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Original Article

Nurse-Led Microclimate Adjustments in Patient Rooms and Their Physiological Impact on Sleep Quality Recovery

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ABSTRACT

Background: Sleep disturbance is common among hospitalized adults and may impair physiological recovery, increase fatigue, and reduce patient comfort. Environmental factors such as room temperature, light exposure, noise, airflow, and bedding comfort are potentially modifiable contributors to inpatient sleep disruption. Objective: To evaluate the effect of nurse-led environmental microclimate adjustment on sleep quality and physiological sleep-recovery markers among hospitalized adults. Methods: A parallel-group randomized controlled trial was conducted in medical and post-surgical recovery wards of a tertiary care hospital in Central Punjab, Pakistan, from August 2025 to January 2026. Seventy-two adults with baseline sleep disturbance were randomized to structured nurse-led microclimate adjustment or routine ward care. The intervention targeted nighttime temperature, lighting, noise, airflow, and bedding comfort over 14 nights. Baseline characteristics were analyzed in all randomized participants, while post-intervention outcomes were analyzed among 65 participants with complete outcome data. Results: Post-intervention PSQI scores were lower in the intervention group than controls (5.9 ± 1.7 vs 8.8 ± 2.0; mean difference −2.9; 95% CI −3.8 to −2.0; $p<0.001$). The intervention group also showed fewer nighttime awakenings, higher oxygen saturation, greater heart rate variability, lower fatigue severity, and higher comfort scores. Comfort was inversely correlated with PSQI score ($r=-0.61$; $p<0.001$). Conclusion: Nurse-led microclimate adjustment was associated with improved sleep quality, comfort, fatigue, and physiological sleep-recovery markers in hospitalized adults. Larger multicenter trials with objective sleep monitoring and adjusted analyses are recommended. Keywords: Circadian Rhythm; Heart Rate Variability; Hospitalization; Nursing Care; Patient Comfort; Sleep Quality; Temperature Comfort.

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INTRODUCTION

Sleep is an essential physiological process that supports tissue repair, immune regulation, neurocognitive restoration, autonomic stability, and overall recovery from illness. In hospitalized patients, sleep assumes particular clinical importance because acute illness, surgical recovery, pain, medication exposure, anxiety, and unfamiliar ward routines can collectively disturb sleep continuity and delay restorative physiological processes (1). Despite this importance, sleep disturbance remains common and often underrecognized in inpatient care, where clinical monitoring, alarms, lighting, nighttime procedures, ward noise, and altered daily routines frequently fragment nocturnal rest. Repeated interruption of sleep may contribute to

sympathetic activation, impaired immune function, metabolic dysregulation, fatigue, delayed wound healing, and prolonged recovery, making sleep preservation a relevant therapeutic component of holistic inpatient management (2).

Among the modifiable contributors to inpatient sleep disturbance, the physical microclimate surrounding the patient is particularly important because it directly influences comfort perception, thermoregulation, sensory arousal, circadian rhythm stability, and autonomic balance. Environmental microclimate refers to the localized conditions within the patient's immediate surroundings, including room temperature, humidity, airflow, light exposure, noise intensity, and bedding comfort (3). These factors may influence sleep initiation, nighttime awakenings, melatonin secretion, slow-wave sleep, rapid eye movement sleep, and physiological recovery during the night. Excessive warmth may impair thermoregulatory cooling required for sleep maintenance, while cold exposure may increase discomfort and sympathetic activity. Similarly, excessive light exposure and avoidable nighttime noise may suppress circadian signaling and increase arousal frequency, thereby reducing the restorative value of sleep even when total time in bed appears adequate (4).

In many hospital settings, environmental conditions are managed primarily through centralized institutional systems designed for operational efficiency, infection prevention, and general ward functioning rather than individualized patient comfort. Although standardized environmental controls are necessary for safe facility management, they may not adequately address variation in age, illness severity, pain level, medication use, mobility restriction, personal thermal preference, and psychological stress among hospitalized adults (5,6). Consequently, patients may remain exposed to environmental conditions that are technically acceptable at the ward level but suboptimal for individual sleep recovery. This creates an important clinical opportunity for low-cost, patient-centered environmental interventions that can be adapted at the bedside without major infrastructural redesign.

Nurses are strategically positioned to deliver such interventions because they maintain continuous bedside presence, observe patient comfort and physiological responses across day and night shifts, and routinely coordinate care activities that may either disturb or protect sleep. Nurse-led microclimate adjustment can include regulating room temperature within a comfortable range, reducing unnecessary light exposure, minimizing avoidable noise, clustering non-urgent nighttime care, optimizing bedding layers, and adjusting airflow according to patient tolerance. These actions are consistent with holistic nursing practice because they integrate comfort promotion, individualized assessment, recovery support, and non-pharmacological care into routine inpatient management (7). Compared with pharmacological sleep aids, environmental optimization has the advantage of being non-invasive, adaptable, and less likely to cause adverse effects such as daytime sedation, delirium, respiratory depression, or impaired mobility in vulnerable patients (8).

Although previous research has examined environmental modification and non-pharmacological sleep-supportive interventions in hospitalized populations, several gaps remain. First, many studies have focused on isolated environmental components such as noise reduction, dimmed lighting, or care clustering rather than evaluating a coordinated microclimate protocol delivered by nursing staff. Second, much of the available evidence has relied mainly on patient-reported sleep outcomes, while fewer studies have incorporated physiological recovery indicators such as heart rate variability, oxygen saturation stability, and morning cardiovascular parameters. Third, evidence from general inpatient medical and post-surgical recovery wards remains less developed than evidence from highly monitored critical care environments. These limitations reduce certainty about whether structured nurse-led environmental optimization can improve both perceived sleep quality and measurable physiological recovery in routine ward settings (9,10).

Therefore, the present randomized controlled trial was designed to evaluate the effect of structured nurse-led microclimate adjustment on sleep recovery among hospitalized adults with baseline sleep disturbance. The primary endpoint was post-intervention sleep quality measured using the Pittsburgh Sleep Quality Index after 14 nights of intervention. Key physiological and clinical outcomes included

nighttime awakenings, nocturnal oxygen saturation stability, heart rate variability, fatigue severity, patient comfort, morning systolic blood pressure, and length of hospital stay. The study tested the hypothesis that individualized nurse-led microclimate optimization would improve sleep quality and related physiological recovery markers compared with routine ward care among hospitalized adults.

MATERIALS AND METHODS

A parallel-group randomized controlled trial was conducted in the inpatient medical and post-surgical recovery wards of a tertiary care hospital in Central Punjab, Pakistan, from August 2025 to January 2026. The trial evaluated whether a structured nurse-led environmental microclimate management protocol improved sleep recovery among hospitalized adults compared with routine ward care. The intervention was delivered during nighttime hours for 14 consecutive nights or until discharge if discharge occurred earlier after completion of post-intervention outcome assessment. The study was designed to compare individualized bedside environmental optimization against usual ward practices while maintaining the routine medical and nursing care required for each patient's primary condition.

Eligible participants were hospitalized adults aged 30–70 years who reported sleep disturbance within the first 48 hours of admission and had a Pittsburgh Sleep Quality Index score greater than 5 at baseline. Participants were considered eligible when they were clinically stable, able to communicate sleep-related symptoms and comfort preferences, and expected at the time of recruitment to remain admitted long enough to complete structured nighttime environmental monitoring. Patients were excluded if they were receiving mechanical ventilation, sedative infusions, active psychiatric treatment, or end-of-life care, or if they had a diagnosed sleep disorder such as obstructive sleep apnea. Additional exclusion criteria included severe cognitive impairment, hemodynamic instability, major sensory deficits interfering with environmental perception, and clinical conditions that prevented reliable sleep or comfort assessment. Participants were screened during the first 48 hours of admission by the study team in coordination with ward nursing staff. Eligible patients were informed about the study purpose, intervention procedures, outcome assessments, voluntary participation, and confidentiality of collected data before enrolment. After baseline assessment, participants were randomly assigned in a 1:1 ratio to the intervention group or control group using a computer-generated randomization sequence prepared independently from the clinical care team. Allocation concealment was maintained using sequentially numbered sealed opaque envelopes that were opened only after enrolment and completion of baseline measurements. Because the intervention involved visible environmental adjustments, blinding of participants and nursing staff was not feasible; however, outcome assessment and data analysis were performed without disclosure of group allocation.

Participants assigned to the intervention group received structured nurse-led microclimate management between 9:00 PM and 6:00 AM. The protocol focused on five modifiable environmental domains: room temperature, light exposure, ambient noise, airflow, and bedding comfort. Room temperature was maintained within a thermally comfortable target range of 22–24°C whenever ward conditions allowed. Unnecessary nighttime light exposure was reduced, with the target illumination kept below 30 lux during sleep periods except when clinical care required temporary lighting. Ambient noise was minimized through clustering of non-urgent nursing activities, reduction of avoidable conversations near patient beds, prompt alarm response, and adjustment of preventable equipment-related disturbance. Airflow was individualized according to patient comfort and physiological tolerance, while bedding layers and pillow positioning were adjusted to support thermal comfort and reduce discomfort-related awakenings. Nurses reassessed environmental conditions and patient comfort every two hours during the nighttime intervention window and documented each assessment on a structured checklist.

Participants assigned to the control group received routine ward care according to existing institutional practice. Routine care included standard nursing observation, medication administration, clinical monitoring, and environmental management performed as part of usual ward functioning, but it did not include the structured two-hourly microclimate assessment checklist or protocolized adjustment of

temperature, light, noise, airflow, and bedding comfort. Both groups continued to receive all prescribed medical and nursing care, and no disease-specific treatment was withheld or altered for study purposes.

The primary endpoint was sleep quality after completion of the intervention period, assessed using the Pittsburgh Sleep Quality Index. Key physiological sleep recovery outcomes included number of nighttime awakenings, nocturnal oxygen saturation stability, and heart rate variability. Secondary outcomes included fatigue severity measured using the Fatigue Severity Scale, patient comfort assessed using a visual analog scale, morning systolic blood pressure, and length of hospital stay. Baseline demographic and clinical variables included age, gender, body mass index, baseline PSQI score, nighttime awakenings, oxygen saturation, and heart rate variability. Nighttime awakenings were recorded through bedside monitoring and nursing observation records during the intervention period. Oxygen saturation and heart rate variability were assessed overnight using available bedside monitoring data, while morning systolic blood pressure was recorded after nighttime observation using standard ward measurement procedures.

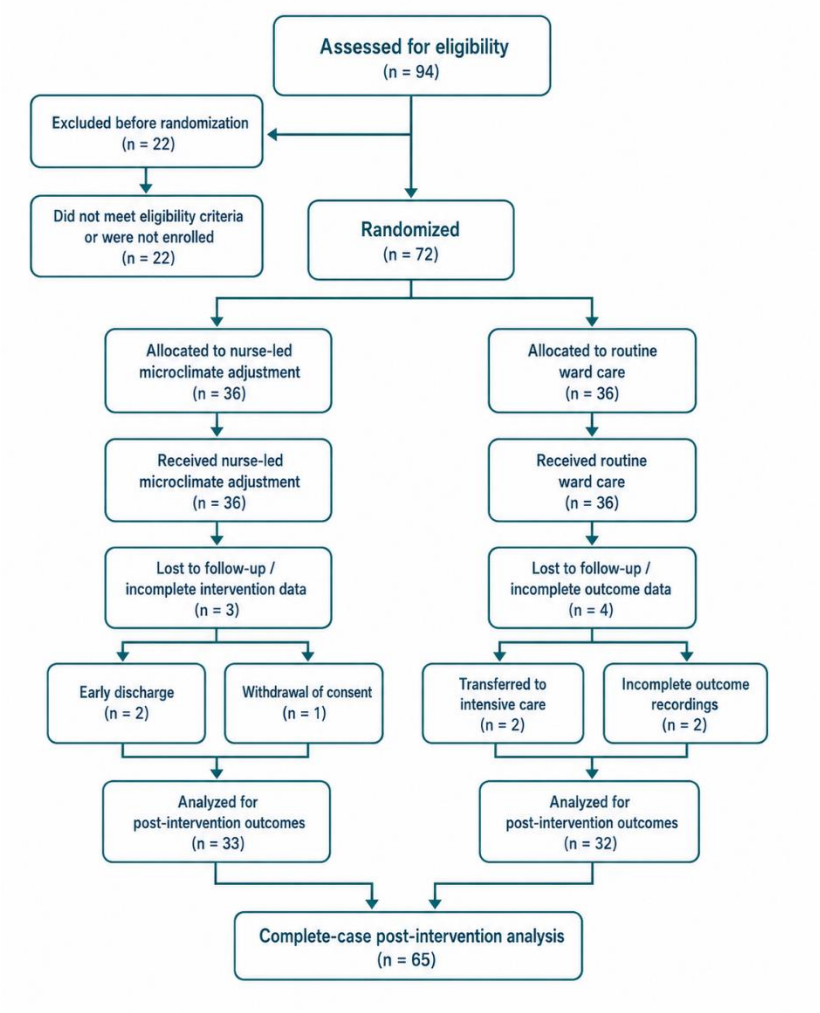

Figure 1 CONSORT Flowchart

To reduce performance and measurement bias, the intervention protocol was standardized through a predefined checklist and applied during the same nighttime window for all intervention participants. Nursing staff documented each scheduled environmental assessment, the environmental domain requiring adjustment, the action taken, and patient comfort response. Outcome assessors were kept unaware of treatment allocation where feasible, and data analysis was conducted using coded group labels. Potential confounding was addressed by comparing baseline demographic, physiological, and sleep-related characteristics between groups before outcome interpretation. Variables with clinically meaningful baseline imbalance were planned for consideration in adjusted analysis where sufficient data were available. Sample size was calculated before recruitment using expected differences in sleep recovery outcomes from previous interventional evidence on environmental modification and inpatient

sleep. With 80% statistical power, a 95% confidence level, and an anticipated dropout rate of 10%, the required sample size was 72 participants, with 36 allocated to each group. Recruitment continued until the planned randomized sample was achieved.

Data were analyzed using a prespecified comparative approach aligned with the randomized group allocation. Baseline characteristics were summarized using the full randomized sample. Continuous variables were reported as mean ± standard deviation when approximately normally distributed, and categorical variables were reported as frequency and percentage. Normality of continuous variables was assessed using the Shapiro–Wilk test. Between-group comparisons of post-intervention continuous outcomes were performed using independent-samples t-tests, while within-group pre–post changes were assessed using paired-samples t-tests. Repeated measures analysis of variance was used to evaluate time-by-group interaction for the primary sleep-quality endpoint. Pearson correlation analysis was used to assess the relationship between patient comfort scores and post-intervention sleep quality where assumptions of linearity and approximate normality were met. Statistical significance was set at $p < 0.05$.

The main post-intervention outcome analysis was conducted using participants with complete baseline and post-intervention outcome data, while baseline comparability was reported using the randomized sample. Participants who withdrew consent, were transferred to intensive care, were discharged before complete outcome recording, or had incomplete post-intervention measurements were documented by group. This approach was used to avoid presenting imputed outcome values as observed data. The analysis denominator was therefore reported separately for baseline characteristics and post-intervention outcomes to maintain transparency. Data integrity was supported through structured case-record forms, nursing adherence checklists, coded data entry, and review of completed forms for missing or inconsistent entries before statistical analysis.

RESULTS

A total of 94 hospitalized adults were screened between August 2025 and January 2026. Of these, 72 participants met the eligibility criteria and were randomized equally to the nurse-led microclimate adjustment group (n=36) and routine care group (n=36). Seven randomized participants did not contribute complete post-intervention outcome data. In the intervention group, two participants were discharged early and one withdrew consent. In the control group, two participants were transferred to intensive care and two had incomplete outcome recordings. Baseline characteristics were therefore summarized using the randomized sample of 72 participants, while post-intervention outcomes were analyzed using the 65 participants with complete outcome data.

Table 1. Participant Disposition

Study Stage	Total	Intervention	Control
Screened	94	—	—
Randomized	72	36	36
Early discharge	2	2	0
Withdrawal of consent	1	1	0
Transfer to intensive care	2	0	2
Incomplete outcome recording	2	0	2
Complete post-intervention data	65	33	32

Baseline demographic, clinical, and sleep-related characteristics were comparable between groups at randomization. The mean age was 51.9 ± 11.2 years in the intervention group and 52.8 ± 10.5 years in the control group. Baseline PSQI scores were similar between groups, with mean scores of 11.1 ± 2.0 and 11.3 ± 2.2, respectively. Baseline nighttime awakenings, oxygen saturation, and heart rate variability were also closely aligned, supporting acceptable comparability before intervention exposure.

The primary endpoint was post-intervention sleep quality measured using the PSQI. In the complete-case analysis, post-intervention PSQI scores were lower in the intervention group than in the control group, with a mean difference of −2.9 points and a 95% confidence interval from −3.8 to −2.0. Nighttime awakenings were also lower in the intervention group, with a mean difference of −1.6 awakenings per night. Physiological sleep recovery markers favored the intervention group, with higher oxygen saturation and

greater heart rate variability. The standardized mean differences were large for PSQI, nighttime awakenings, oxygen saturation, and heart rate variability, indicating that the observed between-group differences were not limited to statistical significance but also reflected substantial separation between groups.

Table 2. Baseline Demographic and Clinical Characteristics of Randomized Participants

Variable	Total Sample (N=72)	Intervention (n=36)	Control (n=36)	p-value
Age, years	52.4 ± 10.8	51.9 ± 11.2	52.8 ± 10.5	0.741
Male gender, n (%)	39 (54.2)	20 (55.6)	19 (52.8)	0.814
BMI, kg/m²	26.1 ± 3.7	25.9 ± 3.5	26.3 ± 3.9	0.662
PSQI score	11.2 ± 2.1	11.1 ± 2.0	11.3 ± 2.2	0.703
Night awakenings/night	4.8 ± 1.3	4.7 ± 1.2	4.9 ± 1.4	0.521
Oxygen saturation, %	93.8 ± 2.4	94.0 ± 2.3	93.6 ± 2.5	0.488
Heart rate variability, ms	28.6 ± 5.2	28.9 ± 5.0	28.3 ± 5.4	0.639

Values are presented as mean ± SD unless otherwise indicated. BMI, body mass index; PSQI, Pittsburgh Sleep Quality Index.

Table 3. Post-Intervention Primary Sleep and Physiological Outcomes

Outcome	Intervention (n=33), Mean ± SD	Control (n=32), Mean ± SD	Mean Difference	95% CI	Cohen's d	p-value
PSQI score	5.9 ± 1.7	8.8 ± 2.0	−2.9	−3.8 to −2.0	−1.56	<0.001
Night awakenings/night	2.1 ± 0.9	3.7 ± 1.1	−1.6	−2.1 to −1.1	−1.59	<0.001
Oxygen saturation, %	96.1 ± 1.4	94.5 ± 1.8	1.6	0.8 to 2.4	0.99	<0.001
Heart rate variability, ms	36.4 ± 5.9	30.8 ± 5.2	5.6	2.9 to 8.4	1.01	<0.001

Mean differences were calculated as intervention minus control. Cohen's d was calculated using pooled standard deviations. CI, confidence interval; PSQI, Pittsburgh Sleep Quality Index.

Within-group pre–post analysis showed larger improvements in the intervention group than in the control group for the available repeated measures. The intervention group showed a mean PSQI reduction of 5.1 points, compared with a 2.4-point reduction in the control group. Nighttime awakenings decreased by 2.6 awakenings per night in the intervention group and by 1.1 awakenings per night in the control group. Heart rate variability increased by 7.4 ms in the intervention group and by 2.3 ms in the control group. Repeated measures analysis for PSQI showed a significant time effect, group effect, and time-by-group interaction, supporting greater sleep-quality improvement in the intervention group over time.

For the primary sleep-quality endpoint, repeated measures analysis demonstrated a time effect, group effect, and time-by-group interaction. The time-by-group interaction indicated that the magnitude of PSQI improvement differed between the intervention and control groups across the study period.

Table 4. Within-Group Pre–Post Changes in Primary Outcomes

Outcome	Intervention Pre, Mean ± SD	Intervention Post, Mean ± SD	Change	p-value	Pre, Mean ± SD	Post, Mean ± SD	Change	p-value
PSQI score	11.0 ± 1.9	5.9 ± 1.7	−5.1	<0.001	11.2 ± 2.1	8.8 ± 2.0	−2.4	0.032
Night awakenings/night	4.7 ± 1.2	2.1 ± 0.9	−2.6	<0.001	4.8 ± 1.3	3.7 ± 1.1	−1.1	0.041
Heart rate variability, ms	29.0 ± 5.1	36.4 ± 5.9	7.4	<0.001	28.5 ± 5.2	30.8 ± 5.2	2.3	0.048

Change was calculated as post-intervention value minus pre-intervention value. PSQI, Pittsburgh Sleep Quality Index.

Table 5. Repeated Measures Analysis for PSQI Score

Outcome	Effect	F	p-value
PSQI score	Time	46.21	<0.001
PSQI score	Group	18.44	<0.001
PSQI score	Time × group	29.67	<0.001

PSQI, Pittsburgh Sleep Quality Index.

Secondary outcomes also differed between groups in the complete-case analysis. Fatigue severity was lower in the intervention group, with a mean difference of −1.4 points and a 95% confidence interval from −1.8 to −1.0. Patient comfort was higher in the intervention group, with a mean difference of 2.2 points. Morning systolic blood pressure was lower in the intervention group by 7.2 mmHg. The reported hospital-stay variable was lower in the intervention group by 2.2 days; however, this variable should be verified against the case-record definition before final submission because its reported values are shorter than the planned 14-night intervention window.

Table 6. Post-Intervention Secondary Outcomes

Outcome	Intervention n=33), Mean ± SD	Control (n=32), Mean ± SD	Mean Difference	95% CI	Cohen's d	p-value
Fatigue Severity Scale	3.2 ± 0.8	4.6 ± 1.0	−1.4	−1.8 to −1.0	−1.55	<0.001
Comfort VAS score	8.4 ± 1.1	6.2 ± 1.3	2.2	1.6 to 2.8	1.83	<0.001
Morning systolic BP, mmHg	124.6 ± 8.9	131.8 ± 10.2	−7.2	−11.9 to −2.5	−0.75	0.004
Hospital stays, days	8.1 ± 1.9	10.3 ± 2.4	−2.2	−3.3 to −1.1	−1.02	<0.001

Mean differences were calculated as intervention minus control. Cohen's d was calculated using pooled standard deviations. BP, blood pressure; CI, confidence interval; VAS, visual analog scale.

Correlation analysis showed an inverse association between patient comfort and post-intervention PSQI score. Higher comfort scores were associated with lower PSQI scores, with a correlation coefficient of −0.61. This finding suggests alignment between perceived environmental comfort and improved sleep quality, although the analysis should be reported with its exact denominator and group-composition basis in the final statistical output.

Table 7. Correlation Between Comfort and Sleep Quality

Variables	r	p-value
Comfort VAS score and PSQI score	**−0.61**	**<0.001**

VAS, visual analog scale; PSQI, Pittsburgh Sleep Quality Index.

Overall, the results showed that nurse-led environmental microclimate adjustment was associated with greater improvement in sleep quality, fewer nighttime awakenings, higher oxygen saturation, greater heart rate variability, lower fatigue severity, higher comfort, and lower morning systolic blood pressure compared with routine ward care. The strongest effects were observed for comfort, nighttime awakenings, PSQI score, and fatigue severity. The hospital-stay finding was retained as reported in the supplied data, but its interpretation requires confirmation of whether the variable represents total admission duration, post-randomization stay, or another prespecified length-of-stay definition.

Figure 2 presents the multidimensional effect profile of nurse-led microclimate adjustment across sleep, physiological, comfort, fatigue, and clinical recovery outcomes. Post-intervention primary outcomes favored the intervention group, with lower PSQI scores by −2.9 points, fewer nighttime awakenings by −1.6 episodes per night, higher oxygen saturation by 1.6%, and greater heart rate variability by 5.6 ms. Directionally standardized effects were largest for comfort VAS (d=1.83), nighttime awakenings (d=1.59), PSQI score (d=1.56), and fatigue severity (d=1.55), indicating a broad recovery pattern extending beyond subjective sleep quality. Baseline-to-post change gradients further showed greater improvement in PSQI, awakenings, and HRV in the intervention arm compared with routine care. Higher comfort scores were inversely associated with poorer sleep quality, with comfort VAS demonstrating a negative correlation with PSQI score (r=−0.61, p<0.001), supporting the clinical relevance of environmental comfort in inpatient sleep recovery.

DISCUSSION

The present randomized controlled trial demonstrated that structured nurse-led environmental microclimate adjustment was associated with greater improvement in sleep quality and selected physiological recovery markers among hospitalized adults compared with routine ward care. Participants

who received individualized nighttime environmental optimization showed lower post-intervention PSQI scores, fewer nighttime awakenings, higher nocturnal oxygen saturation, and greater heart rate variability. These findings support the clinical relevance of the bedside sleep environment as a modifiable component of inpatient recovery and suggest that coordinated nursing actions targeting temperature, lighting, airflow, bedding comfort, and avoidable nighttime disturbance may contribute to more restorative sleep during hospitalization (11).

The reduction in PSQI scores observed in the intervention group is clinically important because inpatient sleep disturbance is frequently multifactorial and often persists despite routine clinical stabilization. Hospitalized patients are exposed to unfamiliar surroundings, repeated nursing and medical procedures, artificial light, equipment alarms, ward noise, discomfort, anxiety, and altered circadian cues, all of which can fragment sleep and reduce perceived sleep quality. The present findings are consistent with the broader understanding that sleep is not only a passive state but also an active physiological process linked with immune regulation, tissue repair, endocrine balance, cardiovascular recovery, and neurocognitive restoration (12). By addressing multiple environmental stressors simultaneously rather than focusing on a single component, the intervention may have improved sleep continuity through cumulative reductions in sensory arousal and discomfort.

The improvement in nighttime awakenings further strengthens the interpretation that microclimate optimization influenced sleep continuity rather than merely improving general satisfaction with care. Frequent awakenings are among the most common inpatient sleep complaints and may be triggered by thermal discomfort, light exposure, noise, clinical interruptions, and poor bedding support. In this study, the intervention group showed a larger reduction in awakenings than the control group, suggesting that systematic environmental assessment during nighttime hours may help identify and correct sleep-disrupting conditions in real time. This is particularly relevant for nursing practice because many of these disturbances are modifiable through bedside-level decisions, including dimming unnecessary lights, reducing preventable noise, clustering non-urgent care, responding promptly to alarms, and adjusting bedding or airflow according to patient preference (13).

The physiological findings provide additional support for the potential recovery value of sleep-focused environmental care. Heart rate variability increased more markedly in the intervention group, which may indicate improved autonomic balance and reduced sympathetic activation during rest. Sleep fragmentation and environmental stress can increase cardiovascular arousal, whereas consolidated and comfortable sleep may favor parasympathetic recovery and more stable overnight physiology. The higher oxygen saturation observed in the intervention group may also reflect improved nocturnal stability, although this finding should be interpreted cautiously because oxygen saturation can be affected by underlying cardiopulmonary status, body position, medication use, pain, and clinical diagnosis. Nevertheless, the concurrent improvement in PSQI, awakenings, HRV, and oxygen saturation suggests a coherent pattern in which improved environmental comfort was accompanied by more favorable sleep-recovery indicators (14).

The secondary outcomes showed a similar direction of benefit. Fatigue severity was lower and patient comfort was higher among participants receiving nurse-led microclimate adjustment. The inverse correlation between comfort scores and PSQI further suggests that perceived environmental comfort was meaningfully related to sleep quality, with higher comfort associated with lower sleep disturbance. This relationship is clinically plausible because comfort integrates multiple patient-level experiences, including temperature tolerance, bedding adequacy, airflow, sensory stimulation, pain-related positioning, and psychological ease. Although subjective outcomes can be influenced by expectation and awareness of intervention allocation, the parallel improvement in physiological indicators adds weight to the interpretation that environmental optimization was associated with measurable recovery-related changes rather than comfort perception alone (15).

The recorded length-of-stay measure was lower in the intervention group than in the control group, but this outcome should be interpreted with caution. Hospital stay is influenced by multiple factors beyond sleep

quality, including primary diagnosis, illness severity, discharge planning, treatment response, bed availability, family readiness, and institutional protocols. Because the present trial focused primarily on sleep quality recovery, length of stay should be viewed as an exploratory clinical outcome rather than as definitive evidence that microclimate adjustment independently shortened hospitalization. Future studies should prespecify the exact length-of-stay definition, distinguish total admission duration from post-randomization or post-intervention stay, and adjust for diagnosis, baseline severity, comorbidity burden, and discharge criteria before drawing firm conclusions about hospitalization duration (16).

An important practical implication of this study is that the intervention was nurse-led and potentially feasible within routine inpatient care. Unlike structural redesign of hospital wards, the protocol relied on repeated bedside assessment and targeted adjustment of modifiable environmental factors. This positions nurses as active agents in sleep recovery rather than passive observers of ward conditions. The intervention also aligns with the broader principles of holistic nursing care, in which comfort, rest, emotional reassurance, physiological monitoring, and recovery support are integrated into patient-centered practice. If implemented with adequate staffing, training, and documentation, microclimate adjustment may represent a low-cost non-pharmacological strategy to complement routine medical management and reduce reliance on sedative sleep aids in appropriate patients (17).

The findings should be interpreted in light of several limitations. First, the trial was conducted in a single tertiary care hospital in Central Punjab, which may limit generalizability to hospitals with different ward layouts, staffing ratios, climate-control systems, patient populations, and institutional routines. Second, blinding of participants and nursing staff was not feasible because the intervention involved visible environmental adjustments, creating potential performance and expectancy bias. Third, although outcome assessment and analysis were performed with group concealment where feasible, subjective measures such as PSQI, fatigue severity, and comfort scores remain vulnerable to response bias. Fourth, the analysis of post-intervention outcomes was based on participants with complete outcome data, while baseline characteristics were reported for the randomized sample; therefore, attrition and missing data should be carefully documented and addressed through sensitivity analysis in future work. Fifth, the study did not use polysomnography or advanced sleep staging, so detailed effects on sleep architecture, rapid eye movement sleep, slow-wave sleep, and sleep efficiency could not be determined (18).

Additional limitations relate to potential confounding and measurement precision. Sleep quality in hospitalized adults can be affected by pain intensity, medication exposure, sedative or analgesic use, comorbid disease, ward type, nursing workload, illness severity, and timing of clinical procedures. Although baseline characteristics were comparable between groups, the available analysis did not fully adjust for all clinically relevant confounders. Environmental measurements were protocolized around clinically practical thresholds for temperature and light, but the manuscript would be strengthened by reporting the exact monitoring devices, calibration procedures, noise measurement approach, adherence rate, and protocol deviations. Future multicenter trials should incorporate more detailed environmental exposure recording, objective sleep monitoring, prespecified adjusted models, and post-discharge follow-up to determine whether inpatient sleep optimization translates into sustained functional recovery, lower readmission risk, or improved patient-reported recovery (19).

Overall, this study contributes to the growing recognition that the hospital environment is not merely a background condition but an active determinant of patient experience and recovery. The results suggest that structured nurse-led microclimate adjustment may improve sleep quality, reduce nighttime awakenings, enhance comfort, and support favorable physiological sleep-recovery markers among hospitalized adults. While the findings are promising, they should be confirmed through larger multicenter trials with stronger control of confounding, clearer length-of-stay definitions, objective sleep measurement, and complete intention-to-treat sensitivity analyses. Within these limits, the study provides clinically useful evidence that individualized environmental management can be integrated into nursing care as a practical non-pharmacological strategy to support restorative sleep during hospitalization (20).

CONCLUSION

Nurse-led environmental microclimate adjustment was associated with improved sleep quality, fewer nighttime awakenings, better patient comfort, lower fatigue severity, and favorable physiological sleep-recovery markers among hospitalized adults compared with routine ward care. Individualized regulation of temperature, lighting, airflow, bedding comfort, and avoidable nighttime disturbance may represent a feasible, low-cost, and patient-centered nursing intervention to support restorative sleep during inpatient recovery. The observed differences in physiological and clinical outcomes are promising, but interpretation should remain cautious because of the single-center design, lack of participant blinding, complete-case post-intervention analysis, and potential confounding from clinical severity, medication exposure, and discharge-related factors. Larger multicenter randomized trials using objective sleep monitoring, prespecified adjusted analyses, and clearly defined length-of-stay outcomes are needed to confirm the effectiveness and implementation value of structured microclimate management in routine hospital care.

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