**Title Page**

**Title of the Manuscript:** Effects of Inhaled Aromatherapy on Sleep Quality and Cognitive Function in Older Adults: A Randomized Controlled Trial

**Short Title:** Inhaled Aromatherapy in Older Adults

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## Abstract

### Background

Sleep disturbances and cognitive decline frequently coexist in older adults and are associated with adverse health outcomes. Aromatherapy has emerged as a potential non-pharmacological intervention; however, evidence from inhalation-based protocols integrating both subjective and objective sleep assessments remains limited.

### Methods

This single-blind, randomised controlled trial was conducted in a residential care facility in Istanbul between January and June 2024. Sixty participants aged ≥65 years were randomly allocated to an intervention group (n=30) or a control group (n=30). The intervention consisted of inhaling a peppermint–palmarosa blend in the morning and a nighttime blend of vetiver, cedarwood, clary sage, petitgrain, and grapefruit oils for 10 minutes daily over 30 days. Outcomes included the Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and Blessed Orientation–Memory–Concentration Test, alongside objective sleep parameters obtained from Oppo Watch Free wearable smartwatches using photoplethysmography and accelerometer-based algorithms.

### Results

Compared with the control group, the intervention group demonstrated significant improvements in total sleep time (d=1.29), REM sleep duration (d=1.34), and deep sleep (N3) duration (d=1.47), along with reduced sleep latency (d=–1.12) (all $p<0.001$). Daytime sleepiness decreased, and subjective sleep quality improved. Cognitive performance also

improved, with significant gains observed in orientation, memory, and concentration, whereas no significant changes were observed in the control group**.**

**Conclusions**

A circadian-aligned, multi-component inhalation aromatherapy protocol may represent a feasible and clinically relevant complementary intervention to improve sleep architecture and cognitive outcomes in older adults residing in residential care settings.

**Keywords:** olfactory stimulation; essential oils; sleep architecture; wearable sleep tracking; residential care

**Trial Registration:**

ClinicalTrials.gov: NCT06208800.

## 1. Introduction (Background)

Global demographic trends indicate a substantial increase in the ageing population, leading to profound transformations in health, economic, and social systems worldwide. Declining fertility rates, extended life expectancy, and advances in healthcare services have accelerated population ageing across societies. According to data from the Turkish Statistical Institute (1), the proportion of individuals aged 65 years and above was 9.7% in 2021 and is projected to reach 25.6% by 2080. Similarly, the World Health Organization (2) estimates that by 2050, one in every six people globally will be aged 65 years or older. This demographic shift underscores the need for early identification of health problems in older adults and the development of specialised geriatric care services.

Sleep disorders are among the most common yet frequently overlooked health problems in older adults. Physiological, psychosocial, and neuroendocrine changes associated with ageing lead to substantial alterations in sleep architecture. Evidence indicates that older adults experience

decreases in total sleep time, sleep efficiency, and REM sleep duration, along with prolonged sleep latency and frequent nocturnal awakenings (3,4). Objective sleep assessments further show that older adults spend more time in light sleep stages (NREM 1–2), whereas deep sleep (NREM 3) and REM stages are markedly reduced (5). More than half of community-dwelling older adults report at least one chronic sleep disturbance (6).

The aetiology of sleep problems in older adults is multifactorial. Chronic diseases such as cardiovascular disorders, arthritis, pulmonary diseases, gastroesophageal reflux, persistent pain, depression, anxiety, and the widespread use of multiple medications negatively affect sleep quality (7,8). Age-related reductions in melatonin and growth hormone secretion, as well as alterations in cortisol and thyrotropin (TSH) rhythms, further impair sleep continuity, leading to fragmented, non-restorative sleep (9). Poor-quality sleep increases the risk of falls, depression, frailty, and cognitive impairment, and predisposes older adults to neuropsychiatric complications, including attention deficits, disorientation, and delirium (10,11). Furthermore, inadequate sleep negatively affects memory consolidation and neuroplasticity (12,13).

Structural brain changes accompanying ageing—particularly volume reductions in the hippocampus and prefrontal cortex—contribute to impairments in memory, attention, and executive functioning (14,15). According to WHO data (2), the number of individuals living with dementia is projected to reach 152 million by 2050. Cognitive impairment decreases quality of life, increases caregiver burden, and imposes substantial demands on healthcare systems (16). Importantly, the relationship between sleep and cognition is bidirectional. The glymphatic system, which facilitates the clearance of neurotoxic metabolites during sleep, becomes less effective with ageing and sleep disruption (17,18). Both REM and deep NREM sleep stages play essential roles in memory consolidation, learning processes, and emotional regulation (19,20).

Pharmacological interventions for sleep problems in older adults are associated with important risks, including falls, cognitive impairment, and dependency (21,22). Consequently, safer and more sustainable non-pharmacological approaches have gained increasing attention. Aromatherapy, a complementary method involving the therapeutic use of essential oils, has demonstrated potential benefits for sleep regulation and cognitive functioning through its modulatory effects on limbic-system neurotransmitters (23). Although interest in the use of aromatherapy as a non-pharmacological intervention has been increasing, important gaps remain in the literatüre (23,24). Previous studies have largely examined sleep or cognitive outcomes separately and have predominantly relied on self-reported measures (23-25). Furthermore, evidence remains limited regarding inhalation-based aromatherapy protocols that integrate both subjective assessments and objective sleep measurements, particularly in older adults residing in residential care settings, who are at high risk for both sleep disturbances and cognitive decline (24-26).

Therefore, there is a need for well-designed randomised controlled trials that simultaneously evaluate sleep patterns and cognitive outcomes using multidimensional assessment approaches. The present study aims to address this gap by investigating the effects of a multi-component inhalation aromatherapy protocol on sleep quality, objective sleep parameters, and cognitive performance (specifically attention, memory, and orientation) in older adults living in residential care facilities.

**Objective**

To evaluate the effects of a multi-component inhalation aromatherapy protocol on sleep quality, sleep architecture (sleep onset latency, total sleep duration, REM duration, N1–N2 duration, N3 duration, night-time awakenings, and daytime sleepiness), and cognitive performance in older adults.

## Hypothesis

$H_1$: There is a statistically significant difference between the intervention and control groups, such that older adults receiving inhalation aromatherapy demonstrate improved objective and subjective sleep outcomes and better cognitive performance (orientation, memory, and concentration) compared with the control group.

$H_0$: There is no statistically significant difference between older adults receiving inhalation aromatherapy and those in the control group in terms of objective and subjective sleep outcomes or cognitive performance (orientation, memory, and concentration).

## 2. Materials and Methods

### 2.1. Study Design

This study was a two-arm, parallel-group randomised controlled trial designed to evaluate the effects of inhaled blended aromatherapy on sleep and cognitive outcomes in older adults. The intervention was delivered over four weeks. The trial was reported in accordance with the CONSORT guidelines (Figure 1). Due to the nature of the intervention (inhalation aromatherapy with a distinct scent), full blinding of participants and the implementing researcher was not feasible. Therefore, participants were aware of their group allocation, and the study cannot be considered fully blinded. To minimise potential bias, all participants were followed under standardised conditions, including identical assessment schedules and procedures across groups.

### 2.2. Participants and Inclusion Criteria

In this randomised controlled trial, 60 older adults residing in a public residential care facility were enrolled. Participants were eligible if they met the following inclusion criteria: (i) aged ≥65 years; (ii) no diagnosis of psychiatric illness or severe cognitive impairment; (iii) no

respiratory disease and no known allergy to essential oils; (iv) Epworth Sleepiness Scale (ESS) score ≥11; and (v) Pittsburgh Sleep Quality Index (PSQI) score >5.

Exclusion criteria were: (i) use of pharmacological treatments known to affect sleep; (ii) body mass index (BMI) ≥30 kg/m²; (iii) severe pain (≥5/10); and (iv) use of any complementary therapy within the last three months. Participants were withdrawn in the event of adverse effects (e.g., allergic reactions or respiratory distress) or at their own request. Participants with severe cognitive impairment were excluded; however, those with mild cognitive impairment were allowed to participate.

### 2.3. Sample Size and Power Analysis

In this study, sample size estimation was based on the effect size coefficient (Cohen's d) as defined by Cohen (27). For the preliminary estimation, findings from the randomised controlled experimental study by Genç et al. (28), which evaluated the effects of aromatherapy on sleep quality and fatigue in older adults, were used. In that study, a significant improvement in Pittsburgh Sleep Quality Index (PSQI) scores was observed following the intervention, with the mean PSQI score in the intervention group decreasing from 8.10 ± 3.13 to 5.06 ± 2.51 ($t = 6.474$, $p < 0.001$). Based on these data, the estimated Cohen's d was approximately 1.07, indicating a large effect size.

This effect size was adopted as the reference criterion for the present trial. Power analysis using G*Power 3.1 software (29) was performed with a two-tailed significance level of $\alpha = 0.05$ (95% confidence level), power of 0.99, and effect size $d = 1.07$. Under these assumptions, a minimum of 28 participants per group was required, yielding a total minimum sample size of 56.

To account for potential attrition (e.g., withdrawal, health complications, or noncompliance with the intervention protocol), the target sample size was increased by approximately 7%,

resulting in 30 participants per group (total n = 60). Randomisation was stratified by sex to ensure balanced allocation of women and men across groups.

### 2.4. Research Environment and Ethical Approval

The study was conducted in a public residential care facility under the supervision of the facility's healthcare and care staff. Ethical approval was obtained from the Istanbul Medipol University GETAT Clinical Research Ethics Committee (Approval No: E-95961207-604.01.01-3755; Date: 15 June 2023). Institutional permission was obtained from the facility management, and clinical research permission was obtained from the national competent health authority. Written informed consent was obtained from all participants before enrolment.

### 2.5. Randomisation

Participants were randomly allocated (1:1) to the intervention or control group using sex-stratified randomisation. Eligible participants were first stratified by sex (women and men). Within each stratum, allocation sequences were generated using a computer-based random number generator. Randomisation was conducted by an independent researcher who was not involved in outcome assessment. To ensure allocation concealment, the computer-generated allocation list was kept by the independent researcher and was not accessible to outcome assessors; group assignment was revealed only after enrolment was completed.

### 2.6. Data Collection Tools

Multidimensional data-collection instruments were used to obtain comprehensive information on subjective and objective sleep outcomes and on cognitive function. Participant demographic and clinical characteristics were collected using a researcher-developed Participant Information Form. Daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS), overall sleep quality using the Pittsburgh Sleep Quality Index (PSQI), and cognitive performance using the Blessed Orientation–Memory–Concentration Test (BOMCT). These instruments were selected

as validated measures suitable for the clinical and functional characteristics of older adults. All questionnaires were administered at baseline (Week 0) and at the end of the intervention (Week 4).

Following questionnaire administration, objective sleep parameters were recorded using wearable smartwatches paired with compatible Android smartphones. Sleep onset time, wake time, bedtime, and wake-up time, REM sleep duration, light and deep sleep durations, and total sleep time during the night were obtained from the wearable devices.

***Participant Information Form***

A researcher-developed Participant Information Form was prepared based on the relevant literature and used to collect sociodemographic and clinical characteristics, including age, sex, body mass index (BMI), and chronic diseases. The form consisted of 21 items assessing demographic and health-related information (30).

*Epworth Sleepiness Scale (ESS)*

The Epworth Sleepiness Scale was developed by Johns (31) to assess daytime sleepiness. It includes eight items that evaluate the likelihood of dozing in routine daily situations. Each item is scored from 0 (would never doze) to 3 (high chance of dozing), yielding a total score of 0–24, with higher scores indicating greater daytime sleepiness. In the present study, Cronbach's alpha was 0.737.

*Pittsburgh Sleep Quality Index (PSQI)*

The Pittsburgh Sleep Quality Index, developed by Buysse et al. (32), assesses sleep quality and sleep disturbances over the preceding month. It comprises seven components and yields a global score ranging from 0 to 21; scores ≥5 indicate poor sleep quality.

*Blessed Orientation–Memory–Concentration Test (BOMCT)*

The original Blessed Orientation–Memory–Concentration Test was developed by Blessed, Tomlinson, and Roth (33) and later modified by Katzman et al. (34) into a six-item version assessing cognitive function, including orientation, memory, and attention. Higher scores indicate greater cognitive impairment. Test–retest reliability has been reported as 0.77, and correlation with the Mini-Mental State Examination (MMSE) as 0.83 (35). In the present study, Cronbach's alpha was 0.758.

*Wearable Smart Devices and Android-Based Application Support*

Objective sleep parameters were obtained using wearable smart devices (Oppo Watch Free, Oppo, China), which provided continuous measurements of sleep onset latency, total sleep time, and sleep-stage durations (REM, deep sleep [N3], and light sleep [N1–N2]). Data were transferred to Android-based mobile devices via Bluetooth technology.

Wearable devices incorporating accelerometers and photoplethysmography (PPG) sensors enable non-invasive monitoring of physical activity, heart rate, and sleep-related parameters and have been widely recommended for use in both clinical and research settings due to their practicality, safety, and feasibility (36,37).

Sleep parameters were derived using the device's proprietary algorithms based on accelerometer and PPG signals, rather than manually processed raw data. These algorithms automatically estimate sleep stages and related sleep variables.

Previous studies have demonstrated that consumer wearable devices show acceptable agreement with polysomnography and can provide reliable estimates of sleep-related parameters (36,37). In addition, validation studies on OPPO Watch-based sleep analysis systems have reported good correlation and agreement with clinical reference measurements (38).

Integrating objective measures with subjective instruments (PSQI and ESS) enabled a multidimensional assessment of sleep outcomes. Data transfer and synchronisation were conducted via Android-based smartphones paired with the wearable devices, and automated acquisition features supported standardisation and data security. Weekly data checks were performed to ensure completeness and accuracy of the recorded measurements.

### 2.7. Intervention

#### 2.7.1. Essential Oils Used in the Study

A multi-component inhalation aromatherapy protocol was implemented using vetiver, cedar, clary sage (musk sage), grapefruit, petitgrain (orange), peppermint (English mint), and palmarosa essential oils. All oils were obtained from the same manufacturer and stored in dark, airtight glass bottles under optimal conditions in accordance with expert recommendations and the relevant literature (39).

Peppermint oil contains bioactive components such as menthol and menthone and has been associated with central nervous system stimulation through cholinesterase inhibition and interactions with GABA-A and nicotinic receptors (40). Clary sage oil, containing linalyl acetate and β-pinene, has demonstrated sedative and antidepressant effects and may reduce cortisol levels when inhaled (41). Vetiver oil, characterised by sesquiterpenes, has been associated with anxiolytic, nootropic, and sleep-modulating effects and may influence sleep–wake regulation and electroencephalographic activity (42).

Petitgrain oil contains linalool and myrcene, which may contribute to the regulation of the autonomic nervous system (43). Cedar oil, particularly its cedrol component, has been linked to sleep-onset facilitation via serotonin- and melatonin-related pathways (44). Grapefruit oil contains compounds such as limonene and sabinene and has been associated with neurophysiological effects involving autonomic regulation (45).

**Rationale for Multi-Component Blended Oils**

The essential oils were selected based on the literature and in consultation with an aromatherapy specialist to develop a protocol targeting both sleep and cognitive outcomes. Previous studies suggest that blending two or more essential oils may enhance therapeutic efficacy compared with single-oil approaches (46,47).

**2.7.2. Intervention Protocol**

After providing study information, written informed consent was obtained from all participants. Each participant in the intervention group received two labelled essential oil bottles prepared for daytime and nighttime use. Bottles were colour-coded (daytime: grey cap; nighttime: blue cap) and labelled accordingly.

Daytime inhalation was administered at 11:30 using a 1:1 blend of peppermint and palmarosa oils. Night-time inhalation was administered at 21:30 using an equal-proportion blend of vetiver, cedar, clary sage (musk sage), petitgrain, and grapefruit oils. For each session, five drops of the prepared blend were applied to sterile cotton and positioned within the participant's breathing area (approximately 20 cm). Each inhalation session lasted 10 minutes and was supervised by the researcher. Based on prior evidence, the physiological effects of inhalation aromatherapy are known to occur rapidly, typically within minutes after exposure.

All aromatherapy sessions were conducted under strictly standardised conditions. The intervention was administered at fixed times (11:30 and 21:30), in the same residential care setting, using identical materials and procedures. The same researcher supervised all sessions,

and the duration, positioning, and administration method were kept consistent for all participants.

### 2.7.3. Data Collection and Follow-up

Objective sleep parameters (total sleep time, sleep onset latency, REM duration, deep sleep [N3] duration, light sleep [N1–N2] duration, and night-time awakenings) were continuously monitored using wearable smartwatches. Data were synchronised with Android-based mobile devices and checked weekly to ensure completeness and data integrity. Assessments were conducted at three time points: baseline (Day 0), mid-intervention (Day 15; device data only), and post-intervention (Day 30). Subjective measures (ESS, PSQI, and BOMCT) were administered via face-to-face interviews at baseline and post-intervention.

### 2.7.4. Intervention Group

Participants allocated to the intervention group received inhalation aromatherapy twice daily (daytime and night-time) for four weeks. All sessions were conducted under the researcher's supervision, with standardised timing and monitoring for potential adverse effects. No adverse events were observed, and all participants completed the protocol.

### 2.7.5. Control Group

Participants in the control group did not receive aromatherapy. However, wearable devices, assessment instruments, and the measurement schedule were implemented identically to the intervention group to enable isolated evaluation of the aromatherapy effect.

Details of the study implementation scheme and intervention schedule are presented in Supplementary eTable 1.

## 2.8. Statistical Analysis

All analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as mean ± standard deviation, median (minimum–maximum), or n (%) as appropriate.

Between-group comparisons were conducted using Welch's t-test for continuous outcome variables, including total sleep time, sleep onset latency, REM sleep duration, deep sleep (N3), light sleep (N1–N2), number of nocturnal awakenings, daytime sleepiness duration, and questionnaire scores (ESS, PSQI, and BOMCT).

Within-group comparisons across repeated measurements (Day 0, Day 15, and Day 30) for objective sleep parameters were analysed using the Friedman test, followed by Bonferroni-adjusted post-hoc comparisons when appropriate.

Effect sizes were calculated using Cohen's d for between-group comparisons and Kendall's W for repeated measures analyses. Two-sided p-values $<0.05$ were considered statistically significant; values $<0.001$ were reported as $p<0.001$.

## 3. Results

This study evaluated the effects of inhalation aromatherapy on objective sleep parameters, subjective sleep quality, daytime sleepiness, and cognitive performance among older adults residing in a residential care facility. Results are presented in Table 1–Table 5 and Supplementary eFigure 1.

### 3.1. Baseline socio-demographic and clinical characteristics

Baseline socio-demographic and clinical characteristics of participants in the intervention and control groups are shown in Table 1. The groups were comparable with respect to age, marital status, education level, leisure activities, presence of chronic disease, history of sleep problems,

difficulty falling asleep, frequency of nocturnal awakenings, medication use, and duration of sleep disturbances (all p>0.05; Table 1). However, the distribution of disease types differed significantly between groups (p=0.002), with endocrine disorders more prevalent in the intervention group and cardiovascular and nephrological conditions more common in the control group (Table 1).

### 3.2. Objective sleep parameters and sleep duration

Objective sleep parameters recorded at baseline (Day 0), mid-intervention (Day 15), and post-intervention (Day 30) are presented in Table 2 and visualised in Supplementary eFigure 1. In the intervention group, significant improvements over time were observed across multiple objective sleep outcomes, including increases in total sleep time, REM duration, and deep sleep (N3) duration, along with reductions in sleep onset latency and the number of nocturnal awakenings (all p<0.001; Table 2). In contrast, no statistically significant changes were observed across time points in the control group (Table 2). Between-group effect sizes indicated large differences for key objective outcomes following the intervention (Table 2).

### 3.3. Subjective sleep quality and daytime sleepiness

Subjective daytime sleepiness and sleep quality outcomes are presented in Table 3 and Table 4. In the intervention group, ESS scores significantly decreased from baseline to Day 30 (p<0.001; Table 3). Similarly, PSQI global scores improved significantly over the intervention period (p<0.001; Table 4). No statistically significant changes were observed in the control group for ESS or PSQI outcomes (Table 3–Table 4). Improvements in the intervention group were observed across PSQI components, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, daytime dysfunction, and use of sleep medication (Table 4).

### 3.4. Cognitive outcomes

Cognitive outcomes assessed using the BOMCT are presented in Table 5. In the intervention group, BOMCT scores improved significantly from baseline to post-intervention ($p<0.001$; Table 5). The control group showed no improvement over the same period (Table 5).

## 4. Discussion

This randomised controlled trial evaluated a multi-component inhalation aromatherapy protocol and found improvements in both subjective and objective sleep outcomes, accompanied by better cognitive performance in older adults residing in a residential care facility. Overall, the findings indicate that inhalation-based aromatherapy may represent a feasible non-pharmacological strategy to support sleep and cognition in this population. In this section, the study outcomes are discussed in relation to the current evidence base and plausible neurophysiological mechanisms.

Aromatherapy was associated with increased total sleep time and shorter sleep onset latency. In the intervention group, total sleep duration increased from 322.07 ± 15.28 to 374.57 ± 11.37 minutes, whereas no significant change was observed in the control group. These findings are consistent with prior studies suggesting that essential oils such as lavender, vetiver, and palmarosa can improve sleep initiation and prolong total sleep time, primarily by reducing sleep latency (48,49).

The observed effects may reflect the complementary properties of the blended oils selected in this study. Vetiver has been linked with sedative and anxiolytic effects, palmarosa with calming properties, and peppermint with enhanced alertness and cognitive clarity (24,50). The daytime peppermint–palmarosa application may have contributed to improved daytime functioning and reduced subjective sleepiness, consistent with the decrease in ESS scores in the intervention group (from 11.8 ± 3.01 to 7.53 ± 2.30). This interpretation aligns with evidence that peppermint may influence alertness and attention via olfactory-driven limbic pathways (50).

Notably, aromatherapy also improved sleep architecture. REM duration increased from 42.57 ± 8.72 to 71.73 ± 9.91 minutes, and deep sleep (N3) increased from 16.97 ± 6.07 to 42.10 ± 14.50 minutes. Similar effects have been reported in studies suggesting that essential oils such as vetiver and lavender may enhance deep-sleep physiology and delta activity (51). Given the established role of sleep, including REM sleep, in memory consolidation (52,53), the observed increase in REM duration is consistent with concurrent improvements in cognitive performance. Additionally, citrus-based oils such as petitgrain and cedar have been associated with neurophysiological effects that may support sleep regulation (54), supporting the potential benefit of blended oil protocols targeting multiple sleep stages.

Aromatherapy was also associated with improved sleep continuity, as evidenced by reduced nocturnal awakenings in the intervention group (from 2.23 ± 0.50 to 1.37 ± 0.49). Comparable improvements have been reported in randomised trials using lavender or blended essential oils (49,55,56). One possible mechanism may involve increased parasympathetic activity, which could facilitate physiological readiness for sleep and reduce sleep fragmentation (45).

Consistent with the objective improvements, subjective sleep quality improved substantially. PSQI global scores decreased from 13.97 ± 1.38 to 7.73 ± 1.86, indicating a meaningful enhancement in perceived sleep quality. These results align with meta-analyses and experimental studies demonstrating the beneficial effects of essential oils on sleep quality in older adults (48,46). Mechanistically, oils containing constituents such as linalool, limonene, and sesquiterpenes may modulate inhibitory neurotransmission, including GABAergic pathways, contributing to sleep-promoting effects (57).

A particularly important finding of the present study is the concurrent improvement in cognitive performance alongside improvements in REM and N3 sleep. BOMCT scores decreased from 12.47 ± 5.10 to 6.80 ± 3.50 in the intervention group, whereas the control group showed no

improvement. This pattern is consistent with evidence that age-related reductions in REM and deep sleep contribute to impairments in memory, attention, and orientation (52,53). The present findings suggest that supporting sleep architecture through aromatherapy may also have downstream benefits for cognitive functioning in older adults.

In addition, aromatherapy may influence cognitive outcomes both directly, through olfactory-mediated neural processing, and indirectly, through improvements in sleep quality and continuity (58,59).

Beyond statistical significance, the magnitude of improvement observed in BOMCT scores suggests potential clinical relevance, particularly in domains such as orientation, memory, and attention. However, given that BOMCT is a screening instrument, further studies using comprehensive neuropsychological assessments are needed to confirm the clinical significance of these findings.

Neurobiological mechanisms underlying these effects have been discussed in prior research. Essential oils such as vetiver, lavender, and cedar have been reported to influence GABAergic and serotonergic pathways and may contribute to anxiolytic and neuroprotective effects (57). In addition, aromatherapy may influence cognitive outcomes both directly, through olfactory-mediated neural processing, and indirectly, through improvements in sleep quality and continuity (58,59).

The findings of the present study are largely consistent with previous research demonstrating the beneficial effects of aromatherapy on sleep quality and duration in older adults (48,55). However, the present study differs from much of the existing literature in several important aspects. While many previous studies have relied primarily on subjective assessments, this study integrated subjective measures with objective sleep data from wearable devices (59). In

addition, the use of a multi-component, circadian-aligned aromatherapy protocol and the concurrent evaluation of cognitive outcomes represent key methodological strengths and novel contributions.

Taken together, the findings indicate that a multi-component inhalation aromatherapy protocol may improve sleep quality, sleep architecture, and cognitive outcomes in older adults. Aromatherapy may be considered a relatively safe and practical complementary nursing intervention in residential care settings; however, replication in larger, more diverse samples is warranted to confirm generalisability and clarify mechanisms and long-term effects. Despite these findings, the literature highlights methodological challenges in aromatherapy research, particularly regarding blinding and placebo control, given the perceptible nature of scent (56).In studies of aromatherapy administered via inhalation, it is methodologically challenging to ensure appropriate blinding due to the perceptible nature of the scent.

Although no adverse events were observed in this study, the safety and feasibility of aromatherapy in populations with sensitive conditions or chronic illnesses should be interpreted with caution. No unexpected or unanticipated effects were observed during the intervention period. Participants were systematically monitored for potential adverse responses, including respiratory discomfort, headache, dizziness, or irritation; however, none were reported.

Due to the study design, individuals with severe respiratory disease and those with known allergies to essential oils were excluded; therefore, the generalisability of the findings to more clinically vulnerable populations with multiple comorbidities is limited.

Essential oils contain biologically active compounds and may affect neurophysiological processes and the autonomic nervous system (57). However, adverse effects associated with their use, including allergic reactions, skin irritation, phototoxicity, and, in rare cases, systemic

toxicity, have been reported in the literature. In addition, certain essential oils may pose potential risks and lead to drug interactions in specific patient groups, such as pregnant women, individuals with epilepsy, or those receiving multiple medications (57).

The present findings suggest that inhalation aromatherapy may be considered a practical complementary approach to support sleep quality and cognitive functioning in older adults, particularly in settings where pharmacological treatments are limited by adverse effects such as falls, residual daytime sedation, and drug interactions (60). Given its non-invasive nature, relatively low cost, and ease of implementation, aromatherapy may be integrated into routine nursing care in residential and home care settings. The use of circadian-aligned daytime and nighttime blends may provide an additional advantage in symptom management. Although psychosocial outcomes were not directly assessed, improvements in sleep quality and daytime alertness may indirectly support daily functioning and social engagement. At a broader level, scalable supportive interventions that enhance sleep and cognitive functioning in later life may contribute to healthy ageing and reduce the burden on healthcare and social care systems.

## 5. Clinical implications

The present findings suggest that inhalation aromatherapy may be considered as a practical complementary approach to support sleep quality and cognitive functioning in older adults, particularly in settings where pharmacological sleep treatments may be limited by adverse effects such as falls, residual daytime sedation, and polypharmacy-related interactions. Given its non-invasive administration, low cost, and feasibility, aromatherapy could be integrated into routine nursing care in residential care facilities and home-care services.

The use of distinct daytime and nighttime blends may also represent a circadian-aligned approach to symptom management. Although psychosocial outcomes were not formally measured, improvements in sleep and daytime alertness may contribute to better daytime

functioning and social engagement. At a broader level, scalable supportive interventions that enhance sleep and cognitive functioning in later life may contribute to healthy ageing and may reduce the burden on health and social care systems**.**

## 6. Limitations

Several limitations should be considered when interpreting the findings of this study. First, the sample was drawn from a single residential care facility, which may limit the generalisability of the results to community-dwelling older adults or populations with different sociocultural and clinical characteristics. In addition, participation was voluntary, which may introduce selection bias.

Second, the study population consisted of older adults, a group often characterised by multimorbidity, physiological vulnerability, and polypharmacy. Although individuals with severe respiratory disease and known allergies to essential oils were excluded, the presence of chronic conditions may influence both responsiveness to the intervention and susceptibility to potential adverse effects. Therefore, the safety and applicability of the findings in more clinically complex older populations should be interpreted with caution.

Third, objective sleep outcomes were obtained using wearable devices based on accelerometer and photoplethysmography algorithms. Although these devices are practical and suitable for continuous monitoring, they may have limited accuracy compared with gold-standard polysomnography, particularly for detailed sleep-stage classification.

Fourth, the intervention involved a multi-component essential oil protocol; therefore, the independent effects of individual oils could not be determined. In addition, individual differences such as odour sensitivity and prior exposure to essential oils were not assessed and may have influenced the results.

Fifth, due to the perceptible nature of aromatherapy, blinding of participants and the implementing researcher was not feasible. This may have introduced placebo effects or expectation bias. Although objective sleep measures were used to reduce reliance on subjective reporting, the potential influence of such bias cannot be completely excluded. In addition, no active placebo or attention-control procedure was applied to the control group, which may further contribute to expectation bias. Furthermore, although efforts were made to minimise cross-contamination by accommodating participants in separate residential blocks, interactions within the same institutional setting could not be fully controlled.

Finally, cognitive outcomes were assessed using a single screening instrument (BOMCT), and a post-intervention follow-up period was not included. Therefore, the long-term sustainability of the observed effects and the clinical significance of cognitive improvements should be interpreted with caution. Future studies should incorporate longer follow-up periods and more comprehensive neuropsychological assessments in diverse and clinically complex populations.

**7. Contribution to the Literature**

This study adds to the growing evidence on inhalation aromatherapy by evaluating both sleep-related outcomes and cognitive performance within a single randomised controlled design in older adults. Unlike many previous studies focusing on either subjective sleep quality or cognition alone, the present trial integrated validated subjective measures (PSQI, ESS, BOMCT) with objective wearable-derived sleep parameters, enabling a more comprehensive assessment of intervention effects.

An additional contribution is the use of distinct day- and night-specific essential oil blends, designed to align with circadian patterns. The concurrent improvements in REM and deep sleep (N3) durations, alongside enhanced cognitive performance, suggest that aromatherapy may influence neurocognitive functioning through sleep-related pathways. Overall, these findings

support considering aromatherapy not only as a relaxation approach but also as a potentially structured complementary intervention targeting sleep architecture and cognitive outcomes. Future studies should replicate these findings in broader populations and explore underlying mechanisms using longer follow-up designs and advanced assessment approaches.

## 9. Conclusion

In this randomised controlled trial, a multi-component inhalation aromatherapy protocol was associated with significant improvements in sleep outcomes and cognitive performance among older adults residing in a residential care facility. Compared with controls, the intervention improved subjective sleep quality (PSQI) and daytime sleepiness (ESS), and enhanced objective sleep architecture, including increased total sleep time, REM duration, and deep sleep (N3) duration, alongside reduced sleep onset latency and nocturnal awakenings. Cognitive performance also improved significantly, as indicated by BOMCT scores. No adverse events were observed during the intervention period. These findings suggest that inhalation aromatherapy may be a feasible complementary approach to support sleep and cognition in older adults; further studies with larger samples and longer follow-up are warranted.

## 10. Clinical Contributions and Implementation Recommendations

Given the risks of pharmacological sleep treatments in later life, inhalation aromatherapy may be a practical complementary nursing intervention, given its low cost, non-invasive delivery, and ease of implementation. A protocol using daytime and night-time blends may support circadian-aligned symptom management. Implementation in routine care would require basic staff training, attention to individual factors (e.g., allergy history and odour sensitivity), and standardised monitoring to ensure safety and adherence.

## DECLARATIONS

### Ethics approval and consent to participate

This study was approved by an institutional clinical research ethics committee (Approval No: E-95961207-604.01.01-3755; Date: 15 June 2023) and authorised by the national competent health authority. Institutional permission was obtained from the management of the residential care facility where the study was conducted. The overall study was carried out between January 2024 and March 2025, and written informed consent was obtained from all participants before enrolment. Participant confidentiality was maintained throughout the study.

**Consent for publication**

Not applicable.

**Data Availability Statement**

All data used in this study are available from the corresponding author upon reasonable scientific request. Shared data will be anonymised and stripped of all personal identifiers in accordance with confidentiality principles and institutional regulations.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors' contributions**

- **Belçim Ede Sarıkaya:** Data curation, Investigation, Visualization, Writing – original draft, Writing – review & editing

- **Sebahat Ateş:** Conceptualization, Formal analysis, Methodology, Validation, Supervision, Writing – review & editing
- **Tuğba Kaman:** Methodology, Resources, Investigation
- **Ayşe Arzu Sayın Şakul:** Resources, Methodology

**Trial registration**

This randomised controlled trial was registered in the ClinicalTrials.gov database **(Identifier: NCT06208800).** The registration process was completed in accordance with international ethical standards.

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## TABLES

**Table 1.** Findings Related to Socio-Demographic and Clinical Characteristics of the Participants in the Intervention and Control Groups

| **Variable** | **Intervention (n=30), n (%)** | **Control (n=30), n (%)** | **$\chi^2$; p** |
|---|---|---|---|
| **Age group** | | | |
| 65–74 years | 17 (56.7) | 15 (50.0) | Fisher's exact test = 0.796 p = 0.796 |
| 75–84 years | 13 (43.3) | 15 (50.0) | |
| **Marital status** | | | |
| Married / Widowed | 28 (93.3) | 30 (100.0) | Fisher's exact test = 0.492, p = 0.472 |
| Single / Divorced / Never married | 2 (6.7) | 0 (0.0) | |
| **Education level** | | | |
| Illiterate | 9 (30.0) | 7 (23.3) | $\chi^2$=3.793; p=0.285 |
| Primary school | 16 (53.3) | 19 (63.3) | |
| High school | 5 (16.7) | 2 (6.7) | |
| University | 0 (0.0) | 2 (6.7) | |
| **Leisure time activities** | | | |

| | | | |
|---|---|---|---|
| Physical activity + hobby + social activity + worship | 10 (33.3) | 7 (23.3) | Fisher's exact test = 0.567 p=0.567 |
| Hobby (watching TV) + social activity | 20 (66.7) | 23 (76.7) | |
| **Chronic disease** | | | |
| Yes | 26 (86.7) | 28 (93.3) | Fisher's exact test=0.671 p=0.667 |
| No | 4 (13.3) | 2 (6.7) | |
| **Sleep problems** | | | |
| Yes | 24 (80.0) | 25 (83.3) | Fisher's exact test = 1.000; p=1.000 |
| No | 6 (20.0) | 5 (16.7) | |
| **Sleep problem duration** | | | |
| 1–6 months | 23 (76.7) | 20 (66.7) | Fisher's exact test = 0.567; p=0.567 |
| ≥6 months | 7 (23.3) | 10 (33.3) | |
| **Previous use of sleep medication** | | | |
| Yes | 3 (10.0) | 6 (20.0) | |
| No | 27 (90.0) | 24 (80.0) | |

| | | | |
|---|---|---|---|
| | | | Fisher's exact test=0.472; p=0.470 |
| **Difficulty falling asleep** | | | |
| Yes | 21 (70.0) | 19 (63.3) | Fisher's exact test=0.785; p=0.784 |
| No | 9 (30.0) | 11 (36.7) | |
| **Ability to sleep comfortably at night** | | | |
| Yes | 7 (23.3) | 9 (30.0) | Fisher's exact test=0.771; p=0.770 |
| No | 23 (76.7) | 21 (70.0) | |
| **Frequent awakening at night** | | | |
| Yes | 19 (63.3) | 22 (73.3) | Fisher's exact test=0.580; p=0.579 |
| No | 11 (36.7) | 8 (26.7) | |
| **Reason for waking up at night** | | | |
| Pain | 0 (0.0) | 2 (6.7) | $\chi^2$=2.85; p=0.416 |
| Stress | 6 (20.0) | 7 (23.3) | |
| Toilet requirement | 11 (36.7) | 12 (40.0) | |
| Environmental factors | 13 (43.3) | 9 (30.0) | |

| | | | |
|---|---|---|---|
| **Regular medication use** | | | |
| Yes | 28 (93.3) | 28 (93.3) | Fisher's exact test=1.000; p=1.000 |
| No | 2 (6.7) | 2 (6.7) | |
| **Pain ≥5/10** | | | |
| Yes | 0 (0.0) | 0 (0.0) | Fisher's exact test=1.000; p=1.000 |
| No | 30 (100.0) | 30 (100.0) | |

Values are n (%).
*Fisher's exact test. †Chi-square test.

**Table 2.** Mean Values and Temporal Changes in Sleep Characteristics of the Intervention and Control Groups with Statistical Comparisons (Day 0, Day 15, and Day 30)

| Outcome | Day | Intervention (n=30) Mean ± SD | Control (n=30) Mean ± SD | Welch's t | p value† | Cohen's d‡ |
|---|---|---|---|---|---|---|
| **Time to fall asleep (min)** | 0 | 63.93 ± 8.82 | 61.53 ± 10.66 | 0.950 | 0.346 | 0.245 |
| | 15 | 46.57 ± 6.09 | 62.47 ± 11.01 | -6.922 | <0.001 | −1.787 |
| | 30 | 38.87 ± 6.13 | 63.83 ± 9.82 | -11.811 | <0.001 | −3.050 |
| Test value | | 54.200 | 1.061 | | | |
| p value | | 0.000 | 0.588 | | | |
| Post-hoc | | a>b>c | – | | | |
| Post-hoc power | | 0.998 | 0.092 | | | |
| Eta squared | | 0.183 | – | | | |
| **Total sleep time (min)** | 0 | 322.07 ± 15.28 | 334.57 ± 20.12 | -2.710 | 0.009 | −0.700 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 356.93 ± 14.40 | 343.50 ± 21.59 | 2.835 | 0.007 | 0.732 |
| | 30 | 374.57 ± 11.37 | 338.03 ± 16.04 | 10.177 | <0.001 | 2.628 |
| Test value | | 47.267 | 1.865 | | | |
| p value | | 0.000 | 0.394 | | | |
| Post-hoc | | a<b<c | – | | | |
| Post-hoc power | | 0.995 | 0.127 | | | |
| Eta squared | | 0.179 | – | | | |
| **REM sleep duration (min)** | 0 | 42.57 ± 8.72 | 41.50 ± 7.42 | 0.510 | 0.612 | 0.132 |
| | 15 | 59.03 ± 9.61 | 40.43 ± 7.28 | 8.451 | <0.001 | 2.182 |
| | 30 | 71.73 ± 9.91 | 44.07 ± 9.63 | 10.964 | <0.001 | 2.831 |
| Test value | | 58.067 | 1.155 | | | |
| p value | | 0.000 | 0.561 | | | |
| Post-hoc | | a<b<c | – | | | |
| Post-hoc power | | 0.999 | 0.096 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Eta squared | | 0.273 | - | | | |
| **Light sleep (N1–N2) duration (min)** | 0 | 262.53 ± 15.35 | 263.13 ± 14.93 | -0.153 | 0.879 | −0.040 |
| | 15 | 268.27 ± 12.51 | 272.93 ± 17.65 | -1.182 | 0.243 | −0.305 |
| | 30 | 260.73 ± 12.52 | 263.77 ± 13.02 | -0.920 | 0.362 | −0.237 |
| Test value | | 28.466 | 3.509 | | | |
| p value | | 0.000 | 0.173 | | | |
| Post-hoc | | a=c<b | – | | | |
| Post-hoc power | | 0.932 | 0.202 | | | |
| Eta squared | | 0.212 | – | | | |
| **Deep sleep (N3) duration (min)** | 0 | 16.97 ± 6.07 | 29.93 ± 14.80 | -4.440 | <0.001 | −1.146 |
| | 15 | 29.63 ± 6.57 | 30.13 ± 9.59 | -0.236 | 0.815 | −0.061 |
| | 30 | 42.10 ± 14.50 | 30.20 ± 9.16 | 3.800 | <0.001 | 0.981 |
| Test value | | 44.866 | 0.622 | | | |
| p value | | 0.000 | 0.733 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Post-hoc | | a<b<c | – | | | |
| Post-hoc power | | 0.992 | 0.074 | | | |
| Eta squared | | 0.218 | – | | | |
| **Number of night-time awakenings** | 0 | 2.23 ± 0.50 | 2.37 ± 0.61 | -0.918 | 0.362 | −0.237 |
| | 15 | 1.70 ± 0.47 | 2.33 ± 0.55 | -4.829 | <0.001 | −1.247 |
| | 30 | 1.37 ± 0.49 | 2.43 ± 0.50 | -8.310 | <0.001 | −2.146 |
| Test value | | 30.100 | 1.750 | | | |
| p value | | 0.000 | 0.417 | | | |
| Post-hoc | | a>b>c | – | | | |
| Post-hoc power | | 0.944 | 0.122 | | | |
| Eta squared | | 0.150 | – | | | |
| **Daytime sleepiness duration (min)** | 0 | 64.30 ± 4.28 | 64.27 ± 7.66 | 0.021 | 0.983 | 0.005 |
| | 15 | 51.60 ± 7.95 | 67.90 ± 10.51 | -6.775 | <0.001 | −1.749 |
| | 30 | 47.43 ± 9.07 | 71.13 ± 14.66 | -7.529 | <0.001 | −1.944 |

| | | |
|---|---|---|
| Test value | 50.235 | 3.681 |
| p value | 0.000 | 0.159 |
| Post-hoc | a>b>c | – |
| Post-hoc power | 0.997 | 0.210 |
| Eta squared | 0.133 | – |

Values are mean ± SD.
†Between-group comparisons were performed using Welch's t-test. p values <0.001 are reported as <0.001.
‡Cohen's d represents the between-group effect size (intervention vs control) at each time point; negative values indicate a reduction in the intervention group relative to control

**Table 3.** Comparison of Temporal Changes in Epworth Sleepiness Scale (ESS) Scores Between the Intervention and Control Groups at Day 0 and Day 30

| **Time point** | **Intervention (n=30) Mean ± SD** | **Control (n=30) Mean ± SD** | **t** | **p value†** | **Cohen's d‡** |
|---|---|---|---|---|---|
| Day 0 | 11.80 ± 3.01 | 12.57 ± 2.50 | -1.073 | 0.288 | −0.277 |
| Day 30 | 7.53 ± 2.30 | 13.20 ± 2.47 | -9.197 | <0.001 | −2.375 |
| **Wilcoxon Test Value** | 465 | 25 | | | |
| **p value** | 0.000 | 0.007 | | | |
| **Effect Size** | 0.876 | 0.519 | | | |

Values are mean ± SD.
†Between-group comparisons were performed using Welch's t-test.

‡Cohen's d represents the between-group effect size (intervention vs control) at each time point; negative values indicate lower scores in the intervention group.

**Table 4.** Comparison of Pittsburgh Sleep Quality Index (PSQI) Total Scores Between the Intervention and Control Groups at Day 0 and Day 30

| Time point | Intervention (n=30) Mean ± SD | Control (n=30) Mean ± SD | t | p value† | Cohen's d‡ |
|---|---|---|---|---|---|
| Day 0 | 13.97 ± 1.38 | 13.93 ± 1.44 | 0.092 | 0.927 | 0.024 |
| Day 30 | 7.73 ± 1.86 | 13.83 ± 1.26 | -14.889 | <0.001 | −3.844 |
| **Wilcoxon Test Val** | 465 | 135 | | | |
| **p value** | 0.000 | 0.787 | | | |
| **Effect Size** | 0.876 | 0.002 | | | |

Values are mean ± SD.
†Between-group comparisons were performed using Welch's t-test.
‡Cohen's d represents the between-group effect size (intervention vs control) at each time point; negative values indicate lower scores in the intervention group.

**Table 5.** Comparison of Blessed Orientation-Memory-Concentration Test (BOMCT) Scores Between the Intervention and Control Groups at Day 0 and Day 30

| Time point | Intervention (n=30) Mean ± SD | Control (n=30) Mean ± SD | t | p value† | Cohen's d‡ |
|---|---|---|---|---|---|
| Day 0 | 12.47 ± 5.07 | 13.37 ± 5.07 | -0.688 | 0.494 | −0.178 |
| Day 30 | 6.80 ± 3.46 | 14.47 ± 5.82 | -6.205 | <0.001 | −1.602 |
| **Wilcoxon Test Val** | 351 | 6.5 | | | |
| **p value** | 0.000 | 0.018* | | | |
| **Effect Size** | 0.857 | 0.404 | | | |

Values are mean ± SD.
†Between-group comparisons were performed using Welch's t-test.
‡Cohen's d represents the between-group effect size (intervention vs control) at each time point; negative values indicate lower scores in the intervention group.

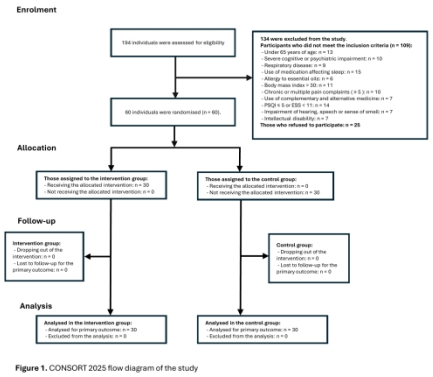


**Figure 1.** CONSORT 2025 flow diagram of the study

Figure1.Consort 2025 Flow Chart of the Research

338x190mm (300 x 300 DPI)