Original Paper

Impact of Hands-On Pediatric Emergency Training on Wound Suturing, Airway Management, and Orthopedic Casting Skills: Prospective Pre-Post Interventional Study

Saeed Alzahrani, MD; Nasser Assiri, MD; Fayez Alharthi, MD; Tariq Al Garni, MD; Asim Alamri, MD; Bader Asiri, MD; Maher Alkuwaiti, MD; Raed Habib, MD

Pediatric Emergency Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia

Corresponding Author:
Saeed Alzahrani, MD
Pediatric Emergency Department
Prince Sultan Military Medical City
Al Qilaa street, Dhahrat Laban Dist, 3117
Riyadh, 13753
Saudi Arabia
Phone: 966 507679144
Email: dr.saeeed.za@gmail.com

Abstract

Background: Opportunities to practice low-frequency skills for high-acuity pediatric emergency procedures in clinical settings are limited. The Basic Emergency Skills Techniques 3N1 (BEST 3N1) workshop was designed as a structured, hands-on training program to support procedural skill development among pediatric emergency care practitioners.

Objective: This study aimed to evaluate preworkshop to postworkshop changes in procedural performance and knowledge after a 3-day hands-on pediatric emergency skills workshop.

Methods: A quasi-experimental prospective pre-post interventional study was conducted during the 8th BEST 3N1 workshop, held from February 11 to 13, 2025, at the Simulation and Skills Development Centre, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia. The workshop included 24 scheduled continuing medical education hours in 3 domains: wound suturing, pediatric airway management, and pediatric orthopedic emergencies and casting. Procedural performance was assessed using complete paired preworkshop and postworkshop data for each assessment. Day 1 wound suturing and day 2 airway management were assessed using 4-item checklists scored from 0 to 8. Day 3 orthopedic casting competence was assessed using a keyword-based rubric covering equipment, procedural steps, and postapplication care, with a total score range of 0 to 30. Written knowledge was assessed using a 30-item multiple-choice test.

Results: The number of paired observations differed in assessments because the analysis was based on complete matched preworkshop and postworkshop data for each outcome. Day 1 wound suturing checklist mean scores increased from 4.14 (SD 1.72) to 7.72 (SD 0.68) among 88 paired participants, with a mean change of 3.58 (SD 1.71; *P*<.001) points. Day 2 airway management checklist scores increased from 5.47 (SD 1.88) to 7.81 (SD 0.56) among 77 paired participants, with a mean change of 2.34 (SD 1.96; *P*<.001) points. Day 3 orthopedic casting total competence scores increased from 4.20 to 6.39 among 77 paired participants, with a mean change of 2.19 (SD 1.72; 95% CI 1.80-2.58; *P*<.001). Written knowledge scores increased from 19.04 (SD 3.77) to 22.32 (SD 3.23) among 94 paired participants, with a mean change of 3.28 (95% CI 2.16-4.39; *P*<.001) points.

Conclusions: The BEST 3N1 workshop was associated with improved checklist-based procedural performance, orthopedic casting competence, and written knowledge among pediatric emergency care practitioners. These findings support the use of structured hands-on workshops for high-acuity, low-frequency pediatric emergency skills.

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KEYWORDS

pediatrics; emergency medicine; simulation training; clinical competence; airway management; surgical casts; continuing medical education; sutures

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Introduction

Maintaining procedural competence is a challenge in pediatric emergency medicine, as essential interventions are performed infrequently. In a high-volume pediatric emergency department, critical procedures represent a small proportion of encounters, and fellows and faculty members often have limited annual exposure [1]. According to a multinational survey, pediatric emergency clinicians believe that most critical procedures should be practiced annually through simulation and supervised training [2]. Exposure is constrained by a variable case mix, competition for procedures, patient safety considerations, and the need for senior clinicians to intervene during unstable cases.

Simulation-based education addresses this gap by allowing repeated practice without exposing patients to preventable harm. A 2023 systematic review found that pediatric simulation programs have been used in diverse clinical scenarios to develop knowledge, technical skills, communication, and team performance, although assessment methods and validation are heterogeneous [3]. Hands-on workshops can combine demonstration, deliberate practice, immediate feedback, and reassessment in a controlled environment. Recent multidisciplinary emergency preparedness training in otolaryngology found that procedure-focused simulation improves learners' preparedness in technical domains [4].

Pediatric airway management exemplifies a high-risk area in which infrequent exposure may threaten readiness. A rapid-cycle deliberate-practice curriculum for pediatric emergency medicine fellows is associated with improved simulated airway performance and better first-attempt intubation performance in clinical practice [5]. Simulation-based airway education also improves knowledge and procedural performance among medical interns [6]. In 2025, a structured pediatric simulation course was found to improve the timing and coordination of advanced airway management during simulated resuscitations [7]. An earlier randomized study found that video-enhanced instruction improves aspects of pediatric intubation performance [8].

Comparable educational deficiencies affect wound closure and orthopedic casting. A systematic review of suturing education identified variation in curricula, teaching approaches, assessment instruments, and opportunities for supervised practice [9]. A 2023 hands-on laboratory course for emergency physicians and trainees reported improvements in suturing performance and perceived educational usefulness after structured instruction [10]. Casting is dependent on equipment selection, sequential technique, molding, and postapplication assessment. In a randomized simulation study, stepwise video-assisted deconstruction produced better immediate forearm-casting performance than continuous demonstration, although performance declined at longer follow-up [11].

Multidisciplinary programs integrate suturing, pediatric airway management, and orthopedic casting for pediatric emergency practitioners and assess procedural performance and knowledge using paired preworkshop and postworkshop measures. Evaluating the 3-day Basic Emergency Skills Techniques 3N1 (BEST 3N1) workshop was necessary to determine whether an integrated, hands-on course would improve several low-frequency, clinically important pediatric emergency skills.

Methods

Study Design and Setting

We conducted a prospective pre-post interventional study during the 8th BEST 3N1 workshop. The workshop was conducted from February 11 to February 13, 2025, at the Simulation and Skills Development Centre, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia. The course was organized under the oversight of the Prince Sultan Military Medical City (PSMMC) BEST 3N1 Scientific Committee.

Participants and Recruitment

The available course registration dataset contained 99 candidate records. All eligible participants attending the workshop and working in pediatric emergency care settings were invited to participate in the study. The registration dataset contained a variable labeled "gender," with "male" and "female" as the available recorded categories, in addition to nationality, physician specialty, physician level, and training center. Sex assigned at birth and additional gender identities were not collected separately. Age and years of clinical experience were not collected. Personal identifiers, including names, mobile numbers, email addresses, and Saudi Commission for Health Specialties registration details, were used only for administrative registration or data matching and are not reported in the manuscript.

Analysis was conducted using complete matched preworkshop and postworkshop data for each assessment. The number of paired observations differed in outcomes because some participants withdrew and did not complete all workshop assessment components. Participants with incomplete or unmatched preworkshop and postworkshop data for a specific assessment were excluded from the specific analysis. The final paired analytic samples were 88 participants (88.9%) for the day 1 wound suturing checklist, 77 participants (77.8%) for the day 2 airway management checklist, 77 participants (77.8%) for the day 3 orthopedic casting competence assessment, and 94 participants (94.9%) for the written knowledge test. All 99 eligible candidates initially agreed to participate, and none declined participation at recruitment.

Intervention

BEST 3N1 is a standardized hands-on educational program introduced by PSMMC in 2017. The workshop evaluated in this study included 3 procedural domains: basic emergency suture techniques, pediatric airway management, and pediatric orthopedic emergencies and casting. The course program listed 24 continuing medical education hours, corresponding to 8 hours of scheduled educational activities per day during 3 consecutive days.

Day 1 focused on basic emergency suture techniques and included registration, welcoming activities, a pretraining competency assessment, introduction to instruments and sutures, supervised hands-on practice, candidate self-training with close feedback, a posttraining competency assessment, and a closing

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discussion. The structured suturing content included simple interrupted sutures, horizontal and vertical mattress sutures, buried and subcuticular sutures, hand injuries, facial injuries, and use of surgical glue and staplers.

Day 2 focused on pediatric airway management and included registration, a pretraining competency assessment, group rotation through airway workshop stations, candidate self-training with close feedback, a posttraining competency assessment, a multiple-choice knowledge examination, and a closing discussion. The airway stations included surgical cricothyrotomy; needle cricothyrotomy; pediatric ear, nose, and throat emergencies; simulation; direct laryngoscopy and supraglottic airways; and video laryngoscopy.

Day 3 focused on pediatric orthopedic emergencies and casting and included registration, a pretraining competency assessment, principles of orthopedic casting, group rotation through orthopedic workshop stations, candidate self-training with close feedback, a posttraining competency assessment, and a closing discussion. The orthopedic stations included hand and wrist casting; humerus, elbow, and clavicle casting; and foot, ankle, and knee casting.

Teaching was delivered by a multidisciplinary faculty. Faculty specialties represented in the course materials included pediatric emergency medicine; anesthesiology; pediatric surgery; plastic and maxillofacial surgery; ear, nose, and throat surgery; and orthopedic surgery, with technical support for relevant procedural stations.

Assessment Tools and Outcomes

Participants completed preworkshop and postworkshop assessments of procedural performance and knowledge. The primary outcomes were changes in checklist-based procedural performance, orthopedic casting competence assessed using a keyword-based rubric, and written knowledge test scores.

Day 1 and Day 2 Procedural Checklists

Day 1 wound suturing performance and day 2 airway management performance were assessed using station-based procedural checklists. Each checklist contained 4 items, and each item was scored from 0 to 2, where 0 indicated not done, 1 indicated partially done, and 2 indicated done well. The total checklist scores therefore ranged from 0 to 8 for each domain.

For day 1, the assessed suturing microskills were holding the instrument, grasping the needle, entering at 90°, and performing the knot-tying technique. Day 2 used the same 0 to 8 checklist-scoring structure for airway management performance. These checklists were program-specific assessment tools aligned with the workshop's learning objectives and station content.

Day 3 Orthopedic Casting Keyword Rubric

Day 3 orthopedic casting competence was assessed using a predefined, program-specific keyword-based rubric covering equipment preparation, procedural steps, and postapplication care. Each domain was scored from 0 to 10, resulting in a total score range of 0 to 30. The free-text responses were converted into scores using the predefined rubric. Separate independent ratings of the same free-text responses by multiple raters were not available, and inter-rater reliability could not be assessed.

Written Knowledge Test

Knowledge was assessed using a 30-item multiple-choice test administered before and after the workshop. Each item was scored as correct or incorrect, and the total score ranged from 0 to 30. Total knowledge scores were analyzed in the main manuscript.

Data Management

Assessment data were exported from the workshop assessment files and organized by assessment type. Participant identifiers were used to match preworkshop and postworkshop assessments. After matching, analyses were performed using only paired records. Participants with incomplete or unmatched data were excluded from the analysis of the affected outcome but were retained in other analyses when complete paired data were available. The course registration dataset was used to summarize available learner characteristics. Personally identifiable information was not included in the analysis tables or reported in the manuscript.

Statistical Analysis

Continuous paired outcomes were summarized using means and SDs, and medians and IQRs were reported where appropriate. Normality of the paired difference scores (postworkshop minus preworkshop) was assessed using the Shapiro-Wilk test and visual inspection of *Q-Q* plots. Day 1 wound suturing and day 2 airway management difference scores showed significant departures from normality (Shapiro-Wilk P=.01 and P=.02, respectively); these outcomes were analyzed using the Wilcoxon signed-rank test. P values were reported as the primary inferential result. Day 3 orthopedic casting competence scores and total written knowledge scores were analyzed using 2-tailed paired t tests. Within-participant effect sizes were reported using Cohen d_z where applicable.

Ethical Considerations

This study was reviewed and approved by the Institutional Review Board of PSMMC, Riyadh, Saudi Arabia (approval E-2598). Written informed consent was obtained from all participants for the use of their workshop assessment data. Participants were informed that study participation was voluntary, their data would be kept confidential, and they could withdraw at any time without consequences. Participants received no financial or nonfinancial compensation for their participation in the study.

Results

Course registration data were available for 99 candidates (Figure 1 and Table 1). Among the 99 participants, the registration gender field recorded 56 (56.6%) participants as male and 43 (43.4%) as female. Most candidates were Saudi (n=94, 95%), and the remaining candidates were Egyptian (n=3, 3%), Omani (n=1, 1%), and Bahraini (n=1, 1%). Most candidates were pediatric emergency fellows (n=93, 93.9%); the remaining participants were pediatric emergency specialists (n=4, 4%), a pediatric senior registrar (n=1, 1%), and a pediatric resident

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(n=1, 1%). By physician level, candidates were mainly fellow F1 (n=89, 89.9%), followed by specialists (n=5, 5.1%), fellow F2 (n=4, 4%), and resident R4 (n=1, 1%). The registration data represented 22 training centers.

Analyses of training outcomes were conducted using complete paired preworkshop and postworkshop data available for each assessment. The number of paired observations differed in outcomes; 88 participants were included in the day 1 wound suturing checklist analysis, 77 in the day 2 airway management checklist analysis, 77 in the day 3 orthopedic casting competence analysis, and 94 in the written knowledge test analysis. The paired sample sizes differed because some participants withdrew and did not complete all components of the workshop assessment. Participants with incomplete or unmatched preworkshop and postworkshop data for a specific outcome were excluded.

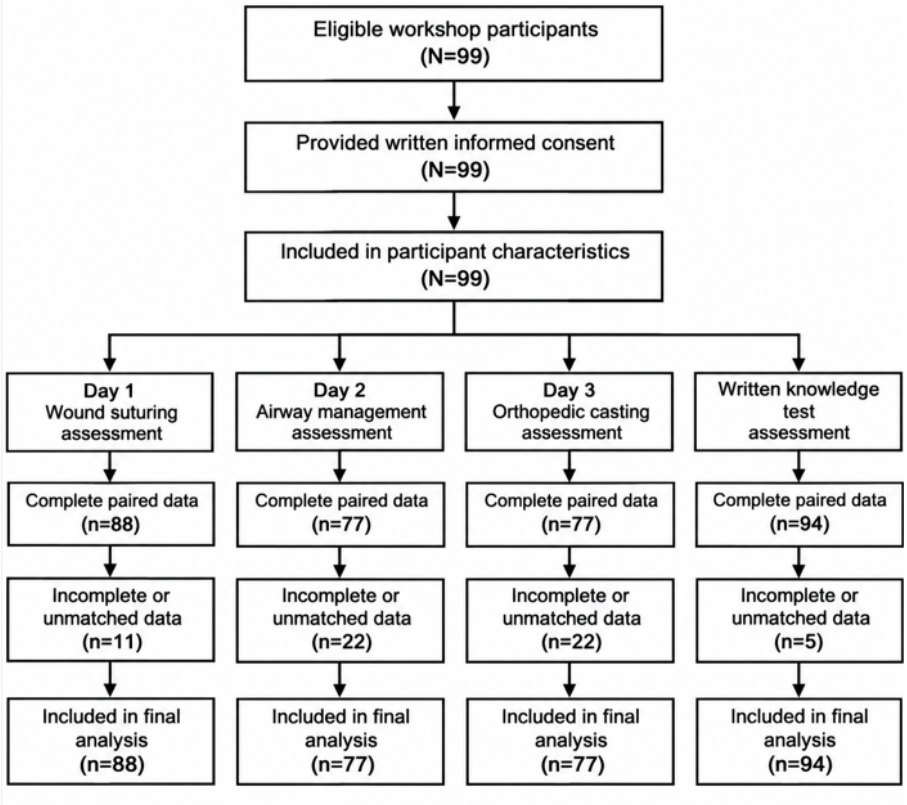
Day 1 focused on wound suturing skills, and checklist-based procedural performance improved after the workshop (Table 2). The mean total checklist score increased from 4.14 (SD 1.72) before training to 7.72 (SD 0.68) after training on a 0 to 8 scale. The mean change was 3.58 (SD 1.71) points, and the median change was 4.00 (IQR 2.75-5.00) points. Among the 88 paired participants, 83 improved, 4 had no change, and 1 had a lower postworkshop score. The Wilcoxon signed-rank test showed a statistically significant pre-post improvement (P<.001).

Day 2 focused on airway management skills, and checklist performance improved after the workshop (Table 2). The mean total score increased from 5.47 (SD 1.88) before training to 7.81 (SD 0.56) after training on the 0 to 8 scale. The mean change was 2.34 (SD 1.96) points, and the median change was 2.00 (IQR 1.00-4.00) points. Of the 77 paired participants, 63 improved, 12 had no change, and 2 had lower scores after the workshop. The Wilcoxon signed-rank test showed a significant improvement (P<.001). Compared with day 1, the mean change was smaller, while postworkshop performance remained high.

Day 3 assessed orthopedic casting competence using a keyword-based covering equipment, procedural steps, and postapplication care (Table 3). All components improved after training. The equipment score increased from 1.87 to 2.61, the procedural steps score increased from 1.49 to 2.43, and the postapplication care score increased from 0.84 to 1.35. The total competence score increased from 4.20 to 6.39 on a 0 to 30 scale, with a mean change of 2.19 (95% CI 1.80-2.58) points. The 2-tailed paired t test showed a significant improvement in the total day 3 score (P<.001), with a large within-participant effect size (Cohen d_z=1.27).

Among 94 participants with paired knowledge test data, the mean score increased from 19.04 (SD 3.77) before training to 22.32 (SD 3.23) after training on a 0 to 30 scale. The mean change was 3.28 (95% CI 2.16-4.39) points, and the 2-tailed paired t test showed a statistically significant improvement (P<.001), with a moderate effect size (Cohen d_z=0.60).

Figure 1. Participant flow.



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Table 1. Candidate characteristics from the course registration dataset (N=99)[a].

Characteristics	Values
Gender, n (%)	
Male	56 (56.6)
Female	43 (43.4)
Nationality, n (%)	
Saudi	94 (95)
Egyptian	3 (3)
Omani	1 (1)
Bahraini	1 (1)
Physician specialty, n (%)	
Pediatric emergency fellow	93 (93.9)
Pediatric emergency specialist	4 (4)
Pediatrics senior registrar	1 (1)
Pediatric resident	1 (1)
Physician level, n (%)	
Fellow F1	89 (89.9)
Fellow F2	4 (4)
Specialist	5 (5.1)
Resident R4	1 (1)

[a]The registration data represents 22 training centers.

Table 2. Pre-post procedural checklist performance by domain.

Workshop domain	Score range	Paired participants, n (%)	Preworkshop score, mean (SD)	Preworkshop score, median (IQR)	Postworkshop score, mean (SD)	Postworkshop score, median (IQR)	Mean change, mean (SD)	Median change (IQR)	Improved score, n (%), n	No change, n (%)	Worsened score, n (%)	Primary test	*P* value
Day 1: wound suturing checklist	0-8	88 (88.9)	4.14 (1.72)	4.00 (3.00-5.00)	7.72 (0.68)	8.00 (8.00-8.00)	3.58 (1.71)	4.00 (2.75-5.00)	83 (94.3)	4 (4.5)	1 (1.1)	Wilcoxon signed-rank test	<.001
Day 2: airway management checklist	0-8	77 (77.8)	5.47 (1.88)	6.00 (4.00-7.00)	7.81 (0.56)	8.00 (8.00-8.00)	2.34 (1.96)	2.00 (1.00-4.00)	63 (81.8)	12 (15.6)	2 (2.6)	Wilcoxon signed-rank test	<.001

Table 3. Pre-post orthopedic casting competence using the day 3 keyword rubric.

Competence domain	Score range	Paired participants, n (%)	Preworkshop score, mean (SD)	Postworkshop score, mean (SD)	Mean change (95% CI)	Effect size (Cohen d_z)	Primary test	*P* value
Equipment score	0-10	77 (77.8)	1.87 (0.91)	2.61 (0.88)	0.74 (0.54-0.93)	0.85	2-tailed paired *t* test	<.001
Procedural steps score	0-10	77 (77.8)	1.49 (1.02)	2.43 (0.97)	0.94 (0.72-1.15)	0.99	2-tailed paired *t* test	<.001
Postapplication care score	0-10	77 (77.8)	0.84 (0.48)	1.35 (0.52)	0.51 (0.42-0.61)	1.18	2-tailed paired *t* test	<.001
Total competence score	0-30	77 (77.8)	4.20 (1.85)	6.39 (1.68)	2.19 (1.80-2.58)	1.27	2-tailed paired *t* test	<.001

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Discussion

Principal Findings

The BEST 3N1 workshop was associated with immediate improvement in wound suturing, pediatric airway management, orthopedic casting competence, and written knowledge. Improvements across all domains indicate that a concentrated course combining demonstration, supervised practice, feedback, and reassessment strengthens performance in low-frequency pediatric emergency procedures. Differences between domains should not be interpreted as evidence that one component was superior because the assessments used different scales, methods, and baseline levels. Waters et al [12] reported that multidisciplinary in situ simulation improved team performance and use of a rapid sequence intubation checklist in a pediatric emergency department. Mustafa et al [13] also found that a collaborative simulation-based intervention improved pediatric advanced airway management processes in general emergency departments, and their findings support structured airway practice.

The suturing findings are consistent with research emphasizing active practice and feedback. Tejos et al [14] found that video-guided practice without peer or expert feedback was insufficient compared with feedback-supported approaches. Tieken et al [15] showed that feedback-containing instruction improved suturing and knot-tying performance, while Hanada et al [16] found improvement in objectively measured suturing quality after extended simulation practice. The supervised BEST 3N1 stations have supported learning by enabling correction of instrument handling, needle positioning, tissue entry, and knot-tying techniques.

The casting results are supported by orthopedic simulation research. Moktar et al [17] developed a cast-application simulator and objective checklist that produced scores reflecting training level and showed high rater reliability. Seeley et al [18] also validated a pediatric distal-radius reduction and casting model using objective procedural and radiographic outcomes. These studies support structured casting assessment and highlight the need to establish the reliability and validity of the program.

The improvement in written knowledge complements the procedural findings and indicates that hands-on instruction reinforces cognitive and psychomotor learning simultaneously. Lammers et al [19] found that simulation and procedural laboratory approaches improved selected pediatric emergency skills, although limited exposure did not consistently improve overall performance. Thim et al [20] concluded that pediatric emergency simulation improves time-critical performance and adherence to expected tasks, while noting variation in interventions and outcomes. A distinctive contribution is the integration of wound suturing, pediatric airway management, and orthopedic casting within one 3-day multidisciplinary program. This approach provides an efficient model for maintaining readiness in several procedural domains rather than organizing separate single-skill courses. Refresher sessions and standardized assessments could improve durability and reproducibility.

Limitations

This study had several limitations, and the findings should be interpreted in the context of its single-center, uncontrolled pre-post design; variable paired sample sizes; unblinded assessments; and program-specific assessment instruments. The day 3 free-text responses were not scored by multiple raters, and interrater reliability was not assessed. The orthopedic casting scores have been affected by subjective interpretation and rater-related measurement error. Long-term retention of procedural skills and transfer of workshop performance to clinical practice or patient outcomes were not assessed. Future evaluations should use independent raters, validated tools, retention testing, and clinical performance indicators.

Conclusions

The 3-day BEST 3N1 workshop was associated with immediate improvements in wound suturing, pediatric airway management, orthopedic casting competence, and written knowledge among pediatric emergency care practitioners. By integrating 3 low-frequency procedural domains within 1 multidisciplinary, hands-on program, the course offers a practical model for structured skills training in pediatric emergency medicine. Long-term retention, transfer of skills to clinical practice, and patient outcomes were not evaluated. Future studies should use validated assessment instruments, independent raters, longer follow-up, and multicenter controlled designs.

Funding

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Data Availability

The datasets generated and analyzed during this study are not publicly available because they contain participant-level information and data collected within an institutional educational program. Data are available from the corresponding author on request.

Generative AI Use

Generative AI, specifically ChatGPT (GPT-5; OpenAI), was used during manuscript revision to assist with language editing, grammatical correction, and the organization and clarity of selected sections of the manuscript. It was not used to collect or generate study data, conduct statistical analyses, determine the study findings, or make scientific or clinical decisions. All

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AI-assisted content was reviewed and revised by the authors and checked against the original study data and cited literature. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

Authors' Contributions

Conceptualization: SA, NA
Methodology: SA, NA, FA, TAG, AA, BA, MA, RH
Investigation: BA, MA, RH
Data curation: NA, FA, TAG, AA, BA
Formal analysis: SA, NA
Project administration: SA, NA
Resources: FA, TAG, AA, BA, MA
Supervision: SA
Visualization: NA, FA, TAG, AA
Writing—original draft: SA, NA, FA, TAG, AA, BA, MA, RH
Writing—review & editing: SA, NA, FA, TAG, ASA, BA, MA, RH
All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.

Conflicts of Interest

None declared.

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Abbreviations

BEST 3N1: Basic Emergency Skills Techniques 3N1
PSMMC: Prince Sultan Military Medical City

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