

Clinical Performance in Critical Care Simulation under Sleep Deprivation: Effects of Power Napping in the Recovery Napping Protocol for Anesthesiologist Performance (R-NAP) Randomized Controlled Trial

Laura Schmidt, Ph.D., Florian Genty, M.D., Thomas Delaire, M.D., Berenice Valero, M.Sc., Isaline Rey, M.Sc., Leslie Galan, R.N., Sacha Mairret-Mabboux, M.Sc., Marion Douplat, M.D., Ph.D., Sophie Schlatter, Ph.D., Thomas Rimmele, M.D., Ph.D., Stephanie Mazza, Ph.D., Marc Lilot, M.D., Ph.D.

ANESTHESIOLOGY 2026; 145:1008–21



ABSTRACT

Background: Sleep deprivation is common among anesthesia residents and impairs both technical and nontechnical skills such as leadership. Napping is recommended in fatigue management across healthcare and other safety-sensitive sectors, yet its effectiveness for healthcare providers remains underexplored. This study evaluated whether a 30-min nap opportunity improved simulated crisis performance after a 24-h shift.

Methods: Residents were tested twice: once rested and once using a 24-h shift to induce partial sleep deprivation. Between sessions, they were trained in fatigue management. In the sleep-deprived condition, they were randomized to a nap opportunity or a control condition. Actigraphy objectively assessed sleep and nap duration. The primary endpoint was overall simulated clinical performance (0 to 200; combined technical and nontechnical scores). Secondary endpoints were technical and nontechnical subscales. Group effects were primarily tested using intention-to-treat regression models adjusted for rested performance, previous sleep, and critical care experience.

Results: Thirty-five residents were enrolled (nap opportunity, $n = 19$; control, $n = 16$). In the primary analysis sample ($n = 27$), clinical performance was 14.8 points higher after the nap opportunity compared with controls (95% CI, 2.8 to 26.9; $P = 0.018$), corresponding to a 7.4% improvement. Technical skills did not differ significantly between groups, although more sleep was associated with better technical performance. Nontechnical skills were higher in the nap opportunity condition (+11.0 points; 95% CI, 2.2 to 19.8; $P = 0.016$), including significant effects of leadership and resource utilization. Exploratory analyses suggested associations between longer nap duration and multiple performance domains, strongest for technical skills ($P = 0.010$).

Conclusions: Napping appears to enhance clinical performance, while the nap opportunity, nap duration, and previous sleep deprivation each influenced technical and nontechnical performance in distinct ways. These findings support integrating napping and recovery into medical education and scheduling.

(ANESTHESIOLOGY 2026; 145:1008–21)

EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Sleep deprivation is common among residents and can lead to impaired clinical judgment
- Napping strategies have been proposed to improve resident performance and well-being, but implementation is limited and effectiveness uncertain

What This Article Tells Us That Is New

- This randomized study from four French university-affiliated sites evaluated performance of sleep-deprived residents during clinical simulation with or without a nap opportunity
- Clinical performance and technical and nontechnical skills were associated with improvement in different domains with napping
- Investigation of these associations in a real-world clinical setting will assist in widespread implementation of such strategies

This article is featured in "This Month in ANESTHESIOLOGY," page A1. This article is accompanied by an editorial on p. 825. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org). Martin J. London, M.D., served as Handling Editor for this article. This article has a video abstract. Part of the work presented in this article was presented at the Congrès Annuel de la Société Française d'Anesthésie et de Réanimation in Paris, France, September 17, 2025. Earlier work on the Recovery Napping Protocol for Anesthesiologist Performance decision-making process was presented at the Association for Medical Education in Europe Conference in Basel, Switzerland, August 24 to 28, 2024. S.M. and M.L. are co-senior authors.

Submitted for publication October 8, 2025. Accepted for publication April 21, 2026. Published online first on May 8, 2026.

Copyright © 2026 American Society of Anesthesiologists. All Rights Reserved. ANESTHESIOLOGY 2026; 145:1008–21. DOI: 10.1097/ALN.0000000000006135

Abbreviations: ITT, intention to treat; TST-Shift, total sleep time from 24-h shift start to afternoon testing session next day

Sleep deprivation is common among anesthesia and intensive care residents, primarily caused by night shifts, extended working hours, and the continued expectations of 24-h shifts.^{1,2} This chronic lack of sleep significantly impacts emotional processing, cognitive function, and behavior.³ It has also been associated with higher risks of medical errors leading to potential serious adverse events in critical care settings.⁴ In addition, shift work and long-term sleep deprivation have been associated with an increase in metabolic and cardiovascular diseases, cancer, and vehicle accidents.⁵ Moreover, the strain of night shifts contributes to burnout, depression, and early career attrition among healthcare professionals.

Impairments in vigilance and attention observed in sleep deprivation protocols^{2,6} have also been demonstrated in anesthesiologists in controlled environments.^{7,8} Only a few studies have evaluated the impact of nighttime work on clinical performance in real-world settings, without directly isolating the specific effect of sleep deprivation.^{9,10} Despite growing awareness of the risks posed by fatigue and a scoping review on the topic,¹¹ most studies have focused on the effects of sleep deprivation, leaving a gap in rigorously evaluating practical recovery strategies for sleep-deprived healthcare professionals.

Workplace napping is a frequent countermeasure among healthcare shift workers.¹² It has been shown to improve alertness, reduce fatigue, and enhance cognitive performance.^{13,14} Such fatigue mitigation strategies have been implemented across other high-pressure environments,

including among National Aeronautics and Space Administration (Washington, D.C.) pilots during critical flight phases¹⁵ and historically in sustained military or commercial operations incorporating planned sleep opportunities.^{16–18} The meta-analysis by Dutheil *et al.* confirmed that short naps, also called power naps, of less than 30 min improve cognitive performance while minimizing the risk of sleep inertia.¹³ Healthcare professionals' napping strategies may deviate from recommendations, and effective napping should consider previous sleep history for optimal results.¹⁹ However, despite the widespread use of napping, nap intervention studies have focused primarily on nurses, with outcomes mostly centered on sleep, fatigue, vigilance, and self-reported measures.²⁰ Otherwise, systemic changes of working hours were evaluated with regard to medical errors.⁴ As a result, there is limited performance-specific evidence to guide best individual practice for medical professionals in anesthesia and intensive care units, whose high-stakes tasks are particularly vulnerable to fatigue.¹¹

Evaluating how hypovigilance translates in real clinical performance remains challenging given the complexity of healthcare environments.²¹ For this purpose, full-scale simulation offers a controlled environment to capture clinical performance under realistic conditions in a high-stress environment.²² Some simulation studies reported successful evaluation using both technical and nontechnical skills to holistically capture clinical performance.^{23,24} Nontechnical skills are defined as the

Laura Schmidt, Ph.D.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Forgetting Team, Lyon Neuroscience Research Center (CRNL) U1028 UMR5292, National Institute of Health and Medical Research (INSERM), National Center for Scientific Research (CNRS), Bron, France.

Florian Genty, M.D.: Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France; Departments of Anesthesia and Intensive Care Medicine, Hospices Civils Lyon, Lyon, France.

Thomas Delaire, M.D.: Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France; Departments of Anesthesia and Intensive Care Medicine, Hospices Civils Lyon, Lyon, France.

Berenice Valero, M.Sc.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Human Sciences Department, Centre Léon Bérard, Lyon, France.

Isaline Rey, M.Sc.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Forgetting Team, Lyon Neuroscience Research Center (CRNL) U1028 UMR5292, National Institute of Health and Medical Research (INSERM), National Center for Scientific Research (CNRS), Bron, France.

Leslie Galan, R.N.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France.

Sacha Mairet-Mabboux, M.Sc.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Hospices Civils Lyon, Pediatric Cardiac Thoracic Vascular

Anesthesia and Intensive Care Unit 11, Medical-Surgical Department of Congenital Cardiology of the Fetus, Child and Adult, Louis Pradel Hospital, Bron, France.

Marion Douplat, M.D., Ph.D.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France; Hospices Civils Lyon, Emergency Department, Lyon Sud Hospital, Lyon, France.

Sophie Schlatter, Ph.D.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France.

Thomas Rimmele, M.D., Ph.D.: University Claude Bernard Lyon 1, Research on Healthcare Performance, INSERM U1290, Lyon, France; Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France; Hospices Civils Lyon, Departments of Anesthesia and Intensive Care Medicine, Lyon, France.

Stephanie Mazza, Ph.D.: Claude Bernard Lyon 1 University, Forgetting Team, Lyon Neuroscience Research Center (CRNL) U1028 UMR5292, National Institute of Health and Medical Research (INSERM), National Center for Scientific Research (CNRS), Bron, France.

Marc Lilot, M.D., Ph.D.: Claude Bernard Lyon 1 University, Research on Healthcare Performance, National Institute of Health and Medical Research (INSERM) U1290, Lyon, France; Claude Bernard Lyon 1 University, Healthcare Simulation Center (CLESS, Centre Lyonnais d'Enseignement par la Simulation en Santé), Lyon University Hospital Health Simulation Center (SimULyon), Lyon, France; Hospices Civils Lyon, Pediatric Cardiac Thoracic Vascular Anesthesia and Intensive Care Unit 11, Medical-Surgical Department of Congenital Cardiology of the Fetus, Child and Adult, Louis Pradel Hospital, Bron, France.

cognitive, social, and personal resource skills that complement technical skills and contribute to safe and efficient task performance.²⁵ Consequently, these skills declined simultaneously among sleep-deprived anesthetists managing critical clinical situations during full-scale simulations.^{26–28}

The current study aimed to close the gap on rigorous interventional studies and to evaluate the effectiveness of a power nap taken during extended wakefulness as a performance-enhancing strategy for sleep-deprived anesthesia and intensive care residents. Sleep deprivation was operationalized with 24-h shifts rather than adding an additional controlled laboratory sleep deprivation protocol to already demanding schedules. Using full-scale simulation with a high-fidelity manikin, we hypothesized that residents who took a nap would demonstrate less deterioration in clinical performance from their rested baseline compared to those who remained awake and engaged in usual activities during the break.

Materials and Methods

Design

The Recovery Napping Protocol for Anesthesiologist Performance (RNAP) trial was a prospective, randomized, parallel-group trial (1:1). Ethical approval was obtained in June 2022 (institutional review board No. 00010254-2022-085). The trial submitted on ClinicalTrials.gov in September 2022 (NCT05619081, <https://clinicaltrials.gov/ct2/show/NCT05619081>; preregistered on November 11, 2022; principal investigator, Marc Lilot) and publicly posted on November 16, 2022. No changes were made to the trial protocol, outcomes, or analyses. All subjects gave their written consent. The study used a pre-post repeated-measures randomized single-blind intervention design, with participants completing two full-scale simulation sessions. At the second session, participants were randomly assigned in a 1:1 ratio to either a nap opportunity (nap) or control condition (no nap) by drawing one of two identical opaque envelopes prepared and shuffled by research staff immediately before allocation.

Due to the nature of the behavioral intervention, participants were not blinded to group assignment. The simulation team and performance assessors were not present during randomization, were blinded to group allocation, and received only coded materials. This study followed the recommendations of the International Committee of Medical Journal Editors, and the results were reported using the Consolidated Standards of Reporting Trials guidelines.²⁹ No monitoring committee or interim analysis was planned.

Population and Setting

Eligible participants were second- to fifth-year residents in anesthesia and intensive care from four affiliated university hospital departments (Claude Bernard Lyon 1 University, Lyon, France), regularly working 24-h shifts on-site (approximately once per week). Residents were recruited *via* email and word of mouth. Simulation sessions were conducted at the Lyon Est teaching medical center for simulation in healthcare (Centre Lyonnais d'Enseignement par Simulation en Santé, Lyon, France; Centre de Simulation Hospitalo-Universitaire en Santé de Lyon, Lyon, France) using a high-fidelity SimMan Essential manikin (Laerdal Medical AS, Norway). Data collection occurred from November 8, 2022, to June 22, 2023, in the afternoons with variable start times ranging from 12:00 PM to 5:00 PM. Sessions were timed to align with the circadian dip and typical nap timing. To test residents sleep-deprived without adding new sleep constraints, partial sleep deprivation was naturally induced through a 24-h shift (8:00 AM to 8:00 AM, from one morning to the next). After shift completion, residents were released from clinical duties, and no restrictions were imposed on their activities until the scheduled study session (minimum interval, 4 h). Additional sleep was permitted provided total sleep during and after the shift did not exceed 5 h. Pre- and postsimulation interventions were delivered by research staff (B.V., I.R.), and sessions conducted by simulation staff (F.G., T.D.) under faculty supervision (M.L.).

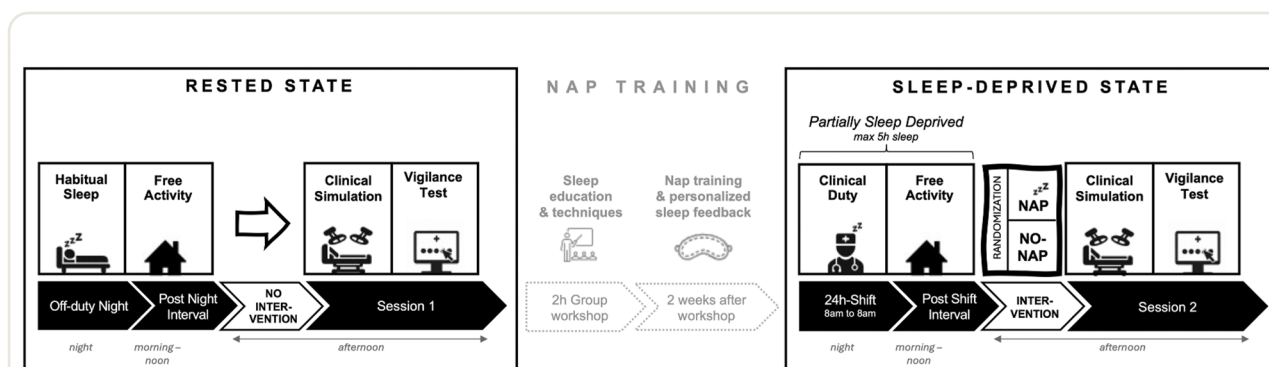


Fig. 1. Study protocol. Study design showing the rested condition, a 2-h nap training workshop with a 2-week practice period, and the sleep-deprived condition after a 24-h shift with or without a 30-min nap opportunity. max, maximum.

Protocol

The chronological protocol is described in fig. 1. Critical care scenarios were deliberately designed as novel stress-testing environments for decision-making under high-pressure, resource-limited conditions, rather than as instructional simulation exercises aimed at skill acquisition with feedback or debriefing.³⁰ This approach was consistent with recent work using simulation to evaluate the impact of physiologic or cognitive states on performance.²³ Each scenario began with a 5-min audio briefing describing the clinical situation of an unconscious patient who needed to be diagnosed and treated for cardiac arrest. Participants then managed a full-scale patient simulation with a pre-defined sequence of deterioration (cardiac arrest, return of spontaneous circulation, secondary instability), limited resource availability, and scripted facilitator responses to ensure standardization across participants. No debriefing was performed to prevent contamination effects. Full scripts and work load ratings (National Aeronautics and Space Administration Task Load Index)³¹ are available in Supplemental Digital Content 1 (<https://links.lww.com/ALN/E542>).

Nap Training

All participants took part in a brief training program led by a health psychologist on sleep physiology and rest optimization strategies followed by a 2-week period of nap training in real-world conditions. Training was supported by objective sleep-wake rhythms discussed in private consultations to provide personalized feedback (details in Supplemental Digital Content 2, <https://links.lww.com/ALN/E543>) and introduced novel content, as no sleep or shift work training is currently covered in French medical curricula.

Intervention

After the night shift, participants were randomly assigned to either the nap group or the no nap group before simulation (fig. 1). Upon arrival in the quiet intervention room, they were fitted with an ambulatory electrocardiogram (data not reported) and completed questionnaires.

Nap Group (Intervention). Participants had a 30-min nap opportunity in a quiet, darkened room on a hospital stretcher under staff supervision. An alarm signaled the end of the nap, after which they followed a brief reactivation routine, completed questionnaires, and walked to the simulation center, providing a 15-min buffer before testing to minimize sleep inertia.³²

No Nap Group (Control). Participants remained in the quiet room for 30 min, reading or using phones under staff supervision to ensure wakefulness. They then completed questionnaires and walked to the simulation center.

No concomitant interventions (*e.g.*, caffeine) were permitted during the intervention period. However, caffeine consumption before the start of the intervention was not monitored. Adherence to protocol (including nap duration and wakefulness) was monitored *via* rest-wake activity in both groups.

Sleep Monitoring

Rest-wake activity was measured using actigraphy bracelets (Actiwatch, Philips Respironics, USA). Participants pressed a button to indicate bedtimes and wake times. Sleep onset/offset were estimated from accelerometer data scored in 30-s epochs using validated thresholds and analyzed with Actiware (Philips Respironics) software (v6.0.1). For personalized recovery training, participants wore actimetry devices during an extended period 1 week before the first session (rested condition) with the main purpose to use these sleep/wake patterns in training consultations. To control partial sleep deprivation, total sleep time from the start of the 24-h shift until the testing session (TST-Shift) was monitored. This variable therefore captured all sleep obtained during the shift as well as any additional sleep during the postshift morning interval when participants were free from clinical duties. Sleep at home between the shift end and noon was not prohibited as long as overall sleep limits (5h) were respected. Furthermore, time since last awakening was computed to determine the period awake since the last sleep bout of at least 30 min to account for differences in sleep timing. Participants who slept more than 5h were rescheduled. Nap duration during the intervention was also monitored.

Questionnaires

Baseline demographic data (sex, age, residency year, critical care and shift experiences, and consumption habits) and validated questionnaires were collected in the first seating: Morningness-Eveningness Questionnaire (chronotype),³³ Insomnia Severity Index,³⁴ Pittsburgh Sleep Quality Index,³⁵ and the emotional exhaustion subscale of the Maslach Burnout Inventory.³⁶ Workload of the 24-h shift before simulation was measured with a visual analog scale (anchored from 0, low workload, to 100, high workload). Sleepiness as a relevant state variable was measured before each session with the Karolinska Sleepiness Scale³⁷ and the Epworth Sleepiness Scale.³⁸

Endpoints

The primary outcome was overall simulated clinical performance, computed as the sum of technical and nontechnical scores (each normalized to 100; total range, 0 to 200), reflecting clinical competence in critical care. The primary analysis compared performance between groups during the postshift simulation (sleep-deprived condition).

Secondary outcomes included technical and nontechnical subscale scores, which are standard in simulation-based

assessment and allow for detailed characterization of performance.²⁴

Technical skills for each of the two scenarios was assessed with a 100-point evaluation grid. Checklists are available in Supplemental Digital Content 1 (<https://links.lww.com/ALN/E542>) and were collaboratively developed by simulation instructors and anesthesia and intensive care physician specialists, with local and national experts on the clinical situation, taking into account available guidelines as well as the particularities of each scenario. Thirty-four points were allocated to cardiac arrest management during the cardiac arrest phase, and 66 points to post-cardiac arrest management (clinical reasoning phase), which involved diagnostic and therapeutic considerations. Actions were scored based on timeliness and self-initiation: full points were awarded for timely, self-initiated actions; partial points for delayed or facilitated actions; and no points for actions not performed or requiring explicit facilitation. For technical scoring, both blinded assessors first rated the same four videos (two videos per scenario) independently to ensure a shared understanding of item definitions. When scoring discrepancies between blinded assessors (E.G. and L.G.) occurred, they were discussed between the two; if consensus could not be reached, a third blinded assessor (M.L.) adjudicated. The final technical score was calculated as the average of all assessments.

Nontechnical skills were assessed using the Ottawa Crisis Resource Management Global Rating Scale,³² developed for medical simulation. The six subscale scores range from 1 to 7 linked to validated behavioral anchors, for a total of 42 raw points normalized to 100 points. The subscales were “Overall,” “Leadership,” “Problem Solving,” “Situational Awareness,” “Resource Utilization,” and “Communication.” Two blinded assessors (L.S. and T.D.), already familiar with the scale, independently scored the first four videos (two videos per scenario), and any discrepancies were reviewed with M.L. (senior simulation expert). This initial concordance round ensured consistent application of the scoring criteria before rating the full dataset. Discrepancies in subjective ratings (defined as differences of 2 or more points on subscales) were discussed and resolved by consensus. If consensus could not be reached, the third blinded assessor (M.L.) adjudicated. The final nontechnical score was calculated as the average of all assessments.

Statistical Analysis

A priori sample size was determined for repeated-measures multivariate testing to detect a medium effect size ($f = 0.25$, equivalent to Cohen's $d = 0.5$ with two groups and two time points, $\alpha = 0.05$, power = 0.95, and 0.5 correlation between measures). Power analysis was performed using G*Power (version 3.1.9.7, Heinrich Heine University Düsseldorf, Germany), which indicated a required total sample size of 42 participants.

Statistical analyses were conducted using Jeffrey's Amazing Statistics Program (v0.18.3, University of

Amsterdam, Netherlands). Descriptive statistics (mean $\pm$ SD, median, interquartile range) summarized the data, with normality assessed *via* Kolmogorov–Smirnov tests and visual inspection. Planned analyses comparing performance across conditions were conducted only on residents completing both sessions. Independent *t* tests and Fisher exact tests compared demographic variables.

For the primary intervention analysis, sleep-deprived performance was modeled as a function of group assignment (nap *vs.* no nap) while controlling for rested performance, TST-Shift, and critical care experience. Analyses focused on intention to treat (ITT); additional per-protocol models assessed robustness. The TST-Shift coefficient was also examined as an index of sleep loss exposure.

To account for varying actual sleep duration during the nap window, an additional exploratory as-treated analysis examined associations between nap duration and performance change (delta between rested and sleep-deprived condition), still controlling for TST-Shift and critical care experience. For comparability, all participants in the no nap group and nap participants who did not sleep were assigned a nap duration of 0 min. The exploratory analysis was hypothesis-generating.

Model assumptions were verified through residual inspection. Effect sizes and 95% CI were reported. Effect sizes are presented as partial η^2 , reflecting the proportion of outcome variance uniquely attributable to each predictor after adjustment for covariates. In the current models, this primarily represents the variance in performance uniquely explained by group assignment. All participants were analyzed according to their randomized group assignment. Participants with missing outcome data for both time points were excluded from analysis; otherwise, available case analysis and intention to treat were applied. Missing data were assumed random; no imputation was performed. Exploratory analyses were *post hoc*; no subgroup or sensitivity analyses were planned. All statistical tests were two-sided, with significance set at $P < 0.05$.

Artificial Intelligence

The authors used an artificial intelligence language model (ChatGPT, OpenAI, USA, GPT-5, 2025) for writing assistance during manuscript drafting, specifically for language editing and style refinement. The artificial intelligence tool was not used for data collection, analysis, or figure generation. All substantive content was produced and verified by the authors, who are fully responsible for the final manuscript.

Results

Population Characteristics

A total of 44 residents were included in the study, of whom 35 completed both sessions. These 35 participants were

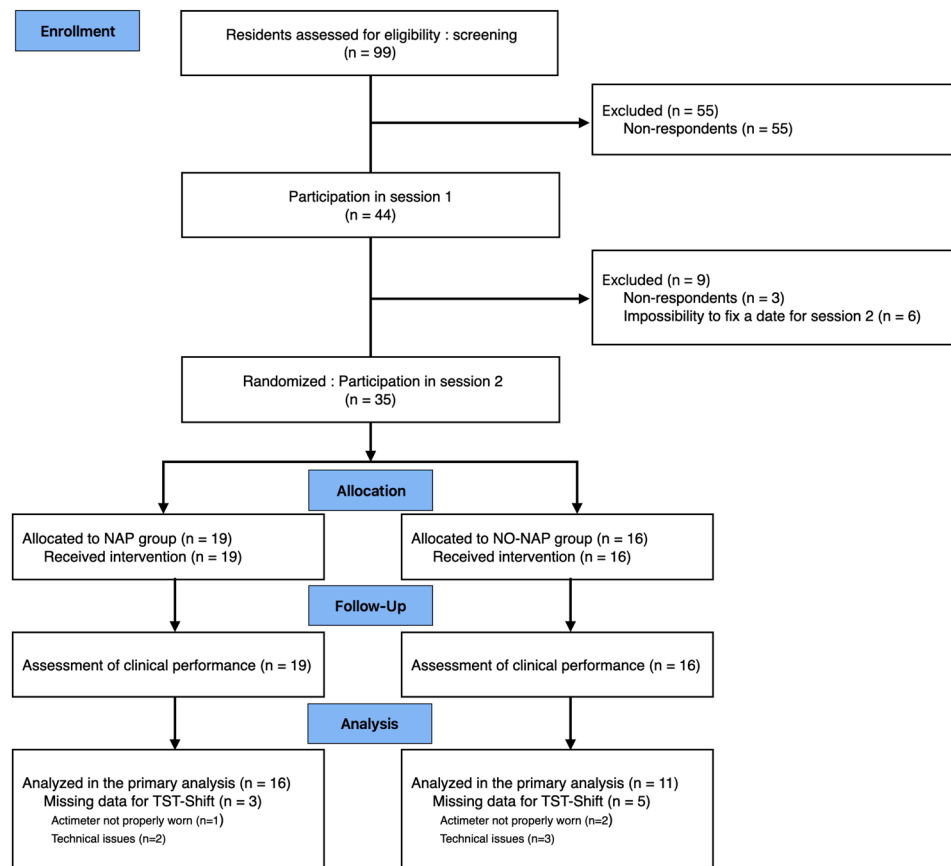


Fig. 2. Study flow chart. Consolidated Standards of Reporting Trials diagram showing participant flow through the trial: screening, enrollment, randomization, allocation to nap or no nap groups, and analysis. TST-shift, total sleep time from 24-h shift start to afternoon testing session next day.

randomized in the sleep-deprived condition, with 19 residents allocated to the nap and 16 to the no nap group. After excluding 8 participants with missing actigraphy sleep data (3 not properly worn, 5 technical issues), 27 residents were retained for the primary ITT model incorporating total sleep time during the sleep-deprived condition (fig. 2). The mean interval between rested (November to January) and sleep-deprived (March to June) simulation sessions was 107 ± 38 days (range, 35 to 204). Demographic data and the results from the sleep and burnout questionnaires are presented in table 1, and no significant differences were observed between the nap and no nap groups. No adverse events or harms related to the interventions were observed during the study.

Sleep Parameters

The median [interquartile range] total sleep time during the rested condition was 6.6 [5.6, 7.5] h, which was as expected significantly higher than in the sleep-deprived condition with 3.6 [2.5, 4.5] h (mean difference, 3.5 h; 95% CI, 2.5 to 4.4; $P < 0.001$). While sleep-deprived, no significant

difference in TST-Shift between groups was observed (no nap, 3.65 ± 1.61 h; nap, 2.84 ± 1.46 h; mean difference, 0.81 h; 95% CI, -0.41 to 2.04 ; $P = 0.185$). Overall sleepiness (table SM1 in Supplemental Digital Content 3, <https://links.lww.com/ALN/E544>) did not change significantly across sessions, and groups did not differ when sleep-deprived ($t = 0.83$; $P = 0.409$). Immediate sleepiness increased substantially from rested to sleep-deprived ($t[34] = 12.4$; $P < 0.0001$) as expected and yielded no group difference either ($t = 1.36$; $P = 0.183$). Seven participants obtained additional sleep between shift completion and testing while remaining within the predefined 5-h sleep limit. Although individual sleep timing varied, time since last awakening values did not differ statistically between groups (no nap, 7.93 ± 8.15 ; nap, 9.54 ± 6.41 ; mean difference, -1.61 ; 95% CI, -7.81 to 4.60 ; $P = 0.59$). Of the 19 participants of the nap group, 17 (89%) slept during the nap opportunity (2 protocol deviations). They spent an average of 22 ± 10 min (mean $\pm$ SD) in bed, and effectively napped 15 ± 8 min. No sleep was detected in the no nap group during the quiet wakefulness period. No protocol crossover or additional interventions occurred in

Table 1. Baseline Characteristics of Participants

	No Nap (n = 16)	Nap (n = 19)
Women	8 (50)	9 (47)
Age, yr	27 [27, 28]	27 [26, 29]
Year of residency		
2	6 (38)	10 (53)
3	9 (56)	5 (26)
≥ 4	1 (6)	4 (21)
Critical care experience, yr	2 [1, 2]	1 [1, 2]
Shift work experience, yr	3 [2, 4]	4 [2, 4]
Shift workload rating (VAS)	62 ± 26	67 ± 21
Cups of coffee per day	3 [2, 3]	3 [2, 4]
Insomnia Severity Index	7 [5, 10]	9 [6, 14]
Pittsburgh Sleep Quality Index	6 [5, 6]	6 [5, 7]
Morningness–Eveningness Questionnaire		
Eveningness	0 (0)	2 (11)
Neutral	8 (50)	12 (63)
Morningness	8 (50)	5 (26)
Emotional exhaustion	16 [11, 22]	20 [11, 25]

Values are expressed as No. (%), median [Q1, Q3], or mean ± SD.
VAS, visual analog scale.

either group. Reclassification applied only in exploratory as-treated analyses.

Primary Outcome: Simulated Clinical Performance

Descriptive results are presented in Supplemental Digital Content 3 (<https://links.lww.com/ALN/E544>), and figure 3 shows performance across conditions and groups. Rater agreement was substantial for both technical and nontechnical performance evaluations. Discrepancies between assessors on technical objectified checklists were all resolved by consensus. For more subjective nontechnical performance evaluation, the raters were able to agree on all 15 discrepancies, and the interrater reliability of the Ottawa Crisis Resource Management Global Rating Scale was substantial for both conditions, in the rested ($K = 0.685$; 95% CI, 0.527 to 0.842) and the sleep-deprived states ($K = 0.672$; 95% CI, 0.515 to 0.828).

Model diagnostics did not indicate major violations of linear regression assumptions. In the ITT model ($n = 27$; table 2), the nap group showed a 14.8-point clinical performance advantage over the no nap group (95% CI, 2.8 to 26.9; $P = 0.018$; partial $\eta^2 = 0.23$, representing the proportion of variance in performance uniquely explained by group assignment) equivalent to a 7.4% gain in clinical performance (adjusted $R^2 = 35\%$), indicating a moderate beneficial effect of the intervention. This was mirrored by the per-protocol model as detailed in figure 4 and table SM2 in Supplemental Digital Content 3 (<https://links.lww.com/ALN/E544>). Beyond group assignment, TST-Shift exhibited a positive but nonsignificant trend within the same adjusted ITT model (table 2; $\beta = 3.87$; $P = 0.056$).

Technical Skills

The group effect was small and nonsignificant for technical skills ($\beta = 3.76$; 95% CI, -2.58 to 10.10 ; $P = 0.232$; partial $\eta^2 = 0.06$). Preshift sleep (TST-Shift) showed a significant positive association ($\beta = 2.61$; $P = 0.020$). When testing the cardiac arrest and clinical reasoning phases individually, there were no significant group effects.

Nontechnical Skills

Nontechnical skills were significantly higher in the nap group ($\beta = 11.03$; 95% CI, 2.22 to 19.84; $P = 0.016$; partial $\eta^2 = 0.23$), amounting to a 11% advantage (adjusted $R^2 = 32\%$). TST-Shift showed no significant association. Across subscales, significant group advantages for the nap condition were observed for “Overall” nontechnical skills ($\beta = 0.77$; $P = 0.036$), “Leadership” ($\beta = 0.73$; $P = 0.037$), and “Resource Utilization” ($\beta = 1.02$; $P = 0.043$). “Problem Solving,” “Situational Awareness,” and “Communication” showed nonsignificant trends in the same direction. TST-Shift was not significantly associated with any subscale.

Exploratory Analysis

In the as-treated analysis ($n = 27$), longer nap duration was associated with better performance across several domains, with significant positive effects for simulated clinical performance ($\beta = 0.83$; 95% CI, 0.19 to 1.47; $P = 0.019$) and the technical post–cardiac arrest clinical reasoning phase ($\beta = 0.39$; 95% CI, 0.12 to 0.66; $P = 0.010$). Nap duration also predicted higher nontechnical skills scores ($\beta = 0.22$; 95% CI, 0.02 to 0.43; $P = 0.038$), as well as improvements on selected subscales, including “Overall” ($\beta = 0.04$; 95% CI, 0.00 to 0.07; $P = 0.050$), “Problem Solving” ($\beta = 0.04$; 95% CI, 0.00 to 0.07; $P = 0.051$), and “Communication” ($\beta = 0.05$; 95% CI, 0.01 to 0.09; $P = 0.019$). TST-Shift was consistently related only to technical outcomes, including total technical skills ($\beta = 3.20$; $P = 0.007$) and the clinical reasoning subscale ($\beta = 2.15$; $P = 0.024$) and a trend for the cardiac arrest phase (fig. 5 and table SM3 in Supplemental Digital Content 3, <https://links.lww.com/ALN/E544>).

See Supplemental Digital Content 3 (<https://links.lww.com/ALN/E544>) for details on cognitive vigilance and performance interrelations.

Discussion

This randomized controlled trial tested whether a short nap improves sleep-deprived residents’ performance in critical care simulation. Adjusting for rested baseline, sleep deprivation and critical care experience, the group assigned to the nap opportunity performed 7% better than controls (up to 8% with effective nap exposure). These findings appear potentially relevant to demanding clinical settings and contribute to evidence on implementable strategies in real-world healthcare.³⁹ Despite a large, standardized effect,

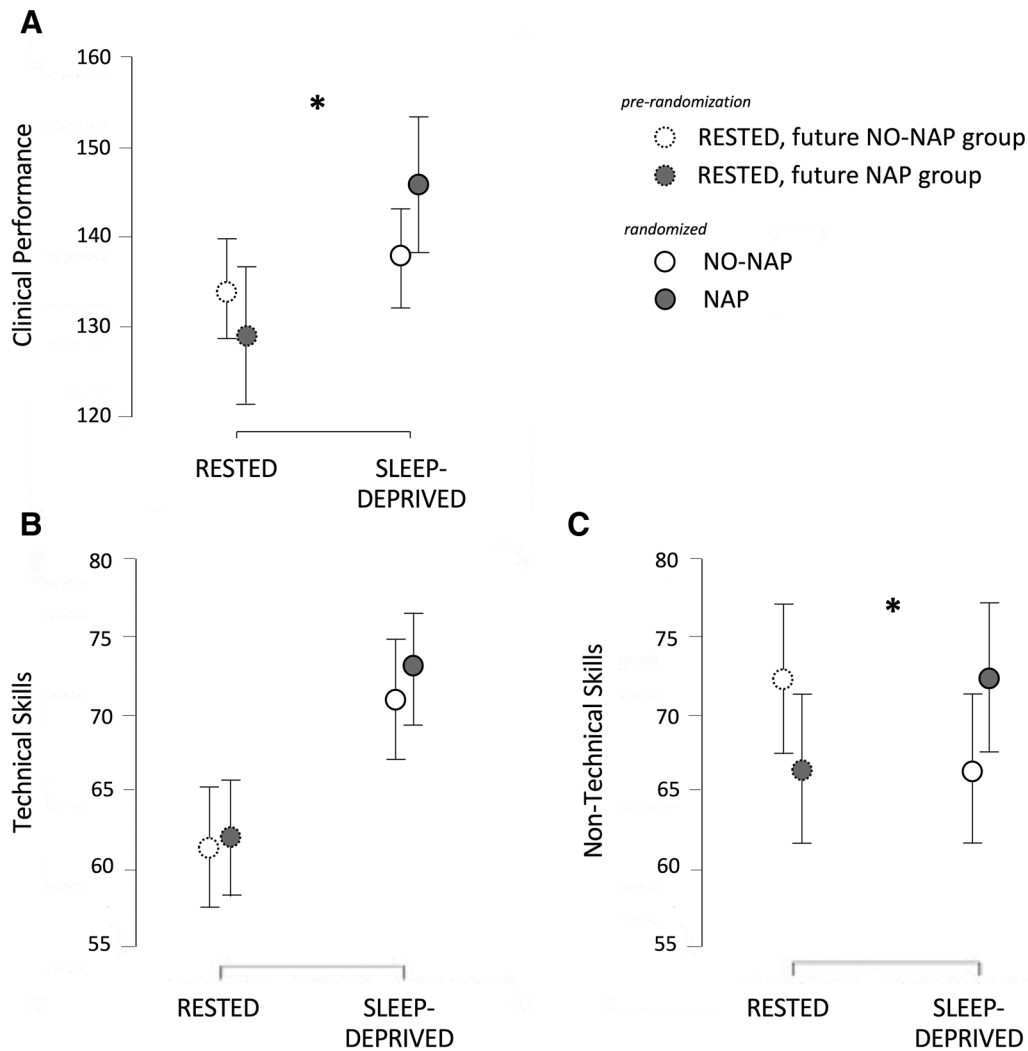


Fig. 3. Performance by group and intervention. Mean $\pm$ SEM performance as a function of experimental condition and intervention group. (A) Clinical performance, (B) technical skills, and (C) nontechnical skills. Nonfilled (white) symbols represent the no nap group and filled (gray) symbols the nap group; in the rested condition, these correspond to participants before randomization (dotted markers). *Significant group effect (nap vs. no nap), $P < 0.05$.

limited precision and absent thresholds restrict clinical interpretation. Nevertheless, even modest gains may be meaningful in high-risk environments, as 3 to 5% performance improvements have been linked to reduced fatigue-related errors and more effective crisis management.^{3,16,40–42} Within this context, the nap intervention's effect are cautiously encouraging for operational settings and support further randomized trials.

Importantly, nap-related benefits seem to depend on the amount of acute sleep deprivation, underscoring that naps cannot fully compensate for sleep debt. Technical skills appeared more sensitive to cumulative sleep loss than they were boosted by the nap. Therefore, naps should not be seen as a substitute for adequate recovery, and postcall clinical work should still be avoided. This study aligns with existing

evidence suggesting that clinicians need to be optimally recovered to ensure high-functioning performance, particularly in unpredictable or complex situations. These results add to the debate on limiting continuous work shifts and may strengthen arguments to reduce sleep deprivation in clinical practice.⁴

Future studies should assess naps implemented onsite within shifts and determine impact across the 24-h duty cycle. Exploratory findings suggest potentially dose-dependent and domain-specific effects. Dose-response effects are unlikely to be linear, as longer naps may include slow-wave sleep and increase sleep inertia,¹⁹ potentially explaining inconsistent associations with nap durations.¹² This highlights the need of integrating electroencephalogram recordings to objectively characterize nap sleep stages and examine

Table 2. ITT Linear Regression Predicting Postshift Simulated Clinical Performance

Outcome	Model		Group Effect					TST-Shift Effect	
	RMSE	Adjusted R^2	β	P Value	Partial η^2	CI Lower	CI Upper	β	P Value
Primary endpoint									
Clinical performance (/200)	13.89	0.35	14.84	0.018	0.23	2.80	26.88	3.87	0.056
Secondary endpoints									
Technical skills (/100)	7.51	0.27	3.76	0.232	0.06	-2.58	10.10	2.61	0.020
Cardiac arrest (/34)	4.19	0.43	-1.01	0.573	0.01	-4.66	2.64	1.24	0.043
Clinical reasoning (/66)	4.90	0.07	2.90	0.167	0.09	-1.31	7.11	1.30	0.066
Nontechnical skills (/100)	9.97	0.32	11.03	0.016	0.23	2.22	19.84	1.18	0.393
Overall performance (/7)	0.81	0.30	0.77	0.036	0.18	0.05	1.48	0.09	0.424
Leadership (/7)	0.79	0.41	0.73	0.037	0.18	0.05	1.41	-0.06	0.589
Problem solving (/7)	0.73	0.22	0.57	0.080	0.13	-0.07	1.21	0.10	0.301
Situational awareness (/7)	0.98	-0.11	0.43	0.335	0.04	-0.47	1.33	0.06	0.640
Resource utilization (/7)	1.15	0.18	1.02	0.043	0.17	0.03	2.00	0.20	0.228
Communication (/7)	0.97	0.31	0.64	0.124	0.10	-0.19	1.48	0.00	0.981

Linear regression models tested the effect of group assignment (nap vs. no nap) on performance in the sleep-deprived condition while adjusting for rested performance, total sleep time across the preceding hours and work shift (TST-Shift), and previous critical care experience. Reported coefficients represent unstandardized estimates. Partial η^2 reflects effect size for the group predictor. TST-Shift coefficients are provided to illustrate associations between previous sleep loss and task performance. All estimates are accompanied by 95% CI. Values in bold denote statistical significance ($P < 0.05$).

RMSE, root mean square error.

Nap Effect on Performance

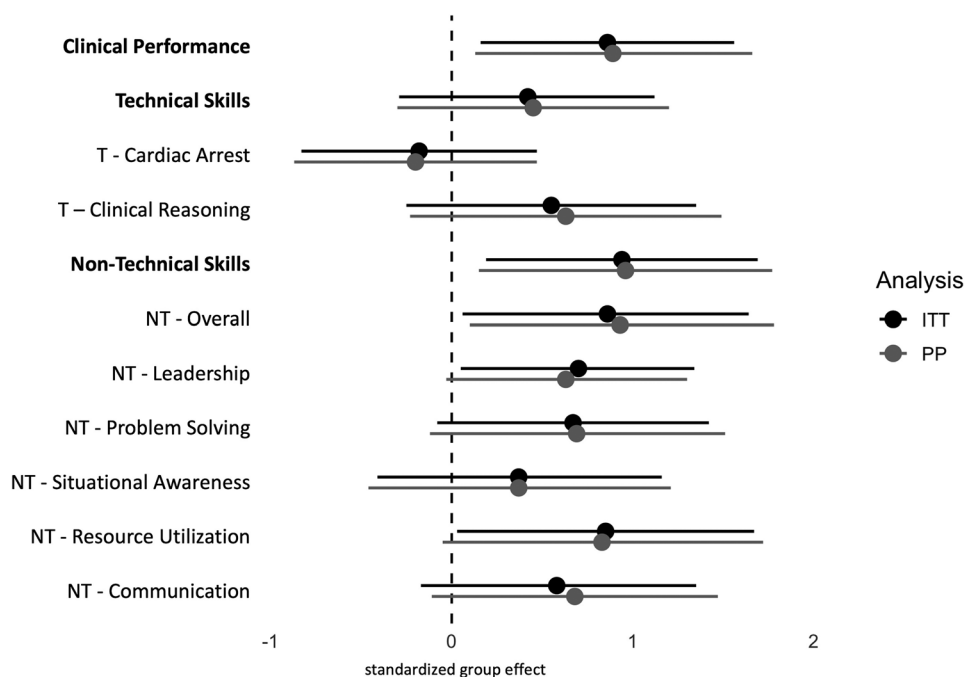


Fig. 4. Group effect estimates across analyses. Standardized effect estimates (β) for intention-to-treat (ITT; black) and per-protocol (PP) models ($n = 27$) with 95% CIs; dashed line indicates zero effect.

how intraindividual variations in lighter sleep contribute to cognitive recovery.⁴³ Distinct sleep pathways may underlie these findings; testing interaction effects between previous sleep deprivation and nap duration would ideally require

counterbalanced nap/sleep-dosing paradigms under controlled circadian laboratory conditions.^{13,19}

Moreover, healthcare providers may start shifts already sleep-deprived due to nonwork factors, such as parenting

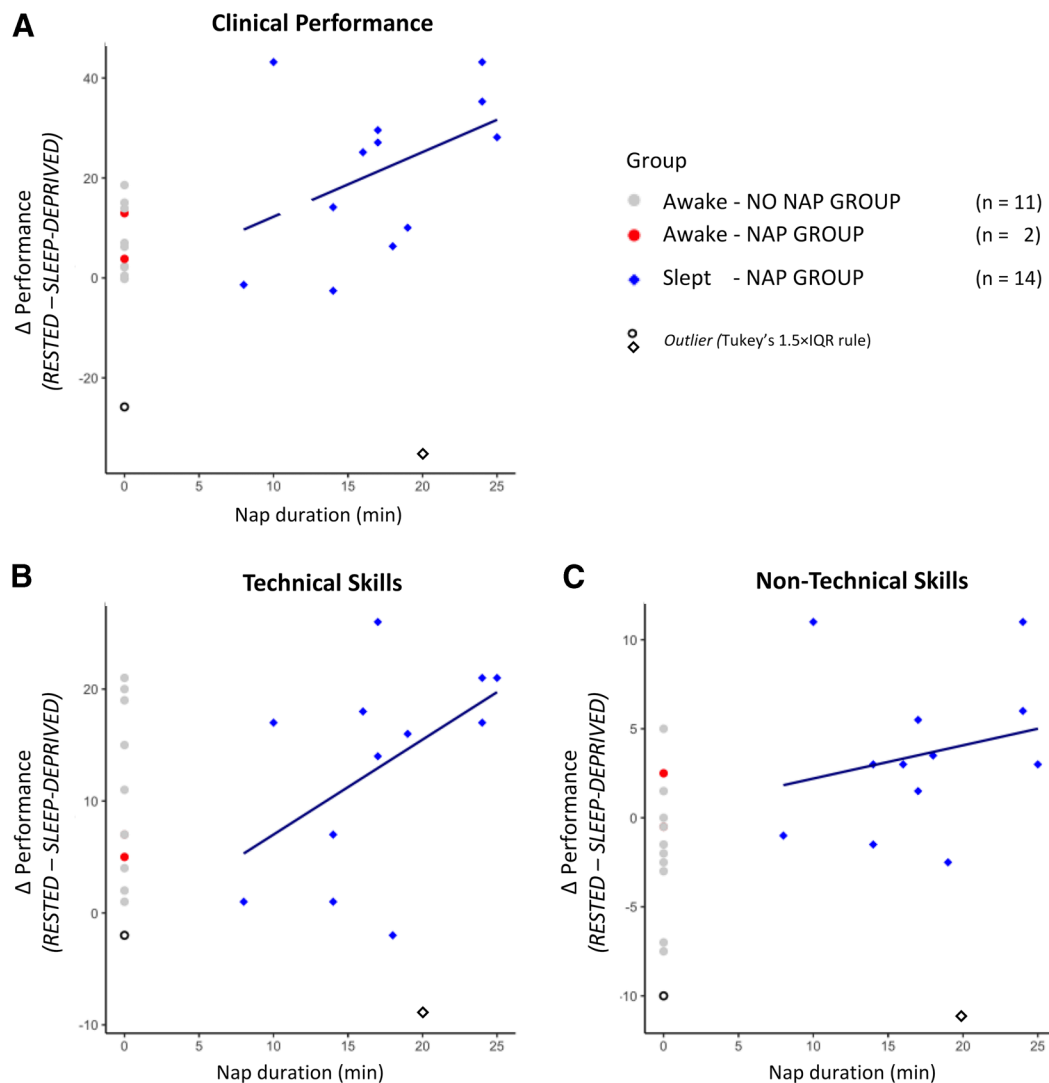


Fig. 5. Nap duration and performance changes. Performance differences between rested and sleep-deprived simulations are shown as a function of actual nap duration. (A) Clinical performance, (B) technical skills, and (C) nontechnical skills. Linear trends are estimated only among participants who slept, excluding Tukey-defined outliers. IQR, interquartile range.

responsibilities or poor nocturnal sleep. Many report excessive daytime sleepiness even during regular daytime work, with physiologic sleepiness levels approaching narcolepsy thresholds.⁴⁴ Nap effectiveness is trainable and contributes to night shift adaptation.⁴³ Nap opportunities, before or during shifts, could potentially mitigate fatigue and increase patient safety. Therefore, nap interventions should be tailored to individual sleep need with sleep hygiene integrated into medical education.⁴⁵ However, educational initiatives alone are insufficient; fostering a supportive culture and organizational responsibility is essential to protect clinicians and patients.⁴⁶ Although this trial did not aim to evaluate nap training effectiveness, its implementation was feasible and well accepted, suggesting potential for structured workplace napping preparation.

Optimal clinical performance requires technical and nontechnical skills.^{24,25} Nontechnical skills appeared more responsive to the nap intervention, with pronounced advantages in leadership and resource utilization. Exploratory findings indicate improved communication with longer nap duration rather than nap opportunity, suggesting selective team benefits.^{26–28} A recent review emphasizes the crucial role of leadership in enhancing patient safety, along with teamwork and open communication.⁴⁷ However, the current study focused on individual performance, whereas real clinical settings involve team members differing in fatigue and collective dynamics.

No direct nap-related gains in technical skills were observed, while greater sleep deprivation predicted larger technical decline, consistent with previous work.²⁶ Exploratory analyses

revealed a modest association with nap duration, particularly during clinical reasoning after simulated patient stabilization. These modest findings suggest that, uniquely in our experimental context, decision-making may be more responsive to naps than procedural execution. This contrasts with nap-related benefits in isolated procedural task studies (*e.g.*, intravenous catheter insertion).^{14,26} Unexpectedly, this procedural performance of handling a well-scripted cardiac arrest, usually considered resilient to extended wakefulness,²⁷ also declined with greater sleep loss. This may reflect the intentional construction of fatigue-sensitive scenarios embedding stressors and real-world clinical complexity. Similarly in aviation,⁴⁸ pilots maintained standard maneuvers under fatigue, but performance deteriorated when unanticipated events occurred. As task complexity increases vulnerability to sleep loss, our results reinforce concerns about maintaining extended duty hours in safety-critical clinical contexts.

These results should be considered alongside previous sleep deprivation protocols, ranging from total sleep loss⁷ to fragmented or reduced sleep during night duty and conducted at different times of day.^{26,28} Routine anesthetic tasks often remained stable, whereas crisis management and nontechnical skills tended to decline after night duty. Our study extends this work by testing a countermeasure, using detailed video-based scoring across performance domains, and incorporating fatigue-sensitive scenarios.

Limitations

This study has several limitations. First, naturalistic sleep variability led to unanticipated exclusion of residents exceeding sleep protocol limits. These randomized control trial findings were likely underpowered to detect subtle effects and should be interpreted as initial evidence. Larger samples are required to refine effect estimates and test individual moderators (*e.g.*, chronotype, baseline sleepiness). Nevertheless, sample size was comparable to or larger than similar randomized studies.^{17,28,49} Second, baseline sleep recordings served primarily coaching purposes and presented lower adherence. Consequently, uncontrolled chronic sleep debt may have influenced performance. However, subjective sleepiness scores were comparable across groups. Third, logistical constraints introduced scheduling and nap timing variability, potentially introducing circadian effects despite afternoon testing. Fourth, behavioral interventions allow rater but not participant blinding, which may introduce performance bias. Overall, large multicenter trial cohorts using detailed physiologic sleep architecture would extend these results.

Fifth, the novel high-pressure simulation design prioritized stress testing over pedagogical training. Scenario unfamiliarity may have increased performance variability and interacted with learning effects between sessions. Scenario order was not counterbalanced, but workload and expert review suggested comparable difficulty. Sixth, long inter-session intervals allowed washout, but ongoing training exposure and participant information exchange cannot be

excluded. Spillover may have affected the cohort globally as randomization limits group-specific bias; crossover designs could further control these effects.

Generalizability to other institutions, specialties, or real-world clinical settings may be limited in this small, single-center study. Long-term retention, actual error rates, and in-shift clinical outcomes remain to be evaluated. The current paradigm assessed postshift performance. Although duty-hour nap interventions exist,^{13,50} in-shift performance assessments have been limited to error rates or brief cognitive or procedural testing.^{14,50} Comprehensive duty-period performance evaluations remain a key step toward greater ecological validity in this field.

Conclusions

This Recovery Napping Protocol for Anesthesiologist Performance trial addresses a critical research gap by providing initial evidence that a brief opportunity to power nap could mitigate the detrimental effects of sleep deprivation on simulated crisis performance in anesthesia and intensive care residents. The nap opportunity seemed to mostly improve nontechnical behaviors, especially leadership and communication, suggesting selective fatigue sensitivity. In contrast, technical skills showed more sensitivity to the nap duration, implying domain-specific responsiveness to napping. These findings point to the potential of incorporating structured napping protocols into medical training and clinical schedules as a targeted tool to sustain performance and possibly mitigate fatigue-related decline. Exploratory analyses linked greater sleep loss to larger technical declines, underscoring the need for adequate sleep across clinical shifts. Future work will be crucial to refine nap-based interventions, clarify their effects on complex, applied clinical tasks, and confirm their benefits for patient care.

Acknowledgments

The authors would like to thank Jean-Jacques Lehot, M.D., Ph.D. (HCL, UCBL1, CLESS), Alice Blet, M.D., Ph.D. (HCL), and Céline Guichon, M.D. (HCL), for their invaluable expertise in clinical simulation. The authors are especially grateful to Sebastian Sygiel and Lucas Denoyel (operational and technical team CLESS, SimULyon) for their critical support in protocol structuring, feasibility checks, logistics, and ongoing on-site assistance, which were central to the functioning of the simulation center. The authors are also grateful to Mouna Alouni, (Lyon Est Faculty, UCBL1) for her dedicated work in data collection during her medical student internship, and to Leo Bironneau and Anne-Sophie Roger (HCL, UCBL1) for their important contributions to the study's first phase and preliminary analyses during their nurse anaesthesia internships. Last, the authors thank their pilot resident, Martin Deslais, M.D. (HCL), for his invaluable feedback and insights during the simulation pilot phase.

Research Support

Support was provided solely from institutional and/or departmental sources.

Competing Interests

The authors declare no competing interests.

Reproducible Science

Full protocol available at: laura.schmidt1@monash.edu.
Raw data available at: laura.schmidt1@monash.edu.

Correspondence

Address correspondence to Dr. Schmidt: INSERM, School of Psychological Sciences Turner Institute for Brain and Mental Health, Monash University, Office 131, Building 1, 270 Ferntree Gully Road, Notting Hill, VIC - 3168 Australia. laura.schmidt1@monash.edu

Supplemental Digital Content

Supplemental Digital Content 1: Scenario description, scenario checklist, scenario comparability with task load ratings, <https://links.lww.com/ALN/E542>

Supplemental Digital Content 2: Nap training, description of workshop, <https://links.lww.com/ALN/E543>

Supplemental Digital Content 3: Additional analysis of clinical performance <https://links.lww.com/ALN/E544>

References

- Sanders M, Perrie H, Scribante J: The perceptions and effects of sleep deprivation in a department of anesthesiology. *Sleep Med Res* 2018; 9:53–7. doi:10.17241/smr.2018.00220
- Gander P, Millar M, Webster C, Merry A: Sleep loss and performance of anaesthesia trainees and specialists. *Chronobiol Int* 2008; 25:1077–91. doi:10.1080/07420520802551428
- Lim J, Dinges DF: A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychol Bull* 2010; 136:375–89. doi:10.1037/a0018883
- Landrigan CP, Rothschild JM, Cronin JW, et al.: Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med* 2004; 351:1838–48. doi:10.1056/NEJMoa041406
- Kecklund G, Axelsson J: Health consequences of shift work and insufficient sleep. *BMJ* 2016; 355:i5210. doi:10.1136/bmj.i5210
- Bartel P, Offermeier W, Smith F, Becker P: Attention and working memory in resident anaesthetists after night duty: Group and individual effects. *Occup Environ Med* 2004; 61:167–70. doi:10.1136/oem.2002.006197
- Howard SK, Gaba DM, Smith BE, et al.: Simulation study of rested versus sleep-deprived anesthesiologists. *ANESTHESIOLOGY* 2003; 98:1345–55; discussion 5A. doi:10.1097/00000542-200306000-00008
- Huffnayer JL, Moncrief M, Tashjian JA, et al.: Driving performance of residents after six consecutive overnight work shifts. *ANESTHESIOLOGY* 2016; 124:1396–403. doi:10.1097/ALN.0000000000001104
- Cao CGL, Weinger MB, Slagle J, et al.: Differences in day and night shift clinical performance in anesthesiology. *Hum Factors* 2008; 50:276–90. doi:10.1518/001872008X288303
- Aya AGM, Mangin R, Robert C, Ferrer JM, Eledjam JJ: Increased risk of unintentional dural puncture in night-time obstetric epidural anesthesia. *Can J Anaesth* 1999; 46:665–9. doi:10.1007/BF03013955
- Scholliers A, Cornelis S, Tosi M, et al.: Impact of fatigue on anaesthesia providers: A scoping review. *Br J Anaesth* 2023; 130:622–35. doi:10.1016/j.bja.2022.12.011
- Dutheil F, Danini B, Bagheri R, et al.: Effects of a short daytime nap on cognitive performance: A systematic review and meta-analysis. *Int J Environ Res Public Health* 2021; 18:10212. doi:10.3390/ijerph181910212
- Dutheil F, Bessonnat B, Pereira B, et al.: Napping and cognitive performance during night shifts: A systematic review and meta-analysis. *Sleep* 2020; 43:zsaa109. doi:10.1093/sleep/zsaa109
- Smith-Coggins R, Howard SK, Mac DT, et al.: Improving alertness and performance in emergency department physicians and nurses: The use of planned naps. *Ann Emerg Med* 2006; 48:596–604, 604.e1. doi:10.1016/j.annemergmed.2006.02.005
- Rosekind MR, Smith RM, Miller DL, et al.: Alertness management: Strategic naps in operational settings. *J Sleep Res* 1995; 4:62–6. doi:10.1111/j.1365-2869.1995.tb00229.x
- Williamson A, Lombardi DA, Folkard S, Stutts J, Courtney TK, Connor JL: The link between fatigue and safety. *Accid Anal Prev* 2011; 43:498–515. doi:10.1016/j.aap.2009.11.011
- Signal TL, Gander PH, Anderson H, Brash S: Scheduled napping as a countermeasure to sleepiness in air traffic controllers. *J Sleep Res* 2009; 18:11–9. doi:10.1111/j.1365-2869.2008.00702.x
- Dinges DF, Orne EC, Evans FJ, Orne MT: Performance after naps in sleep-conductive and alerting environments, *Biological Rhythms, Sleep and Shift Work*. Edited by Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ. New York, S. P. Medical and Scientific Books, 1981, pp 539–52
- Hilditch CJ, Dorrian J, Banks S: A review of short naps and sleep inertia: Do naps of 30 min or less really avoid sleep inertia and slow-wave sleep? *Sleep Med* 2017; 32:176–90. doi:10.1016/j.sleep.2016.12.016

20. Querstret D, O'Brien K, Skene DJ, Maben J: Improving fatigue risk management in healthcare: A scoping review of sleep-related interventions for nurses and midwives. *Int J Nurs Stud* 2020; 112:103745. doi:10.1016/j.ijnurstu.2020.103745
21. Weinger MB, Ancoli-Israel S: Sleep deprivation and clinical performance. *JAMA* 2002; 287:955–7. doi:10.1001/jama.287.8.955
22. Devitt JH, Kurrek MM, Cohen MM, Cleave-Hogg D: The validity of performance assessments using simulation. *ANESTHESIOLOGY* 2001; 95:36–42. doi:10.1097/00000542-200107000-00011
23. Schlatter ST, Thérond CC, Guillot A, 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; 22:422. doi:10.1186/s12909-022-03420-9
24. Sigwalt F, Petit G, Evain JN, et al.: Stress management training improves overall performance during critical simulated situations: A prospective randomized controlled trial. *ANESTHESIOLOGY* 2020; 133:198–211. doi:10.1097/ALN.0000000000003287
25. Flin R, O'Connor P, Crichton M: *Safety at the Sharp End: A Guide to Non-Technical Skills*. London, CRC Press, 2017. doi: 10.1201/9781315607467
26. Arzalier-Daret S, Buléon C, Bocca ML, Denise P, Gérard J-L, Hanouz J-L: Effect of sleep deprivation after a night shift duty on simulated crisis management by residents in anaesthesia: A randomized crossover study. *Anaesth Crit Care Pain Med* 2018; 37:161–6. doi:10.1016/j.accpm.2017.05.010
27. Sharpe R, Koval V, Ronco JJ, et al.: The impact of prolonged continuous wakefulness on resident clinical performance in the intensive care unit: A patient simulator study. *Crit Care Med* 2010; 38:766–70. doi:10.1097/CCM.0b013e3181cd122a
28. Neuschwander A, Job A, Younes A, et al.: Impact of sleep deprivation on anaesthesia residents' non-technical skills: A pilot simulation-based prospective randomized trial. *Br J Anaesth* 2017; 119:125–31. doi:10.1093/bja/aex155
29. Hopewell S, Chan AW, Collins GS, et al.: CONSORT 2025 statement: Updated guideline for reporting randomised trials. *BMJ* 2025; 389:e081123. doi:10.1136/bmj-2024-081123
30. Lorello GR, Cook DA, Johnson RL, Brydges R: Simulation-based training in anaesthesiology: A systematic review and meta-analysis. *Br J Anaesth* 2014; 112:231–45. doi:10.1093/bja/aet414
31. Hart SG, Staveland LE: Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Adv Psychol* 1988; 52:139–83
32. Hilditch CJ, McHill AW: Sleep inertia: Current insights. *Nat Sci Sleep* 2019; 11:155–65. doi:10.2147/NSS.S188911
33. Horne JA, Ostberg O: A self-assessment questionnaire to determine morningness–eveningness in human circadian rhythms. *Int J Chronobiol* 1976; 4:97–110
34. Bastien CH, Vallières A, Morin CM: Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Med* 2001; 2:297–307. doi:10.1016/s1389-9457(00)00065-4
35. Buysse DJ, Hall ML, Strollo PJ, et al.: Relationships between the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), and clinical/polysomnographic measures in a community sample. *J Clin Sleep Med* 2008; 4:563–71
36. Dion G, Tessier R: Validation de la traduction de l'Inventaire d'épuisement professionnel de Maslach et Jackson. *Can J Behav Sci* 1994; 26:210–27. doi: 10.1037/0008-400x.26.2.210
37. Shahid A, Wilkinson K, Marcu S, Shapiro CM.: Karolinska Sleepiness Scale. In: Shahid, A., Wilkinson, K., Marcu, S., Shapiro, C. (eds). *STOP, THAT and One Hundred Other Sleep Scales*. New York, Springer, 2011, pp 209–10. doi:10.1007/978-1-4419-9893-4_47
38. Johns MW: A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep* 1991; 14:540–5. doi:10.1093/sleep/14.6.540
39. Jeon BM, Kim SH, Shin SH: Effectiveness of sleep interventions for rotating night shift workers: A systematic review and meta-analysis. *Front Public Health* 2023; 11:1187382. doi:10.3389/fpubh.2023.1187382
40. Van Dongen HPA, Maislin G, Mullington JM, Dinges DF: Dose–response effects of chronic sleep restriction and total sleep deprivation. *Sleep* 2003; 26:117–26. doi:10.1093/sleep/26.2.117
41. Arora S, Sevdalis N, Nestel D, Woloshynowych M, Darzi A, Kneebone R: The impact of stress on surgical performance: A systematic review. *Surgery* 2010; 147:318–30, 330.e1. doi:10.1016/j.surg.2009.10.007
42. Weinger MB, Slagle J: Human factors research in anesthesia patient safety. *Proc AMIA Symp* 2001:756–60
43. Debellemanniere E, Gomez-Merino D, Erblang M, et al.: Deep, short sleep naps in occupational settings using relaxation techniques. *J Sci Med Sport* 2017; 20:S159–160. doi:10.1016/j.jsams.2017.09.542
44. Howard SK, Gaba DM, Rosekind MR, Zarcone VP: Risks of excessive daytime sleepiness in resident physicians. *Acad Med* 2002; 77:1019–25. doi:10.1097/00001888-200210000-00015
45. Ruet A, Ndiki Mayi EF, Métais A, et al.: Determining the influence of a sleep improvement intervention on medical students' sleep and fatigue: Protocol of the PROMESS-Sleep clinical trial. *BMC Med Educ* 2025; 25:1–14. doi:10.1186/s12909-024-06422-x
46. Owens JA: Sleep loss and fatigue in healthcare professionals. *J Perinat Neonatal Nurs* 2007; 21:92–100; quiz 101. doi:10.1097/01.JPN.0000270624.64584.9d

47. Adams DE: Leadership for reducing medical errors via organizational culture: A literature review. *Meas Bus Excel* 2022; 26:143–62. doi:10.1108/MBE-06-2021-0079
48. Blacker KJ, Beasley NL, Alger SE, Caldwell JL: A daytime nap improves performance on a novel aerial flight maneuvering task. *Sleep* 2025; 48:zsaf062. doi:10.1093/sleep/zsaf062
49. Sallinen M, Härmä M, Åkerstedt T, Rosa R, Lillqvist O: Promoting alertness with a short nap during a night shift. *J Sleep Res* 1998; 7:240–7. doi:10.1046/j.1365-2869.1998.00121.x
50. Tempesta D, Cipolli C, Desideri G, De Gennaro L, Ferrara M: Can taking a nap during a night shift counteract the impairment of executive skills in residents? *Med Educ* 2013; 47:1013–21. doi:10.1111/medu.12256