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Review Article

A Systematic Review of the Effect of Inhaled Essential Oils on Sleep

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Abstract

Objective: Sleep disturbances are recognized as an important health and public health problem that affects physical, mental, and emotional health and well-being. Inhalation of essential oils may be a safe alternative to pharmaceutical interventions for mild to moderate sleep disturbances. Quantitative human studies on the effect of inhaled essential oils on sleep that were published between 1990 to 2012 were reviewed.
Methods: Ovid Medline, PsychINFO, CINAHL, Science Direct, and PubMed databases were searched to extract articles that evaluated the effect of inhaled essential oils on sleep in humans.
***Results*:** The search yielded 15 quantitative studies, including 11 randomized controlled trials that examined hypnotic effects of inhalation of essential oils. A majority of the study findings suggested a positive effect of essential oils on sleep. Lavender was the most frequently studied essential oil. No adverse events were reported.
***Conclusions*:** Inhalation of essential oils may be considered for people with mild sleep disturbances. Further studies with larger samples and stronger methods and endpoints are needed to build on the findings.

Introduction

Difficulties with initiating or maintaining sleep are increasingly recognized as a public health problem. Sleep epidemiology is a growing field that includes the association of sleep disturbances with accidents, human errors, and health, as well as the incidence and prevalence of sleep problems. Health effects of sleep problems are both immediate and long term. The immediate effect of sleep disturbances relate to well-being, daytime sleepiness, fatigue, and impaired performance, with its resulting impact on safety. Long-term health effects include hypertension, inflammation, obesity, and glucose intolerance. These long-term effects can lead to chronic diseases and premature death.[1] Additionally, a strong relationship has been found between sleep disturbances and cognitive functioning, regulation of emotions, social problems, and substance abuse.[2] A recent USA Sleep Poll found that 64% of respondents reported frequent sleep problems, although only 15% received an official diagnosis.[3] Mild sleep disturbances are frequently self-treated, with varying degrees of success, through use of over-the-counter medications (e.g., antihistamines), herbs (e.g., valerian, chamomile, and St. John's wort), alcohol, or behavioral and cognitive techniques that modify the precipitating and contributory factors related to sleep disturbances.[4] More severe sleep disturbances are typically treated with prescription hypnotic medications that are intended for short-term use but are frequently prescribed long term. These hypnotics have many adverse effects, further increasing health care costs and overall morbidity.[5]

Sleep disturbances occur when the normal processes of disengaging from wakefulness and engaging in sleep do not happen. A variety of genetic, environmental, sleep habit, and other psychobiological factors can precipitate problems in the dearousal, homeostatic, and circadian processes that normally occur to allow for good sleep.[6] If the pattern of sleep disturbances continues over time, these factors can build on themselves and create a vicious cycle of ongoing sleep problems.[2]

The inhalation of essential oils with hypnotic properties may provide a safe and effective therapy for some sleep disturbances. Mechanisms of action for the sleep-inducing properties of essential oils are not totally understood but are believed to be multifaceted; properties include biochemical, psychological, and energetic.[7] Several biochemical constituents of essential oils can produce hypnotic, sedative, or antianxiety effects, including acids and esters, coumarins, and monoterpenols. These can act on nerve cell function by antagonizing specified neuronal receptors or binding to other receptors.[8] Many essential oils contain chemical constituents that would suggest a sedative (irritability and excitement decreasing as a precursor to sleep) or hypnotic (sleep-inducing) effect, but few rigorous human studies have explored the sedative or hypnotic effect of essential oils. Several animal studies have demonstrated a sedative effect for certain essential oils, including bergamot,[9] sweet

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orange,[10] lavender,[11–14] valerian and lemon,[15] rose,[16] cedar,[17] and others.[18] The Natural Standard, an international research collaboration that synthesizes data on complementary and alternative therapy studies, reported aromatherapy as having ''unclear or conflicting scientific evidence'' for sleep disorders or sleep disturbances because of lack of scientific research.[19,20] Several systematic reviews have addressed the use of essential oils or sedative effect peripherally,[21–33] and one published review specifically concerned lavender and sleep.[34] However, no previously published systematic and comprehensive reviews of studies have focused on essential oils as a broad category and their effect on sleep in humans. Thus, this review is an important step in informing further research on the use of essential oils to address the growing public health issue of sleep disturbances.

Methods

Literature search

Research articles describing the key area of interest were sought from a range of journals and health disciplines. The strategy for identifying key words for the search involved combinations of the two main variables of interest: (1) sleep disturbances (''sleep initiation and maintenance disorders,'' ''sleep disorder, symptoms,'' ''sleep disturbances,'' ''sleep'') or related therapeutic properties of essential oils (''hypnotics and sedatives,'' [anti]-''anxiety'') AND (2) aromatherapy (''aromatherapy,'' ''oils, volatile,'' ''plants, medicinal,'' ''essential oils,'' ''olfactory stimulation''). ''Relaxation'' was identified as an additional therapeutic property of essential oils related to sleep and was added to the search strategy. Electronic literature searches were carried out in December 2012 using Ovid Medline, PubMed, CINAHL, PsychINFO, Science Direct, Natural Standard, and the Cochrane Library.

The following search inclusion limits and criteria were used: human studies, full paper reported in English, study of inhalation of essential oils rather than topical use or ingestion, study participants without dementia and agitation (those patients are the focus of a separate area of research), measurable outcomes for sleep (subjective and/or objective measures), and quantitative design.

Titles and abstracts were reviewed to identify studies that did not meet the specified criteria. This assessment was confirmed by full-text review prior to exclusion (Fig. 1). The 15 remaining studies identified for systematic review were evaluated by using a structured abstracting form with 10 topics: (1) reference, (2) aim(s), (3) variables, (4) participants and setting, (5) design, (6) measures and key procedures, (7) interventions, (8) analysis and results, (9) discussion, and (10) limitations/critique. In addition, randomized controlled trials (RCTs) were reviewed using the Consolidated Standards of Reporting Trials (CONSORT). This tool provides a minimum set of recommendations for reporting RCTs.[35] Where plant genus and species were specified in the articles, the Latin botanical names are noted in Table 1; where not specified, Latin names could not be assumed.

Data synthesis

Because of the heterogeneity of the study populations, measurement tools, and interventions, a formal meta-analysis could not be conducted. However, a review and synthesizing summary of the study methods and results were completed, along with projected applications of these studies to research, practice, and theory.

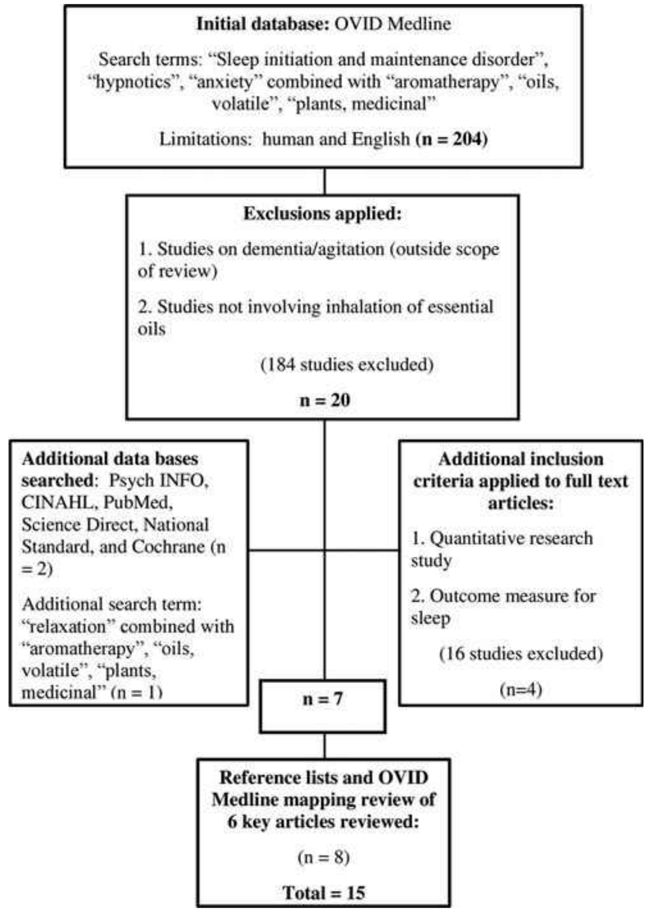

FIG. 1. Search strategy flowchart.

Results

Study description

A multistage search strategy was applied (Fig. 1). Application of the first four inclusion criteria identified 20 studies for review through Ovid Medline. Four additional databases—PsychINFO, CINAHL, Science Direct, and PubMed—were searched to identify additional studies on the sedative/hypnotic effect of inhaled essential oils. The term ''relaxation'' (release of tension) was also searched for in the databases because it is a precursor to sleep and may be a therapeutic effect of essential oils. Two recent studies meeting the criteria were found in CINAHL, and an additional study was found by using ''relaxation'' combined with aromatherapy terms. No further references were identified from review of the Natural Standard and the Cochrane databases. In total, 23 references were identified, abstracted to a reference database, and reviewed in full text to determine whether the initial exclusion/inclusion criteria were met. At this point, the two additional inclusion criteria of quantitative design and hypnotic or sleep outcome were applied. After a full-text screening, six papers met all six

Table 1. Summary of Studies on Essential Oils (Aromatherapy) and Sleep

Author/year country/research topic	Variables: Dependent variable	Variables: Independent variable/ route/dose/frequency	Variables: Control	Sample	Design/setting	Measures	Results/main conclusion	Limitations[a]
Goes et al. (2012), Brazil Effects of orange aroma in healthy volunteers subjected to anxiety task	State-anxiety, subjective tension, tranquilization, sedation heart rate, electromyogram, like/dislike	SO (*Citrus sinensis*), 2.5, 5, or 10 drops on mask for 5 min	TT (*Melaleuca alternifolia*), 2.5 drops, and H_2O, 2.5 drops	40 male grad students, age 18–30 y Excluded: OP, asthma, trait anxiety >48, psychiatric disorders, long-term drug use	RCT/5 groups Setting: Laboratory	Psychological: STAI – state anxiety, Visual Analog Mood Scale for tension, tranquilization, sedation Physiologic: heart rate, gastrocnemius electromyogram	SO2.5 and SO10 demonstrated lack of significant increase in state-anxiety[b] and lack of significant decrease in tranquility,[b] with SO10 seeming to be better at preventing anxiety. (Intermediate dose failed to produce effect [observed in other studies]). Observed anxiolytic effects were not followed by sedative/hypnotic effects.	Demographic variables other than age/sex not reported (all men) Sleep/sedation was secondary outcome Recruitment methods and randomization allocation not documented Limonene, at 54.48%, lower than standard for SO. (Botanical name and GC/MS analysis reported)
Hirokawa et al. (2012), Japan Effect of lavender on quality of sleep in healthy students	Sleepiness on awakening, difficulty falling asleep and maintaining sleep, dream quality, tiredness, duration of sleep	Lavender 2.5-g bottle with 5×5 oil-soaked gauze or H_2O/open bottle before bed and close when awake for 5 nights	Water (no aroma)	15 volunteer undergrad students (5 men and 10 women) Excluded: sleep abnormalities/ medications for sleep	RCT, single-blinded Setting: home	Oguri-Shirakwa-Azumi Sleep (standard tool) + records of bedtime and wake-up time (similar to PSQI)	Treatment group scored higher for improved sleepiness at awakening at post-treatment compared with pretreatment.[b] Daily variations in sleep during treatment not found. No significant effect of sex found.	Demographics other than age/sex not reported Recruitment and randomization methods not documented Adherence with instructions not verified Sleep hygiene issues not controlled for Only one measurement tool Blinded but control odorless
Chien et al. (2011), Taiwan Effect of lavender on midlife women with insomnia	Sleep quality and autonomic nervous system effect (HRV)	25 mL lavender in 50 mL H_2O via diffuser/10–15 cm from diffuser for 20 min, 2 times/wk for 12 wk Good sleep hygiene instruction	Sleep hygiene education	67 women (age 45–55 y) Chinese PSQI > 5; Treatment: $n = 34$; control: $n = 33$ Excluded: OP, hormone replacement therapy	RCT Setting: Laboratory	Chinese version PSQI HRV	Lavender may have persistent short-term effect on HRV with an increase in vagal tonic and a preserved sympathetic tone.[b] Treatment group improved sleep up to 1 week after treatment.[b]	Demographics other than age/sex not reported HRV differences not specific to sleep Participants were peri- and postmenopausal No placebo No assessment of sleep hygiene practices (Study flow chart included) Follow up included]
Stringer et al (2011), United Kingdom Aroma sticks for cancer care	Effect on sleep disturbance, nausea, anxiety, and perception of use of aroma sticks	Lavender blend, valerian blend 1 of 2 self- selected blends inhaled via aroma stick for 7 nights	No control	31 patients with cancer self-selected to try aroma stick for sleep issues	Clinical evaluative study Setting: inpatient	Subjective questionnaires: baseline and 1 week after intervention assessment (assessed for sleep, nausea and anxiety)	55% of sample experienced better sleep, while 48% experienced relaxation. In general, 98% of patients who used aroma stick every 2–3 h for any of the conditions identified found it helpful. (Overall, 30% used them aroma stick every 2–3 h.)	Percentage of oils in blends not reported Self-selected group No report of tool tested for validity and reliability Dose/frequency not specified No randomization

(*continued*)

TABLE 1. (CONTINUED)

Author/year country/research topic	Variables: Dependent variable	Variables: Independent variable/ route/dose/frequency	Variables: Control	Sample	Design/setting	Measures	Results/main conclusion	Limitations[a]
Arzi et al. (2010), Israel Effect of transient odorants given during sleep on wake and respiratory response	Biophysical changes that occur via sleep as measured by PSG; measurements of nasal and oral respirations, intensity and pleasantness	Mildly trigeminal odorants: Lavender—pleasant; vetiver—unpleasant Pure olfactory odorants: vanillin—pleasant; ammonium sulfide—unpleasant Via olfactometer transiently during stage 2 sleep for 1 night	No odor between odor administration initially: mildly trigeminal/ pleasant; pure olfactory/ pleasant; pure olfactory/ unpleasant Added: Mildly trigeminal/ unpleasant	37 healthy adults (age 23–36 y) completed Excluded: abnormal sleep or history of nasal problems 13: lavender; 12: vanillin; 5: ammonium Sulfide; 7: vetiver (added later)	RCT single-blinded Setting: Laboratory	PSG Pneumotachometer for assessing nasal and oral respirationVAS: intensity and pleasantness	Odors did not arouse or waken. Odorants may influence by reducing arousal and wakening.[b] All odorants in study modified breathing during sleep (decreased inhalation and increased exhalation for several breaths after odor onset regardless of pleasant/unpleasant rating.[b]) Lavender trended toward increased arousal in stage 2 and a decrease in wakenings. No significant differences in intensities between odors.	Demographics other than sex/age not reported Recruitment method not reported
Moeini et al. (2010), Iran Effect of aromatherapy on sleep quality in CCU patients with ischemic heart disease	Sleep quality	Lavender oil, 2 drops, placed on cotton and placed in small box near pillow (within 20 cm) for 3 nights	No intervention/ routine care	64 CCU patients (23 in each group) Maximum age 65 y, ischemic heart disease Excluded: risk of heart failure or shock, use of complementary methods in prior week, use of sleep medications (except 10 mg oxazepam), addictions, asthma, plant allergies, smell disorders	RCT ingle-blind Setting: CCU	St. Hospital Sleep Questionnaire Standard 11-item sleep quality survey for inpatient use	Mean score of sleep quality before and after intervention period in control group was not significantly different. Mean score of sleep quality before and after aromatherapy in treatment group was significantly different.[b] Mean score of sleep quality in treatment group after aromatherapy was significantly different than in the control group.[b]	No quantitative measures Convenience sample Sample size larger but no estimation of power
Goel et al. (2006), USA Effects of PPO on PSG sleep, alertness, and mood when given before bedtime	Sleep changes as measured on PSG, alertness, mood, perception of pleasantness, intensity, stimulating	PPO vial placed at chin level while participants wore odorless vinyl gloves Baseline for 1 night Treatment for 2 nights 4 min for each of first 10 min between 23:10 and 23:40 for 2 nights	Distilled H_2O	21 healthy persons age 18–26 y (10 men and 11 women [half in luteal phase and half in follicular phase]) Excluded: extreme M/E, breathing issues, OP, smokers, use of oral contraceptive	RCT/ crossover design single-blind Setting: Laboratory	Sleep logs: 1 wk before treatment Likert scales: stimulus, like, intensity, elation, 23:14 and 23:44 PSG: 21:30–8:00 Stanford Sleepiness Scale: 23:55 & 8:15 POMS : 23:00, 23:14, 23:44	Likert: PPO more pleasant than H_2O.[b] Women found intensity and depressing/elating ratings greater than did men.[b] Individual differences in perception of PPO are associated with sleep changes. Higher-intensity ratings for PPO showed increase in total sleep time and sleep period time and showed more SWS in the treatment session. Higher stimulating ratings for PPO showed more NREM and less REM. Higher sedative ratings showed delayed SWS onset. Sex-specific effects: Women had increased NREM, men had increased morning alertness. All had reduced fatigue and depression immediately after treatment. PPO did not disrupt sleep as hypothesized.	Demographics other than sex/age not reported Recruitment method not reported Blinded but control no odor Dose not exact

(continued)

Table 1. (Continued)

Author/year country/research topic	Variables: Dependent variable	Independent variable/ route/dose/frequency	Control	Sample	Design/setting	Measures	Results/main conclusion	Limitations[a]
Goel et al. (2005), USA Effects of olfactory stimulus on sleep and morning alertness and on sex differences	Nighttime sleep, morning alertness, sex differences for effect	Lavender oil (with unidentified constituents added) Vial at chest level; intermittent exposure between 23:10 and 23:40 for 1 night	Distilled H_2O	31 healthy persons age 18–30 y 16 men (2 smokers) and 15 women (3 taking oral contraceptives, 6 in luteal phase, 6 in follicular phase, 1 smoker) Excluded: extreme M/E, OP, breathing issues, CNS medications	RCT Single-blind Setting: Laboratory	PSG: 24:00 8:00 Stanford Sleepiness Scale: 23:50 and 8:00 POMS: 23:00, 23:12, 23:42, and 8:00	Across entire night, lavender increased deep/SWS percentage sleep period time (first half of night) compared with control, along with higher morning alertness.[b] Lavender also produced sex differences in effect for stage 2 (decrease in men) and REM (increase in men) sleep and wake after sleep onset (decreased in women, increased in men)[b]	Demographics other than sex/age not reported Recruitment method not reported Blinded but control no odor Dose not exact Lavender reported to have constituents added
Lewith et al. (2005), United Kingdom Pilot study: efficacy of lavender on insomnia and effectiveness of method	PSG sleep, self-rated sleepiness mood	Lavender (*Lavandula angustifolia)* vaporized continuously during night via Aromastream device. Drops added each night for 1 wk	Sweet almond oil in identical bottle not labeled	10 patients with insomnia (PSQI > 5; otherwise healthy); 5 men and 5 women Excluded: pregnant, medication, sensitivity to aromatherapy, use of aromatherapy	RCT single-blind/ crossover study Setting: home	A/B: baseline C: treatment or control D: washout E: control or treatment BNQ: A/B PSQI: beginning and at end of each week Holistic Complementary and Alternative Medicine Questionnaire given once	No evidence of carryover effect for crossover design. Findings almost reached statistical significance. Duration of treatment and dose of lavender appear to have had a clinically significant effect in most volunteers (almond oil: little change), but Aromastream is noisy and was not used consistently. Younger participants, women, and those with PSQI scores > 10–12 appeared more responsive to lavender. Responses on BNQ showed less confidence about lavender before treatment (both equally logical) and more confidence after treatment HCAMQ had no significant predictive value.	Demographics other than sex/age not reported No control of environment or adherence. Aromastream device was noisy and some participants turned it off No report of Aromastream in relation to validity and reliability of dose (Study flow diagram included/botanical name reported)
Raudenbush et al. (2003), USA Effect of odorant on sleep, mood, cognitive functioning, and alertness	Sleep patterns as identified by actigraphy mood, cognitive functioning, alertness	Lavender Jasmine, 15 ml of each oil aerated into tubing from O_2 concentrator (tubing not visible) for 1 night under each condition	No odor	20 college students (10 men and 10 women) Excluded: drug/ medication use, OP, or sleep abnormalities 40 adults (10 men and 30 women) Middle class; 43% white; 15% African American; 42% Hispanic	RCT crossover design Setting: Laboratory	Mini-Mitter Actiwatch Sleep Monitor for sleep efficiency, minutes spent moving, movement fragmentation index, sleep time and latency; POMS; Digital-Symbol Substitution Test–cognitive	In comparison to control, jasmine led to greater sleep efficiency and reduced sleep movement, with no difference in total amount of sleep time.[b] Lavender led to elated mood but no other effects were noted.[b]	Demographics other than sex/age not reported Blinded but control no odor No follow-up for long-term effect Actigraphy not reported as to validity and reliability

(*continued*)

TABLE 1. (CONTINUED)

Author/year country/research topic	*Variables*			*Sample*	*Design/setting*	*Measures*	*Results/main conclusion*	*Limitations*[a]
	Dependent variable	*Independent variable/ route/dose/frequency*	*Control*					
Diego et al. (1998). USA Effects of aromatherapy on feelings of relaxation, anxiety, mood; and alertness; EEG activity and math computations	EEG activity alertness, mood	Lavender, rosemary, 3 drops of oil diluted to 10% in grape seed oil and placed on dental swab in 100-mLvial and inhaled as held 3 in from nose for 3 min	No control	10 patients who were inpatient for 2 weeks before the study and 2 weeks during study	RCT Setting: Laboratory	EEG reading: recorded 3 min before, during, and after treatment STAI: Before and after treatment POMS: Before and after treatment VAS: Administered twice (tense/relaxed and drowsy/alert) before and after treatment Math computations: Before and after treatment	Lavender group reported feeling more relaxed and had an increase in β power (suggesting drowsiness)[b] Rosemary group reported increase in alertness and had a decrease in α and beta 1 power (suggesting alertness)*. A subsequent increase in $\beta 2$ power on EEG after rosemary use discontinued suggests effect is short term.[b] Math computations faster for both lavender and rosemary groups, but only lavender group improved accuracy.	Measured immediate short-term effect only Small dose/frequency Outcome measured (EEG recording) related to drowsiness during day, not sleep at night
Cannard (1996), Ireland Effect of aromatherapy on sleep and night sedation in patients	Sleep patterns, night sedation, perception of restful night's sleep	Blend: basil (*Ocimum basilicum*), juniper (*Juniperus communis*), lavender (*L. angustifolia*), sweet marjoram (*Origanum majorana*)/4 drops on mattress before sleep. If not effective, hand massage using almond oil and blend for 2 weeks	No control	9 patients (8 women and 1 man) 4 psychogeriatric patients	Clinical evaluative study Setting: inpatient	Data gathered by nurse at end of night shift: 2 wk before treatment 2 wk of treatment Oil used Route of administration Any night sedation given Report by patient as to whether she/he had a good night's sleep	Before treatment: 73% stated had a refreshing night's sleep, 90% took sedation Post treatment: 97% stated had a refreshing night's sleep, 36% took sedation	No percentage composition of blend reported No results reported for those who had hand massages with oil and those who did not No randomization (Botanical name reported.)
Hudson (1996), UK Effect of lavender on sleep and daytime lethargy for sick elderly patients?	Pilot: sleep, restlessness, daytime alertness rehabilitation participation Detailed: sleep, dozing wakefulness, alertness, confusion	Lavender (*L. angustifolia*) 1 drop on pillow before sleep for 1 wk	No control	10 undergraduate and graduate students (mean age, 22.8 y) (4 men and 6 women) Excluded: medication use, sleep, health or allergy issues, and OP	Clinical evaluative study Setting: Inpatient	Pilot study: objective survey and night nurse comments Detailed study: 24-h charts (sleep, dozing, wakefulness, alertness, and confusion) completed by nurses 1 wk before treatment/ 1 wk of treatment	Trend toward improved quality of daytime wakefulness and more sustained sleep at night.	Turnover of patients Small dose/frequency Usual care, including use of hypnotics 1 outcome measurement and variety of nurses observed No randomization (Botanical name reported.)

(*continued*)

TABLE 1. (CONTINUED)

Author/year country/research topic	Variables: Dependent variable	Variables: Independent variable/ route/dose/frequency	Variables: Control	Sample	Design/setting	Measures	Results/main conclusion	Limitations[a]
Hardy et al. (1995), United Kingdom Lavender in place of drug for insomnia	Time asleep on drug treatment for insomnia vs. lavender oil	Lavender odor delivered via odor diffuser for 2 wk	No control		Small equivalence trial Setting: inpatient	Time spent asleep (measurement tool not documented) 2 wk on drug, 2 wk off, 2 wk lavender Calculation of probability levels with which differences are due to chance	Amount of time spent asleep was significantly reduced after drug stopped, and amount of time asleep returned to same previous level with lavender.	No documentation as to how time asleep was measured Study not well documented
Badia et al. (1990), USA Behavioral and psychophysiologic response to olfactory stimulus presented in sleep	Olfaction in sleep behavioral occurrence of awakening, micro switch closure without awakening, speeding in the EEG tracing, heart rate, respiration rate	PPO inhalation via mask (10)% (0.26 mg/L (10%) selected because subjective intensity of odor in waking was judged maximal at that level, for 1 night	Air alone (constant flow of air through mask to avoid trigeminal cues)		RCT Setting: Laboratory	Olfactory sensitivity test PSG responses recorded at repeated random 3-min periods of air alone or odor via mask during REM (too short for data collection) and stage 2 sleep: occurrence of awakening, micro-switch closure without awakening, speeding in EEG, change in muscle tone on EMG, heart and respiratory rate	Olfactory sense does function in sleep at behavioral, autonomic, and central response levels. More micro-switch, heart rate, and EEG speeding responses to odor and less EMG response. Time of night effect noted where responsiveness greatest earlier in night. No significant effects of awakenings with odor.	Recruitment and randomization methods not addressed

[a]In addition to small sample size, lack of gas chromatography/mass spectrometry analysis, lack of botanical name, report of harms or lack thereof, long-term follow-up, and study flow diagram.
[b]Statistically significant finding.
SO, sweet orange; TT, tea tree oil; OP, sleep and olfactory pathologies; STAI, state anxiety; GC/MS, gas chromatography/mass spectrometry; PSQI, Pittsburgh Sleep Quality Index; HRV, heart rate variability; PSG, polysomnography; VAS, visual analog scale; CCU, critical care unit; PPO, peppermint oil; M/E, morningness/eveningness; POMS, Profile of Mood States Questionnaire; SWS, slow-wave sleep; NREM, non–rapid eye movement; REM, rapid eye movement; CNS, central nervous system; BNQ, Borkovec and Nau questionnaire; HCAMQ, Holistic Complementary and Alternative Medicine Questionnaire; EEG, electroencephalography; EMG, electromyography

inclusion criteria. The reference lists of these identified studies and systematic reviews, along with OVID Medline electronic article mappings, yielded eight additional studies meeting the inclusion criteria. A total of 15 human studies on inhaled essential oils and their effect on sleep were found,[5,36–49] and their methods and results were summarized and compared (Table 1).

Participants and settings

Sample sizes in the 15 studies ranged from 4 to 67 participants and totaled 409 participants. Participant age was not consistently documented. Studies included college undergraduates, graduate students, and the elderly, as well as cancer and other patient populations. Participants were both healthy sleepers and those with sleep disturbances. Men and women were included in all of the studies except for one all-male study[36] and one all-female study.[38] Study locations varied, with some in the home and others in a sleep laboratory or inpatient setting.

Design and intervention

Eleven of the 15 studies were RCTs with single- or double-blinding.[36–38,40–46,49] Blinding is a challenge in essential oil research because of the distinct odor of each essential oil. Blinding techniques included using language that was not specific, avoiding visual cues, embedding blocks of odor stimulus in the airflow, administration during sleep, and use of more than one essential oil or substance with an aroma. The remaining studies were evaluative clinical studies[39,47,48] or a small equivalence trial.[5] Crossover design was used in four of the studies using controls or placebos.[42–44,49] Ten RCTs screened for olfactory abnormalities[36–38,40–43,45,46,49] and 11 screened and controlled for sleep abnormalities in the design.[36,37,40,42,43,45,46,49] In addition, most used more than one measurement tool and combined objective and subjective measurements. Measurement tools varied widely, as noted in Table 1, but several studies used a version of the Pittsburgh Sleep Quality Index[37,38,40,44] and polysomnography.[40,42,43,49] In a majority of the studies, reliability and validity of the measurement tools were documented. The essential oils used for inhalation differed between studies as well. Ten studies reported the use of lavender. *Lavandula angustifolia* was specified for only 3 of these studies.[44,47,48] The other essential oils studied included *Citrus sinensis* (sweet orange), vetiver, peppermint, jasmine, rosemary, and blends of essential oils. With only 4 studies reporting the Latin botanical name[36,44,47,48] and only 1 of the 4 reporting an analysis of the chemical constituents,[36] the exact chemical composition of the materials used for the intervention is unclear in a majority of the studies. Routes of administration included a drop on a pillow, drops on gauze, all-night diffusion, and mask and tubing. Doses varied widely with amount, frequency, and duration unique to each study.

On the basis of the CONSORT criteria,[35] the RCTs met criteria for title, abstract, introduction, and methods, although sample size determination and randomization procedures were less well documented. Other areas where some studies did not meet criteria included demographic characteristics outside of age and sex, incorporation of a study flow diagram, and reference to any harms or the lack thereof.

Outcomes

Although results were mixed, most studies found a positive association between inhalation of essential oils and sleep. Statistically significant results for improved sleep quality were reported for lavender oil,[37,38,41,43] peppermint oil,[42] and jasmine oil.[45] Peppermint oil has stimulating qualities, so this finding was counter to other studies and may have been due to a balancing quality or the exact chemical constituency of the oil, although this was not reported. Other studies reported positive findings (not statistically significant but showing a relationship or trend toward improved sleep quality) for lavender oil;[5,40,44,48] lavender and valerian blends;[39] and a blend of basil, juniper, lavender, and sweet marjoram.[47] A statistically significant negative association with sleep quality was found for lavender oil in one study. This again could be due to the undocumented chemical constituency of the lavender used in the study or use of a different species of lavender.[45] Sweet orange, which has stimulating qualities, was also reported as having statistically negative findings in relationship to sedative/hypnotic effects after an anxiety-eliciting task.[36] In another study, lavender and vetiver modified breathing during sleep.[40] A study examining the behavioral and physiological responsiveness to peppermint oil during sleep found positive associations with micro switch closure, electroencephalographic speeding, heart rate during odor administration, and a decrease electromyographic response. No effect was displayed for respirations and awakenings.[49] The findings generally support that essential oils have an effect on sleep or during sleep, with the exceptions noted. No adverse effects were reported in any of the studies reviewed. However, neither did the studies report the lack of adverse effects.

In addition to sleep outcomes, secondary outcomes were examined in one or more studies: hedonicity (a like/dislike of the essential oil/control), expectancy effect (participant expectancy can be positive or negative and can bias the results), and intensity rating. In the three studies that measured hedonicity, the like/dislike preference had no significant effect on sleep outcomes.[36,40,42] Five of the studies addressed expectancy effect by using language that was not specific, avoiding visual cues, embedding blocks of odor stimulus in the airflow, using questionnaires to assess participant expectancy before the study, and using more than one essential oil. None of these studies identified an expectancy effect.[36,37,40,42,44] In two studies that assessed intensity rating, the rating affected sleep measures.[40,42] In summary, expectancy effect and hedonicity were not found to have an effect on the treatment outcome in these studies; however, participant-rated intensity did affect results.

Four studies explored the effect of sex. One study found no association between sex and the outcomes,[37] two studies did find an association,[42,43] and one noted a significant trend toward an effect.[44] The study findings varied, and there was no uniform association between sex and effects on sleep.

Only 1 of the 15 studies reported verifying the chemical composition of the essential oils studied by gas chromatography analysis/mass spectrometry.[36] In addition, studies that used a blend of essential oils did not identify the exact proportions or composition of the blend. Only 4 of the 15 studies reported the Latin botanical name for plant species identification.[36,44,47,48] Different plant species have different chemical constituencies and therefore different therapeutic properties. With lavender, for example, *Lavandula latifolia* is considered stimulating and *L. angustifolia* is considered relaxing. Each plant species or chemotype can have a slightly different chemical constituency, making gas chromatography analysis/mass spectrometry analysis critical in essential oil research.

Discussion

This is the first comprehensive review of inhaled essential oils and their effects on sleep. The strength of this systematic review includes its coverage of all relevant studies and the use of strict methodologic criteria. Major strengths of this group of studies include study design, the use of blinding, and the quality of measurement tools. Most of the studies (11 of 15) were RCTs. Eight of these incorporated some form of participant blinding despite the difficulty in blinding smells. In addition, most studies incorporated more than one measurement tool with demonstrated validity and reliability, the most commonly used being the Pittsburgh Sleep Quality Index. A majority of the studies originated in the United States or the United Kingdom. However, other countries were represented, thereby providing for some geographic diversity.

Limitations were also identified. Defined geographic locations and small homogeneous samples affect the generalizability of these studies. No studies documented a power analysis to determine the sample sizes needed to demonstrate an effect. In addition, all of the study samples appeared to be convenience samples, and only five studies reported recruitment methods. All of the RCTs applied exclusion criteria to increase the control of such factors as olfactory and sleep disturbances for internal validity, limiting generalizability to similar populations. In addition, many of the studies were conducted in a laboratory setting, again limiting external validity.[36,38,40,42,43,45] Only one study reported follow-up measurements to assess the duration of the effect.[38] In aromatherapy practice, essential oil selection is often individualized according to the match of the therapeutic effects of essential oil and the physical and emotional states of the patient, as well as aroma preference.[50] Therefore, standardization of interventions in research designs limits external validity because of the lack of standardization in actual clinical practice. In addition, lack of botanical name identification and lack of chemical analysis substantially limit the interpretation of results in essential oil research. Although the studies reported no adverse effects, the fact that none mentioned the lack of adverse effects is a limitation of the articles reviewed.

Few ethical issues were identified. Only six studies reported informed consent and approval from an ethics or internal review committee.[36,37,40–43] Potential nonparticipant involvement presents a potential ethical issue in the studies that did not tightly control for the essential oils in the ambient background of a home or an inpatient setting.[5,41,44,47,48]

Only one study compared different dosages and their hypnotic effect, and only as a secondary finding.[36] In that study, the lower dose and higher dose of sweet orange oil were associated with an effect but the intermediate dose was not. This finding has also been noted in other studies[51] and should be explored in future research. The odor of essential oils, the challenge of control conditions, and current lack of knowledge of the therapeutic dose for inhaled essential oils represent limitations in essential oil research that are difficult to avoid. In addition, there is a lack of understanding of the mechanisms of action of essential oils, which are likely to be multifaceted and may be subtle and balancing, making a rigorous scientific inquiry challenging. Moreover, there is still much to be known about the complex systems of sleep and olfaction.

Future research should consider these limitations. Research quality can make a significant difference in the validity and reliability of a study. Unique challenges of essential oil research include subtle and synergistic effects, timing of measurements, blinding difficulties, and the intent to affect the whole person to maximize balance and healing.[52]

Despite the limitations noted, the findings of this review are promising. Essential oils were found to have a short-term effect on sleep measured by variety of sleep outcome measures. Use of essential oils could be a safe and cost-effective therapy or adjunct therapy for sleep disturbances and might decrease overuse of prescription medications and short- and long-term health outcomes from sleep disturbances. Gaps in the evidence identified through this review include study design and measurements to account for the subtle and synergistic effects of essential oils, dose/frequency/duration for therapeutic effect, assessment of long-term effect, mechanism of action, and a need for more rigorous methods.

Several other issues unique to essential oil research were identified in the review process. These issues included hedonicity or the like/dislike of the odor, expectancy effects, the distinct odors of essential oils, and the chemical variability of essential oils due to plant and other natural conditions. Future research on sleep and essential oil inhalation should also consider these issues.

In conclusion, there is still much to be discovered about the complex systems of olfaction, sleep, the mechanism of action for essential oils, and the inter-relationship of these complex systems. This systematic review of the literature creates a basis for continued research into inhaled essential oils and sleep that can lead to better understanding and practice. Gaps in the evidence identified through this review highlight topics for future research. Statistically significant positive and negative effects were found for essential oils on sleep, although most findings were positive. Generalizability of findings from these 15 studies is limited. However, they provide a strong basis for future studies and suggest that essential oils could provide a safe, cost-effective therapy for the growing public health issue of sleep.

Disclosure Statement

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