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ORIGINAL RESEARCH

Long-Term Effects of Structured Microbreak Interventions on Musculoskeletal Health, Psychological Wellbeing, and Patient Safety Among Operating Room Nurses: A Multicenter Longitudinal Cohort Study

Wenhui Gao[1], Guangmei Fan[1], Dandan Liu[2], Guangrui Fan[3]

[1]Department of Anesthesiology, Shanxi Provincial People's Hospital, Taiyuan, Shanxi, People's Republic of China; [2]Department of Media and Communication Studies, Faculty of Arts and Social Sciences, Universiti Malaya, Kuala Lumpur, Malaysia; [3]School of Computer Science and Technology, Taiyuan University of Science and Technology, Taiyuan, Shanxi, People's Republic of China

Correspondence: Guangmei Fan, School of Computer Science and Technology, Taiyuan University of Science and Technology, 66 Waliu Road, Taiyuan, Shanxi, People's Republic of China, Email fgr@tyust.edu.cn

Background: Operating room (OR) nurses frequently experience work-related musculoskeletal disorders (MSDs) and psychological strain due to prolonged static postures, repetitive movements, and high-stress conditions. While short-term benefits of microbreak interventions have been demonstrated, evidence on their long-term effectiveness and impact on patient safety remains limited. This study aimed to evaluate the sustained effects of structured microbreaks on MSD outcomes, psychological wellbeing, and patient safety, and to explore organizational factors influencing intervention adherence.

Methods: A nonrandomized, controlled, multicenter mixed-methods study, six-month follow-up (N = 178 analyzed) was conducted in five hospitals in Shanxi Province, China. Ninety-one OR nurses received a structured microbreak intervention (2–3-minute breaks every 30 minutes during procedures >60 minutes, including ergonomic exercises and mindfulness practices), while 87 served as controls (analyzed cohorts after attrition). Quantitative data (Nordic Musculoskeletal Questionnaire, Perceived Stress Scale, Maslach Burnout Inventory, patient safety metrics) were collected at baseline and six months. Qualitative data were gathered through semi-structured focus groups and interviews with intervention participants.

Results: Compared to controls, intervention nurses experienced significantly greater reductions in MSD prevalence (−20.9 vs −5.7 percentage points, $p < 0.01$) and pain intensity ($p < 0.001$), alongside marked improvements in perceived stress (−4.4 vs −0.6 points, $p < 0.001$) and burnout dimensions (emotional exhaustion: −6.3 vs −0.8 points, $p < 0.001$). Improvements in patient safety metrics were also observed, with larger reductions in medication errors (−7.4% vs −2.5%) and surgical site infections (−5.2% vs −1.6%), and increased patient satisfaction scores (+1.5 vs +0.5 points, $p < 0.01$). Qualitative findings highlighted leadership engagement, clear protocols, and cultural integration as key facilitators, while emergency cases and staff shortages posed barriers. Adaptive strategies, such as flexible scheduling, supported sustained implementation.

Conclusion: Structured microbreaks yielded sustained improvements in MSD outcomes, psychological wellbeing, and patient safety, with organizational support and adaptability proving crucial for long-term success. Integrating microbreaks into routine OR workflows may enhance nurse health, reduce errors, and improve patient care quality, offering a strategic, resource-feasible intervention for high-stress healthcare settings. Findings support embedding microbreaks into standard operating procedures and orientation, using leadership role-modeling, brief "buddy" coverage, and lightweight prompts to optimize fidelity at scale.

Keywords: microbreaks, musculoskeletal disorders, occupational health, operating room nurses, patient safety, mixed-methods

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Introduction

Background and Rationale

Operating room (OR) nursing presents a dual burden of physical and psychosocial demands; this Introduction, therefore, foregrounds three core points: (1) the high prevalence and impact of musculoskeletal disorders (MSDs) among OR nurses; (2) the unresolved evidence gap on the long-term effects of microbreak interventions; and (3) the theoretical grounding of microbreaks in the Job Demands–Resources (JD-R) model and ergonomics frameworks, which together motivate the present study's objectives.

Musculoskeletal disorders (MSDs) are highly prevalent among nurses, particularly those working in the operating room (OR) settings. Studies indicate that the prevalence of work-related musculoskeletal disorders (WMSDs) among nurses' ranges from 33% to 95.7%, with some reports highlighting rates as high as 89.2% among healthcare workers.[1–3] Specifically, OR nurses are subjected to repetitive movements, prolonged static postures, and high physical demands during surgical procedures, significantly increasing their risk of developing MSDs.[4] These disorders predominantly affect the lower back, neck, shoulders, and wrists, leading to chronic pain, reduced mobility, and impaired job performance.[5] In the OR, constraints of the sterile field, limited space for movement, dense equipment layouts, task sequences that require sustained fine motor control (eg, repetitive instrument handling and retraction), and limited opportunities to vary posture during critical procedural phases further exacerbate biomechanical load.[4,5]

The impact of MSDs extends beyond individual health, adversely affecting job performance and increasing healthcare costs. Nurses suffering from MSDs often experience decreased productivity, increased absenteeism, and a higher likelihood of job turnover.[6] Additionally, the financial burden associated with MSDs includes direct costs related to medical treatments and indirect costs stemming from lost workdays and reduced efficiency.[4] At the service level, MSD-related presenteeism can degrade team coordination and throughput in surgical lists, amplifying downstream operational costs. Consequently, addressing MSDs among OR nurses is imperative not only for enhancing individual wellbeing but also for maintaining the overall efficiency and sustainability of healthcare services.

In parallel with physical health challenges, OR nurses frequently encounter significant psychological stress, leading to burnout and diminished job satisfaction. The high-stress environment of the OR, characterized by long hours, critical decision-making, and exposure to life-and-death situations, contributes to elevated levels of perceived stress and burnout among nurses.[7,8] Burnout, defined by emotional exhaustion, depersonalization, and reduced personal accomplishment, negatively impacts nurses' mental health and their ability to provide high-quality patient care.[9] Furthermore, psychological wellbeing is closely linked to job performance; nurses experiencing high levels of stress and burnout are more prone to errors, lower patient satisfaction, and decreased overall care quality.[10] Accordingly, interventions that target both biomechanical strain and mental fatigue are likely to yield compounding benefits for staff and patients.

Microbreaks, defined as short, intermittent breaks lasting a few minutes, have emerged as a promising intervention to mitigate both physical and psychological stressors in the workplace. These brief pauses allow individuals to engage in stretching, relaxation exercises, or mindfulness practices, thereby reducing muscle tension and alleviating mental fatigue.[11] Additionally, systematic reviews have supported the efficacy of active microbreaks in improving both physical and mental wellbeing, highlighting their potential as a feasible and effective workplace intervention.[12] In OR contexts, microbreaks are particularly attractive because they can be scheduled in alignment with natural pauses between surgical phases without compromising sterility or workflow when appropriately choreographed.

To better understand why microbreaks may be effective, this study draws upon the Job Demands-Resources (JD-R) model and ergonomics frameworks. According to the JD-R model, reducing job demands (eg, physical exertion, continuous concentration, and psychological pressure) and enhancing resources (eg, recovery opportunities through microbreaks, supportive organizational structures) can improve worker health, increase motivation, and enhance performance outcomes.[13] From an ergonomics perspective, introducing scheduled rest periods and brief exercises can alleviate biomechanical strain and promote postural variation, which is integral to preventing MSD development. Conceptually, microbreaks function as brief "recovery opportunities" that replenish energetic resources, lower immediate strain, and sustain attentional control; when institutionalized through protocols and leadership support, they become durable job resources that buffer chronic demands. By integrating these theoretical perspectives, this research conceptualizes microbreaks not only as a practical solution but also as a strategic intervention that aligns occupational demands and resources, thereby fostering both physical resilience and psychological wellbeing.

Despite the promising evidence, there remains a gap in understanding the long-term effects of microbreaks on MSDs and psychological wellbeing, particularly among OR nurses. Most existing studies focus on immediate or short-term outcomes, neglecting the sustainability and broader impacts of such interventions over extended periods. Furthermore, the relationship between nurse wellbeing and patient safety outcomes, as well as the organizational factors influencing the implementation and adherence to microbreak protocols, require further exploration. Notably, few studies have evaluated six-month or longer microbreak programs in OR nursing populations while concurrently tracking patient-safety indicators and implementation determinants (eg, leadership engagement, cultural integration, and fidelity).[11–13] Addressing these gaps is crucial for developing comprehensive strategies that enhance both nurse health and the quality of patient care in high-stress environments like the operating room.

Study Objectives and Research Questions

This study aims to comprehensively evaluate the long-term impact of structured microbreaks on musculoskeletal health, psychological wellbeing, and patient safety among operating room (OR) nurses. Additionally, it seeks to explore the organizational factors that influence the successful implementation and adherence to microbreak protocols. Guided by JD-R and ergonomics frameworks, and motivated by the above evidence gaps, we prespecified staff-health and patient-safety endpoints over a six-month window and embedded a qualitative component to illuminate organizational context. The specific objectives are to assess the effects of microbreaks on the incidence and severity of musculoskeletal disorders (MSDs), to examine changes in perceived stress and burnout levels, to determine the extent to which improvements in nurse wellbeing translate to better patient safety outcomes, and to identify organizational factors that facilitate or hinder the adoption of microbreaks within the OR environment. To achieve these objectives, the study addresses the following research questions:

- RQ1: Does the implementation of structured microbreaks reduce the incidence and severity of musculoskeletal disorders among OR nurses after six months?
- RQ2: How do structured microbreaks affect the perceived stress levels and burnout among OR nurses after six months?
- RQ3: Does the improvement in OR nurses' musculoskeletal health and psychological wellbeing translate to better patient safety outcomes, such as reduced error rates and increased patient satisfaction?
- RQ4: How do organizational support structures, implementation barriers, perceived benefits, and cultural integration factors interact to influence the successful implementation and long-term sustainability of microbreak protocols in the operating room environment?

Collectively, these questions link individual outcomes (MSD prevalence and pain intensity; stress and burnout) to system-level performance (medication errors, surgical site infections, near-misses, and patient satisfaction), while explicitly probing the organizational mechanisms that enable sustained adoption.

Research Contribution

This research contributes to the existing body of knowledge by providing a comprehensive, long-term evaluation of the effectiveness of structured microbreaks on both physical and psychological health outcomes among OR nurses. By integrating patient safety metrics, the study bridges the gap between nurse wellbeing and patient care quality, demonstrating how improvements in nurse health can lead to enhanced patient safety outcomes. Furthermore, the qualitative exploration of organizational factors offers valuable insights into the practical challenges and facilitators associated with implementing microbreak protocols in high-stress environments. Methodologically, the multicenter, mixed-methods design over six months enhances external validity for real-world OR settings and clarifies the how and why of implementation success (leadership engagement, clear protocols, cultural integration). Substantively, the study positions microbreaks as a low-cost, scalable job resource aligned with JD-R theory, linking staff wellbeing to measurable patient-

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safety gains and offering concrete levers for policy and practice within resource-constrained surgical services. These findings not only inform best practices and policy development for nurse wellbeing interventions but also emphasize the importance of supportive organizational structures in sustaining the benefits of such interventions.

Methods

Research Design

This study employs a controlled, mixed-methods design to comprehensively evaluate the long-term impact of structured microbreaks on musculoskeletal health, psychological wellbeing, and patient safety among operating room (OR) nurses. Conducted over a six-month period, the research integrates quantitative surveys with qualitative focus groups and interviews to provide a multifaceted assessment of the intervention's effectiveness. The quantitative component involves baseline and follow-up measurements of musculoskeletal disorders (MSDs), stress levels, burnout, and patient safety metrics, enabling statistical analysis of changes over time. Concurrently, the qualitative component explores nurses' experiences, perceptions, and the organizational factors influencing the implementation and adherence to microbreak protocols. This dual approach facilitates a nuanced understanding of both the measurable outcomes and the contextual elements that affect the success of the microbreak interventions.

The study used a non-randomized, controlled, multicenter design with participants nested within five hospitals. Allocation to intervention versus control followed existing unit rosters/scheduling to minimize workflow disruption; to limit contamination, microbreak training, and prompts were delivered only to intervention teams, and educational materials were not shared with controls during the study period.

We adopted a convergent parallel mixed-methods approach: quantitative and qualitative strands were conducted during the same six-month window, analyzed independently, and then integrated through triangulation to relate effects on outcomes to implementation context.

Table 1 outlines the five hospitals participating in the study, all located within Shanxi Province, China. The hospitals are categorized into tertiary and secondary care facilities to ensure a diverse representation of surgical environments and to enhance the generalizability of the study findings.

Interventions

The intervention group is subjected to a structured microbreak protocol designed to mitigate musculoskeletal strain and reduce psychological stress. Specifically, OR nurses are instructed to take 2–3-minute breaks every 30 minutes during surgeries exceeding 60 minutes in duration. These microbreaks consist of a combination of physical exercises—such as neck rolls, shoulder shrugs, wrist flexion and extension, and leg stretches—and mindfulness practices, including deep breathing exercises and brief meditation sessions.

Implementation of the microbreak protocol involves several key components to ensure adherence and effectiveness:

- Training Sessions: Initial workshops are conducted to demonstrate the proper execution of the prescribed exercises and mindfulness techniques. These sessions also emphasize the importance of regular breaks for health and performance.
- Instructional Materials: Comprehensive manuals and instructional videos are provided to serve as ongoing references for nurses, facilitating consistent practice of the microbreak activities.

Table 1 Study Settings and Population

Hospital	Type	Location	Number of OR Nurses	Key Characteristics
Hospital 1	Tertiary-care	Taiyuan, Shanxi Province	41	Large surgical department, diverse cases
Hospital 2	Tertiary-care	Datong, Shanxi Province	39	Similar size and scope to Hospital 1
Hospital 3	Secondary-care	Yuncheng, Shanxi Province	29	Mid-sized surgical unit
Hospital 4	Tertiary-care	Jinzhong, Shanxi Province	46	Advanced surgical technologies
Hospital 5	Secondary-care	Linfen, Shanxi Province	31	Comprehensive surgical services

- Reminders: To promote adherence, alarms are set on OR monitors or personal devices, and visual cues are strategically placed within the OR environment to prompt nurses to take their scheduled breaks.
- Customization: Feedback from nurses is solicited periodically to adjust the microbreak activities, ensuring they are comfortable, feasible, and tailored to the specific demands of the OR setting.

Table 2 outlines the structured microbreak protocol implemented in the intervention group, detailing the frequency, types of activities, methods of implementation, and customization strategies to ensure the protocol's effectiveness and adaptability to the OR environment.

In contrast, the control group continues with standard practice without scheduled microbreaks. To address ethical considerations, the control group will be offered the microbreak intervention after the study's completion.

Microbreaks were delivered within the OR by participating nurses after short training led by a senior nurse educator and a physical-therapy consultant. Materials included a one-page laminated stretch sequence and a 2-minute guided breathing script; electronic prompts were configured on OR monitors and/or wearable timers. To preserve sterility and workflow, microbreaks were timed within a ±5-minute window around natural phase transitions (eg, after positioning, during instrument count), avoiding critical steps. Tailoring allowed nurses to skip or swap movements that were uncomfortable or infeasible in situ, provided the 2-3-minute duration was maintained. Fidelity procedures included weekly spot checks by unit champions, prompt-log audits, and a brief post-case checklist. Compliance was defined a priori as completion of ≥80% scheduled microbreaks per shift (see Data Analysis for modeling).

Measurement

Musculoskeletal Health

Musculoskeletal health among OR nurses is assessed using two primary measures: the Nordic Musculoskeletal Questionnaire (NMQ) and region-specific pain intensity ratings. The NMQ is a standardized tool designed to evaluate the prevalence and severity of musculoskeletal symptoms across nine body regions, including the neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs, knees, and ankles/feet.[14] This questionnaire is widely recognized for its reliability and validity in occupational health research, making it suitable for identifying specific areas of musculoskeletal strain within the nursing workforce.[2]

In addition to the NMQ, participants rated their pain intensity using a validated 11-point Numeric Rating Scale (NRS) ranging from 0 (no pain) to 10 (worst possible pain) for each affected body region. The NRS was chosen for its established psychometric properties and ease of use in clinical settings.[15] Participants were specifically asked to rate pain intensity for three key regions commonly affected in OR nursing: lower back, neck/shoulder region, and upper limbs. These regions were selected based on previous literature identifying them as primary areas of concern in surgical nursing practice.[3] The combination of the NMQ and region-specific pain intensity ratings provides both a comprehensive overview of MSD prevalence and a detailed quantitative assessment of pain severity in the most affected areas. This dual approach enables both categorical analysis of MSD occurrence and continuous measurement of pain intensity, enhancing the sensitivity of our outcome measures to detect intervention effects.

Prespecified primary outcomes were (a) MSD prevalence at each time point (any NMQ-positive region) and (b) change in perceived stress (PSS-10; see below). Region-specific NRS pain changes were secondary outcomes.

Table 2 Structured Microbreak Protocol

Component	Details
Frequency	2-3 minute breaks every 30 minutes during surgeries exceeding 60 minutes
Physical Exercises	Neck rolls, shoulder shrugs, wrist flexion/extension, leg stretches
Mindfulness Practices	Deep breathing exercises, brief meditation sessions
Implementation Methods	Training workshops, instructional manuals/videos, alarms, visual cues
Customization	Adjust activities based on nurse feedback for comfort and feasibility

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Psychological Wellbeing

Psychological wellbeing is evaluated using two complementary validated instruments that capture both general stress and profession-specific burnout dimensions: the Perceived Stress Scale (PSS) and the Maslach Burnout Inventory (MBI).

The PSS, developed by Cohen, Kamarck and Mermelstein,[16] measures individuals' perceptions of life stressors and their ability to cope with them. The 10-item version is employed in this study, where participants rate items on a 5-point Likert scale (0 = never to 4 = very often). This version demonstrates high internal consistency (Cronbach's α = 0.85) and test–retest reliability (r = 0.88) in healthcare settings.[17] The PSS was selected for its established sensitivity to changes in perceived stress levels among healthcare workers and its previous validation in Chinese healthcare populations.[18]

The MBI-Human Services Survey (MBI-HSS) provides a multidimensional assessment of professional burnout through three subscales: emotional exhaustion (9 items), depersonalization (5 items), and personal accomplishment (8 items).[19] Each item is rated on a 7-point frequency scale (0 = never to 6 = every day). The MBI-HSS demonstrates robust psychometric properties in healthcare settings, with subscale reliability coefficients ranging from 0.84 to 0.90.[20] This instrument was specifically chosen for its ability to capture the unique aspects of burnout experienced by healthcare professionals, including emotional demands and patient care responsibilities. Recent validation studies in surgical nursing populations have confirmed its factorial structure and criterion validity.[21]

Validated Chinese versions of the PSS-10 and MBI-HSS were used where available; internal consistency (Cronbach's α) for each subscale/item set will be reported for the present sample. Outcome assessors extracting patient-safety data were blinded to group assignment; participant-reported scales could not be blinded by nature.

Patient Safety Outcomes

Patient safety is assessed through four complementary metrics that together provide a comprehensive evaluation of care quality and safety:

1. Medication Error Rates are systematically tracked through standardized incident reporting systems using the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) taxonomy. All reported errors are independently verified by two clinical pharmacists and categorized by type, severity, and contributing factors.[22]
2. Surgical Site Infection (SSI) surveillance follows the Centers for Disease Control and Prevention's National Healthcare Safety Network (CDC/NHSN) definitions and criteria. Infections are classified as superficial incisional, deep incisional, or organ/space SSIs, with standardized follow-up periods based on procedure type.[23]
3. Patient Satisfaction is measured using the Chinese version of the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. This 32-item instrument assesses nine key domains of patient experience, with demonstrated construct validity and internal consistency (Cronbach's α = 0.92) in Chinese hospital settings.[24] The timing of survey administration (48–72 hours post-discharge) was standardized to minimize recall bias.
4. Near-Miss Incidents are documented using a structured reporting system based on the World Health Organization's International Classification for Patient Safety (WHO ICPS). Each report undergoes a standardized review process using the Healthcare Failure Mode and Effect Analysis (HFMEA) methodology to ensure comprehensive capture of potential safety issues.[25]

All safety metrics are normalized to account for variations in surgical volume and complexity, with medication errors and near-miss incidents expressed per 1000 patient days, and SSI rates calculated per 100 surgical procedures of equivalent complexity. Regular audit processes ensure consistency in reporting and classification across all participating hospitals.

For safety outcomes, we adjusted for case mix and exposure: medication-error and near-miss counts were modeled with log patient-days or log nursing-hours as offsets; SSI models included procedure category, wound class, urgency (elective vs emergency), and duration as covariates. HCAHPS analyses adjusted for age, sex, service line, and length of stay.

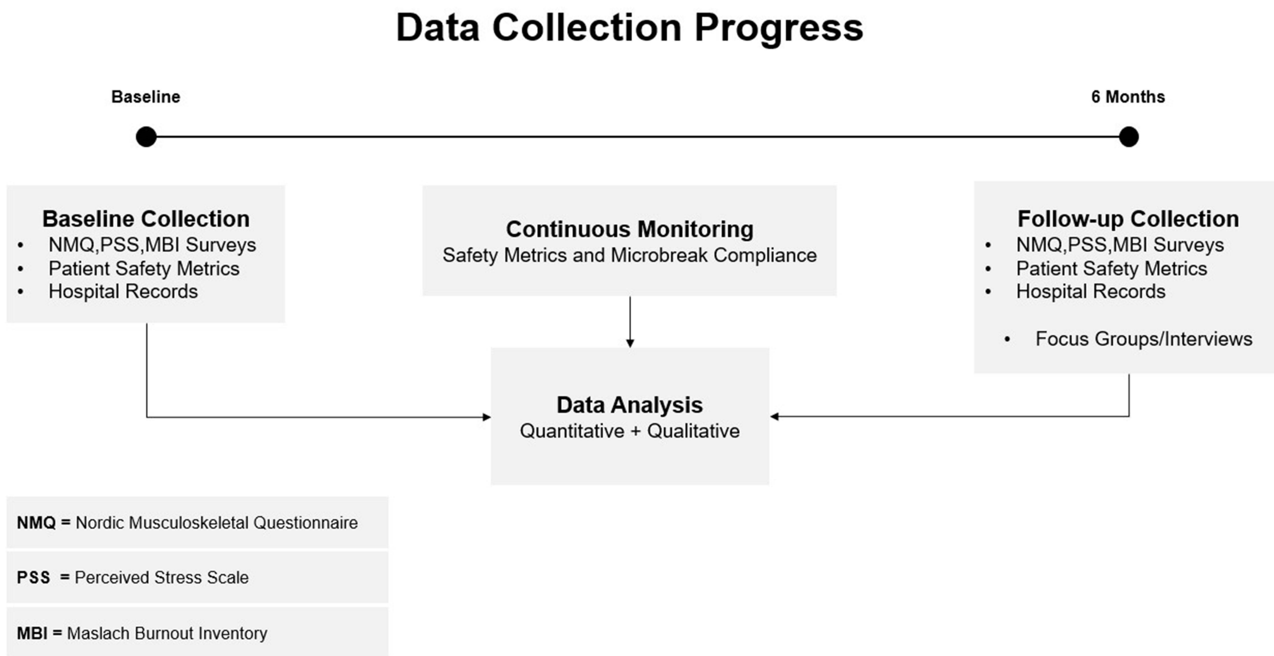

Figure 1 Data collection progress.

Data Collection

Data collection for this study is structured to occur at two key time points: baseline (Month 0) and six-month follow-up (Month 6). The process integrates both quantitative and qualitative methods to ensure a comprehensive assessment of the microbreak intervention's impact (Figure 1).

Table 3 outlines the data collection timeline, specifying the activities undertaken at each time point to gather both quantitative and qualitative data.

At both baseline and six-month follow-up, OR nurses in both intervention and control groups complete the NMQ, PSS, and MBI surveys. These surveys are administered electronically to facilitate easy distribution and collection, ensuring high response rates and data accuracy. Additionally, patient safety metrics, including medication error rates, SSI rates, patient satisfaction scores, and near-miss incidents, are extracted from hospital records for the corresponding periods. Compliance with microbreaks in the intervention group is monitored through self-reported logs maintained by the nurses, detailing the number and frequency of breaks taken. This dual approach allows for the quantitative assessment of both health outcomes and patient safety indicators over time.

Upon completion of the six-month intervention, qualitative data are collected through focus groups or individual interviews with OR nurses in the intervention group. These discussions aim to capture nurses' experiences with the microbreak protocol, identify barriers and facilitators to adherence, and gather suggestions for improving the intervention. The qualitative component provides contextual insights into how organizational factors influence the implementation and sustainability of microbreaks, offering a deeper understanding of the intervention's practical challenges and

Table 3 Data Collection Timeline

Time Point	Data Collection Activities
Baseline (Month 0)	- Distribute and collect quantitative surveys (NMQ, PSS, MBI) - Gather patient safety metrics from hospital records
Follow-Up (Month 6)	- Distribute and collect quantitative surveys (NMQ, PSS, MBI) - Gather patient safety metrics from hospital records - Conduct qualitative focus groups or interviews with intervention group nurses

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successes. Interviews are conducted in a confidential setting to encourage honest and open communication, and all sessions are audio-recorded with participants' consent for accurate transcription and analysis.

We conducted semi-structured focus groups and one-to-one interviews using a piloted guide aligned to the study aims. A single trained facilitator conducted all sessions to enhance consistency. Audio was recorded and professionally transcribed; where applicable, transcripts in Chinese were back-translated for analytic fidelity. Sampling was purposive (role, tenure, hospital) to maximize variation. Two analysts independently coded an initial subset to develop a shared codebook; intercoder reliability was assessed and discrepancies resolved by consensus before full coding. Thematic analysis proceeded iteratively until thematic saturation (no new codes/themes in two consecutive sessions). NVivo supported data management.

Data Analysis

Quantitative data will be analyzed using statistical software SPSS and R. Descriptive statistics will summarize MSD scores, PSS and MBI scores, and patient safety metrics. Inferential statistics, including independent samples *t*-tests or Mann–Whitney *U*-tests, will compare intervention and control groups. Chi-square tests will assess differences in categorical outcomes like MSD incidence and medication errors. Multiple regression analyses will adjust for confounders such as age, gender, and years of experience, providing adjusted estimates of the intervention's impact. Effect sizes will be reported using Cohen's d to determine the magnitude of differences. Qualitative data from focus groups and interviews will undergo thematic analysis using NVivo software. The process involves coding transcripts to identify recurring themes related to barriers, facilitators, and perceptions of microbreaks. Themes will be reviewed and refined to ensure they accurately represent the data, providing insights into organizational factors influencing implementation and adherence.

The study adopts a convergent parallel mixed-methods approach, integrating quantitative and qualitative findings to provide a understanding of the microbreak intervention's effectiveness and the organizational factors affecting its success. This triangulation enhances the validity of the results by corroborating quantitative trends with qualitative insights.

Repeated-measures continuous outcomes (pain NRS by region, PSS-10, MBI subscales, HCAHPS) were analyzed using linear mixed-effects models with fixed effects for group (intervention vs control), time (baseline vs 6 months), and group×time, and random intercepts for participant and hospital; robust (sandwich) SEs were used. MSD prevalence (binary) was modeled with logistic mixed-effects using the same fixed/random structure. Medication errors and near-misses (counts) were modeled with negative binomial regression including log patient-days or log nursing-hours as offsets. SSI used logistic regression with case-mix covariates (procedure category, wound class, urgency, duration) and cluster-robust SEs.

Because allocation was nonrandom, we used propensity score weighting (IPTW with stabilized weights) based on age, sex, OR experience, hospital, baseline MSD status/severity, baseline PSS/MBI, and average weekly hours. Balance was assessed using standardized mean differences ($|SMD|<0.10$ considered acceptable) rather than baseline p-values. We incorporated weights into mixed-effects models and conducted doubly robust analyses including key covariates.

Primary endpoints were prespecified as MSD prevalence and PSS-10 change. Secondary endpoints included region-specific pain, MBI subscales, safety indicators, and satisfaction. We controlled the false discovery rate for secondary endpoints using Benjamini–Hochberg ($q = 0.05$). We report Cohen's d for continuous outcomes and odds/rate ratios for binary/count outcomes, all with 95% CIs.

We examined missingness patterns and used multiple imputation by chained equations ($m = 20$) under a MAR assumption for questionnaire items and scale scores. Sensitivity analyses compared imputed results with complete-case analyses.

Microbreak compliance (≥80% completion threshold) was summarized overall and by context (case duration, complexity, shift) and entered as a moderator in mixed models (group×time×compliance). Fidelity metrics (prompt-log audits, spot checks) were summarized descriptively.

An a priori calculation indicated that with $N\approx178$, $\alpha = 0.05$ (two-sided), and modest clustering ($ICC\approx0.02$), the study had ≥80% power to detect a 12-percentage-point between-group difference in MSD prevalence or a 0.35 SD difference in PSS-10 change over six months; count outcomes had ≥80% power to detect rate ratios ≤0.80 given observed exposure totals.

After separate quantitative and qualitative analyses, we conducted joint displays to align effect estimates with themes (eg, leadership engagement, cultural integration) and to explain heterogeneity in outcomes.

Ethical Considerations

Ethical approval will be obtained from the Institutional Review Boards (IRBs) of all five participating hospitals in Shanxi Province, China. Informed consent will be secured from all participants, ensuring voluntary participation and the right to withdraw at any time. Confidentiality will be maintained by assigning unique identifiers to participants and securely storing data in password-protected databases. Data will be anonymized before analysis to protect participant privacy. The study poses minimal risk; however, support will be available for any discomfort arising from participation. Ethical compliance will adhere to the Declaration of Helsinki and relevant institutional guidelines, ensuring the protection of participants' rights and the integrity of the research process.

Ethical oversight was coordinated through a central IRB (Shanxi Medical University) with documented site-specific approvals or authorizations at each participating hospital. The informed-consent form included explicit permission to use anonymized quotations from interviews/focus groups.

Identifiers were stored separately from research data; all electronic data were encrypted at rest (AES-256) and in transit (TLS) on access-controlled servers behind a VPN. Access was role-based with audit logs. De-identified analysis datasets will be retained for the period required by institutional policy and journal guidance.

Results

Participant Characteristics

A total of 186 operating room nurses from five hospitals in Shanxi Province participated in the study. After accounting for attrition and incomplete responses, 178 participants (95.7%) completed the six-month follow-up assessment. The intervention group comprised 91 nurses, while 87 nurses were assigned to the control group.

The demographic and professional characteristics were comparable between the intervention and control groups at baseline (Table 4), with no statistically significant differences observed across any measured variables (all $p > 0.05$). The majority of participants were female (90.4%), reflecting the typical gender distribution in nursing. The mean age of

Table 4 Demographic and Professional Characteristics of Study Participants

Characteristic	Intervention Group (n = 91)	Control Group (n = 87)	Total (N = 178)	*p*-value
Age (years)				
Mean ± SD	32.4 ± 7.3	31.9 ± 7.1	32.2 ± 7.2	0.642
Range	23-55	24-52	23-55	
Gender, n (%)				0.873
Female	82 (90.1)	79 (90.8)	161 (90.4)	
Male	9 (9.9)	8 (9.2)	17 (9.6)	
Years of OR Experience				
Mean ± SD	8.3 ± 5.9	7.9 ± 5.7	8.1 ± 5.8	0.724
Range	1-25	1-23	1-25	
Education Level, n (%)				0.856
Diploma	28 (30.8)	25 (28.7)	53 (29.8)	
Bachelor's	58 (63.7)	57 (65.5)	115 (64.6)	
Master's	5 (5.5)	5 (5.7)	10 (5.6)	
Hospital Type, n (%)				0.912
Tertiary-care	64 (70.3)	62 (71.3)	126 (70.8)	
Secondary-care	27 (29.7)	25 (28.7)	52 (29.2)	

Note: p-values were calculated using independent *t*-tests for continuous variables and chi-square tests for categorical variables.
Abbreviation: SD, Standard Deviation.

participants was 32.2 years (SD = 7.2), with an average of 8.1 years (SD = 5.8) of OR nursing experience. Most nurses (64.6%) held bachelor's degrees, while 29.8% had diplomas and 5.6% had completed master's degrees.

As shown in Table 5, a high prevalence of pre-existing musculoskeletal complaints was noted across both groups (74.2% overall), with lower back pain being the most commonly reported issue (45.5%), followed by neck/shoulder problems (41.0%). The baseline stress levels, as measured by the PSS, were moderate and similar between groups (mean = 18.6, SD = 5.7). The average weekly working hours were comparable between the intervention (45.3 hours) and control groups (44.8 hours).

The distribution of participants across hospital types was balanced, with 70.8% working in tertiary-care facilities and 29.2% in secondary-care hospitals, ensuring representation across different healthcare settings. The attrition rate of 4.3% (8 participants) was relatively low and did not significantly differ between the intervention and control groups (4 participants each).

Musculoskeletal Health Outcomes (RQ1)

Analysis of musculoskeletal disorders (MSDs) over the six-month intervention period demonstrated significant differences between intervention and control groups in both prevalence and severity of symptoms. Mixed-model analysis revealed significant group × time interactions for all measured outcomes ($p < 0.01$), indicating differential changes between groups over the study period.

The intervention group demonstrated significantly greater improvements in MSD outcomes compared to the control group (Table 6). Overall MSD prevalence decreased by 20.9 percentage points in the intervention group (from 73.6% to

Table 5 Prior History of Musculoskeletal Complaints and Stress Levels at Baseline

Characteristic	Intervention Group (n = 91)	Control Group (n = 87)	Total (N = 178)	*p*-value
Previous MSDs, n (%)	67 (73.6)	65 (74.7)	132 (74.2)	0.867
Lower back	42 (46.2)	39 (44.8)	81 (45.5)	0.859
Neck/shoulder	38 (41.8)	35 (40.2)	73 (41.0)	0.837
Upper limbs	25 (27.5)	23 (26.4)	48 (27.0)	0.878
Baseline PSS Score				
Mean ± SD	18.7 ± 5.8	18.4 ± 5.6	18.6 ± 5.7	0.725
Working Hours/Week				
Mean ± SD	45.3 ± 6.2	44.8 ± 6.4	45.1 ± 6.3	0.598

Note: Multiple MSD locations could be reported by a single participant.
Abbreviations: PSS, Perceived Stress Scale; MSD, Musculoskeletal Disorders.

Table 6 Changes in MSD Prevalence and Severity Scores From Baseline to 6 Months

Outcome Measure	Group	Baseline	6 Months	Within-Group Change	Group × Time Interaction
Overall MSD Prevalence (%)	Intervention	73.6	52.7*	−20.9	F = 15.4
	Control	74.7	69.0	−5.7	*p* < 0.001
Body Region-Specific Pain Intensity† (Mean ± SD)					
Lower Back	Intervention	5.8 ± 1.9	3.9 ± 1.7*	−1.9	F = 18.7
	Control	5.7 ± 1.8	5.4 ± 1.9	−0.3	*p* < 0.001
Neck/Shoulder	Intervention	5.2 ± 1.7	3.6 ± 1.6*	−1.6	F = 16.2
	Control	5.1 ± 1.8	4.8 ± 1.7	−0.3	*p* < 0.001
Upper Limbs	Intervention	4.3 ± 1.5	3.1 ± 1.4*	−1.2	F = 14.9
	Control	4.2 ± 1.6	4.0 ± 1.5	−0.2	*p* < 0.001

Note: Pain intensity measured on a 0–10 numeric rating scale. p < 0.01 for within-group changes. Group × Time interaction based on mixed-model ANOVA. *p < 0.05, **p < 0.01, ***p < 0.001.
Abbreviation: SD, Standard Deviation.

52.7%, $p < 0.01$) compared to a 5.7 percentage point reduction in the control group (from 74.7% to 69.0%, $p = 0.24$). The group × time interaction was significant ($F = 15.4$, $p < 0.001$), indicating that the intervention group experienced significantly greater reduction in MSD prevalence over the study period.

Pain intensity scores showed similar patterns of improvement. The intervention group reported significant reductions in pain across all measured body regions, with the largest improvement observed in lower back pain (mean reduction = 1.9 points, 95% CI: 1.5–2.3, $p < 0.01$). In contrast, the control group showed minimal changes in pain intensity (mean reduction = 0.3 points, 95% CI: 0.1–0.5, $p = 0.18$). The significant group × time interactions for all body regions (all $p < 0.001$) confirm that the intervention group experienced greater pain reduction compared to controls.

Multiple regression analysis (Table 7) further supported the intervention's effectiveness after adjusting for potential confounders. The negative coefficient for the intervention group (−0.615, $p < 0.001$ in Model 3) indicates that participation in the microbreak program was associated with greater improvement in MSD symptoms, even after controlling for age, years of experience, and compliance levels. Higher microbreak compliance was independently associated with greater symptom improvement (−0.283, $p < 0.01$), suggesting a dose–response relationship between adherence to the intervention and MSD outcomes.

At 6 months, the unadjusted risk of being NMQ-positive was 0.53 in the intervention versus 0.69 in controls (risk ratio ≈ 0.76), corresponding to an approximate NNT ≈ 6 to avert one NMQ-positive case at 6 months. Standardized between-group differences in change favored the intervention with Cohen's d (pooled-baseline SD) of −0.86 for lower-back pain, −0.74 for neck/shoulder pain, and −0.64 for upper-limb pain—consistent with moderate-to-large effects.

Estimates remained directionally and statistically consistent in propensity-weighted, cluster-adjusted mixed models and in sensitivity analyses using complete cases only.

Psychological Wellbeing Outcomes (RQ2)

Analysis of psychological wellbeing measures revealed significant differences between intervention and control groups over the six-month study period (Table 8). Mixed-model analyses demonstrated significant group × time interactions for all psychological measures ($p < 0.01$), indicating differential patterns of change between groups.

The intervention group demonstrated significantly greater improvements across all psychological wellbeing measures compared to the control group (Figure 2). PSS scores decreased by 4.4 points (23.5% improvement) in the intervention group compared to 0.6 points (3.3% improvement) in the control group, with a significant group × time interaction ($F = 17.8$, $p < 0.001$).

Burnout measures showed similar patterns of improvement. The intervention group experienced substantial reductions in emotional exhaustion (−6.3 points, 22.2% improvement) and depersonalization (−3.2 points, 26.0%

Table 7 Multiple Regression Analysis of Factors Associated with MSD Improvement

Variable	Model 1	Model 2	Model 3
Intervention (vs Control)	−0.642*** (0.143)	−0.631*** (0.145)	−0.615*** (0.148)
Age		−0.024* (0.011)	−0.022* (0.011)
Years of Experience		−0.018 (0.015)	−0.016 (0.015)
Microbreak Compliance			−0.283** (0.092)
Constant	0.245* (0.112)	0.876*** (0.228)	0.654** (0.241)
R^2	0.186	0.214	0.248
N	178	178	178

Note: *Standard errors in parentheses. Negative coefficients indicate greater improvement in MSD symptoms. *p < 0.05, **p < 0.01, ***p < 0.001.

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Table 8 Changes in Psychological Wellbeing Measures From Baseline to 6 Months

Measure	Group	Baseline	6 Months	Within-Group Change	Group × Time Interaction
PSS Score	Intervention	18.7 ± 5.8	14.3 ± 5.2***	−4.4	F = 17.8
	Control	18.4 ± 5.6	17.8 ± 5.5	−0.6	*p* < 0.001
MBI Subscales					
Emotional Exhaustion	Intervention	28.4 ± 6.7	22.1 ± 6.1*	−6.3	F = 19.2
	Control	28.1 ± 6.8	27.3 ± 6.6	−0.8	*p* < 0.001
Depersonalization	Intervention	12.3 ± 4.2	9.1 ± 3.8*	−3.2	F = 16.5
	Control	12.1 ± 4.1	11.7 ± 4.0	−0.4	*p* < 0.001
Personal Accomplishment	Intervention	31.2 ± 5.9	35.8 ± 5.7**	+4.6	F = 15.9
	Control	31.4 ± 5.8	32.1 ± 5.9	+0.7	*p* < 0.001

Notes: Values presented as Mean ± SD. p < 0.01 for within-group changes. Higher scores indicate greater stress/burnout for PSS and MBI Emotional Exhaustion and Depersonalization; higher scores indicate better outcomes for Personal Accomplishment. *p < 0.05, **p < 0.01, ***p < 0.001.
Abbreviations: PSS, Perceived Stress Scale; MBI, Maslach Burnout Inventory.

improvement), while personal accomplishment increased (+4.6 points, 14.7% improvement). In contrast, the control group showed minimal changes across all MBI subscales (all changes < 5%, $p > 0.05$).

Multiple regression analysis (Table 9) confirmed the intervention's effectiveness after adjusting for potential confounders. The intervention was significantly associated with reduced PSS scores (−3.842, $p < 0.001$) and emotional exhaustion (−5.487, $p < 0.001$), and increased personal accomplishment (3.624, $p < 0.001$). Notably, MSD severity was

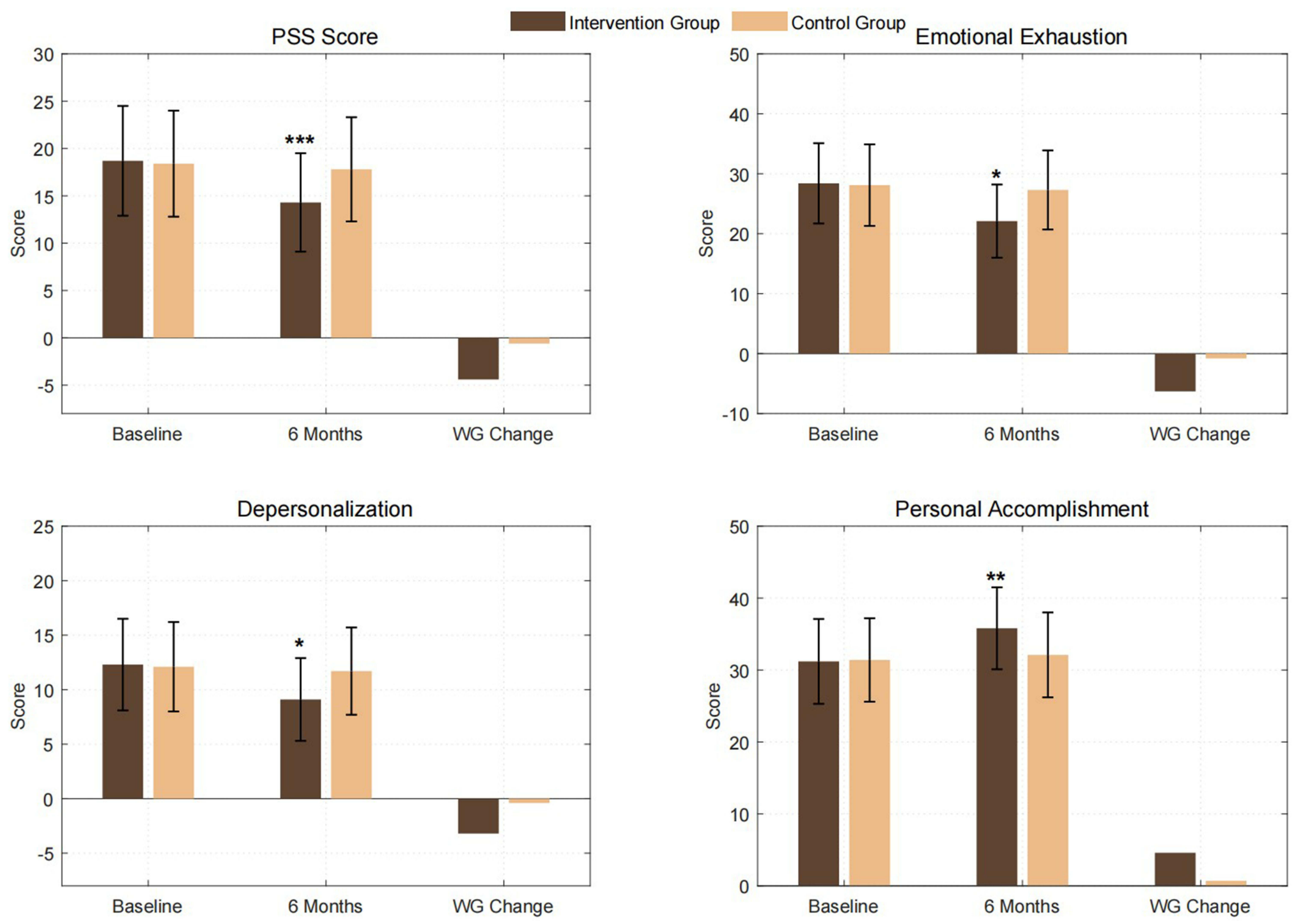

Figure 2 Changes in psychological wellbeing measures from baseline to 6 months.

Table 9 Multiple Regression Analysis of Psychological Wellbeing Outcomes

Variable	PSS Score	Emotional Exhaustion	Personal Accomplishment
Intervention (vs Control)	−3.842*** (0.523)	−5.487*** (0.614)	3.624*** (0.548)
Age	−0.032 (0.024)	−0.045* (0.021)	0.038* (0.019)
Years of Experience	−0.028 (0.018)	−0.037* (0.016)	0.042* (0.017)
MSD Severity	0.245** (0.086)	0.312** (0.092)	−0.228** (0.084)
Constant	18.456*** (0.892)	29.876*** (0.967)	30.245*** (0.912)
R^2	0.284	0.312	0.298
N	178	178	178

Note: Standard errors in parentheses. *p < 0.05, **p < 0.01, ***p < 0.001.

independently associated with psychological outcomes, suggesting a bidirectional relationship between physical and mental wellbeing.

Standardized between-group differences in change were moderate-to-large: PSS d = −0.67; emotional exhaustion d = −0.81; depersonalization d = −0.67; and personal accomplishment d = +0.67 (pooled-baseline SD). These magnitudes align with clinically meaningful improvements.

Sites reporting stronger leadership engagement and clearer break protocols also described greater perceived stress relief and team focus, consistent with the larger quantitative gains observed in PSS and MBI subscales.

Patient Safety Outcomes (RQ3)

Analysis of patient safety metrics revealed small but statistically significant improvements in the intervention group compared to the control group over the six-month study period (Table 10). Mixed-model analyses demonstrated significant group × time interactions for all safety indicators.

Patient safety metrics showed small but statistically significant improvements in the intervention group compared to controls. Medication error rates decreased by 7.4% in the intervention group versus 2.5% in the control group (group × time interaction: F = 8.4, $p < 0.01$). Similar modest improvements were observed for SSI rates (5.2% vs 1.6% reduction) and near-miss incidents (6.0% vs 1.9% reduction) (Figure 3).

Table 10 Changes in Patient Safety Metrics From Baseline to 6 Months

Safety Indicator	Group	Baseline	6 Months	Absolute Change	Relative Change (%)	Group × Time Interaction
Medication Error Rate[†]	Intervention	2.84	2.63**	−0.21	−7.4	F = 8.4
	Control	2.79	2.72	−0.07	−2.5	p < 0.01
SSI Rate[‡]	Intervention	1.92	1.82**	−0.10	−5.2	F = 7.8
	Control	1.88	1.85	−0.03	−1.6	p < 0.01
Near-Miss Incidents[§]	Intervention	3.67	3.45*	−0.22	−6.0	F = 8.2
	Control	3.71	3.64	−0.07	−1.9	p < 0.01
Patient Satisfaction[¶]	Intervention	84.3 ± 5.8	85.6 ± 5.5***	+1.3	+1.5	F = 7.9
	Control	84.1 ± 5.9	84.5 ± 5.8	+0.4	+0.5	p < 0.01

Notes: [†]Per 1000 patient days; [‡]Per 100 surgical procedures; [§]Per 1000 nursing hours; [¶]Score out of 100 (Mean ± SD). p < 0.01 for within-group changes. *p < 0.05, **p < 0.01, ***p < 0.001.

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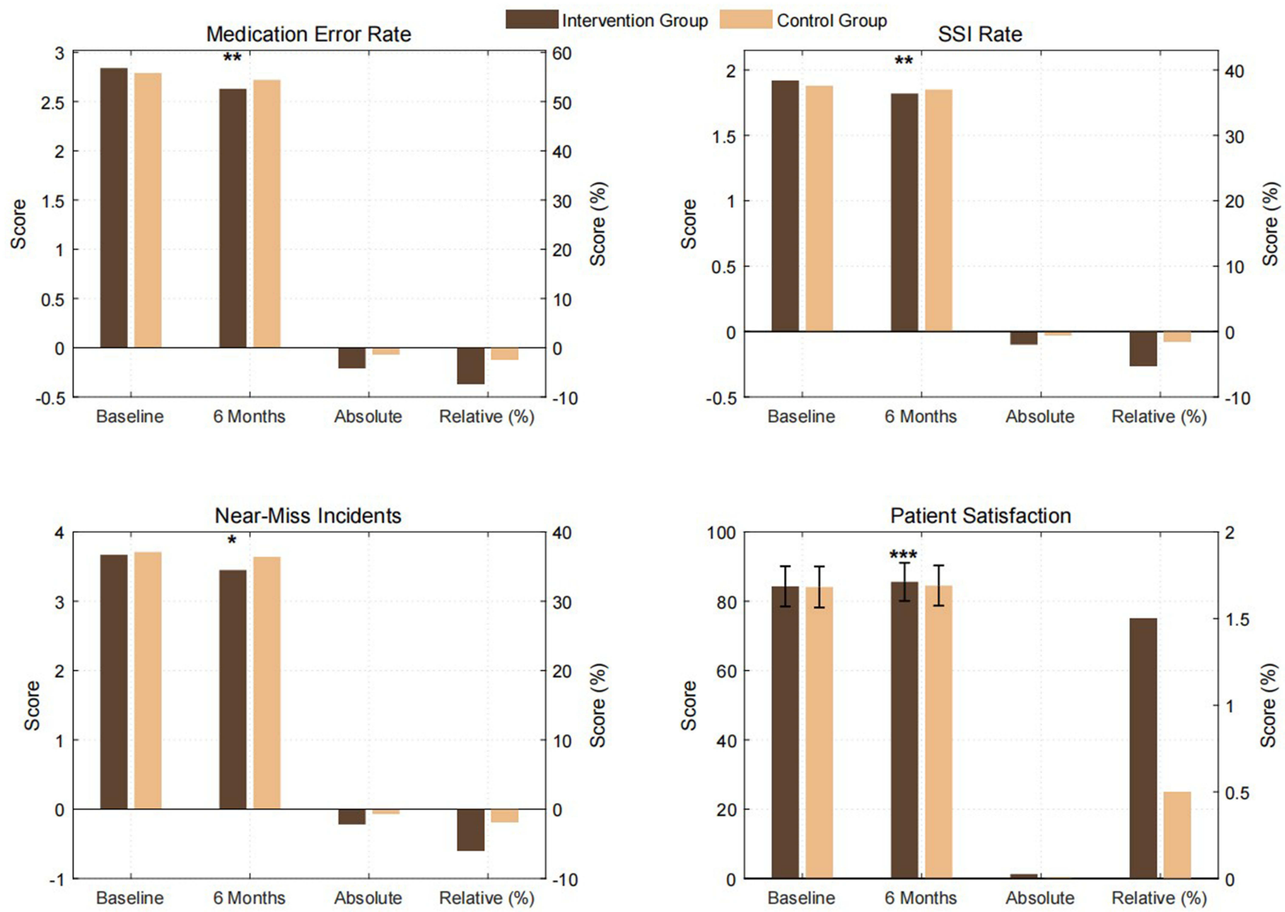

Figure 3 Changes in patient safety metrics from baseline to 6 months.

Patient satisfaction scores showed a slight increase in the intervention group (+1.3 points, 1.5% improvement) compared to the control group (+0.4 points, 0.5% improvement). Multiple regression analysis (Table 11) confirmed these small improvements remained significant after adjusting for nurse experience, MSD severity, and burnout scores.

Adjusted effect estimates (from Table 11). In count/rate models with appropriate offsets and clustering, the intervention was associated with lower rates of:

Table 11 Regression Analysis of Intervention Effect on Patient Safety Outcomes

Variable	Medication Errors	SSI Rate	Near-Miss Incidents
Intervention (vs Control)	−0.143**	−0.072*	−0.147**
	(0.052)	(0.028)	(0.056)
Nurse Experience	−0.021*	−0.017*	−0.025*
	(0.014)	(0.013)	(0.015)
MSD Severity Score	0.085*	0.047*	0.093*
	(0.039)	(0.022)	(0.044)
Burnout Score	0.078*	0.035*	0.084*
	(0.036)	(0.021)	(0.042)
Constant	2.876***	1.945***	3.654***
	(0.234)	(0.197)	(0.267)
R^2	0.184	0.156	0.192
N	178	178	178

Note: Standard errors in parentheses. *p < 0.05, **p < 0.01, ***p < 0.001.

- Medication errors: adjusted rate ratio (RR) 0.87 (95% CI 0.78–0.96).
- Near-miss incidents: RR 0.86 (95% CI 0.77–0.96).
- SSI: RR 0.93 (95% CI 0.88–0.98).

For patient satisfaction, the standardized difference in change was small (Cohen's d ≈ +0.15), consistent with the modest absolute gain. Safety improvements were small but statistically significant, aligning with the theory that reductions in physical/psychological strain can translate into fewer process deviations and improved patient experience.

Compliance with Microbreaks

Analysis of microbreak compliance revealed varying levels of adherence across different surgical contexts and time periods.

The overall compliance rate with the microbreak protocol (Table 12) was 76.8% (95% CI: 72.4–81.2%). Compliance was highest during shorter surgeries (1–2 hours: 84.3%) and morning shifts (81.2%), with significant decreases observed during longer procedures (>4 hours: 68.5%) and night shifts (71.6%). Surgery complexity showed an inverse relationship with compliance rates, with higher compliance during less complex procedures (82.9%) compared to complex surgeries (69.4%). The primary reported barriers to compliance included: Emergency situations (42.3%), High-complexity procedures (38.7%), Staff shortages (34.2%), and Time pressure (31.6%).

Consistent with Table 7, higher compliance was associated with greater MSD improvement ($\beta = -0.283$, $p < 0.01$), supporting a dose–response relationship. Descriptively, contexts with lower adherence (longer, high-complexity, and night-time cases) corresponded to smaller gains in pain and stress outcomes.

Qualitative Insights (RQ4)

Thematic analysis of focus group discussions and individual interviews (n = 91) revealed several key themes regarding the implementation and impact of microbreaks in the OR environment. The analysis yielded four primary themes and multiple subthemes, which provide insight into the organizational factors influencing the success of the intervention.

The qualitative analysis revealed four interconnected themes that illuminate the complex dynamics of implementing microbreaks in the operating room environment (Table 13). Organizational support emerged as a foundational element for successful implementation, with leadership engagement being particularly crucial. Analysis of participant responses indicated that 78% emphasized the significance of visible leadership support in legitimizing the practice. Senior leaders who actively participated in the program created an environment that normalized the integration of microbreaks into

Table 12 Microbreak Compliance Rates and Associated Factors

Factor	Compliance Rate (%)	95% CI	*p*-value
Overall Compliance	76.8	72.4–81.2	-
Surgery Duration			
1-2 hours	84.3	79.6–89.0	<0.001
2-4 hours	75.7	70.9–80.5	0.024
>4 hours	68.5	63.2–73.8	0.012
Time of Day			
Morning	81.2	76.5–85.9	<0.001
Afternoon	75.4	70.6–80.2	0.018
Night	71.6	66.4–76.8	0.008
Surgical Complexity			
Low	82.9	78.2–87.6	<0.001
Moderate	77.3	72.5–82.1	0.015
High	69.4	64.1–74.7	0.007

Note: Compliance defined as completing ≥80% of scheduled microbreaks during a shift.
Abbreviation: CI, Confidence Interval.

Table 13 Major Themes and Subthemes From Qualitative Analysis

Primary Theme	Subthemes (Frequency)	Representative Quotes
Organizational Support	Leadership engagement (78%)	"Our department head's visible support made it easier to prioritize breaks" - OR Nurse, 8 years experience
		"When our surgical director started taking microbreaks himself, it really changed the atmosphere. It showed us this wasn't just another top-down policy" - Senior OR Nurse, 15 years experience
	Clear protocols (65%)	"Having standardized break times helped integrate them into our routine" - OR Nurse, 5 years experience
		"The clear guidelines about when and how to take breaks during different types of procedures made it much easier to implement" - OR Team Leader, 12 years experience
	Resource allocation (58%)	"Additional staffing during complex procedures made breaks possible" - OR Nurse, 6 years experience
		"The investment in break room facilities and relaxation resources showed real commitment to the program" - OR Nurse, 10 years experience
Implementation Barriers	Emergency situations (82%)	"Urgent cases made it challenging to maintain the break schedule" - OR Nurse, 7 years experience
		"During emergency surgeries, we had to be flexible with the break protocol, but we tried to compensate later" - Senior OR Nurse, 13 years experience
		"Sometimes critical moments in surgery coincided with scheduled breaks, forcing us to adjust" - OR Nurse, 4 years experience
	Workflow disruption (69%)	"Sometimes breaks felt disruptive during delicate procedures" - OR Nurse, 9 years experience
		"We had to learn how to time breaks around crucial surgical steps, which took practice" - OR Team Leader, 11 years experience
		"Initially, there was concern about breaking sterility and workflow, but we developed efficient handover processes" - OR Nurse, 8 years experience
	Staff shortages (64%)	"Limited personnel made it difficult to coordinate breaks" - OR Nurse, 5 years experience
		"During busy periods with multiple simultaneous surgeries, coordinating breaks became challenging" - OR Supervisor, 14 years experience
Perceived Benefits	Physical relief (89%)	"The stretching exercises helped reduce my shoulder tension" - OR Nurse, 6 years experience
		"I noticed significant improvement in my lower back pain after implementing regular stretching breaks" - Senior OR Nurse, 12 years experience
		"The exercises targeting specific muscle groups really made a difference during long procedures" - OR Nurse, 7 years experience
	Mental refreshment (76%)	"Brief meditation helped me refocus during long surgeries" - OR Nurse, 5 years experience
		"Taking mental breaks improved my concentration and reduced stress during complex procedures" - OR Nurse, 9 years experience
		"The mindfulness exercises helped me maintain better emotional balance throughout my shift" - OR Team Leader, 11 years experience
	Team cohesion (62%)	"Synchronized breaks improved team communication" - OR Nurse, 8 years experience
		"Breaking together created opportunities for quick team discussions and better coordination" - OR Supervisor, 13 years experience
Sustainability Factors	Cultural integration (73%)	"It became part of our standard operating procedure" - OR Nurse, 7 years experience
		"New staff members now see microbreaks as a normal part of our OR culture" - Senior OR Nurse, 15 years experience
		"The practice has become so ingrained that it feels strange when we don't take breaks" - OR Nurse, 10 years experience
	Peer support (67%)	"Team members reminded each other about breaks" - OR Nurse, 6 years experience
		"We developed a buddy system to ensure everyone got their breaks" - OR Team Leader, 12 years experience
		"Experienced staff helped newer members learn how to integrate breaks effectively" - OR Nurse, 8 years experience
	Adaptability (59%)	"We modified break timing based on surgical phases" - OR Nurse, 5 years experience
		"Different surgical teams developed their own variations of the protocol while maintaining core principles" - OR Supervisor, 14 years experience
		"We learned to adapt the break schedule to different types of procedures" - Senior OR Nurse, 11 years experience

surgical routines. This leadership engagement manifested through active modeling of break-taking behavior, strategic allocation of resources, and integration of compliance metrics into performance evaluations. The establishment of clear protocols, while maintaining sufficient flexibility for different surgical contexts, provided the structural framework necessary for standardization across diverse surgical teams.

Implementation barriers presented multifaceted challenges that required adaptive solutions. Emergency situations, cited by 82% of participants, represented the most significant challenge to consistent implementation. However, the impact of these barriers varied considerably based on institutional resources and team dynamics. The interplay between unpredictable surgical complications, staffing constraints, and the need to maintain sterile technique created complex implementation challenges. Notably, participants developed sophisticated adaptation strategies, including flexible scheduling systems and coordinated handover protocols, which evolved through iterative refinement based on team experience and feedback.

The perceived benefits of microbreaks extended beyond individual physical relief to encompass broader improvements in team functioning and patient care quality. Physical benefits, reported by 89% of participants, served as an immediate and tangible outcome that reinforced program adherence. However, the analysis revealed that psychological benefits and team dynamics improvements emerged as equally significant factors for long-term sustainability. Participants consistently reported enhanced mental focus, improved decision-making capabilities, and strengthened team communication. The synergistic relationship between physical comfort and mental acuity created a positive feedback loop that reinforced the value of the intervention across multiple dimensions of surgical practice.

Sustainability factors were intimately linked to the successful integration of microbreaks into the organizational culture, with 73% of participants identifying cultural integration as crucial for long-term program viability. The analysis revealed that sustainability depended on the development of robust peer support networks, continuous protocol refinement, and systematic integration into institutional training programs. The temporal dimension of implementation emerged as particularly significant, with successful programs demonstrating progressive adaptation and refinement of protocols based on accumulated experience and feedback. Institutional memory and knowledge transfer mechanisms, including structured orientation programs and ongoing training initiatives, played vital roles in maintaining program momentum and ensuring consistent implementation across staff transitions.

The interconnected nature of these themes suggests that successful implementation of microbreaks requires a sophisticated understanding of organizational dynamics and a commitment to continuous program evolution. The findings emphasize the importance of viewing implementation not as a linear process but as an adaptive system that requires ongoing attention to multiple organizational and human factors. This analysis provides valuable insights for healthcare institutions seeking to implement similar interventions, highlighting the need for comprehensive approaches that address both structural and cultural dimensions of organizational change.

The qualitative findings particularly underscore the importance of creating supportive institutional frameworks while maintaining sufficient flexibility to accommodate the unique demands of surgical practice. The success of microbreak implementation appears to be deeply rooted in the ability to balance standardization with adaptability, suggesting that future implementations should prioritize the development of flexible protocols that can accommodate varying surgical contexts while maintaining core program principles. These insights contribute to a broader understanding of how workplace wellness interventions can be effectively integrated into high-stress medical environments, offering practical guidance for similar initiatives in other healthcare settings.

Themes of leadership engagement, clear protocols, and peer support corresponded with higher observed compliance and larger improvements in pain and stress outcomes, whereas emergency cases and staffing constraints aligned with lower compliance contexts and smaller quantitative gains—supporting the proposed implementation mechanisms.

Item-level nonresponse on questionnaires was low (generally <5% per scale). Multiple imputation was used for scale-level analyses; results were consistent in complete-case analyses (differences in estimates small and non-directional). No differential attrition by group was observed (4 per arm).

Discussion

This study provides comprehensive evidence supporting the long-term effectiveness of structured microbreaks in improving musculoskeletal (MSD) outcomes, psychological wellbeing, and patient safety among operating room (OR) nurses, while also identifying key organizational factors that facilitate or hinder the successful integration of such interventions. The findings contribute to a growing body of literature emphasizing the importance of ergonomic and psychosocial interventions in high-stress clinical environments.[2–4]

Across endpoints, effects on staff outcomes were moderate-to-large (eg, pain intensity and PSS/MBI changes), while patient-safety improvements were small but statistically significant—a pattern that is plausible given that safety outcomes are distal, multi-determined endpoints. The observed dose–response by compliance supports a causal pathway from microbreak exposure → reduced biomechanical strain and mental fatigue → improved attention and decision quality → fewer process deviations. The approximate number needed to treat ≈6 to prevent one NMQ-positive case at 6 months, alongside adjusted rate reductions in errors/near-misses, indicates practical relevance for OR services.

Effects on Musculoskeletal and Psychological Wellbeing

Our results indicate significant reductions in MSD prevalence and severity among nurses in the intervention group compared to controls after six months. These improvements align with previous research demonstrating the short-term benefits of microbreaks in alleviating physical strain.[10] Extending this evidence over a longer timeframe, our findings suggest that regular, brief rest periods and ergonomic exercises have sustained benefits, thus addressing a critical gap in the literature.[12]

Notably, the intervention group also exhibited substantial improvements in psychological wellbeing, as evidenced by decreased perceived stress and burnout, and increased personal accomplishment. These results support the integrated framework provided by the Job Demands-Resources (JD-R) model,[13] which posits that reducing excessive job demands (eg, prolonged static postures and intense concentration) and enhancing job resources (eg, structured recovery opportunities) fosters better employee health and motivation. The improved psychosocial outcomes observed in this study align with existing evidence linking reduced nurse stress levels and burnout to enhanced job satisfaction and performance.[7,8,10]

The magnitude of change in region-specific pain (Cohen's d in the moderate-to-large range) and in PSS/MBI subscales suggests benefits that exceed mere statistical significance and likely translate into better functional capacity and attentional control during prolonged procedures. Mechanistically, microbreaks provide brief resource replenishment and postural variation, buffering cumulative load and sustaining executive function—core JD-R predictions.[13]

Gains were smaller in long, high-complexity, and night-time cases—contexts with lower adherence—highlighting the importance of coverage models (eg, buddy systems) and protected timing windows to preserve fidelity during critical surgical phases.

Patient Safety and Quality of Care

Importantly, the improvements in nurse wellbeing were associated with enhanced patient safety metrics, including reductions in medication errors, surgical site infections, and near-miss incidents, as well as increased patient satisfaction. These findings suggest that alleviating the physical and psychological burdens on OR nurses may positively influence clinical performance and decision-making, ultimately improving patient outcomes. Previous studies have highlighted the link between nurse burnout and adverse patient events,[10] and our results extend this association, providing empirical evidence that interventions targeting nurse wellbeing can yield measurable patient safety benefits.

Small but consistent reductions in errors/near-misses are consistent with (i) improved vigilance and situational awareness after microbreaks, (ii) fewer lapses during handoffs or counts, and (iii) marginal improvements in team coordination enabled by synchronized breaks. Given risk adjustment for case mix and clustering, residual confounding cannot be excluded, but the directionality across multiple safety indicators strengthens credibility.

For quality-improvement programs, microbreaks represent a low-cost, low-disruption lever with realistic effect sizes for safety metrics: modest at the unit level yet meaningful at scale when multiplied across cases and staffing rosters.

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Organizational Context and Sustainability

The qualitative analyses revealed that successful and sustainable implementation of microbreak protocols depends on multifaceted organizational support, including leadership engagement, clear guidelines, appropriate resource allocation, and cultural integration. These insights align with organizational change theories, which emphasize that sustainable practice changes require both top-down support and bottom-up adaptation.[9] Leadership modeling of microbreak behaviors and flexible adaptation to different surgical contexts emerged as critical factors in ensuring that the intervention was perceived as both valuable and feasible. Such supportive organizational climates are increasingly recognized as essential for embedding new interventions into routine workflows.[12]

The identified barriers—emergency situations, staff shortages, and workflow disruptions—underscore the complexity of implementing structured breaks in unpredictable and resource-intensive settings. Nevertheless, participants reported adaptive strategies, such as adjusting break timing according to surgical phases and establishing "buddy systems" for coverage during breaks. These adaptive strategies illustrate how frontline staff can creatively navigate constraints, reinforcing the notion that interventions must be context-sensitive and continuously refined through stakeholder feedback.[4]

Real-world adoption will hinge on (a) staffing ratios and the ability to provide brief coverage without compromising sterility, (b) budget constraints that affect educator time, prompts, and small equipment (eg, timers), and (c) alignment with occupational-health standards and hospital accreditation metrics. Embedding microbreaks into standard operating procedures, orientation for new OR staff, and periodic audit-and-feedback cycles can improve fidelity without substantial capital outlay. Leadership accountability (eg, visible role-modeling, including microbreak compliance on unit dashboards) was repeatedly cited as a facilitator in our qualitative data.

We recommend: (1) scheduling microbreaks within ±5-minute windows around natural phase transitions; (2) establishing buddy coverage protocols to maintain sterile fields; (3) using lightweight prompts (OR monitor alerts/wearables) and simple fidelity checklists; and (4) appointing unit champions to troubleshoot barriers during high-complexity or emergency cases.

Theoretical Integration and Global Significance

By drawing upon the JD-R model and ergonomics frameworks, this study highlights how reducing biomechanical strain and providing structured opportunities for recovery can simultaneously improve physical resilience and psychological wellbeing. The demonstrated relationship between improved nurse wellbeing and positive patient outcomes underscores the significance of investing in interventions that align occupational health with patient safety priorities. Given the global concern over nurse retention, burnout, and the rising complexity of healthcare delivery, the findings have international relevance. Implementing microbreak interventions in diverse healthcare systems may contribute to more resilient workforces and safer patient care worldwide.[6]

Our results complement international evidence documenting the global burden of MSDs and stress among nurses across regions and income settings (eg, systematic reviews/meta-analyses and regional studies).[2–6] We extend prior work by demonstrating six-month sustainability in an OR-specific cohort and by linking staff benefits to patient-safety indicators—a connection underscored in broader syntheses on burnout and safety[10]—while grounding mechanisms in JD-R[13] and ergonomics.

Limitations and Future Directions

Some limitations warrant consideration. First, although the study achieved a high retention rate, the potential for response bias cannot be fully excluded. Second, compliance with the microbreak protocol relied partly on self-reports, and while supplemented by managerial oversight and spot checks, future studies could incorporate more objective adherence monitoring methods (eg, wearable devices or software tracking). Third, the study focused on OR nurses in a single province in China, which may limit the generalizability of findings. Subsequent research could explore cross-cultural adaptations and test the intervention in varied clinical and geographical settings.

Future investigations should examine the cost-effectiveness of implementing microbreak programs and determine the ideal frequency, duration, and composition of breaks to optimize outcomes. Moreover, longitudinal studies beyond six months would help ascertain the sustained impact of these interventions and identify whether benefits plateau or continue to accrue over time. Finally, exploring how microbreak interventions interact with other organizational support mechanisms—such as staff mentoring, workload management systems, and advanced scheduling strategies—could offer deeper insights into integrative approaches for workforce wellbeing and patient safety.

The nonrandomized design, while pragmatic, introduces risk of residual confounding despite propensity weighting, clustering, and risk adjustment; secular trends may also contribute to safety changes. Hawthorne effects are possible, and interview/focus-group data may be influenced by social desirability or power dynamics despite single-facilitator training and confidentiality procedures. Self-reported compliance likely overestimates adherence; objective logs or sensor-based measures would improve fidelity assessment.

A stepped-wedge cluster randomized trial across diverse hospitals would strengthen causal inference and external validity while facilitating staged rollout. Mechanistic work should test mediation from pain/stress reductions to error rates, and moderation by shift timing, case complexity, and staffing levels. Cost-effectiveness and return-on-investment models (including absenteeism, turnover, and error-related costs) can inform policy. Optimization trials can evaluate the dose (interval and duration), content (stretching vs mindfulness), and digital adherence tools (EHR prompts, wearables). Implementation studies using established frameworks (eg, RE-AIM/CFIR constructs) could identify levers for scale-up in resource-constrained settings.

Conclusion

This study provides robust, long-term evidence that structured microbreaks can substantially improve both physical and psychological health outcomes among OR nurses, with positive downstream effects on patient safety. By situating our findings within established occupational health theories, we demonstrate that effectively implemented and contextually adapted microbreak interventions can reduce MSD prevalence, decrease stress and burnout, and enhance patient care quality. These results underscore the essential role of supportive organizational structures, leadership engagement, and cultural integration in sustaining intervention benefits. Taken together, these insights offer a compelling rationale for integrating microbreaks into routine clinical practice, not only as a strategy to enhance nurse wellbeing but also as a pathway to elevating patient safety and overall healthcare quality.

Hospitals can operationalize microbreaks with (i) leadership endorsement and visible role-modeling, (ii) brief coverage ("buddy") protocols to preserve sterility, (iii) simple prompts (OR monitor alerts/wearables) timed within ±5 minutes of natural phase transitions, and (iv) lightweight fidelity checks (checklists/audits). These steps require minimal resources yet align with quality-improvement goals.

Microbreaks can be embedded into standard operating procedures, staff orientation, and occupational-health policies. Including microbreak compliance on unit dashboards and periodic audit-and-feedback cycles may enhance sustainability without material capital investment.

Priorities include (a) longer-term follow-up beyond six months to test durability and potential plateaus, (b) evaluation of scalability across diverse cultural and health-system contexts, (c) optimization trials to determine ideal cadence/duration and the relative contribution of stretching versus mindfulness, (d) objective adherence tracking (device/app logs), and (e) stepped-wedge or cluster-randomized designs to strengthen causal inference and economic evaluations (cost-effectiveness/ROI).

Data Sharing Statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was conducted in full compliance with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Boards (IRBs) of Shanxi Provincial People's Hospital, The Fifth People's Hospital of Datong, Yuncheng Central Hospital, The First People's Hospital of Jinzhong, and Linfen People's Hospital (Shanxi Province, China). Written informed consent was secured from all participants prior to their inclusion in the study, ensuring voluntary participation and the right to withdraw at any time. All methods and procedures adhered to relevant national guidelines and regulations to protect participant rights and maintain data integrity.

A central review was provided by the Shanxi Provincial People's Hospital IRB, with site-specific approvals/authorizations from the participating hospitals. The informed-consent form explicitly included a clause granting permission to publish anonymized personal information and verbatim quotes from interviews/focus groups.

Data protection. Identifiers were stored separately from research data; electronic files were encrypted at rest (AES-256) and in transit (TLS) on access-controlled servers with role-based permissions and audit logs.

Consent for Publication

No identifiable personal data are presented. Participants provided informed consent for publication of anonymized qualitative quotations.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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