Critical Care

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Based -evidence, an intervention study to improve sleep quality in awake adult ICU patients: a prospective, single-blind, clustered controlled trial

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Abstract

Background Evidence-based guidelines advocate promoting sleep in intensive care unit (ICU) patients, yet many patients experience poor sleep quality. We sought to develop a collaborative evidence-based intervention with healthcare providers and assess whether evidence-based sleep interventions could improve sleep quality in awake adult ICU patients.

Methods We conducted a prospective, nonrandomized cluster control trial in two intensive care units (ICUs) at a tertiary general teaching hospital in China. Patients aged 18 years or older who stayed in the ICU for one night or more and were conscious were eligible for enrollment. We only blinded the patients, not the outcome assessors. On the basis of evidence-based practice and clinical reality, we developed intervention measures for the intervention group, which mainly included four aspects: reducing environmental noise in the ICU, adjusting nursing actions, modifying nighttime lighting, and other measures. The assessment tools used were wearable actigraphy sleep monitoring devices and the Richards-Campbell Sleep Questionnaire (RCSQ). The primary outcomes were patient sleep quality, including total sleep time, deep sleep time, light sleep time, rapid eye movement (REM) time, number of awakenings, overall sleep score, and patients' self-assessment of their sleep quality that night. The data collected were analyzed via SPSS and Mplus statistical software for between-group analysis, pre-post comparison, profile analysis, and calculation of the intervention effect size.

Results From September 1, 2023, to January 31, 2024, 713 patients underwent eligibility assessment, and ultimately 246 patients were included in the analysis, with 125 in the intervention group and 121 in the control group. Comparative analysis revealed no statistically significant differences in sleep quality between the two groups when the duration in the ICU = 1 night ($P > 0.05$), with a small intervention effect size. However, the intervention group had higher sleep quality scores (sleep monitoring wristband: $57.74 \pm 22.55 > 57.72 \pm 19.39$; RCSQ questionnaire: $60.58 \pm 22.14 > 57.61 \pm 24.4$) and total sleep time ($440.42 \pm 262.11 > 420.31 \pm 236.89$), a lower awakening frequency ($3.98 \pm 2.69 < 6.09 \pm 4.66$) and a lower awakening frequency ($3.976 \pm 2.693 < 6.09 \pm 4.664$) than did the control group. The sleep quality of patients who stayed in the ICU for > 1 night significantly improved in all the parameters except rapid eye movement time (min) according to the pre-post-test analyses ($P < 0.05$), with a medium to large intervention effect size and favorable intervention effects.

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Conclusion Evidence-based interventions significantly improve sleep quality in ICU patients hospitalized for more than one day. However, our results do not support the improvement of sleep quality in patients admitted to the ICU for one day.

Clinical trial registration: ChiCTR2300075763, Registered 14 September 2023—Retrospectively registered, https://www.chictr.org.cn/bin/userProject

Keywords Evidence-based nursing, Intensive care unit, Awake patients, Sleep quality, Controlled study

Background

Sleep disturbances, characterized by diminished sleep quality, are a prevalent issue among patients in the intensive care unit (ICU) during their hospitalization [1]. Research indicates that approximately 68% of ICU patients experience severe sleep disturbances, with around 38% suffering from sleep disorders [2, 3]. In non-sedated patients, the incidence of sleep disturbances can reach as high as 73.9%. One study found that all 22 critically ill patients enrolled had abnormal physiological rhythms (wake/sleep cycles), with about 50% sleeping during the daytime [4]. These sleep disturbances not only impair patients' cognitive function and immune systems but also increase the risk of delirium, leading to extended hospital stays and delayed recovery [5, 6]. Moreover, insufficient sleep following ICU discharge can persist for up to six months, significantly impacting an individual's quality of life [7]. It has been shown that various environmental factors in the ICU, such as noise, light, disease-related factors (e.g., pain), nursing activities, physical examinations, clinical diagnoses, and medical rounds, disrupt patients' nighttime sleep [8].

Currently, interventions aimed at improving sleep quality in ICU patients encompass both pharmacological (such as sedatives and hypnotics) and non-pharmacological approaches (including noise reduction, aromatherapy, earplugs, and eye masks), all of which have been validated to some extent through clinical trials [8, 9]. However, the effectiveness of these interventions varies. This study aims to integrate relevant interventions based on existing research, implement evidence-based practices, and explore the impact of these interventions on the sleep quality of awake adult ICU patients through clinical translation.

Evidence-based practice involves the process of collecting, interpreting, evaluating, and integrating effective, clinically meaningful, and evidence-based interventions [10]. Currently, healthcare organizations prioritize the integration of evidence-based practice to improve patient outcomes, nursing quality, and consistency globally [11, 12]. While evidence-based practice can prevent unsafe or ineffective practices and enhance healthcare quality, its implementation remains challenging because of the gap between research and practice [13]. To verify the effectiveness of existing sleep-related interventions for improving the sleep quality of awake adult ICU patients, we integrated clinically meaningful evidence and constructed an intervention program tailored to clinical scenarios. We conducted a non-randomized controlled trial to validate the effectiveness and feasibility of this evidence-based intervention program and to analyze the effect size of the interventions on the sleep quality of awake adult ICU patients.

Methods

Study design

A prospective, single-blinded, non-randomized cluster-controlled trial was conducted in two comprehensive intensive care units (ICUs) at a tertiary teaching hospital in China from September 1, 2023, to January 31, 2024. Each ICU served as a cluster, comprising a control group and an intervention group. To minimize the risk of interference, there was no crossover between the two clusters. Hospital staff (physicians and nurses) at the study site were aware of the nursing intervention study but remained blinded to group allocations and specific intervention protocols. Additionally, physicians and nurses from both wards did not overlap. The outcome assessors were aware of the participant group assignments. The study received approval from the Ethics Committee of Zhongnan Hospital of Wuhan University (Approval No. [2023023 K]). All participants provided informed consent, participated anonymously, and were informed of their right to withdraw from the study at any time.

Participants and setting

The inclusion criteria were as follows: (1) age ≥ 18 years; (2) length of ICU stay ≥ 1 night; and (3) a Richmond Agitation-Sedation Scale (RASS) score of 0 and ntensive Care Delirium Screening Checklist (ICDSC) score < 4.

The exclusion criteria were as follows: cognitive impairment or altered mental status (determined by a neurology specialist); psychiatric illness (determined by a psychiatric specialist); and the presence of delirium (ICDSC score ≥ 4).

Setting: The layout of the ICU wards where the study was conducted included an intervention group ward

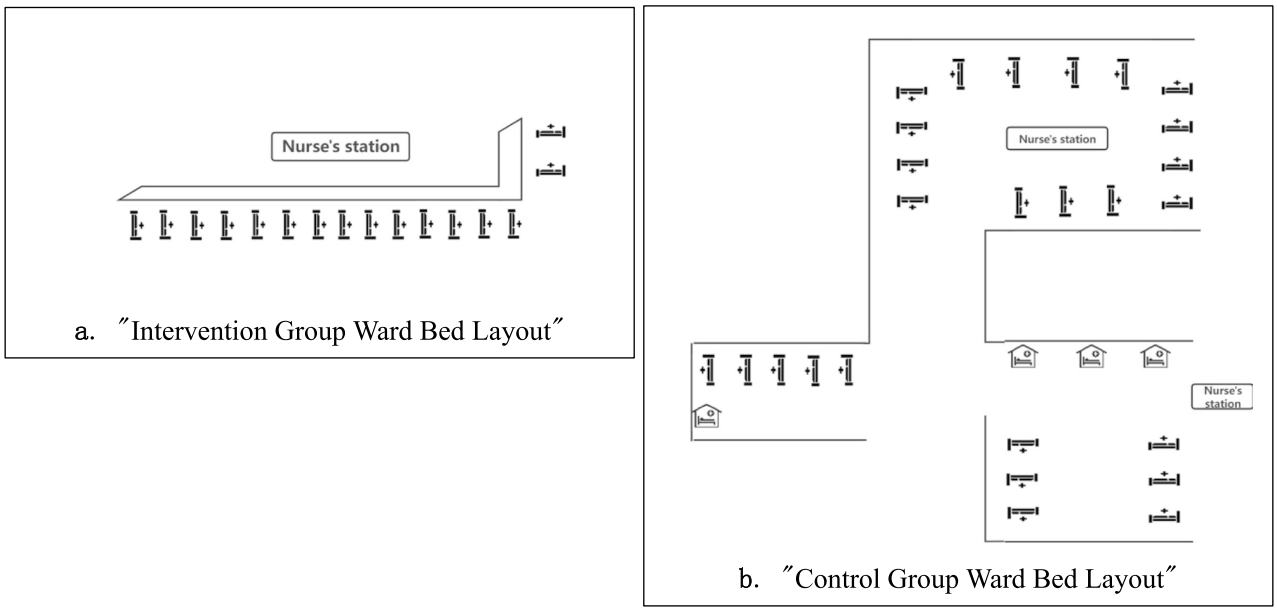

Fig. 1 Layout of beds for the two groups

with 16 beds in an open-space layout without individual rooms (see Fig. 1a). The control group ward included 30 beds, including 4 individual rooms, with the remaining beds located in an open-space layout. In this study, awake patients were accommodated in open-space beds, whereas beds in individual rooms were reserved for critically ill patients requiring protective isolation, strict isolation, or other forms of isolation, who were excluded from the study (see Fig. 1b).

Sample size calculation: Based on the effect size analysis, d = 0.5 was set according to previous literature [14], α was set to 0.05, the test power P was set to 0.8, and the sample size calculation was performed via G-power. Considering a 10% dropout rate, the final calculated sample size was 116 cases for the intervention group and 116 cases for the control group, with a total of at least 232 cases needed for the study.

Procedures

Intervention Group: In the preliminary stage of this study, the "6S" model, the "6S" model (System, Summaries, Synopses of syntheses, Syntheses, Synopses of studies, Studies) [15] was integrated on the basis of evidence from evidence-based medicine, following a top-down approach. Relevant keywords such as "sleep disorder, sleep deprivation, sleep wake disorder, dyssomnias, intrinsic sleep disorders, circadian rhythm sleep disorders, intensive care unit, ICU, guidelines, and systematic review" were systematically searched across 19 Chinese and English databases. The quality of the literature was subsequently evaluated, evidence levels were assigned, evidence was summarized, and scholars in the relevant field were organized to determine recommendation levels and topics on the basis of the FAME structure of the Australian Joanna Briggs Institute (JBI), including feasibility, appropriateness, clinical significance, and effectiveness of clinical evidence. Finally, 17 pieces of evidence across 4 themes were summarized from 12 articles [16]. Based on the evidence-based and clinical context, relevant measures for the intervention group were formulated and are presented in Table 1. The content mainly includes four aspects: reducing ICU environmental noise, adjusting nursing-related actions, adjusting nighttime lighting, and others.

Control Group: Patients received routine care according to the ICU night nursing protocol, without additional improvement or intervention specifically targeting their sleep. This included maintaining regular ward environment conditions (i.e., lights not being turned off or dimmed, instrument alarm volumes not set to low levels, no provision of tools like eye masks and earplugs, but mobile phone ringtones adjusted to vibrate or mute). Analgesics were used routinely based on patient conditions, such as for postoperative patients, though dynamic assessments were rarely conducted.

Measurements

Demographic and disease-related data

Based on the literature review, this study selected general demographic characteristics and relevant disease-related variables that may affect the sleep quality of awake ICU patients. Demographic data included age, gender,

Table 1 Interventions and details of measures undertaken

Intervention theme	Intervention Details
Reduce Environmental Noise in the ICU	1. Set the alarm volume of equipment to a low level during the night, restoring it to normal at 7:00 AM the next day 2. Reduce the volume of telephone ring tones 3. Set mobile phones of healthcare providers to vibrate/silent mode 4. Lower conversation volume 5. Avoid moving and dragging chairs at night 6. Use silent wheels on treatment carts at night 7. Install a decibel meter in the ward to remind healthcare providers to keep noise below 50 decibels at night and below 55 decibels during the day 8. Attach noise-reducing pads to all trash bins in the ward to minimize noise from opening and closing
Adjust Nursing Actions	1. Perform imaging examinations, blood sampling, catheter/gastric tube insertion, dressing changes, CVP/glucose/temperature monitoring, physical therapy, enteral feeding, etc., only when necessary between 10:00 PM and 7:00 AM 2. Collaborate with physicians to establish night care plans, avoiding procedures such as large fluid infusions at night whenever possible 3. Actively manage pain in patients with NRS scores < 3 according to the clear pain management process 4. For patients with blood glucose levels between 7.8 and 11.1 mmol/L, blood glucose monitoring via finger pricks is not necessary at night (routine monitoring with a continuous blood glucose monitor if available) 5. In hemodynamically stable patients with arterial blood pressure monitoring, overnight cuff blood pressure measurement is not needed 6. Schedule nonurgent nursing procedures during patient sleep intervals or after waking up from sleep, or postpone them until after 7:00 AM (e.g., turning, changing drainage bags, wound checks, catheter care, blood specimen collection, etc.)
Adjust Night Lighting	1. Install bedside lamps with sleep-friendly (dusk-colored) lighting to avoid stimulating patients' eyes during night shift handovers and disturb their sleep 2. Turn off bedside lights at 10:00 PM, leaving only common area lighting, and turn them back on at 7:00 AM the next day
Other	1. Provide eye masks and earplugs free of charge according to patient needs 2. Fit patients with sleep monitoring wristbands before 10:00 PM each night, remove them at 7:00 AM the next day, objectively assess patient sleep quality, and adjust intervention strategies promptly 3. Inquire about patient sleep quality every morning at 7:00 AM and complete the Richards-Campbell Sleep Questionnaire (RCSQ) for subjective sleep assessment, describing it in the nursing records

education level, medical insurance type, and marital status. Disease-related data included clinical diagnosis upon ICU admission, postoperative status, number of catheters carried (urinary catheters, drainage catheters, and middle and long venous catheters), oxygen delivery method, disease severity, pain score, use of analgesics, use of sleep aids, and use of earplugs and eye masks.

Acute physiology and chronic health evaluation II (APACHE II)

The Acute Physiology and Chronic Health Evaluation II (APACHE II) is an objective system used to assess the severity of illness and prognosis in various critically ill patients. The APACHE II score consists of three parts: the acute physiology score (APS), age score, and chronic health status score, with a total theoretical maximum score of 71 points. In the comprehensive ICU, the APACHE II score is positively correlated with the severity of illness to some extent, with higher scores indicating a higher risk of death and more severe illness [17]. In this study, the APACHE II score was assessed by ICU clinical physicians within the first 24 h of ICU admission.

Numerical rating scale (NRS) for pain assessment

The Numerical Rating Scale (NRS) for pain assessment is accurate and concise, using a scale of 0–10 to represent different degrees of pain (0 indicates no pain, 10 indicates severe pain). Scores of 0–3 indicating mild pain, 4–6 indicating moderate pain, and > 6 indicating severe pain. The Cronbach's α coefficient is 0.94 [18]. Patients select different values to quantify the intensity of their pain, with higher scores indicating greater pain intensity. The NRS is suitable for patients aged 10 years and above who have a certain level of education and understanding of abstract scales and text reading comprehension [19].

Richards-campbell sleep questionnaire (RCSQ)

The Richards-Campbell Sleep Questionnaire (RCSQ) was developed by American nursing expert Richards in 2000 [20] and is used mainly to measure the sleep quality of patients in the intensive care unit (ICU). The questionnaire consists of 5 items, and uses a 0–100 mm visual analog scale to assess sleep depth, sleep latency, awakening, return to sleep, and overall sleep quality. The left end of the line represents 100 points, indicating good sleep, whereas the right end represents 0 points, indicating poor sleep. Patients mark the point on the line that represents their sleep quality the previous night, and the distance from the marked point to the right end of the line is measured using a ruler and recorded as the patient's score for this item. The RCSQ sleep score is the average

score of the 5 items, with higher scores indicating better sleep. This study used the Chinese version of the RCSQ translated by Yang Hui et al. [21]. in 2016, with content validity of 0.840, a Cronbach's α coefficient of 0.874, and test–retest reliability of 0.912.

Objective sleep monitoring tool

Activity recorders continuously measure human movement using devices similar to watches (ACT-Trust AT0503, São Paulio, Brazil), providing an objective method for quantifying sleep and circadian rhythms. This study used wearable activity recorders for sleep monitoring: the Huawei Honor 7 Sports Bracelet, which objectively evaluates patient sleep quality. The TruSleep2.0™ sleep monitoring technology inside the device assesses sleep quality based on motion data obtained from an accelerometer, pulse wave signals obtained from a heart rate sensor, and device wearing status detected by wearing detection sensors. According to validation by the University of Bern, Switzerland, compared with polysomnography (PSG), the TruSleep2.0™ sleep monitoring technology has an accuracy rate of 96.3% in identifying sleep states [22]. Chen et al. [23] conducted a validation study of its use in monitoring sleep in ICU patients, confirming the value of the technology in improving sleep quality in critically ill patients, reducing the use of sedative drugs, and reducing the rate of acquired delirium in the ICU. Participants wore the bracelet before sleep, and the Huawei Sports Health App's sleep module displayed the TruSleep2.0™ sleep monitoring technology's assessment of the participant's sleep quality the previous night when connected to the smartphone via Bluetooth in the morning. This assessment included total sleep time, deep sleep time, light sleep time, rapid eye movement (REM) duration, number of awakenings, sporadic naps, and overall sleep score.

Outcomes

The primary outcome measure of this study was the sleep quality of awake ICU patients (total scores on the RCSQ scale and sleep monitoring device), whereas secondary outcome measures include changes in sleep quality among who stayed in the ICU for 2 nights or more.

Data collection

Before data collection commenced, the participants were briefed on the purpose, procedures, and confidentiality of the study, and written informed consent was obtained. Demographic and disease-related data of the participants were collected from electronic medical records. On the first night of ICU admission (not exceeding 10 pm), participants were fitted with sleep monitoring devices, which were removed at 7 am on the following day, and participants completed relevant questionnaire items (RCSQs). Completing the questionnaire took approximately 2–3 min.

Quality control

① Selection bias control: Strict adherence to inclusion and exclusion criteria in selecting participants for the study.

② Intervention implementation control: Based on evidence-based clinical evidence, quality review indicators were developed with credibility, effectiveness, and measurability principles in mind. A total of 14 quality control review indicators were established, including 1 structural indicator, 11 process indicators, and 2 outcome indicators. The quality control objects and methods of the quality control indicators were determined item by item, as shown in Table 1 of Supplementary file 1. The degree of implementation of the review indicators was supervised using the "Improving Adult ICU Patient Sleep Quality Evidence Application Review Indicator Clinical Compliance Inspection Checklist" (see Table 2 in Supplementary File 1). Additionally, to ensure the effectiveness of the intervention group, the "ICU Patient Nighttime Sleep Improvement Checklist" was developed (see Table 3 in Supplementary File 1).

Data analysis

The data were entered and cross-checked by two individuals to ensure accuracy. Statistical analysis was conducted via SPSS 26.0 software and Mplus 8.3 software. The sleep quality data for both groups are expressed as the means ± standard deviations, The baseline characteristics of both groups are presented as frequencies and percentages (n (%)) and were compared via t-tests and chi-square tests. Pearson correlation analysis was used to explore the relationship between ICU length of stay and sleep quality, while between-group comparisons were performed using one-way analysis of variance (ANOVA), with $P < 0.05$ indicating statistical significance. The feasibility of intervention implementation was explored through frequency data. Cohen's d was used to determine the effect size of the intervention group's sleep quality-related data, with effect sizes classified as small, medium, or large at critical points of 0.20, 0.50, and 0.80, respectively [24]. Paired sample t-tests were used to analyze sleep quality between the first night and the night before transfer from the ICU in the intervention group.

Exploratory latent profile analysis was conducted to compare heterogeneity in sleep quality among awake

Table 2 Patient characteristics

Variables		Intervention group (n = 125)		Control group (n = 121)		t/X^2 value	*P* value
		n	%	n	%		
Gender	Male	46	36.8	76	62.8	0.102	0.919
	Female	79	63.2	45	37.2		
Age	18 ~ 35	26	20.8	11	9.1	1.383	0.501
	36 ~ 59	46	36.8	48	39.7		
	≥ 60	53	42.4	62	51.2		
Education	Illiterate (No Formal education)	8	6.4	9	7.4	2.442	0.668
	Primary school	25	20.0	22	18.2		
	Junior high school	43	34.4	37	29.8		
	Secondary vocational school/High school	22	17.6	32	26.4		
	Associate degree and above	27	21.6	21	17.4		
Marital status	Single	8	6.4	9	6.6	1.756	0.416
	Divorced	2	1.6	4	3.3		
	Married	115	92.0	108	89.3		
Medical insurance	Self-pay	49	39.2	17	14.0	5.126	0.077
	Provincial medical insurance	52	41.6	75	62.0		
	Municipal medical insurance	24	19.2	29	24.0		
Reasons for ICU admission	Respiratory distress	12	9.6	19	15.7	11.664	0.112
	Obstetrics and gynecology	47	37.6	1	.8		
	Trauma	29	23.2	5	4.1		
	Metabolic abnormalities/Renal	5	4.0	9	7.4		
	Cardiovascular	11	8.8	9	7.4		
	Sepsis / Shock	15	12.0	17	14.0		
	Digestive system	6	4.8	46	38.0		
	Other	0	0.0	15	12.4		
Number of catheters carried	≤ 3	44	35.2	21	17.4	1.717	0.424
	4 ~ 6	72	57.6	66	54.5		
	> 6	9	7.2	34	28.1		
Methods of oxygen therapy	Not receiving oxygen	8	6.4	5	4.1	0.066	0.968
	Nasal cannula oxygen therapy	102	81.6	95	78.5		
	Non-invasive mechanical ventilation	15	12.0	21	17.4		
NRS pain score	0	39	31.2	83	68.6	3.188	0.671
	1.0	25	20.0	5	4.1		
	2.0	61	48.8	11	9.1		
	3	0	0.0	8	6.6		
	4	0	0.0	13	10.7		
	6	0	0.0	1	.8		
APACHE-II score	≤ 10	52	41.6	45	37.2	9.728	0.008
	11 ~ 20	60	48.0	64	52.9		
	≥ 21	13	10.4	12	9.9		
Surgical intervention within 3 days	No	39	31.2	79	65.3	1.042	0.299
	Yes	86	68.8	42	34.7		
Use of analgesics	1.0	49	39.2	90	74.4	0.946	0.346
	2.0	76	60.8	31	25.6		
Use of sedatives	1.0	75	60.0	109	90.1	0.529	0.598
	2.0	50	40.0	12	9.9		

Table 3 Results of the partial intervention measures implemented (n = 125)

Variables		n	%
Earplugs	Yes	38	30.4
	No	87	69.6
Eye mask	Yes	40	32
	No	85	68
Simultaneous use of earplugs and eye mask	Yes	34	27.2
	No	91	72.8
Adjustment of nighttime lighting	Yes	115	92
	No	10	8
Adjustment of instrument/equipment alarm volume	Yes	121	96.8
	No	4	3.2

adult ICU patients in the two groups. Likelihood ratio chi-square tests, the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the sample size-adjusted BIC (aBIC) were used to compare differences between expected and actual values to assess model fit. Lower values indicate better fit. Bootstrap likelihood ratio tests (BLRTs) and Lo-Mendell-Rubin likelihood ratio tests (LMRs) were used to compare fit differences between models with K-1 and K profiles. Statistical significance ($P < 0.05$) indicates that the model with K profiles is superior to the model with K-1 profiles, where K represents the number of freely estimated parameters [25]. The entropy value approaches 1 as the classification precision increases.

Results

Demographic characteristics of the sample

Among the 714 patients admitted to two ICU wards between September 1, 2023, and January 31, 2024, a total of 324 met the criteria, with 78 excluded patients. Ultimately, data from 246 patients were included for analysis, with 125 in the intervention group and 121 in the control group. The flowchart detailing the participant selection and enrollment processes is depicted in Fig. 2. Except for the APACHE-II score(intervention group: 12.53 ± 5.43, control group:12.89 ± 5.50), there were no statistically significant differences in baseline characteristics between the two groups ($P = 0.008$). In the intervention group, 68.8% (86/125) of the patients underwent surgery within 3 days, compared to 34.7% (42/121) of the patients in the control group did. Among the intervention group, 60.8% (76/125) received analgesics at night, and 40% (50/125) used sleep aids. In the control group, 25.6% (31/121) used analgesics at night, and 9.9% (12/121) used sleep aids. Other baseline characteristic information is presented in Table 2.

Partial intervention implementation results

In the intervention group, on the basis of voluntary requests or our recommendation, 27.2% (34/125) of patients used both earplugs and eye masks. As part of the intervention measures, nurses were instructed to adjust lighting at night (such as turning off lights in public areas and leaving only bedside lights) and adjust

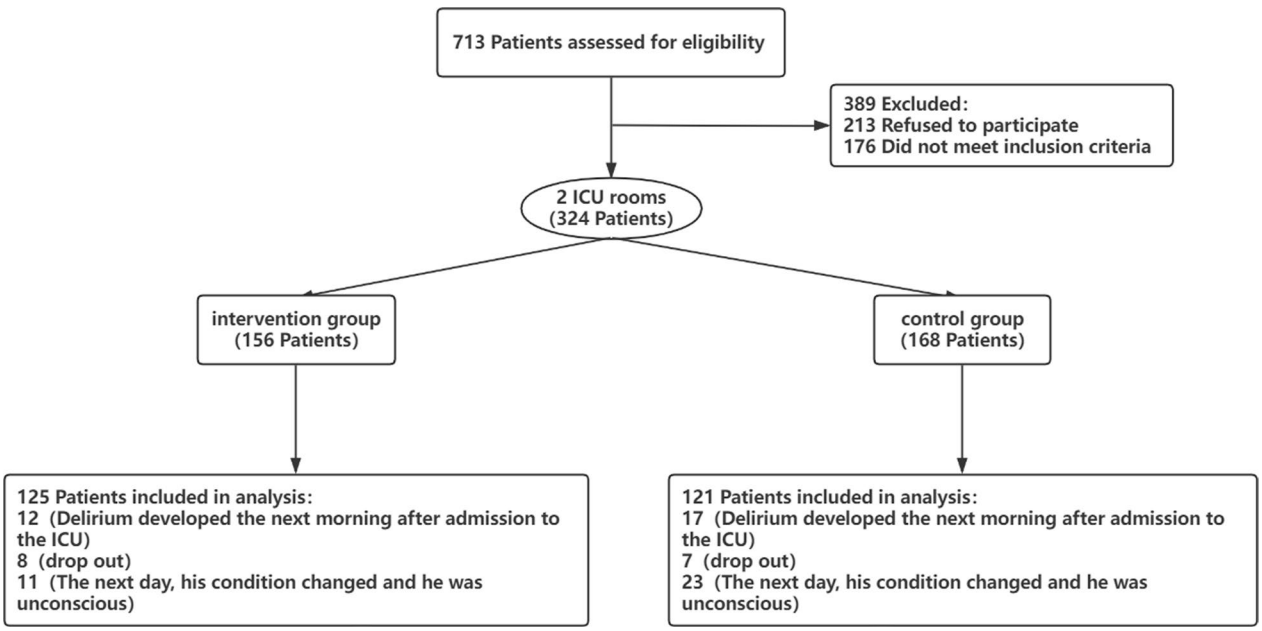

Fig. 2 Consolidated standards of reporting trials (CONSORT) flow study diagram

the volume of equipment alarms. The implementation rates for these measures were 92% and 96.8%, respectively, as shown in Table 3.

Comparison of sleep quality between the intervention and control groups (1 night in the ICU)

We assessed the consistency between the sleep monitoring device data and RCSQ questionnaire data for the intervention and control groups separately. The results revealed no significant consistency between the two sets of data (intervention group: kappa = 0.005, $p = 0.694$; control group: kappa = 0.019, $p = 0.066$). Therefore, we analyzed and presented the results of the two sets of data separately.

In this study, we found no statistically significant difference in sleep quality among awake adult ICU patients between the intervention and control groups on the first night of ICU admission ($P > 0.05$). However, the intervention group presented greater sleep quality across various dimensions than did to the control group, with fewer awakenings (intervention group: 3.976 ± 2.693 vs. control group: 6.09 ± 4.664). In the RCSQ questionnaire, there was a statistically significant difference between the two groups in the 'awakening' dimension ($P = 0.034$), as shown in Table 4.

Sleep quality of intervention group patients with multiple nights in the ICU (ICU > 1 night)

By analyzing the correlation between ICU length of stay and sleep quality, we found a significant correlation between adult ICU awake patients' length of stay and total sleep duration (r = 0.343, $p = 0.024$), duration of deep sleep (r = 0.328, $p = 0.032$), and overall sleep score (r = 0.332, $p = 0.030$). The average ICU length of stay was 2.767 ± 1.212 days, with a median of 2 days.

When comparing the sleep quality of intervention group patients who stayed in the ICU for more than one night between their first night and the night before leaving the ICU (i.e., a before-and-after comparison), significant differences were observed in all variables collected from the sleep monitoring device data, except for rapid eye movement duration (min) ($P < 0.05$). In the data collected by the RCSQ questionnaire, there were significant differences in sleep quality between the first night and the night before leaving the ICU for awake adult ICU patients ($P < 0.05$). Additionally, the sleep quality across all dimensions on the night before leaving the ICU was higher compared to the first night in the ICU, as shown in Table 5.

Comparison of sleep quality heterogeneity in adult ICU awake patients

Due to inconsistent units in sleep monitoring device data, we only plotted data from the RCSQ questionnaire. On the basis of the assessment of sleep quality in adult awake ICU patients, latent class models were fitted, with 5 latent class models fitted for each group in this study. The fit indices for each model are provided in Supplementary File 2. A comparison of the AIC, BIC, aBIC values, LMR, BLRT p-values, and Entropy values in Table 6 shows the final selection of latent class models for this profile analysis. The results indicate that the sleep quality of adult ICU awake patients in both the intervention and control groups was mostly divided into 2 classes, which we named "Sleep Quality—Low" and "Sleep Quality—High". The proportions

Table 4 Comparison of sleep quality in awake adult ICU patients (intervention group vs. control group, ICU stay = 1 night)

Variables		Sleep quality		F	*P*
		Control group(N = 121)	Intervention group(N = 125)		
Sleep monitoring wristband	Total sleep duration (minutes)	420.31 ± 236.88	440.42 ± 262.11	.760	.799
	Duration of deep sleep (minutes)	90.09 ± 78.65	102.37 ± 87.78	.931	.613
	Duration of light sleep (minutes)	256.83 ± 195.51	247.68 ± 189.47	.865	.714
	Duration of rapid eye movement (REM) sleep (minutes)	35.18 ± 41.96	47.81 ± 3.45	.747	.871
	Number of awakenings	6.09 ± 4.66	3.98 ± 2.69	.468	.919
	Overall sleep score	57.72 ± 19.39	57.74 ± 22.55	.702	.906
RCSQ questionnaire	Sleep depth	60.12 ± 26.35	59.84 ± 24.33	1.264	.260
	Sleep onset latency	58.60 ± 27.30	62.40 ± 25.35	.844	.588
	Awakenings	51.16 ± 25.44	57.04 ± 22.65	2.055	.034
	Return to sleep	57.44 ± 26.79	61.28 ± 25.62	1.167	.321
	Overall sleep quality	60.41 ± 24.85	62.32 ± 23.78	.731	.694
	RCSQ sleep score	57.61 ± 24.40	60.58 ± 22.14	.931	.589

Table 5 Comparison of sleep quality in awake adult ICU patients (intervention group, ICU > 1 night)

Variables		Sleep quality		T value	95% Confidence interval value		*P* value
		First night (N = 43)	Before transfer from ICU (N = 43)		Lower limit	Upper limit	
Sleep monitoring wristband	Total sleep duration (minutes)	373 ± 261.219	555.488 ± 185.781	4.002	90.4611	274.5156	.000
	Duration of deep sleep (minutes)	76.419 ± 76.987	128.581 ± 68.575	3.564	22.6293	81.6963	.001
	Duration of light sleep (minutes)	208.930 ± 203.325	357.535 ± 141.456	4.220	77.5451	219.6642	.000
	Duration of rapid eye movement (REM) sleep (minutes)	40.767 ± 54.802	55.907 ± 46.803	1.463	-5.7372	36.0163	.151
	Number of awakenings	4.023 ± 2.816	3 ± 1.800	-2.341	-1.9053	-.1412	.024
	Overall sleep score	51.837 ± 21.033	69.140 ± 13.462	5.708	11.1845	23.4201	.000
RCSQ questionnaire	Sleep depth	47.674 ± 21.026	74.884 ± 16.814	8.374	20.6524	33.7662	.000
	Sleep onset latency	50.930 ± 22.127	76.047 ± 16.056	6.967	17.8405	32.3920	.000
	Awakenings	45.349 ± 20.857	71.628 ± 16.893	7.395	19.1079	33.4503	.000
	Return to sleep	44.884 ± 22.717	74.884 ± 16.529	8.407	22.7982	37.2018	.000
	Overall sleep quality	53.023 ± 23.149	76.744 ± 16.435	6.427	16.2721	31.1698	.000
	RCSQ sleep score	48.372 ± 19.343	74.837 ± 14.204	9.019	20.5433	32.3869	.000

Table 6 Heterogeneity characteristics of sleep quality in awake adult ICU patients (profile analysis)

Geoup	Model	AIC	BIC	aBIC	Entropy	*P* Value		Category proportions
						LMR	BLRT	
Intervention group (sleep monitoring wristband ICU = 1 night, N = 125)	2	7427.400	7481.138	7421.057	0.985	< 0.001	< 0.001	0.314/ 0.686
Control group (sleep monitoring wristband ICU = 1 night, N = 121)	2	7013.167	7066.287	7006.215	1.000	< 0.001	< 0.001	0.376/0.624
Intervention group (RCSQ questionnaire ICU = 1 night, N = 125)	3	6135.856	6209.392	6127.175	0.986	< 0.001	< 0.001	0.352/0.552/ 0.096
Control group (RCSQ questionnaire ICU = 1 night, N = 121)	2	6137.774	6190.894	6130.823	0.985	< 0.001	< 0.001	0.405/ 0.595
Intervention group (sleep monitoring wristband ICU > 1 night, N = 43)	2	2524.701	2558.164	2498.644	1.000	< 0.001	< 0.001	0.067/ 0.9302
Intervention group (RCSQ questionnaire ICU > 1 night, N = 43)	2	2013.919	2047.382	1987.862	0.998	0.0004	< 0.001	0.279/ 0.721

AIC = Akaike Information Criterion, BIC = Bayesian Information Criterion, aBIC = Sample-corrected Bayesian Information Criterion, entropy = entropy, LMR = Likelihood Ratio Test, BLRT = Bootstrap Likelihood Ratio Test, and $p < 0.05$ indicates statistically significant differences

of the "Sleep Quality—Low" and "Sleep Quality—High" populations in each group are shown in Table 6. Notably, compared with the control group, the intervention group had a lower proportion of "Sleep Quality—Low" individuals on the first night in the ICU (31.4% < 37.6%) on the basis of the data collected via the sleep monitoring device; however, on the basis of the data collected by the RCSQ questionnaire, the intervention group was divided into 3 classes, with a lower proportion of "Sleep Quality—High" individuals than the control group (55.2% < 59.5%). When the number of ICU stays exceeded 1 night, both the sleep monitoring device and RCSQ questionnaire data revealed a low proportion of "Sleep Quality—Low" individuals in the intervention group, at 6.7% and 27.9%, respectively (Fig. 3).

Magnitude of the intervention effect

The intervention effect size results revealed a medium effect size for the number of awakenings (Cohen's d absolute value = 0.557) on the first night in the ICU, indicating a moderate effect. The intervention effect sizes for other dimensions of sleep quality were small. For ICU

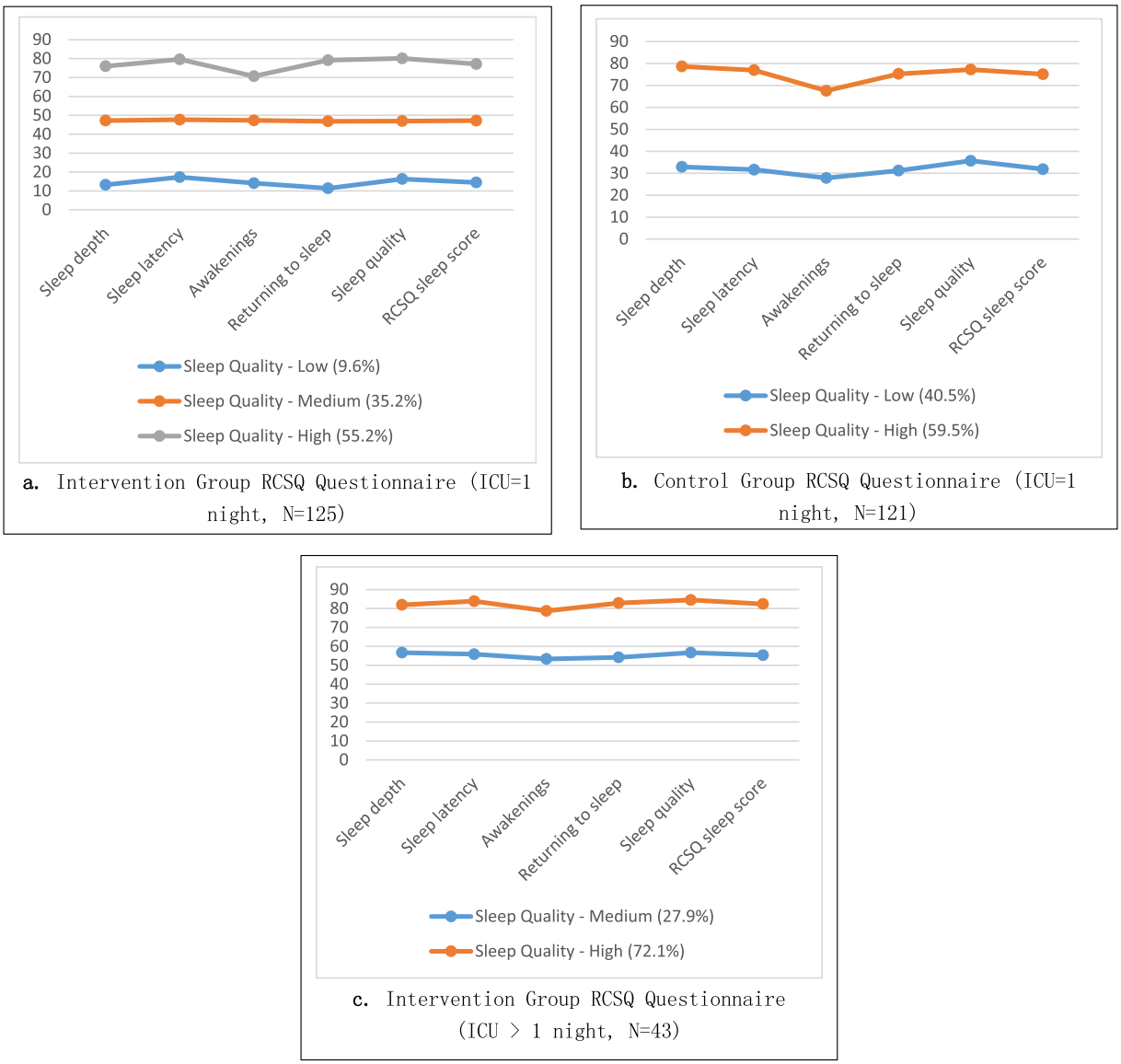

Fig. 3 Population heterogeneity profile analysis of sleep quality in adult awake ICU patients. (Figures **a** and **b** depict the heterogeneity profile analysis of sleep quality in the intervention and control groups on the first night in the ICU, while Figure **c** shows the heterogeneity profile analysis of sleep quality in the intervention group patients whose duration in the ICU exceeded 1 night)

stays exceeding 1 night, the intervention effect size range for sleep quality in awake adult ICU patients was 0.223 ~ 1.375, with a medium to large intervention effect, indicating a good intervention effect and effectiveness of the intervention measures, as shown in Table 7.

Discussion

Evidence-based sleep intervention measures may not significantly improve the sleep quality of adult ICU patients who stay in the ICU for only one night in an open environment. In our study, there was no crossover between the two clusters. However, there were no statistically significant differences in sleep quality-related variables between the two groups, including total sleep time, deep sleep time, light sleep time, rapid eye movement time, number of awakenings, and overall sleep score. Although the intervention group had slightly higher total sleep time and deep sleep time compared to the control group, the difference was minimal. Simple follow-up interviews with these patients revealed similar reasons in both groups: they experienced fear and anxiety upon admission to the ICU and were concerned about changes in their condition due to unfamiliarity with the ICU environment and a stereotypical impression of the ICU as a place where

Table 7 Intervention effect size

Variables		ICU = 1 night (intervention group vs. control group)	ICU > 1 night (pre-test vs. post-test)
Sleep monitoring wristband	Total sleep duration (minutes)	0.080	0.610
	Duration of deep sleep (minutes)	0.147	0.544
	Duration of light sleep (minutes)	−0.047	0.644
	Duration of rapid eye movement (REM) sleep (minutes)	0.262	0.223
	Number of awakenings	−0.557	−0.357
	Overall sleep score	0.001	0.870
RCSQ questionnaire	Sleep depth	0.011	1.277
	Sleep onset latency	0.153	1.062
	Awakenings	0.244	1.128
	Return to sleep	0.147	1.282
	Overall sleep quality	0.079	0.980
	RCSQ sleep score	0.127	1.375

patients are in critical condition and near death. These factors adversely affected the patients' sleep quality. Since we only conducted simple follow-up interviews, the results may not be very rigorous. However, these reasons are consistent with the findings of Baow [26] and Li et al. [27], who found that the emotional state and anxiety level of ICU patients affect their sleep quality. Additionally, Zhang Yan [28] pointed out that ICU patients become more negatively affected due to their unfamiliarity with the environment, leading to reduced treatment compliance and sleep quality, which hinders the smooth progress of clinical treatment.

Furthermore, our study revealed that the measurements from wearable actigraphy sleep monitoring devices did not consistently align with those obtained from the RCSQ. This finding is consistent with the results reported by Locihová et al. [29]. However, there remains a lack of robust correlational evidence to support the relationship between RCSQ and actigraphy. Due to the limited number of previous studies exploring this relationship, we were unable to draw definitive conclusions on this matter. Consequently, in our study, we presented the results from both measurement methods to serve as a reference for future research. Notably, prior studies have established the reliability of the RCSQ when compared to PSG. In the study conducted by Richards et al. [30], the RCSQ demonstrated a moderately strong correlation with PSG, indicating that the RCSQ is a reliable tool for assessing sleep quality in ICU patients.

In our study, due to unfamiliar surroundings, ICU patients often struggle to adapt on the first night, typically experiencing poor sleep quality. From the second night onwards, they gradually begin to learn how to sleep in the new environment, a point not explicitly stated in other studies. However, evidence-based sleep intervention measures were effective for adult awake patients staying in the ICU for more than one night, significantly improving their sleep quality. This included increasing total sleep time and deep sleep time while reducing light sleep time and the number of awakenings. This was also significantly demonstrated in the analysis of intervention effect sizes.In implementing these intervention measures, adjustments to lighting at night and reducing noise were generally feasible, while providing earplugs and eye masks was only accepted by one-third of patients. This is because when providing earplugs or eye masks, we respected the patients' personal preferences and sought their consent before use. Some patients complained of discomfort, ear pain, or even developed claustrophobia when wearing eye masks [31]. In our previous related studies, the use of earplugs and eye masks did not have a statistically significant effect on the sleep quality of ICU awake patients, whether used alone or in combination, consistent with the findings of Huang et al. [32]. However, this finding was inconsistent with the systematic review results conducted by Fang et al. [9, 33], who believed that eye masks and earplugs combined or individually were the most effective intervention measures to improve sleep quality in critically ill patients. Therefore, further research is needed to verify this point.Although studies analyzing the correlation between ICU length of stay and sleep quality of ICU awake patients have not been found, in our study, there was a significant correlation between ICU length of stay and sleep quality (total sleep time and deep sleep time) of adult ICU awake patients, with a median of 2 days. This further indicates that relevant intervention measures can be taken to improve sleep quality for adult ICU awake patients staying in the ICU

for more than one night. However, multicenter studies are still needed for verification.

The sleep quality of adult ICU awake patients exhibits heterogeneity within the population. Overall, whether staying in the ICU for one night or more, the sleep quality of ICU awake patients can be categorized into two types: low sleep quality and high sleep quality. Notably, when staying in the ICU for one night, data collected by the RCSQ questionnaire showed that the intervention group was divided into three classes, with a lower proportion of "High Sleep Quality" individuals compared to the control group by 4.3%. However, the average score of the intervention group was between 70 and 80, while the average score of the control group was between 60 and 80, indicating that overall, the sleep quality of the intervention group remained higher. After continuous intervention for multiple nights (i.e., an ICU stay exceeding one night), the scores of the intervention group patients classified as "High Sleep Quality" were between 80 and 90, and those classified as "Medium Sleep Quality" were between 50 and 60, significantly improving sleep quality compared to a single-night ICU stay. Regarding the heterogeneity of sleep quality in adult ICU awake patients, those initially classified as "High Sleep Quality" should receive continuous assessment or non-pharmacological intervention measures to maintain stable high sleep quality. Conversely, those classified as having low or medium sleep quality require special attention. Our study results indicate that evidence-based sleep intervention measures can improve the sleep quality of adult ICU awake patients, shifting their sleep quality towards medium to high quality and showing a trend of continuous improvement.

Limitations

There are several points worth noting about this study. First, due to the open ICU environment (i.e., no single-room wards) in our study, although the sleep quality of patients in the intervention group improved, there was no statistically significant difference in sleep quality between the two groups on the first night, which we did not find in other studies. Second, although the sample sizes of the two groups included in the analysis (intervention n = 125, control n = 121) were almost equal, there may be unequal cluster sizes, which may weaken the reliability of the results. Third, we did not collect psychological data from patients, such as anxiety, stress, and depression, which may be important risk factors for sleep disorders in adult ICU patients and may be influenced by our related intervention measures, contributing to the analysis and discussion of the research results. Moreover, we did not intervene in the psychological aspects of the patients, which may have affected the effectiveness of the intervention, especially for patients who stayed in the ICU for only one night. Fourth, PSG is the gold standard for obtaining information on sleep duration and structure, but due to its high cost, complexity, and time-consuming procedures, its utility in the ICU is limited. Therefore, the objective measurement tool we used to assess patient sleep was actigraphy, and compared with PSG, the measurement results of total sleep time may be greater [34]; thus, further validation of the study results using PSG is needed in the future.

In addition, this study employed a cluster control design. Since there were only two clusters, randomization of the clusters was not performed. Moreover, due to the nature of patients' diseases in this study environment, the wards assigned to the two groups were fixed; thus, individual randomization was not conducted. This approach may reduce the reliability of the results. However, adopting the cluster control method ensures the effectiveness of the intervention measures implemented.

Conclusions

In managing the sleep quality of awake adult ICU patients, implementing systematic nursing measures can help improve their sleep quality. This is particularly true for patients staying in the ICU for more than one night, as their sleep quality will see a significant improvement. In our study, however, the degree of improvement in sleep quality for patients staying only one night in the ICU may not be ideal. This could be related to the open environment of the ICU where they are located. Further measures will be taken in the future to improve the sleep quality of adult ICU patients in such environments.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13054-024-05161-1.

Additional file 1.

Additional file 2.

Acknowledgements

We would like to thank Zhongnan Hospital of Wuhan University for their support of our study and all the staff and patients who participated in this study for their cooperation.

Author contributions

All listed authors have contributed substantially to the manuscript in the following ways: Yanting Zhang (Conception, Design, Data Collection, Writer, Literature Review, Analysis and Interpretation); Yihua Yang, Chong Cheng, Gui Hou (Data Processing, Data Collection and Interpretation); Xinbo Ding (Literature Review, Critical Review); Jing Ma (Literature Review, Writer, Critical Review).

Funding

This study was supported by the Clinical Nursing Research Program of Zhongnan Hospital of Wuhan University in 2022 (LCHLYJ202210).

Availability of data and materials
The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Zhongnan Hospital of Wuhan University [2023023 K]. All participants participated in the study voluntarily and anonymously and were told that they had the right to withdraw from the study at any time.

Consent for publication
All participants in this study were made aware that their data could be used in publications and gave approval for this use.

Competing interests
The authors declare no competing interests.

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Received: 18 June 2024 Accepted: 4 November 2024
Published online: 12 November 2024

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