice and prevent or reduce future adverse events.

An interesting result is that the training teams mostly were 2–5 members, although critical care teams are more prominent in numerous places in the world. The reasons for this are unclear, but possible explanations include the expense of SBT and a high turnover of qualified healthcare personnel [135]. Moreover, the participants are often volunteers, and the likely absence of volunteers can explain.

It is important to understand learning holistically, integrating the individual, brain, body and surroundings [136]. All levels of education involve both physical and cognitive stimulations, and if the content is too vast, the learning decreases. The results suggest that focusing exclusively on HFS in SBT can lead to a deeper awareness of HFS’s effect on patient safety among teams and, possibly consequently larger learning potential. However, further research will have to study to what degree HFS transfers to competence in clinical practice. The results show that SBT for HFS alone, combined with didactics and workshops may lead to the most significant improvement in teams’ HFS. This is substantiated by Maturana’s theory of suitable disturbances [137, 138], which deals with how disturbances should be moderated. If a disturbance is too big, the learners might lose attention, and if the disturbances are too small, the learners

might not even notice. Accordingly, if TS and HFS are trained together, the educational disturbance to participants’ behaviour might be too massive for participants to engage with. However, the link to clinical practice is still underdeveloped.

Conclusion

This systematic review demonstrates a strong indication that SBT is an effective learning tool to improve HFS in-hospital healthcare settings. However, HFS are inconsistently described, interpreted, taught and assessed and the lack of real-world assessment or follow-up makes the transfer to everyday practice challenging. This systematic review does not entirely answer if SBT improves HFS in qualified healthcare teams. Still, it highlights the gaps in the literature and underpins the necessity of increasing the focus on HFS or routine care in SBT to improve outcomes. There is a need for more long-term studies and studies about how we translate assessment of skills to clinical work. However, there is a lack of knowledge about the transfer and retention of the HFS developed, from SBT to actual competencies in clinical practice. The culture of viewing HFS as innate and complicated to train could be one of the obstacles. Healthcare, in general, must support the necessity and significance for HFS. Otherwise, the HFS will not be effectively transferred to everyday practice. Also, design issues such as positioning of the equipment, cognitive aids and process changes are needed to support ideal human performance such as not relying on memory or complex decision-making in complex time-pressed situations. More research is required to increase knowledge about the transfer of competencies to daily clinical practice, examining why many studies use non-validated assessment strategies and the barriers to training HFS.

Limitations

A few limitations of this review need to be highlighted. Firstly, three authors screened a vast number of studies, but only the first author did a full-text reading and assessment of the included studies. This increases the possibility of selection bias and influences the internal validity and reliability. The bias was sought to be minimised by bringing any doubts about selected studies to the broader author group. Nevertheless, the intercoder reliability is inevitably affected when human coders are used in content analysis [139]. Secondly, the Hawthorne effect (behaviour alteration simply because HFS were studied) represents a possible bias [140]. Thirdly, 48% of the participants in the included studies courses were volunteers, but the results from volunteer studies do not deviate from the enhancement among mandatory participants.

Nevertheless, the number of volunteers could lead to a positively biased result because they agreed to SBT as a learning method. Moreover, it is essential to point out that 20 of the included studies were from an emergency medicine setting, which can have influenced the results. A review focusing on HFS, in general, could have elucidated studies from other settings. Finally, the results may be affected by publication bias because studies with unfavourable results of SBT might not have been published, which could mean an endorsement of the results in the direction of a favourable analysis.

Implications for practice

It is evident that SBT can improve qualified teams' HFS. SBT is an effective learning tool for use with novices and experts, and with unqualified or qualified personnel. A change of focus is recommended for healthcare providers to train emergencies or rare situations and everyday non-emergency situations, such as admission to hospital, rounds, or the unprepared talk with next-in-kind in the hallway. This review shows that even qualified teams' can develop their HFS significantly through SBT. Using SBT to train the healthcare personnel for everyday clinical practice are essential. Firstly, because the everyday routine takes up most of the performance tasks in the hospitals, the personnel are constantly in different forms of teamwork. Secondly, as learned from Safety II, it is necessary to enhance the ability to succeed (reduce adverse events) under varying conditions [141]. Thirdly, healthcare personnel are constantly interchangeably with new demands (e.g. professional, environmental and technical) to the personnel. Finally, yet significantly, the high degree of personnel turnover in healthcare affects the quality of care, a quality that the use of continual SBT can increase. If the personnel's HFS are capable in everyday practice, they will in all probability be in acute and high-intensity situations.

All human interactions in hospitals need to be efficient and trained just as seriously as TS and clinical procedures because interactions are just as prone, if not more, to errors. Cultural, social and people skills, together termed HFS, are not innate and untrainable. Instead, they are generic and essential in reducing adverse events within healthcare and demands an increased focus on systematic multidisciplinary training of HFS among healthcare teams.

Abbreviations

AMSTAR-2: A measurement tool to assess systematic reviews—2nd edition; ANTS: Anaesthetists' non-technical skills; CASP: Critical appraisal skills programme; CINAHL: Cumulative index of nursing and allied health literature (database); COVID-19: Coronavirus disease 2019; COVIDENCE: An online tool that streamlines parts of the systematic review process; CRM: Crisis resource management; EBSCO: Elton B. Stephens company (online

access); EMBASETM: Excerpta Medica database (database); ERIC: Educational resources information center (database); HFS: Human factor skills; MMAT: Mixed methods appraisal tool; MEDLINE: Medical literature analysis and retrieval system online (database); NTS: Non-technical skills; Non-RCT: Non-randomized controlled trial; OVID: Part of the Wolters Kluwer group of companies (online access); PICO: Problem/population, intervention, comparison, and outcome; PROSPERO: Prospective register of systematic reviews; PRISMA: Preferred reporting items for systematic reviews and meta-analyses; PsycINFO: Psychological information (database); RCT: Randomized controlled trial; SCOPUS: Elsevier's abstract and citation database; SBT: Simulation-based training; SPICE: Setting, perspective, intervention, comparison, and evaluation; TS: Technical skills.

Supplementary Information

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Additional file 1. Supplement A—Searches.

Additional file 2. Supplement B—Results summary.

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Authors' contributions

LA drafted the manuscript. LA, ABN and MLH conducted the title and abstract selection. LA conducted the full-text reading and the interpretation of data. All authors critically revised the manuscript and the authors read and approved the final manuscript.

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Availability of data and materials

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Declarations

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Competing interests

The authors declare that they have no competing interests.

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