REVIEW ARTICLE

Volume 17 Issue 4 2025

DOI: 10.21315/eimj2025.17.4.2

ARTICLE INFO

Submitted: 20-12-2024
Accepted: 08-06-2025
Online: 31-12-2025

Stress among Anaesthesiologists during Simulation Sessions: A Systematic Review

Mohammed Hassan[1], Fatma Mahmoud[2], Bassem Alhadi[3]

[1]*Mater Misericordiae University Hospital, Eccles Street, Dublin 7, IRELAND*

[2]*University College Dublin, IRELAND*

[3]*Connolly Hospital, RCSI, Mill Road, Blanchardstown, Dublin 15, IRELAND*

To cite this article: Hassan M, Mahmoud F, Alhadi B. Stress among anaesthesiologists during simulation sessions: a systematic review. Education in Medicine Journal. 2025;17(4):11–30. https://doi.org/10.21315/eimj2025.17.4.2

To link to this article: https://doi.org/10.21315/eimj2025.17.4.2

ABSTRACT

Simulation training plays a crucial role in anaesthesia training. However, there is a potential for simulation to induce stress in trainees, which could impact their performance and psychological well-being. Therefore, this systematic review aimed to synthesise research that has considered the stress—both physiological and psychological—associated with participation in simulation activities among anaesthesiology doctors. A systematic search was conducted through five databases to identify relevant articles for inclusion. All the included studies underwent a quality assessment using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD), and data were extracted on relevant variables. Narrative synthesis was employed due to the heterogeneity of the studies included. A total of 19 studies were included. Eleven studies used subjective tools to assess the degree of stress developed, while eight used a mix of subjective and objective tools. Our results demonstrated how simulation training can impact learners' psychological well-being through the development of stress and other variables related to that type of stress (i.e., performance, memory). High-fidelity simulation training is crucial for anaesthesiologists to master both clinical and non-clinical skills. Psychological and physiological stress often develops during these activities. Whenever stress develops, it could affect participants' performance, memory, and participation in future activities. Ensuring psychological safety is a crucial tool to optimise learning outcomes. Acknowledging participants' efforts and avoiding judgment are vital tools to decrease the stress that can develop through these educational activities.

Keywords: *Stress, Simulation, Anaesthesiologists, Psychological, Anxiety, Review examination*

CORRESPONDING AUTHOR

Mohammed Hassan, Mater Misericordiae University Hospital, Eccles Street, Dublin 7, Ireland

Email: Dr_msayedfared@hotmail.com

INTRODUCTION

Managing critical medical situations is a primary aspect of being an anaesthesiologist. Careful, correct management of such situations is essential. Errors can occur in seconds, leading to catastrophic consequences for both patients and healthcare professionals (1). Traditionally, anaesthesia training was mainly dependent on traditional lectures and the experiences gained through repeated exposure (2). However, in recent decades, healthcare simulation has become a primary component of anaesthesia training worldwide, as it creates a safe environment for teaching and acquiring new skills, including both clinical and non-clinical ones (2). The word simulate means to create an effect of, or to imitate (3). Professor Gaba mentioned that the definition of simulation as an educational technique that replaces or amplifies real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner (4).

The application of simulation training in anaesthesiology practice has undergone various stages. Laerdal's Rescue Anne was the first ever simulator used for cardiopulmonary resuscitation programmes (5). In 1960, 'Sim One' was created at the University of Southern California. It was one of the earliest versions of high-fidelity simulators (5). The Harvey cardiology mannequin was also developed around that time and could simulate approximately 27 cardiac conditions (5).

High-fidelity simulation training is gaining considerable popularity nowadays, and several studies have demonstrated its impact on the learning process of healthcare professionals (6–8). The positive impacts of using high-fidelity simulation training include improving learners' self-confidence, knowledge, and skills without causing harm to real patients (9). Using high-fidelity simulators in training may enable participants to recall previously experienced events, learn from their mistakes or inaction, and manage similar situations more effectively the next time they face them (10, 11). However, high-fidelity simulations have also been criticised in many studies regarding their cost compared to other low and medium-fidelity simulators (12), the amount of knowledge gained and improvement of skills (13–15), the self-confidence level during decision-making scenarios (16, 17), and the level of stress and anxiety experienced by participants (18, 19).

The impact of high-fidelity simulation training is usually related to the extent to which it can immerse learners in these learning situations (20). It has been suggested that the more realistic the simulation scenario, the greater the benefit the learner will receive (21, 22). A realistic scenario not only affects the participant's learning but can also impact their psychological well-being (21, 22). There is often consideration of learner well-being when planning for simulation activities and when deciding to what extent the simulation activity should be realistic or challenging (21, 22). The death of the mannequin or the presentation of a severe complication during the simulation activity are good examples of scenarios where a learning opportunity may arise. However, careful consideration of the learner's well-being is required. Some studies have suggested that death or other serious patient deterioration should not happen during the simulation to ensure the psychological safety of the participants (21, 22). However, other scholars argue that such events should be liable to occur according to the consequences of events and actions produced by the participants (1, 23). Other causes that could contribute to the development of psychological stress during simulation activities are the fear of negative evaluation (FNE) (24) and the highly anxious personality (25). Participants who are afraid to practice in front of others usually develop high levels of stress during these educational activities (24). They often fear being judged or

criticised while dealing with complicated cases (24). The same happens with those who are very anxious and have high scores of trait anxiety (25). For these reasons, many participants in simulation activities experience a certain degree of stress (26, 27).

It is widely agreed that simulation facilitators should ensure psychological safety for all learners to achieve a good learning outcome (28, 29). Understanding how, when, and what aspects of healthcare simulation may cause stress to participants is crucial for supporting simulation educators in addressing this issue (28, 29). Given the widespread use of simulation within anaesthesiology, it seems particularly important to understand learner experiences in this discipline. Therefore, this systematic review aimed to synthesise research that has considered the stress—both physiological and psychological—associated with participation in simulation activities among anaesthesiology doctors.

METHODOLOGY

Study Design

A systematic review was chosen as the most suitable method for this study, as it could answer questions that could not be answered by individual studies. This systematic review adhered to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (30). No ethical approval was required as the review synthesised previously published studies and did not involve the collection of any original research data.

Study Eligibility

This review included studies that (a) focused on healthcare simulation activities delivered for anaesthesiologists of any grade; (b) used a subjective or objective tool for stress assessment; (c) were published in peer-reviewed journals in the English language; and (d) were published between the first of January 2001 and the end of February 2023. This is common practice in reviews of research relevant to patient safety, as To Err is Human (31) was published this year and is considered to have started the modern patient safety movement, of which simulation is a key component.

Studies were excluded if they (a) focused on learning or teaching activities other than simulation activities; or (b) if it was not possible to extract the data specific to participating anaesthesiologists; (c) not in the English language; and/or (d) were not published in peer-reviewed journals.

Study Identification and Selection

The search strategy included five electronic databases, utilising a search strategy comprising Medical Subject Headings (MESH) terms and other free-text search terms: Medline, CINAHL Complete, Psychology and Behavioural Sciences Collection, ERIC, and APA PsycINFO. Table 1 presents the search strategy for Medline; this strategy was adapted as necessary for the other databases. The search strategy comprised two discrete sets of keywords. The first set of words includes variations of "psychological stress" and its subtypes. The second set of words includes variations of "simulation" and its subtypes. The search strategy was informed by engagement with several other review papers (20, 31–36). The search trial commenced in

December 2022 and concluded in March 2023. Two authors reviewed the titles and abstracts of the returned papers to assess their eligibility for inclusion. Where eligibility was unclear, a full text was obtained, and studies were examined in more detail to make an informed decision on inclusion or exclusion. An Excel file was used to categorise database returns into one of four categories: include, exclude, to be confirmed, and duplicate. Any conflicts or uncertainties during the categorisation process were resolved through discussion among the three authors.

Another search was conducted through the references of the included studies by screening the titles to identify any additional studies that could be added. Searching the reference list is one of the essential tools for providing an excellent, comprehensive review, as it empowers the information provided and gathered in it (37).

Table 1: Medline search strategy

Searching Titles and Abstracts		Searching Titles and Abstracts
1. exp *Stress, Psychological/		10. exp *High Fidelity Simulation Training/
2. exp *Stress, Physiological/		11. exp *Patient Simulation/
3. exp *Psychological Distress/		12. (healthcare or medical) adj1 Simulation*1)
4. stress		13. (manikin*1 or mannequin*1)
5. distress		14. (simulated or standardi?ed) adj1 patient*1)
6. psychological	And	15. (Simulated adj1 practice).
7. anxiety*		16. 10 or 11 or 12 or 13 or 14 or 15
8. (mental adj1 exhaustion)		
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8		

Data Extraction

Data extracted from each study included were the publication details, characteristics of the sample, characteristics of the simulation activity done, details of the method used to measure the degree of mental stress (i.e., type of measure (psychological/physiological) and information on the measure), findings (i.e., detail on measurements of stress and any association with participants' performance), and if there were any other variables mentioned related to that stress on the participants (i.e., association between stress and performance, association between stress and personality). The experience level of participants was divided into two categories based on the level of training they had, namely juniors (one to three years of training) and seniors (more than three years of training).

Duplicate Data Extraction

A random sample of studies (n = 5; 20%) was reviewed by the third researcher and examined independently to determine if they were suitable for inclusion in the review. The importance of this step is to avoid any errors in data extraction, which could be missed if no other extractor is available (38). Any conflicts in the choice trial were resolved through discussion among the three researchers.

Quality Appraisal

The methodological rigour of the studies included in our review was examined using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) (39). QATSDD is a validated tool used for assessing the quality of different quantitative, qualitative, and mixed studies. It consists of 16 items that deal with various aspects of the study, including the theoretical framework of the study, a clear description of the research methods, sample size selection, a detailed description of the data collection and recruitment process, and points of strength and limitation. Fourteen out of 16 items included in the QATSDD are suitable for qualitative studies, 14 out of 16 are suitable for quantitative studies, and all 16 items are suitable for mixed studies (39). The primary author assessed each study and assigned it a score based on the quality appraisal, recorded in an Excel sheet, on a 0–4 scale. Total scores were then converted to a percentage (the total score was divided by the maximum score that could be obtained and multiplied by 100). Studies were classified according to a percentage scale into high quality (>75%), good quality (50%–75%), moderate quality (25%–50%), and poor quality (<25%) (40).

Data Synthesis

Narrative synthesis was employed in the current review due to the heterogeneity of the studies included. A textual description approach is considered the most suitable tool for describing the results and findings of each study, providing a more in-depth explanation of the interventions in each study (41). Three themes were identified through our review: (a) the relationship between stress and simulation; (b) the association between stress and performance; and (c) other factors related to the development of stress. Previous studies employed narrative synthesis in their reviews and served as a guide for our data synthesis (42, 43).

RESULTS

Our electronic search identified 900 studies, 857 studies through the Medline database and 43 studies from other databases. Ultimately, 14 studies were deemed eligible for inclusion. The reference list reviews conducted yielded an additional five studies. As a result, 19 studies were included in this review. The search process is illustrated in the PRISMA diagram (Figure 1).

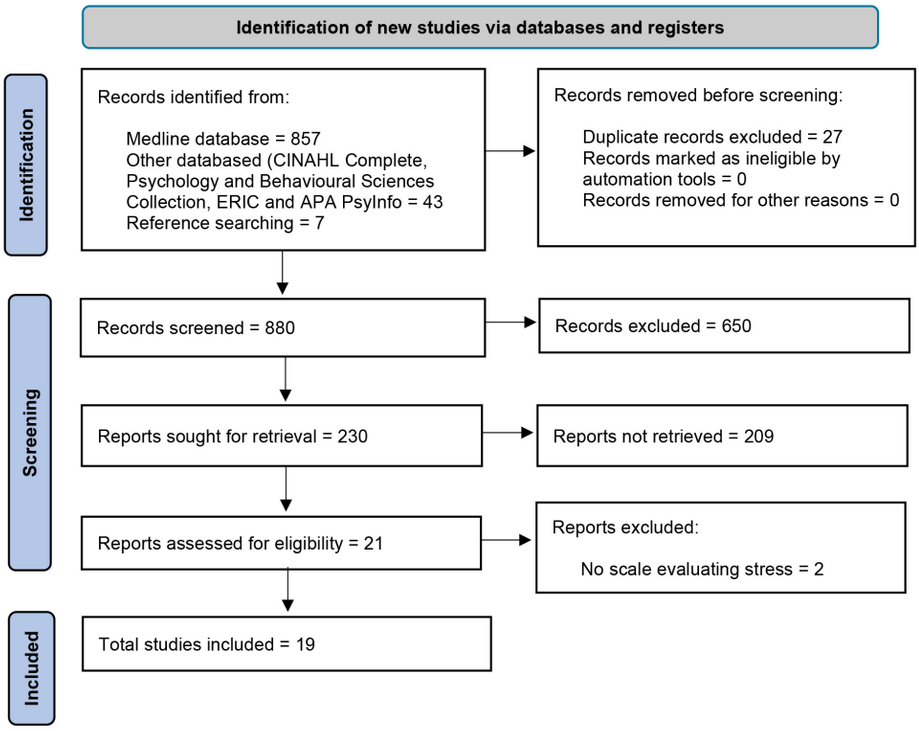

Figure 1: PRISMA flow diagram showing the selection process of studies included.

Study Population

The number of participants varied between studies, ranging from eight participants in the smallest study (44) to 149 participants in the more extensive population study (45). The mean number of participants per study is 54. All of the studies included anaesthesiologists from different grades as per the study's inclusion criteria. Eight studies (42%) focused on junior trainees (1, 20, 27, 44, 46–49). One study focused on seniors (50), and the rest (52%) included a mixture of junior and senior doctors (18, 20, 45, 51–58). Three out of the 19 studies (15%) included participants from other specialities, such as nurses (51), critical care doctors (50), general surgeons and surgical technologists (58), as well as anaesthesiologists.

Regarding the previous simulation experiences, participants in four studies had no prior exposure to simulation activities (20, 44, 51, 56). In two studies, only 48% (47) and 66% (18) of the participants had previous exposure to simulation activities, and in one study (46), all participants had prior experience with simulation training. In another study, participants were previously Advanced Cardiac Life Support (ACLS) certified (48), and in another study, participants were excluded if they had attended more than three simulation courses (27). The remaining studies did not mention prior simulation experiences.

Characteristics of the simulation activity

All the included studies focused on various simulation activities related to anaesthesiology training. Eighteen studies (94%) used high-fidelity simulation training, and only one used the Resusci Ann mannequin (57). Nine studies (47%) were concerned with different anaesthesia

emergencies (1, 44, 45, 47, 51, 53, 55–57), one (5%) with mortality experience (46), four (21%) with operating room crisis (18, 50, 54, 58), one (5%) with problems during patients' transport (20), two (10%) with paediatric crisis (27, 52), one (5%) with ACLS training (48) and one (5%) with communication skills (49).

Methodological rigour

Quality assessments were conducted for all included studies. No study was excluded depending on this assessment. Seven studies (36%) were identified as good quality (18, 27, 45, 50, 52–54) with scores ranging between 50% and 70%, and the rest were marked as moderate quality with scores ranging between 25% and 47%. Most studies scored high values on items related to the description of the research settings. On the other hand, lower scores were obtained on items related to the involvement of users in the study and to the statistical assessment of the reliability and validity of the tools used.

Assessment of stress and its relationship with simulation

Different tools were used to assess the degree of stress participants felt during the simulation activities. These tools varied between subjective (i.e., measuring self-reported stress) and objective (i.e., obtaining a physiological measure of stress) ones. Table 2 presents the assessment tools and main findings from each study. In 11 studies, subjective tools only were used to measure the degree of stress perceived by participants. State-Trait Anxiety Inventory (STAI) (1, 45, 46, 54, 56) was used in five studies, the visual analogue scale (VAS) was used in four studies (45, 50, 53, 54), the Likert scale was used in two studies (44, 55), FNE scale was used in two studies (45, 54), and the French validated translation of perceived stress was used in one study (46). In one study (57), a questionnaire designed by Calamassi et al. (59) was used. In another study (50), a Thayer questionnaire (60) was used to assess the degree of stress that participants experienced. The National Aeronautics and Space Administration Task Load Index (NASA-TLX) (61) was used in the study conducted by Guris et al. (49).

In eight studies (Table 2), subjective and objective tools were used together to investigate the occurrence of stress. These objective and subjective tools were a variety of salivary amylase levels combined with a numerical scale (47), heart rate monitoring combined with STAI and VAS (18), heart rate monitoring combined with a numerical scale (51), heart rate and blood pressure measurements combined with STAI and FNE scale (20), heart rate variability combined with STAI and the French version of the Perceived Stress Scale (52), electrodermal activity combined with heart rate variability and STAI (48), Galvanic Skin Response combined with STAI (58), and salivary cortisol level combined with heart rate measurements and Depression Anxiety Stress Scale (27).

The STAI was the most commonly used tool in various studies to measure stress; it was employed either alone in some studies or in combination with other objective tools. Most studies that used the STAI to measure stress levels during simulation activities reported low to moderate stress levels, with scores below 44/80. Only two studies (1, 54) reported a higher degree of stress during simulation activities, with scores exceeding 45/80, as shown in Table 2. STAI was used in one study (18) to describe the residual anxiety participants experienced after the end of the simulation activity. It was noted that this type of anxiety affected nearly 21% of the participants. When STAI was combined with other subjective tools, such as VAS used in the study of Lilot et al. (45), to focus on the effect of relaxing breaks between two groups participating in a simulation activity, a slight difference was observed

between the two scales in the findings obtained. In the mentioned study (45), STAI measured at the end of debriefing correlated with moderate stress, while the VAS score measured at the same point indicated a low degree of stress. However, when the VAS was used after the simulation activity ended, the score correlated with moderate stress (45). When STAI was used in conjunction with objective tools, it showed a correlation with heart rate changes (20, 48) and with Galvanic Skin Response (58).

The second most commonly used tool by researchers for measuring stress during simulation activities was the VAS. In the study performed by Evain et al. (53), both the intervention and control groups scored more than 60 points out of 100. This high score was achieved despite the intervention group receiving a team planning discussion during the break during the simulation activity. Similar results were obtained in two additional studies performed by Lilot et al. (45) and Sigwalt et al. (54).

Schlatter et al. (50) also used the VAS in their assessment of the effect of relaxing breathing paired with cardiac feedback on performance during simulation activities. They found that the relaxing breathing training decreased the degree of stress perceived by participants in the intervention group compared to the control group, which did not receive this particular intervention and reported high stress (Table 2). This finding correlated with the results of the Thayer questionnaire, which was used in the same study (50).

The Likert scale was used by McMullen et al. (44) and Suet et al. (55) in their studies. In both studies, participants reported a significant degree of stress. In the study of McMullen et al. (44), the reported stress led to the activation of the pause button in 50% of the scenarios. A questionnaire developed by Calamassi et al. (59) was used by Shailaja et al. (57), which showed that 14% of the participants in that study reported feeling anxious during the high-fidelity simulation activity. NASA-TLX was used by Guris et al. (49) to detect the occurrence of cognitive burden among all learners during various simulation activities they participated in.

Physiological stress was assessed using different parameters, as stated earlier (Table 2). Studies that utilised heart rate and blood pressure monitoring revealed an increase in these values during the simulation activities. This finding was correlated with other subjective tools used in these studies (18, 20, 51). In another two studies, the hemodynamic parameters used showed a decrease in their values in groups that received a specific preparation compared to other groups that did not (48, 52). Again, in the study of Bong et al. (27), they found that participants who acted as observers showed lower stress values than those in the active group, as evidenced by low physiological and psychological parameters. The salivary amylase levels were used by Geeraerts et al. (47) in their study. They found higher values detected in participants' post-simulation scores than before and correlated with the numerical scale used to assess psychological stress (47) (Table 2).

Table 2: Characteristics of studies included regarding the methods used to measure the stress and the main findings

Authors and year of publication	Methods used to measure the degree of stress	Main findings
a) Studies used subjective tools only for the assessment of stress:		
Goldberg et al. (46)	STAI	Groups showed increased STAI scores immediately before entering their first simulation training scenarios. The always death group showed elevated STAI scores post-training (moderate anxiety) and preceding the assessment scenarios compared to the other two groups.
Evain et al. (53)	VAS (0–100)	Perceived level of stress (PLS) was similar between intervention and control groups (moderate stress) at the three time-points measured.
McMullen et al. (44)	Likert scale	Some participants reported increased levels of stress after the start of the simulation activity, which led to the activation of the pause button in 50% of the scenarios.
Lilot et al. (45)	STAI and iterative VAS for anxiety VAS-A (0–100) and FNE	No significant difference between relax and control groups with regards to the mean end of debriefing STAI-state score (moderate anxiety), the mean end of the debriefing VAS-A (low degree of stress). VAS post-scenario showed no difference (moderate degree of stress) between the relax and the control one in the active participant group.
Suet et al. (55)	Likert scale	Those played active roles experienced more stress compared to the observers.
Sigwalt et al. (54)	The French validated translation of the Perceived Stress Scale, STAI-Trait and the FNE scale, VAS of stress	No significant difference between groups with regard to the VAS of stress and STAI-State before specific preparation (moderate–high degree of stress). No significant difference between groups regarding post-scenario VAS of stress, post-debriefing VAS of stress. The median VAS of stress was 17% lower in the tactics to optimise the potential group than in the control group after the specific preparation.
Büyük et al. (56)	STAI	No difference between the pre- and post-state-trait anxiety scores between the two groups. Moderate level of anxiety.
Schlatter et al. (50)	VAS-stress, Thayer questionnaire scores	The control group showed high degree of stress compared to the other two groups.
Goldberg et al. (1)	STAI	STAI-Trait were similar between groups at baseline. The independent group having higher STAI-State scores (high stress) after the first exposure. In contrast, after the phase 2 scenario, STAI-state levels were similar between groups (moderate stress).
Guris et al. (49)	NASA-TLX	The scenarios showed different degrees of cognitive load; assessed by NASA-TLX. The greatest cognitive load was noted in the third scenario, and no difference in cognitive burden reported between groups.

(*Continued on next page*)

Table 2: (*Continued*)

Authors and year of publication	Methods used to measure the degree of stress	Main findings
Shailaja et al. (57)	Questionnaire designed by Calamassi	14% of the participants reported being anxious during the activity.
b) Studies used subjective and objective tools for assessment of stress:		
Evain et al. (18)	STAI-Y, instructor estimate subject's anxiety using VAS, PS using VAS, HR monitoring	HR increased during scenario. PS before scenarios was significantly lower among anaesthetists. PS after debriefing was significantly lower than before and after the simulation. RA (>36/ 80) was observed for 15 subjects. There was a correlation between RA and trait-anxiety.
Gouin et al. (51)	Numerical scale (0–10), haemodynamic response by continuous recording of HR by a Holter ECG system	Median perceived stress was high in the first three sessions for junior and senior doctors. Four participants exceeded 80% of the TMHR. HR change was not related to the participant's experience.
Bauer et al. (20)	STAI: Gauthier and Bouchard's French-Canadian adaptation, FNE, HR and BP measurements	STAI-1 and 2 were in the low categorisation. FNE score was at the moderate level. HR increased by nearly 24% compared to baseline.
Bertrand et al. (52)	Validated French version of the STAI. Fifteen days before the simulation activity; trait anxiety was measured, as well as basal stress level, using the French version of the Perceived Stress Scale. HR variability was measured throughout the activity.	Psychological and physiological stress responses were lower in the intervention group. Median PLS after handover and median state anxiety at discharge were lower in the intervention group compared to the control group (both low degree of anxiety).
Bhoja et al. (48)	STAI-1, electrocardiography (HR variability) and EDA.	Both control and intervention groups showed moderate level of state anxiety pre-simulation. Subjects in the intervention group showed significantly less state anxiety provoked by the second ACLS simulation compared to the control group. Subjects in the intervention group showed significant reduction in LF/HF ratio compared to the control group.
Bong et al. (27)	DASS, HR and salivary cortisol level.	The observer role is less stressful than those in the 'hot-seat'. The hot-seat role is associated with a high physiological stress response. Mean SC was significantly elevated from baseline in all three sessions in the hot-seat. HR (beats/min) was elevated in sessions 1 and 2.
Phitayakorn et al. (58)	Subjective and objective: STAI and GSR.	Anaesthesiologists, anaesthesia nurses and general surgery residents reported similar STAI-Trait and higher scores than nurses and surgical technicians. After the debrief session, no differences in the STAI-State between specialities (moderated degree of anxiety) or between resident physicians and the nurses/ CRNAs/surgical technicians' group (moderated degree of anxiety). Anaesthesiologists and CRNAs showed an increase in maximal GSR from the orientation to the case phases.

(*Continued on next page*)

Table 2: (*Continued*)

Authors and year of publication	Methods used to measure the degree of stress	Main findings
Geeraerts et al. (47)	Numerical scale for stress and salivary amylase levels.	A moderate degree of stress was reported before the beginning of the scenario, and a high degree of stress was noted post the simulation session. Salivary amylase concentration was higher at the end of the activity compared to before.

Notes: STAI = State-Trait Anxiety Inventory; ANTS = Anaesthetists' non-technical skills; VAS = Visual analogue scale; FNE = Fear of negative evaluation scale; NASA-TLX = National Aeronautics and Space Administration Task Load Index; HR = Heart rate; RA = Residual anxiety; PS = Psychological stress; TMHR = Theoretical maximum heart rate; BP = Blood pressure; PLS = Perceived level of stress; EDA = Electrodermal activity; ACLS = Advanced Cardiac Life Support; LF = Low frequency; HF = High frequency; DASS = Depression Anxiety Stress Scale; SC = Salivary cortisol; GSR = Galvanic Skin Response; CRNAs = Certified Registered Nurse Anaesthetists

Association between stress and other variables

The association between developing stress and participants' clinical and non-clinical performance was studied in nine studies. Four out of the nine studies (44%) showed an inverse relationship between the development of psychological or physiological stress and learners' performance (50, 51, 53, 54). A similar finding was reported in another study by Goldberg et al. (46); higher scores on technical skills were observed in the variable death group compared to the always-death group (46). Studies performed by Geerarts et al. (47) and Bong et al. (27) showed no correlation between the development of stress and participants' performance. Lilot et al. (45) found in their study that the rate of recalling important messages from the simulation activity was 13% higher in the intervention group (which received a relaxation break before debriefing) compared to the control group. Anxious personality, inappropriate debriefing and female sex were noted in two studies (18, 20) as critical factors associated with the development of stress during simulation practice.

DISCUSSION

Simulation training has become one of the cornerstones of medical education nowadays (62). It enhances the acquisition of non-technical skills and enables participants to master a range of clinical and non-clinical skills (62). One of the main drawbacks of participating in simulation activities is the development of stress (51). We aim to focus the light on the development of stress during these educational activities and explain how stress is assessed, as well as the factors associated with its development. We found through this review a high link between participation in simulation activities and the development of stress. Other findings include the inverse relationship between stress and performance (clinically and non-clinically).

Simulation Activity and Experience of Stress

In our systematic review, all included studies showed a certain degree of stress occurring with all simulation activities. Although the assessment tools were different between studies, they reported the same event: the experience of stress during these simulation activities. These findings ranged from higher scores on the subjective tools to increases in the participant's vitals or a rise in the hormonal assay conducted during the activity. These findings correlate with those in a study done by Price et al. (63), who surveyed 599 candidates (167 of the included personnel were anaesthesiologists) and reported that a high degree

of anxiety was noted in the simulation activities they participated in. In another study by Savoldelli et al. (19), 30% of the participants reported feeling anxious during the simulation activity. McGuire et al. (64) reported similar findings to ours in their review, which included studies from 2009 to 2016 on medical students and various healthcare practitioners. They mentioned that simulation activities were associated with stress development, as evident by the rise in cortisol levels measured during these activities (64).

Ensuring psychological safety for all participants and applying strategies to alleviate any stress that may develop during simulation activities are key to improving the learning outcomes of these educational activities. LeBlanc et al. (65) reported various options available to improve psychological safety in their study. These tools include creating an environment where the fear of negative evaluation is absent. Other options include early detection of other emotions associated with simulation activities, such as facial expressions that could be difficult to manage or detect. Distracting the learner's attention whenever emotional instability or stress is detected is a goal to alleviate any stress that may develop (65).

Stress and Performance

As noted, participation in healthcare simulation was associated with experiencing stress. Elevated STAI scores are typically considered a hindrance to good performance due to their impact on the body's cognitive processes and memory functions (66). Studies (18, 20, 48, 52) in our review showed a correlation between high STAI and an increase in participants' cardiovascular parameters, and these findings also correlated with other studies that used both STAI and cardiovascular parameters as assessment tools for stress development (67). Cassady et al. (68) found that elevated STAI is associated with difficulty recalling information from previous experiences, which affects problem-solving exams among different learners. These facts were also apparent in our review of studies that used STAI to measure the degree of participants' experiences during simulation activity (45, 54).

Our findings in this review align with those of other reviews (69) regarding the impact of stress on both clinical and non-clinical performance. Tjønnås et al. (69) reported in their review that the effect of stress on performance was controversial; one of the studies (70) included in it reported an inverse relationship between the development of acute mental stress and clinical performance. On the other hand, another study included in the review of Tjønnås et al. (69) reported increased efficiency in performance with the development of stress. However, this efficiency came at the expense of accuracy during surgical procedures, where more errors were recorded with the development of stress (71).

Another variable which is usually affected by the development of stress is working memory. Working memory is the capacity of our cognitive system to store and recall information for a specific period (72). The effect of stress on memory is a topic of controversy in various studies (72). Some studies have shown that experiences developed in association with negative emotions usually last longer than those with neutral ones (72, 73). Other researchers argued that decreasing the stress level during any learning process could empower and boost memory-recalling power (74–76). This controversy may be related to the neuro-hormonal response involving different hormones, such as cortisol and catecholamines, and the difference in their release times that occur with stressful events (72). One of the studies in our review showed a better recall of the messages gained during the simulation activity in the intervention group (offered a relaxation break) than in the control group (45).

This finding correlates with another study by Beilock et al. (77) which showed that stress is typically associated with poor problem-solving in mathematics, often relying on recalling events through working memory.

A previous study by Saunders et al. (78) demonstrated that stress inoculation training is an effective method for relieving stress and anxiety associated with clinical practice and training sessions. Applying this way of thinking and behaviour during a simulation session is one of the ways that can change the direction of a stressful activity to a more productive one (78, 79).

Other Factors Contributing to the Experience of Stress during Simulation

Highly stressful scenarios were associated with the development of anxiety and stress (18). Goldberg et al. (46) reported in their study that exposure to the mortality of the mannequin is associated with a high degree of stress compared to other groups. This finding correlates with the results of previous research conducted by Truog and Meyer (80), who documented how stressful simulation activities, such as exposure to a patient's death, can affect participants' well-being and may have future consequences for their clinical practice or participation in other simulation activities. Another factor that could be related to the development of stress is the anxious personality and the female gender. Evain et al. (18) found that anxious participants with high STAI-Trait were associated with the development of high STAI-State and residual anxiety than those with lower STAI-Trait scores. These findings correlated with the results of a study done by Laidlaw (24), which showed that individuals with high levels of anxiety due to fear of negative evaluation are usually afraid to participate in high-fidelity simulation or other training activities with other individuals. These types of learners typically experience a high degree of stress during simulation activities (24).

The difference between male and female psychology could also contribute to the development of stress during simulation activities. Previous studies (81, 83) have shown that females are more prone to develop anxiety and stress than males of the same age.

Another important factor Evain et al. (18) flagged for the development of stress and residual anxiety is the low-quality debriefing. Debriefing is considered one of the cornerstones of simulation activity. Doing it correctly is usually associated with better learning outcomes and reducing the fear of participation in future activities (84, 85). Many novice participants fear participating in simulation activities because of the debriefing session. Due to their lack of knowledge, they believe they will be judged by their peers, which could increase their stress levels and prompt them to avoid these teaching sessions (19).

Because of the differences between individuals and their reactions to a simulation scenario, educators should pay attention to these differences in personality, gender, and emotional responses to the simulation event (65). Educators should expect varied responses from learners in the same event, and they should sometimes be able to adjust the scenario if they discover that emotional instability or anxiety has developed in any of the participants (65).

Correlation between Subjective and Objective Stress Assessment Tools

By combining the STAI with other objective tools (20), the STAI was used to identify an anxious group of learners who scored more than 40/80 during the simulation activity (20). This finding correlated with other tests used in the study, such as the FNE scale and heart

rate change, which both showed an increase in their values in the anxious group (20). Bhoja et al. (48) used the STAI, combined with physiological parameters, to detect the degree of stress occurring during a healthcare simulation scenario. In this study, the STAI scores in the intervention group were lower compared to the control group, and they were correlated with the heart rate variability measured for participants, indicating a less sympathetic tone throughout the scenario (48). In another study reported by Phitayakorn et al. (58), STAI correlated with the Galvanic Skin Response; both anaesthesiology doctors and certified registered nurses showed an increase in both STAI and the Galvanic Skin Response during the simulation activity.

Strengths and Limitations

The review was conducted in accordance with the PRISMA guidelines (30). The search strategy was comprehensive, encompassing electronic database searches and reviews of the reference list. It is the first of its kind to address the experience of stress during simulation activities among anaesthesiologists. There are, nonetheless, several limitations to our systematic review. First, it was limited to English language studies only. There were insufficient resources to search outside of the English research literature. Second, it was limited to include studies where anaesthesiologists were the main participants in the simulation activities. Third, due to the different tools used to assess the stress developed during simulation activities and the heterogeneity of the included studies, it was not possible to conduct a meta-analytic synthesis; therefore, a narrative synthesis of the results was performed.

CONCLUSION

Simulation teaching is vital to mastering clinical and non-clinical skills in anaesthesiology training. Psychological stress is one of the elements associated with these educational activities. Several factors are associated with the development of stress, including the scenario itself, the participants' personalities and genders, and the debriefer. Stress not only affects the participant's performance but also impacts their memory and motivation to participate in future sessions. Ensuring psychological safety for all participants, as well as encouraging and acknowledging their efforts, are essential tools for achieving better learning outcomes. Debriefing is an excellent opportunity to gather participant feedback and address knowledge gaps in a safe and comfortable environment. Stress and anxiety reduction through improved supervision during simulation activities and avoidance of unnecessary stressors are the goals of achieving informative training sessions.

REFERENCES

1. Goldberg A, Silverman E, Samuelson S, Katz D, Lin HM, Levine A, et al. Learning through simulated independent practice leads to better future performance in a simulated crisis than learning through simulated supervised practice. Br J Anaesth. 2015;114(5):794–800. https://doi.org/10.1093/bja/aeu457

2. Lorello GR, Cook DA, Johnson RL, Brydges R. Simulation-based training in anaesthesiology: a systematic review and meta-analysis. Br J Anaesth. 2014;112(2):231–45. https://doi.org/10.1093/bja/aet414

3. Bhagwat M. Simulation and anaesthesia. Indian J Anaesth. 2012;56(1):14–20. https://doi.org/10.4103/0019-5049.93338

4. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care. 2004;13(Suppl_1):2–10. https://doi.org/10.1136/qhc.13.suppl_1.i2

5. Green M, Tariq R, Green P. Improving patient safety through simulation training in anesthesiology: Where are we? Anesthesiol Res Pract. 2016;2016:4237523. https://doi.org/10.1155/2016/4237523

6. Yee B, Naik VN, Joo HS, Savoldelli GL, Chung DY, Houston PL, et al. Nontechnical skills in anesthesia crisis management with repeated exposure to simulation-based education. Anesthesiology. 2005;103(2):241–8. https://doi.org/10.1097/00000542-200508000-00006

7. Bruppacher HR, Alam SK, LeBlanc VR, Latter D, Naik VN, Savoldelli GL, et al. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. Anesthesiology. 2010;112(4):985–92. https://doi.org/10.1097/ALN.0b013e3181d3e31c

8. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: A systematic review and meta-analysis. JAMA. 2011;306(9):978–88. https://doi.org/10.1001/jama.2011.1234

9. Lateef F. Simulation-based learning: Just like the real thing. J Emerg Trauma Shock. 2010;3(4):348–52. https://doi.org/10.4103/0974-2700.70743

10. Weinstock PH, Kappus LJ, Garden A, Burns JP. Simulation at the point of care: reduced-cost, in situ training via a mobile cart. Pediatr Criti Care Med. 2009;10(2):176–81. https://doi.org/10.1097/pcc.0b013e3181956c6f

11. McFetrich J. A structured literature review on the use of high-fidelity patient simulators for teaching in emergency medicine. Emerg Med J. 2006;23(7):509–11. https://doi.org/10.1136/emj.2005.030544

12. Lapkin S, Levett-Jones T. A cost-utility analysis of medium vs. high-fidelity human patient simulation manikins in nursing education. J Clin Nurs. 2011;20(23–24):3543–52. https://doi.org/10.1111/j.1365-2702.2011.03843.x

13. Finan E, Bismilla Z, Whyte HE, LeBlanc V, McNamara PJ. High-fidelity simulator technology may not be superior to traditional low-fidelity equipment for neonatal resuscitation training. J Perinatol. 2012;32(4):287–92. https://doi.org/10.1038/jp.2011.96

14. Nimbalkar A, Patel D, Kungwani A, Phatak A, Vasa R, Nimbalkar S. Randomized control trial of high-fidelity vs low fidelity simulation for training undergraduate students in neonatal resuscitation. BMC Res Notes. 2015;8(1):636. https://doi.org/10.1186/s13104-015-1623-9

15. Cheng A, Lockey A, Bhanji F, Lin Y, Hunt EA, Lang E. The use of high-fidelity manikins for advanced life support training—a systematic review and meta-analysis. Resuscitation. 2015;93:142–9. https://doi.org/10.1016/j.resuscitation.2015.04.004

16. Labrague LJ, McEnroe-Petitte DM, Bowling AM, Nwafor CE, Tsaras K. High-fidelity simulation and nursing students' anxiety and self-confidence: a systematic review. Nurs Forum. 2019;54(3):358–68. https://doi.org/10.1111/nuf.12337

17. La Cerra C, Dante A, Caponnetto V, Franconi I, Gaxhja E, Petrucci C, et al. Effects of high-fidelity simulation based on life-threatening clinical condition scenarios on learning outcomes of undergraduate and postgraduate nursing students: a systematic review and meta-analysis. BMJ Open. 2019;9(2):e025306. https://doi.org/10.1136/bmjopen-2018-025306

18. Evain J-N, Zoric L, Mattatia L, Picard O, Ripart J, Cuvillon P. Residual anxiety after high fidelity simulation in anaesthesiology: an observational, prospective, pilot study. Anaesth Crit Care Pain Med. 2017;36(4):205–12. https://doi.org/10.1016/j.accpm.2016.09.008

19. Savoldelli GL, Naik VN, Hamstra SJ, Morgan PJ. Barriers to use of simulation-based education. Can J Anaesth. 2005;52(9):944–50. https://doi.org/10.1007/bf03022056

20. Bauer C, Rimmelé T, Duclos A, Prieto N, Cejka J-C, Carry P-Y, et al. Anxiety and stress among anaesthesiology and critical care residents during high-fidelity simulation sessions. Anaesth Crit Care Pain Med. 2016;35(6):407–16. https://doi.org/10.1016/j.accpm.2016.01.004

21. Leighton K. Death of a simulator. CSN. 2009;5(2):e59–62. https://doi.org/10.1016/j.ecns.2009.01.001

22. Corvetto MA, Taekman JM. To die or not to die? A review of simulated death. Simul Healthc. 2013;8(1):8–12. https://doi.org/10.1097/sih.0b013e3182689aff

23. Goldberg AT, Katz D, Levine AI, Demaria S. The importance of deception in simulation: An imperative to train in realism. Simul Healthc. 2015;10(6):386–7. https://doi.org/10.1097/sih.0000000000000121

24. Laidlaw AH. Social anxiety in medical students: implications for communication skills teaching. Med Teach. 2009;31(7):649–54. https://doi.org/10.1080/01421590802208867

25. Eysenck MW, Derakshan N, Santos R, Calvo MG. Anxiety and cognitive performance: attentional control theory. Emotion. 2007;7(2):336–53. https://doi.org/10.1037/1528-3542.7.2.336

26. Müller MP, Hänsel M, Fichtner A, Hardt F, Weber S, Kirschbaum C, et al. Excellence in performance and stress reduction during two different full scale simulator training courses: a pilot study. Resuscitation. 2009;80(8):919–24. https://doi.org/10.1016/j.resuscitation.2009.04.027

27. Bong CL, Lee S, Ng ASB, Allen JC, Lim EHL, Vidyarthi A. The effects of active (hot-seat) versus observer roles during simulation-based training on stress levels and non-technical performance: a randomized trial. Adv Simul. 2017;2(1):7. https://doi.org/10.1186/s41077-017-0040-7

28. Al-Ghareeb AZ, Cooper SJ, McKenna LG. Anxiety and clinical performance in simulated setting in undergraduate health professionals' education: an integrative review. CSN. 2017;13(10):478–91. https://doi.org/10.1016/j.ecns.2017.05.015

29. Nielsen B, Harder N. Causes of student anxiety during simulation: what the literature says. CSN. 2013;9(11):e507–12. https://doi.org/10.1016/j.ecns.2013.03.003

30. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 2009;339:b2700. https://doi.org/10.1136/bmj.b2700

31. Clarke S, Horeczko T, Cotton D, Bair A. Heart rate, anxiety and performance of residents during a simulated critical clinical encounter: a pilot study. BMC Med Educ. 2014;14(1):153. https://doi.org/10.1186/1472-6920-14-153

32. Weiler DT, Gibson AL, Saleem JJ. The effect of role assignment in high fidelity patient simulation on nursing students: an experimental research study. Nurse Educ Today. 2018;63:29–34. https://doi.org/10.1016/j.nedt.2018.01.012

33. Girzadas Jr DV, Delis S, Bose S, Hall J, Rzechula K, Kulstad EB. Measures of stress and learning seem to be equally affected among all roles in a simulation scenario. Simul Healthc. 2009;4(3):149–54. https://doi.org/10.1097/sih.0b013e3181abe9f2

34. Harvey A, Nathens AB, Bandiera G, LeBlanc VR. Threat and challenge: cognitive appraisal and stress responses in simulated trauma resuscitations. Med Educ. 2010;44(6):587–94. https://doi.org/10.1111/j.1365-2923.2010.03634.x

35. Pai DR, Ram S, Madan SS, Soe HHK, Barua A. Causes of stress and their change with repeated sessions as perceived by undergraduate medical students during high-fidelity trauma simulation. Natl Med J India. 2014;27(4):192–7.

36. Georgiou K, Larentzakis A, Papavassiliou AG. Surgeons' and surgical trainees' acute stress in real operations or simulation: a systematic review. Surgeon. 2017;15(6):355–65. https://doi.org/10.1016/j.surge.2017.06.003

37. Horsley T, Dingwall O, Sampson M. Checking reference lists to find additional studies for systematic reviews. Cochrane Database Syst Rev. 2011;2011(8):MR000026. https://doi.org/10.1002/14651858.mr000026.pub2

38. Munn Z, Tufanaru C, Aromataris E. JBI's systematic reviews: data extraction and synthesis. Am J Nurs. 2014;114(7):49–54. https://doi.org/10.1097/01.naj.0000451683.66447.89

39. Sirriyeh R, Lawton R, Gardner P, Armitage G. Reviewing studies with diverse designs: the development and evaluation of a new tool. J Eval Clin Pract 2012;18(4):746–52. https://doi.org/10.1111/j.1365-2753.2011.01662.x

40. Wolfenden C, Wittkowski A, Hare DJ. Symptoms of autism spectrum disorder (ASD) in individuals with mucopolysaccharide disease type III (sanfilippo syndrome): a systematic review. J Autism Dev Disord. 2017;47(11):3620–33. https://doi.org/10.1007/s10803-017-3262-6

41. Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, et al. Guidance on the conduct of narrative synthesis in systematic reviews: a product from the ESRC methods programme. Peninsula Medical School, Universities of Exeter and Plymouth; 2006.

42. Schwarz CM, Hoffmann M, Schwarz P, Kamolz L-P, Brunner G, Sendlhofer G. A systematic literature review and narrative synthesis on the risks of medical discharge letters for patients' safety. BMC Health Serv Res. 2019;19:158. https://doi.org/10.1186/s12913-019-3989-1

43. Connolly F, De Brún A, McAuliffe E. A narrative synthesis of learners' experiences of barriers and facilitators related to effective interprofessional simulation. J Interprof Care. 2022;36(2):222–33. https://doi.org/10.1080/13561820.2021.1880381

44. McMullen M, Wilson R, Fleming M, Mark D, Sydor D, Wang L, et al. "Debriefing-on-Demand": a pilot assessment of using a "pause button" in medical simulation. Simul Healthc. 2016;11(3):157–63. https://doi.org/10.1097/sih.0000000000000140

45. Lilot M, Evain J-N, Bauer C, Cejka J-C, Faure A, Balança B, et al. Relaxation before debriefing during high-fidelity simulation improves memory retention of residents at three months: a prospective randomized controlled study. Anesthesiology. 2018;128(3):638–49. https://doi.org/10.1097/aln.0000000000002045

46. Goldberg A, Samuelson S, Khelemsky Y, Katz D, Weinberg A, Levine A, et al. Exposure to simulated mortality affects resident performance during assessment scenarios. Simul Healthc. 2017;12(5):282–8. https://doi.org/10.1097/sih.0000000000000257

47. Geeraerts T, Roulleau P, Cheisson G, Marhar F, Aidan K, Lallali K, et al. Physiological and self-assessed psychological stress induced by a high-fidelity simulation course among third year anesthesia and critical care residents: an observational study. Anaesth Crit Care Pain Med. 2017;36(6):403–6. https://doi.org/10.1016/j.accpm.2017.06.002

48. Bhoja R, Guttman OT, Fox AA, Melikman E, Kosemund M, Gingrich KJ. Psychophysiological stress indicators of heart rate variability and electrodermal activity with application in healthcare simulation research. Simul Healthc. 2020;15(1):39–45. https://doi.org/10.1097/sih.0000000000000402

49. Guris RJD, Duarte SS, Miller CR, Schiavi A, Toy S. Training novice anaesthesiology trainees to speak up for patient safety. Br J Anaesth. 2019;122(6):767–75. https://doi.org/10.1016/j.bja.2019.01.017

50. Schlatter ST, Thérond CC, Guillot A, Louisy SP, Duclos A, Lehot J-J, et al. Effects of relaxing breathing paired with cardiac biofeedback on performance and relaxation during critical simulated situations: a prospective randomized controlled trial. BMC Med Educ. 2022;22(1):422. https://doi.org/10.1186/s12909-022-03420-9

51. Gouin A, Damm C, Wood G, Cartier S, Borel M, Villette-Baron K, et al. Evolution of stress in anaesthesia registrars with repeated simulated courses: an observational study. Anaesth Crit Care Pain Med. 2017;36(1):21–6. https://doi.org/10.1016/j.accpm.2016.02.008

52. Bertrand B, Evain J-N, Piot J, Wolf R, Bertrand P-M, Louys V, et al. Positive communication behaviour during handover and team-based clinical performance in critical situations: a msimulation randomised controlled trial. Br J Anaesth. 2021;126(4):854–61. https://doi.org/10.1016/j.bja.2020.12.011

53. Evain J-N, Perrot A, Vincent A, Cejka J-C, Bauer C, Duclos A, et al. Team planning discussion and clinical performance: a prospective, randomised, controlled simulation trial. Anaesthesia. 2019;74(4):488–96. https://doi.org/10.1111/anae.14602

54. Sigwalt F, Petit G, Evain J-N, Claverie D, Bui M, Guinet-Lebreton A, et al. Stress management training improves overall performance during critical simulated situations: a prospective randomized controlled trial. Anesthesiology. 2020;133(1):198–211. https://doi.org/10.1097/aln.0000000000003287

55. Suet G, Blanie A, De Montblanc J, Benhamou D. Use of an observer tool to enhance observers' learning of anesthesia residents during high-fidelity simulation: a randomized controlled trial. Simul Healthc. 2022;17(1):e75–82. https://doi.org/10.1097/sih.0000000000000584

56. Büyük S, Bermede O, Erkoç S, Alkış N, Lilot M, Meço B. Use of simulation to teach in the operating room – Don't let the COVID-19 pandemic interrupt education: an observational clinical trial. Braz J Anesthesiol. 2022;72(2):185–8. https://doi.org/10.1016/j.bjane.2021.11.010

57. Shailaja S, Hilda SS, Pinto PA, D'Cunha RJ, Mahmood LS, Hegde RB. Evaluation of resident satisfaction and change in knowledge following use of high-fidelity simulation teaching for anaesthesia residents. Indian J Anaesth. 2019;63(11):908–14. https://doi.org/10.4103/ija.IJA_133_19

58. Phitayakorn R, Minehart RD, Hemingway MW, Pian-Smith MCM, Petrusa E. Relationship between physiologic and psychological measures of autonomic activation in operating room teams during a simulated airway emergency. Am J Surg. 2015;209(1):86–92. https://doi.org/10.1016/j.amjsurg.2014.08.036

59. Calamassi D, Nannelli T, Guazzini A, Bambi S, Gioachin G, Pini R, et al. High-fidelity in urgency-emergency simulation: validation of a tool to determine the satisfaction of participants. Acta Biomed. 2016;87 Suppl 2:28–37.

60. Thayer RE. Factor analytic and reliability studies on the activation-deactivation adjective check list. Psychol Rep. 1978;42(3):747–56. https://psycnet.apa.org/doi/10.2466/pr0.1978.42.3.747

61. Hart SG, Staveland LE. Development of NASA-TLX (task load index): results of empirical and theoretical research. Adv Psychol 1988;52:139–83. https://doi.org/10.1016/S0166-4115(08)62386-9

62. Morgan PJ, Cleave-Hogg D. A worldwide survey of the use of simulation in anesthesia. Can J Anesth. 2002;49(7):659–62. https://doi.org/10.1007/bf03017441

63. Price JW, Price JR, Pratt DD, Collins JB, McDonald J. High-fidelity simulation in anesthesiology training: a survey of Canadian anesthesiology residents' simulator experience. Can J Anesth. 2010;57(2):134–42. https://doi.org/10.1007/s12630-009-9224-5

64. McGuire K, Lorenz R. Effect of simulation on learner stress as measured by cortisol: an integrative review. Nurse Educ. 2018;43(1):45–9. https://doi.org/10.1097/nne.0000000000000393

65. LeBlanc VR, Posner GD. Emotions in simulation-based education: friends or foes of learning? Adv Simul. 2022;7(1):3. https://doi.org/10.1186/s41077-021-00198-6

66. Derakshan N, Smyth S, Eysenck MW. Effects of state anxiety on performance using a task-switching paradigm: an investigation of attentional control theory. Psychon Bull Rev. 2009;16(6):1112–7. https://doi.org/10.3758/pbr.16.6.1112

67. Hulsman RL, Pranger S, Koot S, Fabriek M, Karemaker JM, Smets EMA. How stressful is doctor-patient communication? Physiological and psychological stress of medical students in simulated history taking and bad-news consultations. Int J Psychophysiol. 2010;77(1):26–34. https://doi.org/10.1016/j.ijpsycho.2010.04.001

68. Cassady JC, Johnson RE. Cognitive test anxiety and academic performance. Contemp Educ Psychol. 2002;27(2):270–95. https://doi.org/10.1006/ceps.2001.1094

69. Tjønnås MS, Guzmán-García C, Sánchez-González P, Gómez EJ, Oropesa I, Våpenstad C. Stress in surgical educational environments: a systematic review. BMC Med Educ. 2022;22(1):791. https://doi.org/10.1186/s12909-022-03841-6

70. Grantcharov PD, Boillat T, Elkabany S, Wac K, Rivas H. Acute mental stress and surgical performance. BJS Open. 2018;3(1):119–25. https://doi.org/10.1002/bjs5.104

71. Moawad GN, Tyan P, Kumar D, Krapf J, Marfori C, Khalil EDA, et al. Determining the effect of external stressors on laparoscopic skills and performance between obstetrics and gynecology residents. J Surg Educ. 2017;74(5):862–6. https://doi.org/10.1016/j.jsurg.2017.03.001

72. Vogel S, Schwabe L. Learning and memory under stress: implications for the classroom. NPJ Sci Learn. 2016;1(1):16011. https://doi.org/10.1038/npjscilearn.2016.11

73. Kensinger EA. Remembering the details: effects of emotion. Emot Rev. 2009;1(2):99–113. https://doi.org/10.1177/1754073908100432

74. Schwabe L, Bohringer A, Chatterjee M, Schachinger H. Effects of pre-learning stress on memory for neutral, positive and negative words: different roles of cortisol and autonomic arousal. Neurobiol Learn Mem. 2008;90(1):44–53. https://doi.org/10.1016/j.nlm.2008.02.002

75. Zoladz PR, Clark B, Warnecke A, Smith L, Tabar J, Talbot JN. Pre-learning stress differentially affects long-term memory for emotional words, depending on temporal proximity to the learning experience. Physiol Behav. 2011;103(5):467–76. https://doi.org/10.1016/j.physbeh.2011.01.016

76. Smeets T, Giesbrecht T, Jelicic M, Merckelbach H. Context-dependent enhancement of declarative memory performance following acute psychosocial stress. Biol Psychol. 2007;76(1–2):116–23. https://doi.org/10.1016/j.biopsycho.2007.07.001

77. Beilock SL, Carr TH. When high-powered people fail: Working memory and “choking under pressure” in math. Psychol Sci. 2005;16(2):101–5. https://doi.org/10.1111/j.0956-7976.2005.00789.x

78. Saunders T, Driskell JE, Johnston JH, Salas E. The effect of stress inoculation training on anxiety and performance. J Occup Health Psychol. 1996;1(2):170–86. https://doi.org/10.1037//1076-8998.1.2.170

79. Meichenbaum DH, Deffenbacher JL. Stress inoculation training. Couns Psychol. 1988;16(1):69–90. https://doi.org/10.1177/00110000881610

80. Truog RD, Meyer EC. Deception and death in medical simulation. Simul Healthc. 2013;8(1):1–3. https://doi.org/10.1097/sih.0b013e3182869fc2

81. Hojat M, Glaser K, Xu G, Veloski JJ, Christian EB. Gender comparisons of medical students’ psychosocial profiles. Med Educ. 1999;33(5):342–9. https://doi.org/10.1046/j.1365-2923.1999.00331.x

82. Kudielka BM, Hellhammer DH, Wüst S. Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. Psychoneuroendocrinology. 200934(1):2–18. https://doi.org/10.1016/j.psyneuen.2008.10.004

83. Stopa L, Clark DM. Social phobia: comments on the viability and validity of an analogue research strategy and British norms for the fear of negative evaluation questionnaire. Behav Cogn Psychother. 2001;29(4):423–30. https://psycnet.apa.org/doi/10.1017/S1352465801004039

84. Fanning RM, Gaba DM. The role of debriefing in simulation-based learning. Simul Healthc. 2007;2(2):115–25. https://doi.org/10.1097/sih.0b013e3180315539

85. Issenberg SB, Mcgaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach. 2005;27(1):10–28. https://doi.org/10.1080/01421590500046924