Original Article

Effectiveness of Citrus sinensis Aromatherapy and Nature Sound Therapy on Pain, Vital Signs, and Postoperative Nausea and Vomiting: A Quasi-Experimental Study

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ABSTRACT

Background: Postoperative recovery in the early hours after surgery is often accompanied by pain, vital-sign fluctuations, and postoperative nausea and vomiting (PONV). Complementary therapies such as Citrus sinensis aromatherapy and nature sound therapy have been used as adjuncts to pharmacological management; however, evidence on their combined effects on multiple recovery indicators in the early postoperative period remains limited. This study evaluated the effectiveness of these interventions compared with standard postoperative care.

Methods: Three-group pretest–posttest quasi-experimental study was conducted in two hospitals using purposive sampling. Participants were conscious and hemodynamically stable adult patients 8–12 hours after surgery. Patients with chronic pain, hearing impairment, or olfactory dysfunction were excluded. Based on G*Power analysis (f = 0.25, α = 0.05, power = 0.80), 30 participants per group were required; therefore, 32 were recruited per group. Interventions were provided 8–12 hours post-surgery alongside standard care: Citrus sinensis aromatherapy (25 minutes) and nature sound therapy (30 minutes). Outcomes included pain intensity (Numeric Rating Scale), vital signs, and PONV severity (4-point scale). Data were analyzed using repeated-measures ANOVA in SPSS version 26.

Results: Both Citrus sinensis aromatherapy and nature sound therapy showed significant improvements in pain, vital-sign stability, and reduced PONV severity compared with the control condition ($p < 0.05$). No adverse effects were observed. Aromatherapy demonstrated a moderate effect on PONV reduction, while nature sound therapy showed a large effect on pain reduction and vital-sign stabilization.

Conclusion: Citrus sinensis aromatherapy and nature sound therapy are safe adjunctive interventions that may enhance early postoperative recovery by improving symptom burden and supporting physiological stability, with strong potential for integration into sensory-based postoperative comfort protocols.

Keywords: Aromatherapy; Citrus sinensis; Nature Sound Therapy; Postoperative Pain; Postoperative Nausea and Vomiting; Vital Signs.

Implications for Practice:

- Citrus sinensis aromatherapy may be applied in postoperative nursing care as a sensory adjunct to support the reduction of nausea and vomiting.
- Nature sound therapy may be used as a supportive non-pharmacological comfort intervention to assist pain control and vital-sign stabilization.
- Clinical adoption of structured sensory complementary interventions can inform refinement of postoperative nursing workflows and patient-comfort protocols.

Introduction

Postoperative recovery is often complicated by pain, hemodynamic instability, and postoperative nausea and vomiting (PONV), which collectively impair comfort, delay mobilization, and prolong hospitalization (Abebe et al., 2022; Amirshahi et al., 2020; Kubulus et al., 2025). Globally, PONV affects about 20–30% of all surgical patients and up to 80% in high-risk groups (Jin et al., 2020); Pang & Chan, 2024). Evidence synthesis suggests that up to 80% of patients experience postoperative pain, and over 70% of these report moderate to severe intensity despite advances in care, highlighting the persistent global burden of postoperative pain (Park et al., 2020). Despite advancements in multimodal analgesia and antiemetic prophylaxis, many patients still experience inadequate symptom control or drug-related side effects (Elvir-Lazo et al., 2020); Reinert et al., 2024). This highlights the need for safe, accessible, and evidence-based complementary strategies to enhance postoperative outcomes.

Among these, aromatherapy and nature sound therapy have shown promise as adjunctive modalities because they target sensory mechanisms that influence both physiological and psychological adaptation, domains that are continuously managed by nurses during early postoperative recovery. *Citrus sinensis* essential oil was selected due to its high limonene content, a terpene compound known to modulate nausea reflexes, emotional distress, and pain processing via limbic system regulation and serotonergic signaling (Chen et al., 2024); Saini et al., 2022; Tayeb et al., 2025). This mechanism provides a logical basis for addressing PONV and pain concurrently, which are common focal stimuli in postoperative patients. Clinical trials further support that citrus-based aromatherapy significantly reduces postoperative nausea and vomiting in surgical patients (Rambod et al., 2023). while additional evidence demonstrates the benefits of *Citrus sinensis* aromatherapy in reducing pain intensity and stabilizing physiological parameters routinely monitored by nurses (Caballero-Gallardo et al., 2025; M. D. M. Nascimento, 2021). However, existing studies often assess these outcomes separately, offering limited insight into the broader adaptive process during recovery.

Nature sound therapy was chosen based on evidence that auditory exposure to nature environmental sounds, such as birdsong, can regulate autonomic nervous system activity, reduce sympathetic overactivation, and promote relaxation responses, which are theorized to support physiological stabilization and pain modulation, key targets of non-pharmacological nursing interventions at the bedside (Kumpulainen et al., 2025; Zhu et al., 2024). Prior studies also indicate that nature-based auditory stimulation may reduce postoperative pain and anxiety while helping maintain hemodynamic stability, outcomes aligned with nursing goals of promoting comfort and supporting safe recovery (Fan & Baharum, 2024; Thoma et al., 2018). As both interventions are noninvasive, easy to deliver, and require no specialized infrastructure, they offer a practical rationale for integration into postoperative nursing workflows, yet

evidence examining their combined impact on adaptive outcomes within nursing care remains limited.

From a nursing perspective, postoperative care emphasizes symptom monitoring, physiological regulation, and comfort facilitation, consistent with holistic and patient-centered care principles (Tsegaye et al., 2023). Nurses manage focal recovery stressors, including pain, vital-sign instability, and PONV, while delivering supportive contextual stimuli to promote adaptation. The application of sensory adjuncts such as aromatherapy and nature sound may logically complement standard pharmacological regimens by enhancing comfort and supporting physiological regulation without adding treatment burden (Gian-Nguyen, 2024; Hedigan et al., 2023; Moore et al., 2019). Nevertheless, nursing-specific evidence on the use of *Citrus sinensis* aromatherapy and nature sound therapy across multiple adaptive recovery outcomes remains scarce.

This study is grounded in Roy's Adaptation Model (RAM), which conceptualizes patients as adaptive systems responding to focal internal stimuli such as surgical trauma, pain, and nausea. In contrast, contextual external stimuli, including sensory interventions, may facilitate more effective adaptive responses (Jennings, 2017). Within this framework, *Citrus sinensis* aromatherapy and nature sound therapy function as contextual stimuli that may influence physiological regulation and symptom adaptation, responses that nurses monitor and support during early recovery ((Browning) Callis, 2020).

In Indonesian clinical settings, postoperative nausea and vomiting (PONV) remains a common recovery challenge that directly affects patient comfort, early mobilization, and nursing workload. A cross-sectional observational study in the central surgery unit at Prof. Dr. I.G.N.G. Ngoerah General Hospital in Bali reported that approximately 31% of postoperative patients experienced PONV, demonstrating its significant prevalence in routine surgical care (Bagaskara et al., 2025). Similarly, descriptive research in Jakarta showed that PONV occurred in 11.5% of patients following general anesthesia for gynecological procedures, further indicating the clinical burden of this condition in the Indonesian context (Karnina & Ismah, 2021). Other local studies suggest that PONV affects about one-third of section caesarea patients under spinal anesthesia, with age, parity, and anxiety influencing its occurrence, highlighting the multifactorial nature of postoperative recovery outcomes that nurses must continuously manage (Muntasir et al., 2025).

Despite this consistent evidence of PONV prevalence, existing Indonesian studies remain predominantly descriptive and focus on single outcomes or isolated risk factors, with limited exploration of integrative, non-pharmacological nursing interventions. Specifically, there is a paucity of locally generated evidence examining the combined or comparative effects of sensory-based interventions, such as Citrus sinensis aromatherapy and nature sound therapy, on multiple postoperative outcomes, including pain intensity, physiological responses, and PONV incidence, within routine nursing care settings. This lack of multidimensional and intervention-focused research represents a critical gap in evidence-based postoperative nursing practice in Indonesia.

The aim of this study was, therefore, to evaluate the adjunctive effects of Citrus sinensis aromatherapy and nature sound therapy, each delivered alongside standard postoperative care, on pain intensity, vital signs, and the incidence of PONV in postoperative patients, while examining

their relevance as sensory-based adaptive support in nursing care.

Methods

Study Design

This study followed the TREND reporting guideline for non-randomized intervention studies (Haynes et al., 2021). A quasi-experimental pretest–posttest design was employed, with participants assigned to one of three groups: Citrus sinensis aromatherapy, nature sound therapy, or a control group receiving standard postoperative care. Baseline measurements were collected prior to the intervention, followed by post-intervention assessments to evaluate changes in pain intensity, vital signs, and the incidence of postoperative nausea and vomiting (PONV).

Participants

A total of 96 postoperative patients undergoing elective surgery were recruited from two regional public hospitals in East Java, Indonesia: RSUD Ngudi Waluyo Wlingi and RSUD Bangil. Participants were assigned to one of three groups: Citrus sinensis aromatherapy, nature sound therapy, or control (standard care), with 32 participants per group. The hospitals were selected due to their comparable surgical services, standardized postoperative nursing protocols, and sufficient elective surgery volume, enabling consistent intervention delivery and participant recruitment (**Figure 1**).

Purposive sampling was applied to select patients with characteristics relevant to the study objectives to ensure that participants could safely and effectively receive the interventions. The inclusion criteria were patients aged ≥18 years who underwent elective surgery under general anesthesia, were able to understand and follow instructions, and were willing to provide written informed consent. Participants also had no severe intraoperative or postoperative complications, no known allergy to Citrus sinensis essential oil, and had normal hearing without olfactory dysfunction.

Patients with olfactory dysfunction and hearing impairment were excluded to ensure the validity of the sensory-based interventions, as impaired smell or auditory perception could limit the effective reception of *Citrus sinensis* aromatherapy or nature sound therapy and confound the evaluation of their therapeutic effects.

The required sample size was calculated using G*Power version 3.1 for a repeated measures ANOVA, between factors, reflecting the study's pretest–posttest design with three groups (Citrus sinensis aromatherapy, nature sound therapy, and control). Assuming a moderate effect size ($f = 0.25$), $\alpha = 0.05$, power $(1-\beta) = 0.80$, two measurements per participant, and three groups, the calculation indicated a minimum of 30 participants per group. To account for potential dropouts, 32 participants per group were recruited.

Purposive sampling was used to recruit eligible postoperative patients who could feasibly receive the sensory-based interventions within routine clinical care. Participants were approached preoperatively by the research team at both hospitals based on predefined eligibility criteria and provided with study information. Written informed consent was obtained prior to enrollment. All participants completed the interventions and assessments, with no dropouts or withdrawals. While appropriate for this clinical context, the use of purposive sampling may introduce selection bias and limit the generalizability of the findings to similar clinical settings.

All participants were continuously observed for any adverse events during and immediately after the interventions. This included monitoring for allergic reactions, dizziness, nausea exacerbation, or other

unexpected discomforts. Any adverse events were documented, and appropriate clinical responses were implemented according to hospital protocols. No serious adverse events were reported in this study.

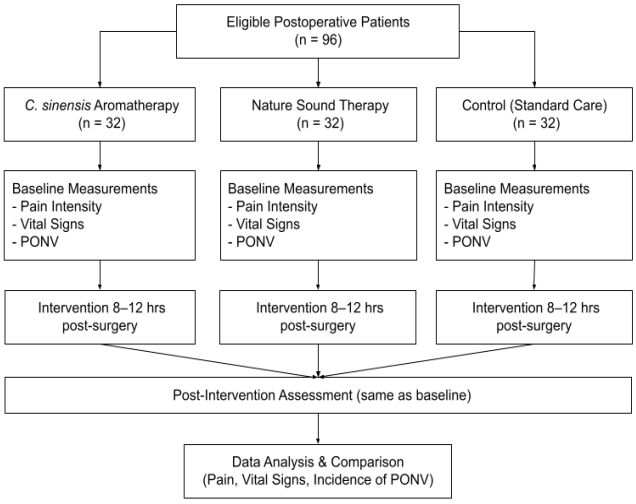

Figure 1. Flowchart of the 3-Group Quasi-Experimental Study on *Citrus sinensis* Aromatherapy and Nature Sound Therapy in Postoperative Patients

Instruments

This study used validated and reliable instruments to assess postoperative outcomes:

Pain Intensity: Pain was measured using the Numeric Rating Scale (NRS) with a 0–10 numeric scale, where 0 indicates no pain and 10 indicates the worst imaginable pain. Participants were asked to self-report their pain intensity, with interviewer assistance provided when necessary to ensure comprehension. The NRS is widely used in postoperative care and demonstrates high reliability (Baamer et al., 2022).

Postoperative Nausea and Vomiting (PONV): Postoperative Nausea and Vomiting (PONV): PONV was assessed using a self-reported 4-point scale (0 = none, 1 = mild, 2 = moderate, 3 = severe) measuring the incidence and severity of nausea and vomiting. This instrument has been used in prior postoperative studies (Honarmand et al., 2016), and has previously been applied in Indonesian clinical settings, supporting its cultural relevance for postoperative monitoring.

Vital Signs: Heart rate, blood pressure, respiratory rate, and oxygen saturation were measured using standard clinical monitoring devices commonly used in Indonesian hospitals, calibrated according to manufacturer recommendations. Measurements were performed by trained nursing staff following routine postoperative care procedures to ensure consistency.

Intervention

Citrus sinensis Aromatherapy Group

The essential oil used in this study was commercially obtained from Naturalpedia Sweet Orange Essential Oil. It is extracted from Citrus sinensis peel via cold-press extraction, preserving its bioactive compounds. Major secondary metabolites include limonene, linalool, and citral, which contribute to its aroma and potential therapeutic effects. The aromatherapy intervention involved 10% Citrus sinensis essential oil diluted in sweet almond oil, applied on a cotton pad placed near the patient's collar. Prior to administration, patients received briefing, allergy screening, and instruction in deep breathing to optimize relaxation effects. The intervention was delivered 8–12 hours postoperatively and lasted 25 minutes, following a standardized operating procedure (Nascimento et al., 2025; Rashidi-Fakari et al., 2015). Facilitators were trained nurses who ensured adherence to the protocol and monitored patients for any adverse reactions throughout the session.

Olfactory stimulation from citrus aromatherapy was intended to act as a contextual environmental stimulus that supports physiological and psychological

adaptation by promoting autonomic balance and relaxation. Consistent with Roy's Adaptation Model, this process facilitates adaptive responses such as reduced pain perception, nausea, and improved comfort during postoperative recovery. Intervention fidelity was ensured through delivery by trained nurses using a standardized protocol. Adherence to oil concentration, placement, and duration was monitored using an intervention checklist, with supervision and documentation of any deviations or adverse responses.

Nature Sound Therapy Group

The natural sound used in this study was "Relaxing Nature Sounds", featuring forest and water sounds. The sound frequency ranged approximately 250–4000 Hz, following therapeutic sound protocols, and was played for 30 minutes per session at a comfortable listening volume. The nature sound intervention consisted of patient-selected nature sounds (e.g., birdsong, ocean waves) played through Active Noise Cancellation (ANC) headphones with single-use covers. Patients were briefed on the procedure, had the volume adjusted to a comfortable level, and were positioned in a relaxed environment. The intervention was administered 8–12 hours postoperatively for 30 minutes ((Dimitriou et al., 2017; Mishra et al., 2022). Facilitators ensured protocol adherence and monitored patient safety.

Auditory exposure to natural sounds functioned as a calming environmental stimulus that supports adaptive regulation by reducing arousal and stabilizing physiological responses. In line with Roy's Adaptation Model, this intervention promoted adaptive responses such as improved comfort, reduced anxiety, and stabilized vital signs. Fidelity was maintained through a standardized protocol specifying sound type, duration, and volume range, with session completion and patient tolerance documented by facilitators under routine supervision.

Control Group

Participants in the control group received standard postoperative care, including routine monitoring, vital sign assessment, and pharmacological management, without additional sensory interventions.

Data Collection

Data were collected 8–12 hours post-surgery in the surgical wards of the General Hospital. Pre-intervention values were measured immediately before, and post-intervention values immediately after, every session. Protocol adherence was ensured by study staff supervised by the principal investigator, guided patients to fill out the NRS and PONV questionnaires, and monitored vital signs during the intervention.

Data Analysis

Data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY). Pre- and post-intervention comparisons within each group were conducted using paired t-tests or Wilcoxon signed-rank tests, depending on normality. Between-group comparisons across the three groups (Citrus sinensis aromatherapy, nature sound therapy, and control) were performed using one-way ANOVA with post-hoc tests or Kruskal–Wallis tests for non-normal data. Effect sizes were calculated using Cohen's d for pairwise comparisons and partial eta squared for ANOVA. Ninety-five percent confidence intervals (95% CI) were reported where applicable. A p-value < 0.05 was considered statistically significant.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and relevant national regulations on human subject research. Ethical approval was

obtained from the Health Research Ethics Committee, Faculty of Health Sciences, Universitas Brawijaya (Ethical Approval Letter No. 194/UN10.F17.10.4/TU/2025). All participants received detailed information about the study procedures and provided written informed consent prior to enrollment. Participants were informed of their right to withdraw from the study at any time without any consequences to their medical care. Participant privacy and confidentiality were strictly maintained, and all data were anonymized and securely stored in password-protected files accessible only to the research team.

Results

The demographic characteristics of participants across the three study groups are presented in **Table 1.** Overall, the distribution of age, gender, education, marital status, occupation, smoking history, and comorbidities was relatively balanced between groups, indicating comparable baseline profiles. Most respondents were middle-aged adults, predominantly married, and had completed senior high school education.

Table 1. Distribution of Respondents' Demographic Characteristics by Intervention Group (n = 96)

Variable	Category	*Citrus sinensis* Aromatherapy n (%)	Nature Sound n (%)	Control n (%)	Total n (%)
Age	<20 years (Adolescent)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	20–39 years (Young adult)	12 (37.5)	9 (28.1)	8 (25.0)	29 (30.2)
	40–59 years (Middle-aged adult)	15 (46.9)	20 (62.5)	19 (59.4)	54 (56.3)
	≥60 years (Older adult)	5 (15.6)	3 (9.4)	5 (15.6)	13 (13.5)
Gender	Male	18 (56.3)	15 (46.9)	18 (56.3)	51 (53.1)
	Female	14 (43.7)	17 (53.1)	14 (43.7)	45 (46.9)
Education level	Primary school	7 (21.9)	8 (25.0)	5 (15.6)	20 (20.8)
	Junior high school	5 (15.6)	8 (25.0)	7 (21.9)	20 (20.8)
	Senior high school	17 (53.1)	13 (40.6)	17 (53.1)	47 (49.0)
	College / University	3 (9.4)	3 (9.4)	3 (9.4)	9 (9.4)
Marital status	Single / Divorced	6 (18.8)	9 (28.1)	5 (15.6)	20 (20.8)
	Married	26 (81.2)	23 (71.9)	27 (84.4)	76 (79.2)
Occupation	Unemployed / Housewife / Student	10 (31.2)	11 (34.4)	9 (28.1)	30 (31.3)
	Private employee / Entrepreneur	16 (50.0)	9 (28.1)	15 (46.9)	40 (41.7)
	Farmer / Laborer	4 (12.5)	5 (15.6)	4 (12.5)	13 (13.5)
	Civil servant	2 (6.3)	7 (21.9)	4 (12.5)	13 (13.5)
Smoking history	Yes	13 (40.6)	13 (40.6)	14 (43.8)	40 (41.7)
	No	19 (59.4)	19 (59.4)	18 (56.2)	56 (58.3)
Co-morbidities	None	13 (40.6)	11 (34.4)	10 (31.3)	34 (35.4)
	Hypertension (HT)	8 (25.0)	9 (28.1)	9 (28.1)	26 (27.1)
	Diabetes mellitus (DM)	4 (12.5)	5 (15.6)	4 (12.5)	13 (13.5)
	HT + DM	3 (9.4)	4 (12.5)	5 (15.6)	12 (12.5)
	Others	4 (12.5)	3 (9.4)	4 (12.5)	11 (11.5)

The sample showed a slight predominance of male participants, and the majority were engaged in private employment or entrepreneurship. A smaller proportion were housewives, students, or farmers. Regarding health profiles, nearly

one-third of participants had no comorbid diseases, while hypertension was the most frequently reported chronic condition, followed by diabetes mellitus and the combination of both. Approximately two-fifths of participants reported a history of smoking.

Effects of *Citrus sinensis* Aromatherapy and Nature Sound on Pain, Vital Signs, and PONV. The comparison of vital signs, pain intensity, and postoperative nausea and vomiting (PONV) between the *Citrus sinensis* aromatherapy, nature sound and control groups is presented in **Table 2**.

Table 2. Comparison of Postoperative Pain, Vital Signs, and PONV Between Control, Citrus sinensis Aromatherapy, and Nature Sound Therapy Groups.

Outcomes	Time	*Citrus sinensis* (Mean ± SD)	Nature Sound (Mean ± SD)	Control (Mean ± SD)	*p*-value (Between Groups)	*Effect Size*	*95% CI*
Heart rate	Pretest	85.7 ± 12.4	84.2 ± 12.1	80.1 ± 11.9	0.008*	0.28	1.2–7.5
	Posttest	78.6 ± 10.2	79.5 ± 10.8	83.4 ± 11.5			
Respiratory rate	Pretest	20.1 ± 1.9	20.2 ± 1.8	20.3 ± 2.1	0.015*	0.22	0.3–2.4
	Posttest	18.4 ± 1.3	18.8 ± 1.4	20.5 ± 2.0			
Temperature (°C)	Pretest	36.64 ± 0.18	36.65 ± 0.17	36.64 ± 0.16	0.148	0.05	-0.02–0.14
	Posttest	36.55 ± 0.15	36.58 ± 0.16	36.65 ± 0.18			
Systolic BP (mmHg)	Pretest	137.8 ± 21.6	136.5 ± 19.8	128.3 ± 13.2	0.023*	0.25	-7.5 – -0.8
	Posttest	124.8 ± 6.7	126.2 ± 8.3	129.7 ± 12.8			
Diastolic BP (mmHg)	Pretest	81.7 ± 12.5	81.2 ± 11.7	80.5 ± 9.4	0.03*	0.21	-5.8 – -0.5
	Posttest	77.6 ± 6.0	78.1 ± 6.2	81.4 ± 9.8			
Pain (0-10)	Pretest	5.69 ± 1.14	5.81 ± 1.02	6.44 ± 0.80	0.001*	0.48	0.9–1.8
	Posttest	4.72 ± 1.12	4.95 ± 1.06	6.03 ± 0.78			
PONV score	Pretest	2.69 ± 2.24	2.73 ± 2.05	3.19 ± 2.17	0.001*	0.39	0.8–1.9
	Posttest						

**Notes: Values are presented as mean ± SD. Between-group comparisons were performed using ANOVA or Kruskal–Wallis tests. Effect sizes were calculated using partial eta squared. CI = 95% confidence interval. BP = blood pressure; PONV = postoperative nausea and vomiting. *p < 0.05.*

Within-group pre–post analyses showed significant improvements in both intervention groups, whereas changes in the control group were minimal. In the Citrus sinensis group, pain intensity and PONV scores decreased markedly from pretest to posttest, indicating a strong analgesic and antiemetic response. Similarly, the nature sound therapy group demonstrated significant reductions in pain intensity and respiratory rate, along with stabilization of heart rate following the intervention. In contrast, the control group showed no clinically meaningful pre–post changes across outcomes.

Between-group comparisons revealed significant post-intervention differences in heart rate, respiratory rate, systolic and diastolic blood pressure, pain intensity, and PONV scores ($p < 0.05$), except for body temperature. Within-group effect size estimates indicated moderate effects for pain reduction and PONV improvement in the Citrus sinensis group, and small-to-moderate effects for autonomic stabilization (heart rate and respiratory rate) in the nature sound therapy group, supporting the internal consistency of the intervention effects.

From a clinical perspective, the observed reductions in heart rate (≈5–7 beats/min) and respiratory rate (≈1–2 breaths/min) in the intervention groups reflect meaningful autonomic calming responses rather than abrupt physiological shifts, suggesting improved postoperative comfort and stress modulation. Likewise, the modest but consistent decreases in

systolic and diastolic blood pressure indicate enhanced hemodynamic stability without compromising safety. Pain score reductions of approximately 1 point on the NRS exceed commonly cited thresholds for minimal clinically important difference in postoperative pain, reinforcing the practical relevance of these findings.

Discussion

This study demonstrated that both *Citrus sinensis* aromatherapy and nature sound therapy significantly enhanced postoperative recovery indicators, including reductions in pain intensity, blood pressure, heart rate, respiratory rate, and postoperative nausea and vomiting (PONV), compared with the control group. These results add to the growing body of literature suggesting that sensory-based, non-pharmacological interventions can effectively complement conventional analgesic and antiemetic regimens by promoting physiological relaxation and psychological well-being (Hsieh et al., 2025; Miller et al., 2025).

Comparing our results for *Citrus sinensis* aromatherapy with previous trials, the randomized controlled trial of (Noruzi Zamenjani et al., 2021) is especially applicable: inhalation of *Citrus sinensis* essential oil after laparotomy (open abdominal surgery) was more effective at reducing pain than placebo and rose aromatherapy 8 and 12 hours after surgery. Their results support the analgesic benefit of *Citrus sinensis* inhalation in a surgical population, in line with our result of pain reduction. Meanwhile, a meta-analysis by Lakhan et al. (2016) determined that aromatherapy has a large effect size in reducing postoperative pain irrespective of the nature of surgery. These validations are in support of the external validity of our aromatherapy results and suggest our intervention parameters (timing, dose) were within a therapeutically effective range.

The beneficial effects of *Citrus sinensis* aromatherapy are supported by clinical and mechanistic evidence. For example, a randomized clinical trial showed inhalation of *Citrus sinensis* essential oil reduced pain, anxiety, mean blood pressure, heart rate, and respiratory rate during labor (J. C. Nascimento et al., 2025). In another study among hemodialysis patients, *Citrus sinensis* aromatherapy lowered pain and anxiety scores compared to control groups (Reyes et al., 2020). Mechanistically, research in rodents indicates that *Citrus sinensis* essential oil exerts anxiolytic-like activity via modulation of nitric oxide (NO) signaling pathways, suggesting a neurochemical basis for autonomic effects (Hocayen et al., 2019). Additionally, reviews on *citrus essential* oils describe their calming, mood-uplifting, and relaxing properties, which support their use in stress and pain modulation (Agarwal et al., 2022). The predominance of limonene in C. sinensis oil (~85-90%) has been documented in chemical profiling studies, lending plausibility to its bioactive influence (El Hachlafi et al., 2024).

On the auditory side, nature sound (or nature-based acoustic stimuli) has also been examined in clinical settings for pain and stress mitigation. In a randomized controlled trial among ventilated ICU patients, exposure to pleasant nature sounds for 90 minutes significantly reduced self-reported pain compared to a no-sound control (Saadatmand et al., 2015). More recently, a real-world controlled study found that nature sound therapy (as part of a holistic bundle) significantly reduced pain intensity and agitation during endotracheal suctioning in surgical ICU patients (Ruan et al., 2024). Broad reviews of sound/music interventions also report that sound-based therapies can reduce pain, modulate cortisol, and influence physiological stress

markers (Papathanassoglou et al., 2025). Moreover, music and guided acoustic stimuli in ICU settings have been shown to improve heart rate variability (a marker of autonomic balance) and reduce subjective pain in patients who can self-report (Richard-Lalonde et al., 2020). A recent study in burn patients also demonstrated shifts in electrophysiological signals (EEG, HRV) consistent with increased parasympathetic activity during music-assisted relaxation (Cordoba-Silva et al., 2024).

These findings are in accordance with theories that suggest sensory input, olfactory or auditory, modulates pain through central and autonomic pathways. Olfactory stimulation may reduce sympathetic activity and stimulate limbic structures, while auditory stimulation may distract, reduce stress response, and enhance vagal tone. The concordance with past evidence reinforces the potential effectiveness of nonpharmacologic sensory interventions as adjuncts during the postoperative period.

A strength of this study is the concurrent evaluation of *Citrus sinensis* aromatherapy and nature sound therapy in a combined postoperative model. Unlike previous studies that have examined each modality separately, findings indicate both modalities independently promote physiologic stabilization and analgesia comparable to standard care. With multiple outcome variables, vital signs, pain, and PONV, this study builds the empirical model for both interventions as parallel, evidence-based adjuncts in the promotion of postoperative recovery.

Implications and limitations

While this study provides evidence supporting Citrus sinensis aromatherapy and nature sound therapy as effective nonpharmacologic adjuvants in postoperative care, several limitations should be noted. Individual differences in sensory sensitivity, baseline mood, prior exposure to aromatherapy or sound interventions, and environmental factors may have influenced the outcomes. Variability in pain tolerance and analgesic response among participants also represents a potential source of bias. Additionally, the study was conducted at a single center with a relatively short follow-up period, limiting generalizability. Future research should include multi-center trials with larger sample sizes, longer follow-up, and objective physiological measurements to confirm and extend these findings, and to better understand the mechanisms underlying combined sensory-based interventions in postoperative recovery.

Relevance to Practice

Clinically, these findings indicate that *Citrus sinensis* aromatherapy and nature sound therapy are viable, useful adjuncts to promote postoperative comfort and recovery. These therapies can be administered by nurses during standard monitoring to augment relaxation, stabilize vital signs, and reduce pain and nausea, without pharmacologic side effects. Because they require minimal resources and augment holistic, patient-centered care, their integration into perioperative routines and staff training may improve patient outcomes and satisfaction.

Conclusion

Citrus sinensis aromatherapy and nature sound therapy improved postoperative recovery by reducing pain, stabilizing vital signs, and lowering PONV. These findings highlight the effectiveness of sensory-based, patient-centered interventions as integrative adjuncts in nursing care. Future studies should employ randomized controlled trial designs to strengthen causal inference, explore the combined or synergistic effects of multiple

sensory interventions, and evaluate their long-term outcomes across diverse surgical populations.

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CrediT Authorship Contributions Statement
Rustiana Tasya Ariningpraja: Conceptualization, Methodology, Investigation, Data Curation, Writing – Original Draft.
Endah Panca Lydia Fatma: Methodology, Supervision, Validation, Writing – Review & Editing.
Retno Lestari: Formal Analysis, Software, Data Curation, Visualization, Writing – Review & Editing.
Laely Hidayati: Investigation, Resources, Project Administration, Writing – Review & Editing.
Luis Figo Febriano: Supervision, Validation, Funding Acquisition, Writing – Review & Editing.

Conflicts of Interest
There is no conflict of interest.

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Supplementary Materials
Supplementary File S1: Questionnaire contains the full questionnaire used for data collection.

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