ORIGINAL RESEARCH

The Influence of Stress on Student Performance during Simulation-based Learning

A Pilot Randomized Trial

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ABSTRACT

Background: Simulation-based learning is an important educational medium that is being implemented increasingly for the purpose of improved patient care and safety. However, there is evidence to suggest that simulation-based education (SBE) may increase anxiety, as illustrated through self-reporting and physiological responses. Despite such data, no studies have investigated whether anxiety and stress can be manipulated through SBE scenario design and delivery to facilitate optimal learning conditions.

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Objective: This pilot study examined perceived anxiety and physiological stress experienced by entry-level physiotherapy students while learning a skill using SBE and the relationship between this anxiety and their subsequent skill performance.

Methods: Final-year physiotherapy students were randomly allocated to one of three SBE experiences: low, medium, or high stress. The experiences were designed to induce increasing levels of stress and anxiety. Performance of the learned skill (endotracheal airway suctioning) was measured after the SBE using a bespoke assessment form. Cortisol levels, heart rate, and perceived anxiety measurements (State-Trait Anxiety Inventory and visual analog scale) were also collected.

Results: Twenty-seven participants completed the trial. There were significant differences in perceived stress and physiological response between the groups. The low-stress group demonstrated significantly better performance of airway suctioning than the higher-stress groups ($P = 0.02$). Higher anxiety was correlated with poorer skill performance ($r = -0.410$).

Conclusions: Students report SBE to be stressful, and scenarios themselves can influence the stress and anxiety experienced. Greater stress is associated with poor learning outcomes during SBE. Healthcare educators involved in SBE scenario design need to consider the stress levels experienced. Future research to determine optimal stress and embed measurement of stress in SBE experiences is warranted.

Keywords:
simulation-based learning, anxiety, stress, physiotherapy

Simulation-based education (SBE) is a technique that allows students to be immersed in an interactive environment replicating aspects of real life. In the context of healthcare professional curricula, this educational approach can assist with the development of clinical competency (1). Indeed, emerging literature in healthcare professional education has demonstrated that SBE is an important educational medium that is being increasingly implemented for the purpose of improved patient care and safety (2).

Simulation-based education offers multiple advantages during the learning process. In SBE, the clinical scenario being explored can be manipulated to allow time for the student to pause and reflect, rewind and repeat significant stages, or improve performance through repetition (2). This creates opportunities for mastery of learning in a safe environment in which mistakes can be made with no potential for harm to the student or “patient” (3). Students can also be introduced to clinical events that are challenging or typically have a low tolerance for error. For example, students can engage with high-fidelity intensive care unit (ICU) scenarios, experiencing the benefits of “hands-on” training in a safe environment that poses no risk to patients (3, 4). SBE has also been designed to support students’ self-reflection through debriefing, which can include targeted feedback from teachers and peers (5). The debriefing sessions following SBE assist in elucidating the clinical decision-making framework and developing a student’s reflective processes (3). Moreover, SBE environments are more accessible and can therefore be used in a nonclinical setting such as a standard classroom, which enriches and potentially expedites development of clinical skills (6).

The aforementioned benefits of SBE have been observed in entry-level physiotherapy education, with SBE becoming an important medium in supporting the development of students' competencies in clinical practice (2). There is strong evidence that SBE is useful in entry-level physiotherapy education and that SBE can be embedded in physiotherapy curricula to decrease the burden of sourcing clinical learning opportunities (2).

Despite the potential benefits of SBE, emerging evidence suggests that stress and anxiety may be felt by students, and this may negatively impact the attainment of learning outcomes and student engagement with SBE. Healthcare students, at times, experience increased stress and anxiety in SBE, as illustrated through self-reporting, physiologic responses, and biochemical markers (7–9). Anxiety experienced by students can enhance the retention of knowledge or compromise it depending on the learner and the level of anxiety experienced (9, 10). In the context of clinical practice, the psychological state of healthcare professionals has been shown to negatively impact attention, memory, and clinical decision-making (11).

Although there is evidence supporting the impact of anxiety on performance among health professionals in clinical settings, there have been no direct investigations of the impact of anxiety on the initial attainment of skills or knowledge. Additionally, although it is known that anxiety may elicit disparate learning effects depending on its severity, no studies have investigated the role that manipulating SBE may have in titrating stress or anxiety for optimal learning. Through subtly changing a scenario to trigger a specific stress response (or minimizing the stress response in a learner who is not coping with the SBE complexity and delivery mode), can SBE create optimal learning environments at all times? The aim of this pilot study was, therefore, to examine the perceived anxiety and physiological stress experienced by entry-level physiotherapy students while learning a skill (orotracheal airway suctioning) during an SBE experience and determine the relationship between this anxiety experienced in the SBE and the students' subsequent performance of the skill after completing the SBE.

METHODS

Trial Design and Participants

A pilot randomized trial was used to examine the effects of reported anxiety and stress on learning within an SBE experience, in which the outcome of learning was measured by performance of the skill after the SBE had been completed. Participants were entry-level, final-year physiotherapy students enrolled in a Bachelor of Physiotherapy program at a research institution in Australia. The trial was conducted in the clinical suites of the enrolling university. Participants completed a self-assessment checklist to determine eligibility and were excluded if they reported diagnoses known to significantly impact cortisol or stress, such as clinical anxiety requiring prescription medications; had previously failed the unit in which the airway suctioning was taught; had been diagnosed with a cardiac condition; or had an infective acute illness. This study was approved by the local institutional human research ethics committee (approval no. H12616). All participants provided written informed consent and were recruited 3 weeks before the SBE experience to allow for scheduling of sessions with sufficient notice, questions to be asked, and reconsideration of involvement. The funding body was Western Sydney University, under its operational budget for delivery of curriculum, consumables, infrastructure, and staff salaries. The funder played no role in the design, conduct, or reporting of this study.

The trial aimed to recruit a total of 40 participants, allowing for a 20% dropout rate and the final inclusion of 30 participants, as this was a pilot study intended to have 10 participants in each intervention group. A pilot sample size of 10 is considered appropriate for the purpose of establishing an effect size for future fully powered randomized controlled trials (12). Participants were randomized to one of three different SBE scenario groups (low, medium, or high stress; $n = 10$ per group) using a computer-generated random number sequence, stratified for grade point average. Group allocation was at random, concealed at the time of recruitment, and completed by the lead researcher (F.B.). Participants were not informed of the scenario to which they were allocated or that the stress of the scenario would be different across the groups, in an attempt to blind them to the intervention. Students were also requested to not discuss their experience with peers until the conclusion of the trial.

Simulation Scenario and Intervention

A foundation SBE simulation scenario was used across all three groups. Before engaging with the scenario, students had viewed an online educational pack detailing the purpose and mechanisms underlying endotracheal suctioning. The online educational package included instruction on the steps for suctioning, along with demonstration videos. This ensured that all students had an equivalent level of foundational knowledge before commencing the simulation. The scenario was created by a team of six SBE and cardiorespiratory physiotherapy experts for use in a previous physiotherapy SBE study (13). The scenarios and process of debriefing reflected existing guidelines commonly used throughout Australia (14). More specifically, each scenario underwent peer review, clinical expert review, and an evidence review as a part of this process.

The base scenario was then adapted for the specific learning outcomes related to this trial, and three versions were written, with variations in the features of the environment and the patient's status such that stress and cognitive load were sequentially increased. The learning outcomes were as follows:

1. Synthesize complex assessment information using clinical reasoning and client-centered approaches to design and critically reflect on a management plan for clients with complex presentations.
2. Plan, justify, implement, and evaluate a safe and effective treatment of the impairments and activity limitations in clients with respiratory failure with and without multisystem comorbidities.
3. Perform management in a safe manner while appropriately monitoring for changes in patient presentation.

The changes across the scenarios from low stress to medium and high stress are detailed in Table 1.

The simulation room was set up with a computerized mannequin (MegaCode Kelly; Laerdal) to replicate an ICU bed space. All participants were guided during the SBE experience to complete an assessment of the patient, followed by activities to develop the skill of airway

Table 1. Variations to SBE experience to create low-, medium-, and high-stress scenarios

Variable	Scenario		
	Low Stress	Medium Stress	High Stress
People in the room	No additional people in the room	No additional people in the room	Nurse enters room during the simulation. They: - Wash hands - Ask students to move out of the way - Write on bed chart - Inspect drug pumps
Facilitator questions	Facilitator asks: - What is the patient's oxygenation and fraction of inspired oxygen? - What is the patient's HR and BP? - Name one method to decrease the risk of infection for a patient	Facilitator asks: - Are there any issues with the patient's oxygenation for suctioning? - Are there any issues with the patients BP and HR for suctioning? - What steps will you take to decrease the chance that a lung infection may occur?	Facilitator asks: - Are there any ventilator settings that suggest you should not do suctioning? - Are they hemodynamically stable for suctioning? - What is the risk of infection spread while suctioning and how can you minimize?
Patient vital signs	Stable all signs	HR increases by 20 BPM	- HR increases by 20 BPM - Decrease in BP on monitor from 112/58 to 83/42 mm Hg - MAP decreases to 52 mm Hg
Bed chart	- Remove neurological information other than RASS score showing sedation - Removes fluids	As per scenario	- Add extra ABGS - Add cuff pressure and leak - Add ETT size, CVC size, IDC
Demonstration	Demonstrate slowly with extensive verbal instruction and chunking of task	Demonstrate with limited verbal instruction and multiple steps at once	Demonstrate with limited verbal instruction and multiple steps at once
Additional clinical tasks in scenario	—	—	Patient poorly positioned and needs to be repositioned

Definition of abbreviations: ABGS = arterial blood gases; BP = blood pressure; BPM = beats per minute; CVC = central venous catheter; ETT = endotracheal tube; Hg = mercury; HR = heart rate; IDC = indwelling catheter; MAP = mean arterial pressure; mmHg = millimeters of mercury; RASS = Richmond Agitation-Sedation Scale; SBE = simulation-based education.

suctioning using a closed suctioning catheter. Participants completed the patient interaction component of the SBE in pairs over a period of 30 minutes. No specific student was allocated as the leader of the interaction unless students did so independently and without prompting of the educators before entering the simulation room. The simulation was facilitated by a physiotherapy educator with expertise in SBE methodology and cardiorespiratory physiotherapy practice (F.B.). During the simulation, both students were afforded the opportunity to practice the skills of assessment and suctioning an intubated patient.

Immediately after the 30-minute SBE experience, participants completed a 30-minute debrief, facilitated by an experienced physiotherapy educator (K.J.C.) who was blinded to group allocation and not present during the SBE experience.

The debrief was conducted in pairs of students who had just completed the SBE experience together and was explicitly student-led. The debriefing process followed the "SHARP" approach for structured debriefing, ensuring clear objectives were set, engaging the participants to reflect on their performance, ensuring feedback was tailored to the learning objectives, and assisting in translating feedback to improving future practice (15). The SHARP approach provides a series of questions to lead learners to analyze their experience, including "How did it go?," "What went well and why?," "What did not go well and why?," "Were your learning objectives met? What did you learn about your skills? What did you learn about your teamwork skills?," and "Based on your learning today, how will you improve future practice?" Because debriefing is individually tailored to the experience of the learners, the specifics of each debrief varied for each pair of students, even though the framework and principles were the same across the study. Students were provided with a paper copy of the SHARP framework to document any notes and guide their conversations with visual cueing of the reflective questions.

Students were each allocated to a specific time for the SBE experience. The SBE experiences were scheduled in the morning across three consecutive days in an attempt to minimize the variations in cortisol production across the day. Participants were kept in closed rooms for the duration of their simulation experience and were clearly instructed not to discuss the simulation until all participants had completed their learning experience on Day 3 of the trial. The scheduling of the SBE experience was also timed to have a specific time period of 4 hours between learning in the SBE and having that learning assessed.

Data Collection

Data collected for this study included demographic information, measures of perceived anxiety, physiological stress response to the SBE, and performance (i.e., attainment of learning objectives) of airway suctioning of an intubated and sedated patient, completed in a simulated environment using a computerized mannequin. Figure 1 summarizes the measures and the time points at which data were collected.

Demographic information. Demographic information was collected the morning of the SBE experience, immediately before students entered the SBE. Data were collected using a paper-based questionnaire that requested age, gender, experience with assessment of ICU patients, and experience with airways suctioning.

Measures of anxiety and stress.

State-Trait Anxiety Inventory. To measure state and trait anxiety, the State-Trait Anxiety Inventory (STAI) was used. The STAI is a reliable and valid questionnaire (16, 17) consisting of 40 statements that are graded on a Likert scale from 0 to 4. The measure was completed by participants upon their arrival to the SBE experience and was repeated after the simulation and debrief.

Cortisol levels. A stress response can activate the pituitary–adrenal axis, leading to hypothalamic secretions of corticotrophin-releasing factor, stimulating the pituitary gland to release adrenocorticotropin, and synthesis of cortisol (18). Salivary cortisol measurement is a noninvasive measure that reacts to psychological stressors (19), subsequently indicating an

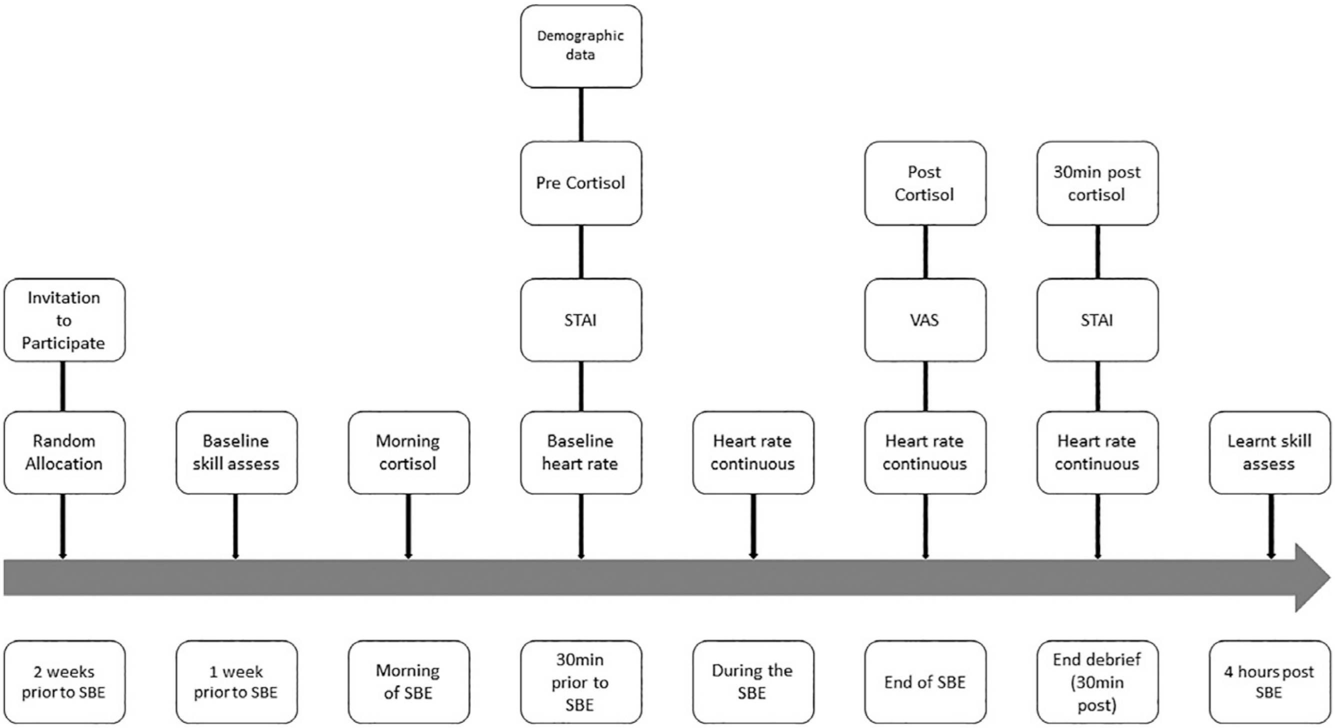

Figure 1. Experimental procedures and data-collection timeline. Assess = assessment; SBE = simulation-based education; STAI = State-Trait Anxiety Inventory; VAS = visual analog scale.

alteration in mood or emotion of the participants.

Baseline samples were taken upon waking in the morning of the SBE experience. A second sample was taken immediately before the commencement of the SBE scenario, and a third sample was taken within 5 minutes of scenario completion. A final, fourth sample was taken at the conclusion of the debrief to ensure that the peak cortisol level was captured at the 30-minute post-SBE time point.

Samples were obtained using a Salivette system and stored per the manufacturer's recommendations (Salimetrics, 2011). Because smoking and consumption of food or beverages (apart from water) may influence salivary cortisol levels, participants were requested to abstain from these activities before providing the morning sample and for 2 hours before the SBE experience (20). The most recent food and beverage intake (other than water) was recorded before the commencement of the SBE experience to confirm compliance. Participants were provided with written instructions for home collection of the sample, and reminder text messages were sent to participants' mobile phones at 6.30 A.M. on the morning of their scheduled SBE experience. The results of the saliva analysis were provided to the researchers in an electronic format that was deidentified.

Heart rate response: physiological arousal. Heart rate (HR) is considered a valid tool for measuring physiological arousal and has been used in a variety of studies to measure anxiety during SBE experiences (7, 8). In this study, participants wore an HR monitor (Polar Team Pro with remote recording) throughout the SBE experience.

Participants were monitored throughout the SBE experience for their resting HR and HR every 15 minutes thereafter. Mean HR during the SBE was used during data analyses.

Perception of anxiety. The visual analog scale (VAS) is an efficient method for assessing a participant's perception of stress and anxiety. The VAS measurements were taken before the simulation and at 30 minutes after completion of the SBE experience using a paper-based 10-cm VAS line that the participant marked, whereby 0 represented no anxiety and 10 represented the worst anxiety they had ever experienced. The distance from 0 marked by the participant was recorded in millimeters.

Measures of performance. Participant attainment of the learning objectives was assessed in a practical skills demonstration under examination conditions. The duration of the examination was 10 minutes, with the participants requested to demonstrate their ability to perform closed airway suctioning. The assessment was performed using the same computerized mannequin in the room used for the SBE scenario setup to replicate the exact environment and equipment used in the SBE experience. The patient setup used during the examination included the medium-stress scenario parameters and the SBE environment setup. The assessment criteria for performance are presented in the data supplement. Although the tool was not assessed specifically for reliability and validity in application, it was mapped to learning outcomes and had been used in the entry-level physiotherapy program in assessing competency for the preceding 5 years.

Baseline assessment of the performance of the airway suctioning skill was assessed 1 week before the SBE activity. A second measure of performance was then completed in the afternoon >4 hours after the SBE scenario. All performance assessments were completed by an assessor blinded to group allocation. The assessor was an expert cardiorespiratory physiotherapist who had minimal recent contact with the student participants.

Statistical Analysis

Analyses were performed in consultation with a biostatistician and completed using SPSS software (version 25; IBM), with the *P* value set at less than 0.05.

Effect of SBE on anxiety and physiological stress. One-way analyses of variance (ANOVAs) were conducted to explore between-group differences in perceived anxiety (i.e., VAS score) and HR. Repeated-measures ANOVAs (within-subject factor "group," between-subject factor "time") were also conducted to determine whether there were significant differences in STAI and cortisol levels over time. When appropriate, *post hoc* analyses were performed using Šidák-adjusted multiple comparison tests. Given the exploratory nature of the study, no further adjustments for multiplicity were made (21).

Effect of SBE on skill performance. Repeated-measures ANOVAs (within-subject factor "group," between-subject factor "time") were performed to explore differences between groups and over time in terms of performance (skill preparation, implementation, safety, and overall assessment scores). Because of the small sample and exploratory nature of this study, preplanned pairwise comparisons were also conducted to evaluate differences in performance and anxiety levels between the low-, medium-, and high-stress groups. The overall one-way ANOVA tests the null hypothesis that all treatment groups have identical mean values, so any difference observed is the result of random sampling. Each *post hoc* test assesses the null hypothesis that two particular groups have identical means. The *post hoc* tests are more focused and have power to find differences between groups with smaller samples even when the overall ANOVA result is not significant (22).

A Pearson's correlation was used to examine for correlations between the level of anxiety experienced (on the VAS) and its impact on subsequent skill performance.

RESULTS

Thirty students among a total of 47 consented to participate. Of these 30 participants, three withdrew (one from the medium-stress group and two from the high-stress group), leaving 27 who completed the study. The three withdrawals occurred the day before the SBE experience as a result of student illness and an inability to attend. Recruitment was completed within a 2-week period in November 2018. There were no significant differences between groups in terms of demographic characteristics or baseline levels of stress and anxiety (i.e., HR and cortisol level) (Table 2). All students had completed the same curriculum in the physiotherapy 4-year degree program and had the same level of experience with the SBE. No adverse events were observed throughout the duration of the study.

There were also no differences between groups in terms of their baseline performance of the suctioning skill as measured on a scale to 20 (low-stress mean [standard deviation (SD)] = 1.9 [1.4], medium-stress mean [SD] = 1.6 [1.3], high-stress mean [SD] = 1.3 [0.8]; all $P > 0.05$).

Effect of SBE on Anxiety and Physiological Stress

There was a significant difference between groups in terms of perceived anxiety (assessed using the VAS) at the conclusion of the SBE ($F_{2,24} = 21.1$, $P < 0.001$). Indeed, perceived anxiety scores progressively increased from the low-stress group (mean [SD] = 17 [8.5] mm) to the medium-stress (mean [SD] = 55.9 [24.9] mm) and high-stress (mean [SD] = 66.4 [14.8] mm) groups. The low-stress group had significantly lower perceived anxiety scores than the medium-stress ($P < 0.001$) and the high-stress ($P < 0.001$) groups. The medium-stress group did not differ from the high-stress group in terms of perceived anxiety ($P = 0.158$). Mean HR during the simulation also increased from the low-stress group (mean [SD] = 87 [18] beats/min) to the medium-stress (mean [SD] = 90 [14] beats/min) and high-stress (mean [SD] = 103 [14] beats/min) groups. The low-stress ($P = 0.043$) and medium-stress ($P = 0.035$) groups had lower mean HR recordings than the high-stress group.

A repeated-measures ANOVA revealed significant differences in STAI scores between groups over time (time: $F_{1,24} = 11.95$, $P = 0.002$; group: $F_{2,24} = 1.24$, $P = 0.308$; group × time: $F_{2,24} = 6.41$, $P = 0.006$). As with perceived anxiety and mean HR, STAI scores following the SBE were lowest in the low-stress group (mean [SD] = 32 [7]), moderate for the medium-stress group (mean [SD] = 41 [12]), and highest in the high-stress group (mean [SD] = 44 [12]). The low-stress group had lower STAI scores following simulation than the medium-stress ($P = 0.035$) and high-stress ($P = 0.009$) groups. The medium-stress group did not have significantly different

Table 2. Participant characteristics and demographic information

Characteristic	Low Stress (*n* = 10)	Medium Stress (*n* = 9)	High Stress (*n* = 8)
Age, yr	23 ± 3	24 ± 5	22 ± 1
Gender, M:F	5:5	2:7	3:5
GPA	5.8 ± 0.5	5.7 ± 0.7	5.3 ± 0.9
Years studying physiotherapy	4.2 ± 0.4	4.4 ± 0.5	4.5 ± 0.8
Years at university	5.0 ± 1.3	5.0 ± 1.1	4.8 ± 0.7
Hours of sleep night before SBE	7.3 ± 0.5	6.8 ± 1.2	6.9 ± 1.6
Trait anxiety (STAI component)	39.8 ± 7.7	40.6 ± 8.0	37.3 ± 6.7
Previous exposure to ICU	7 (70%)	8 (89%)	5 (63%)
Previous exposure to airway suctioning in ICU	6 (60%)	5 (56%)	3 (38%)
Performed independent ICU assessment previously	3 (30%)	3 (33%)	2 (25%)
Performed airway suctioning previously	2 (20%)	2 (22%)	3 (38%)
Pre-simulation state scores (STAI component)	34 ± 6	35 ± 8	30 ± 8
Morning cortisol	0.4 ± 0.2	0.7 ± 0.5	0.6 ± 0.5
Baseline HR (15 min before simulation)	74 ± 14	76 ± 11	83 ± 14

Definition of abbreviations: HR = heart rate; GPA = grade point average; ICU = intensive care unit; M:F = Male:Female; SBE = simulation-based education; STAI = State-Trait Anxiety Inventory.
Results are presented as group mean ± standard deviation where applicable.

STAI scores compared with the high-stress group ($P = 0.267$). Cumulatively, these data suggest that groups experienced progressively increasing levels of anxiety and physiological stress when assessed using a VAS, HR, and STAI. Conversely, there were no significant group × time interactions observed in terms of cortisol levels assessed upon completion of the simulation ($F_{2,24} = 0.743$, $P = 0.486$) or at 30 minutes after the simulation ($F_{2,24} = 0.892$, $P = 0.423$).

Effect of SBE on Skill Performance

All groups demonstrated significant improvements in performing the skill of endotracheal suctioning over time in terms of preparation ($F_{1,24} = 380.93$, $P < 0.001$), implementation ($F_{1,24} = 161.51$, $P < 0.001$), safety ($F_{1,24} = 836.33$, $P < 0.001$), and overall assessment score ($F_{1,24} = 819.35$, $P < 0.001$). There was a significant difference between groups for preparation ($F_{2,24} = 4.14$, $P = 0.029$) and a trend toward between-group differences in terms of overall assessment score ($F_{2,24} = 2.75$, $P = 0.084$), but no difference was shown for implementation ($F_{2,24} = 1.34$, $P = 0.280$) or safety ($F_{2,24} = 0.640$, $P = 0.536$). No significant group × time interactions were identified for analyses involving skill performance (all $P > 0.241$).

Preplanned pairwise comparisons revealed that the low-stress group had higher scores in terms of preparation ($P = 0.016$) and implementation ($P = 0.035$) compared with the medium-stress group. The low-stress

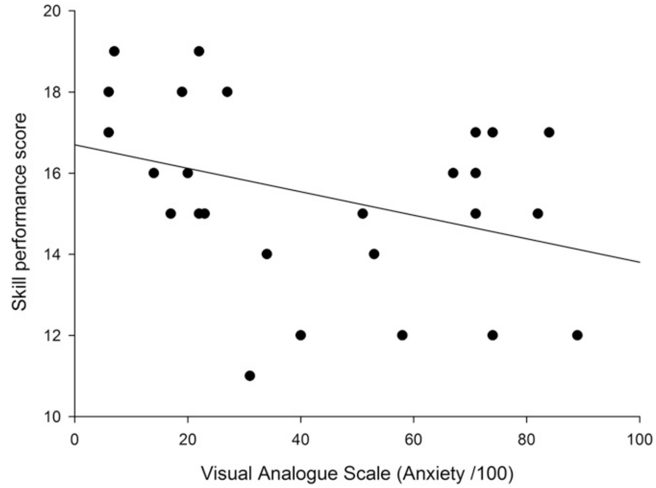

Figure 2. Correlation between anxiety visual analog scale score and skill performance.

group also had higher scores for preparation ($P = 0.023$) and overall assessment ($P = 0.022$) compared with the high-stress group. However, there were no significant differences between the medium- and high-stress groups. All other preplanned pairwise comparisons for skill performance had nonsignificant findings ($P > 0.05$).

Given that perceived anxiety (assessed using a VAS) varied among the low-, medium-, and high-stress groups, we explored the relationship between this outcome and skill performance. There was a significant moderate inverse correlation between perceived anxiety (i.e., VAS score) and overall assessment scores, whereby lower VAS scores were associated with higher performance ($r = -0.410$, $P = 0.034$; Figure 2).

DISCUSSION

This is the first randomized study to examine the relationship between anxiety experienced in SBE and attainment and demonstration of learning outcomes. The results indicate that anxiety can be experienced by students during SBE and that the degree of scenario stress influences anxiety level and attainment of learning outcomes (i.e., observed performance of the learned skill). This finding is comparable to those of other studies that have examined anxiety in SBE, strengthening the evidence that SBE is not always a stress- or anxiety-free environment for learning (7–9, 23). The novel finding from this study is that, by changing the complexity of the scenario while maintaining learning outcomes and the SBE scenario core features, the levels of anxiety and stress experienced can effectively be manipulated. These effects appear to influence student performance and skill acquisition. SBE designers need to give due consideration to complexity being targeted for an appropriate stress response. Intentionally manipulating scenario variables based on physiological stress response while completing an SBE could be an additional approach used by SBE facilitators to ensure an optimal environment for learning. Additionally, the physiological stress response is associated with the perceived stress of the SBE experience and the learning outcomes. This finding indicates that measurement of physiological response during an SBE experience could provide educators with insights into whether the current scenario design and delivery mode are leading to too much stress and potential for poor learning outcomes. Scenarios could then be changed in real time to decrease stress levels for learners.

The anxiety experienced by physiotherapy students appeared to be related to the level of scenario stress (or complexity), with the lowest-stress group experiencing lower levels of anxiety than the medium- and high-stress groups. The processes outlined by the general adaptation syndrome may explain the relationship between complexity of the SBE and the level of anxiety experienced (24). The initial phase of the general adaptation syndrome consists of an alarm phase in which the participant is faced with a sudden critical situation and responds with an appraisal of threat and challenge (24). If the demands required of the participant during the SBE experience are perceived as greater than their resources and ability to cope with the demands, the situation is perceived as a threat and the participants are more likely to experience negative psychological and physiological responses (25). By increasing the cognitive load and complexity of the simulation scenario, there was a likely subsequent increase in demand. This increase may have been beyond the participants' perceived resources and ability to cope in the medium- and high-stress groups. The notion that cognitive load influences subsequent anxiety is supported by the work of Harvey and colleagues (26), who examined the effect of cognitive appraisal in determining whether a situation is a threat or challenge on subjective and physiological stress. Harvey and colleagues found a significant correlation between high-stress scenarios and increased cortisol levels, as well as between postscenario cognitive appraisal and peak cortisol level, in emergency medicine and general surgery residents (26).

The level of scenario stress and complexity for learning, and the subsequent anxiety experienced during SBE, appear to impact subsequent performance of the learned skill. In the present study, participants performed the skill of suctioning an artificial airway to a lower level of competency when their perceived anxiety during the learning experience was higher. The relationship between increased anxiety during SBE and poorer performance of the skill after the SBE has concluded is unsurprising because the processing efficiency theory suggests that increased state anxiety can preempt the functioning of the working memory system, impacting cognitive processing and the transient storage of information, thereby inhibiting learning (27). However, it is important to note that this study was not designed to determine the mechanisms by which lower levels of learning occurred. There are multiple reasons why learning could be influenced, including perceived emotional stress level, physiological response, disengagement, decreased deliberate practice, increased cognitive load, specifics about the approach to learning such as educator support, and observational learning versus auditory or kinesiological learning. Future studies with larger sample sizes are warranted to understand mechanisms that inhibit attainment of learning in SBE for different individuals that are related to generating stress. These studies should also explore methods to measure the mechanisms that inhibit learning in real time, such that educators can be informed of the stress state of a learner and adjust the scenario for optimal learning.

One such mechanism to monitor student experience to inform changes to the SBE scenario delivery could be a physiological stress response. There was a significant physiological stress response during the SBE, as measured by difference in mean HR, that, as with perceived anxiety, varied accordingly between the low-, medium-, and high-complexity scenario groups. This observed difference in HR is likely to be related to an increase in the activation of the sympathetic nervous system in response to cognitive processes associated with the threat and challenge appraisal. The interesting aspect of this finding is the real-time measurement of stress levels during an SBE experience. Perceived anxiety is not possible to measure without disrupting the learning activities to ask the learner whether they feel stressed. However, HR can be measured with a remote device such as the Polar HR monitor used in this study. If an optimal anxiety and stress level for learning was to be determined, it is possible that scenarios could be altered in real time based on observed learner HR change. By observing physiological response to the learning experience in SBE, stress and anxiety levels could be monitored and the scenario complexity increased or decreased to reach the optimal level of stress and subsequent learning. However, for this to be accurately applied in healthcare education, thresholds for stress response before learning is negatively impacted would need to be determined. Identification of a meaningful VAS score, HR change, and STAI state score at which learning is impacted would assist educators in making decisions regarding the level of stress that is tolerable and appropriate. Future research exploring this could significantly shape the application of SBE for learning to achieve the most efficient learning for each individual.

The main limitation of this study is that it was a single-center pilot trial with a small sample size and therefore had insufficient power to detect a difference between medium- and high-stress scenarios in some cases. However, the study has demonstrated proof of concept, with differences in learning outcomes observed with variable levels of scenario complexity and a relationship demonstrated between stress and performance after the SBE. Future research with larger sample sizes is therefore justified, and the effect sizes observed in this study can be used to calculate appropriate sample sizes for a fully powered randomized controlled trial.

As is the case in many studies in education, another limitation was the validity and reliability of the assessment tools used to measure performance of the learned skill. The measurement tool used to assess performance of airway suctioning had not undergone any official validity testing. However, steps were taken to ensure that the tool had construct validity: it was developed by experts in cardiorespiratory physiotherapy and educational design and has been used for many years at Western Sydney University as a performance measure for the skill of airway suctioning. Interrater reliability concerns were minimized because participants were assessed by the same assessor for their pre- and post-SBE performance reviews. Additionally, the SBE experience was conducted over a period of multiple days for logistical reasons, and participants were, therefore, able to discuss their experience with other participants who had yet to complete their SBE. Participants may have spoken to each other, consequently decreasing their anxiety and stress by altering their expectations entering the SBE. In attempting to control for this variable, participants were strongly requested not to discuss the SBE with other participants. The participants were also relatively homogenous in terms of their prior training and skill level, so exploration of these findings across a range of students and clinicians is warranted to better elucidate the generalizability of the findings. Further, it is important to note that differences identified between groups could have been attributable to deviations in the demonstration method adopted between scenarios. The aim was to have equivalent levels of knowledge and skill communicated across scenarios, but for the delivery of this knowledge and skill to occur under progressively more stressful circumstances. However, one may argue that the poorer performance observed in the high-stress group was attributable to poorer instruction as opposed to increased stress. In an attempt to overcome this issue, students were all provided with an educational pack before the scenario. This meant that students had already received a consistent level of foundational knowledge, with the demonstration during the scenario itself being a means of reinforcing this baseline level of knowledge and manipulating student stress. Nonetheless, the influence of instruction delivery is an important consideration that warrants further investigation. Despite the limitations of this study, it was designed with methodological rigor as a randomized trial in an attempt to minimize as many biases as possible. Biases were minimized through allocation concealment, blinded assessment of group allocation, and maintenance of 85% retention (28).

Conclusions

Physiotherapy students completing SBE experiences to learn the skill of airway suctioning report that the experience can be stressful and anxiety-provoking, with an observed physiological stress response that is greater when the scenario SBE delivery has intentionally greater stress and complexity for learning. The observed physiological response and reported level of anxiety were associated with their subsequent ability to perform the skill after the SBE had concluded. Healthcare educators should consider putting greater emphasis on understanding how design and delivery of an SBE experience influences learners' stress. This study has demonstrated that physiological monitoring of stress response during an SBE could be used to track stress levels and ensure that learners are not overly stressed during an SBE. The SBE experience could then be titrated for stress that fosters an optimal learning environment. Future research with larger sample sizes is needed to determine the mechanisms by which stress can influence learning in SBE. Research exploring the best methods for the measurement of stress and the associated thresholds for stress levels before learning is impacted is also warranted. Educators should be purposeful in their design of SBE scenarios and educational activities in SBE delivery to ensure that students are not overstressed by the complexity of the scenario.

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