





RESEARCH ARTICLE

The impact of sleep hygiene education and lavender essential oil inhalation on the sleep quality and overall well-being of athletes who undergo late-evening training: a randomized controlled trial [version 1; peer review: 1 approved]

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Abstract

Background

Sleep hygiene education (SHE) and lavender essential oil (LEO) inhalation are two effective strategies aimed at enhancing sleep quality and mood states. This study investigated the effects of a single SHE session combined with nightly LEO inhalation for 7 days of late-evening resistance training sessions on sleep quality and mood states

Open Peer Review


Approval Status 

1

version 1 

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[view](#)

1. **Martha J Greenberg** , Pace University, Pleasantville, USA

Any reports and responses or comments on the

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article can be found at the end of the article.

Methods

Forty-two athletes were randomly assigned to four groups: a control group (CG), a SHE group (SHEG), a LEO group (LEOG), and a SHE + LEO group (CSLG). CG and LEOG maintained their sleep habits during the intervention, while SHEG and CSLG followed SHE recommendations. Additionally, LEOG and CSLG inhaled LEO nightly before sleep. Sleep patterns were recorded via actigraphy. The Brunel Mood Scale and the Hooper questionnaires were completed before and after the intervention.

Results

Sleep latency was lower in SHEG ($p=0.001$) and CSLG ($p=0.012$) compared to the CG. The subjective sleep score improved in SHEG, LEOG, and CSLG ($p < 0.001$), with greater improvement observed in SHEG ($p = 0.002$) and CSLG ($p < 0.001$) compared to CG at post-intervention. Additionally, significant improvements were observed in the Hooper index in the SHEG ($p=0.048$) and CSLG ($p=0.027$), with CSLG demonstrating higher scores compared to CG at the post-intervention assessment ($p=0.026$). Furthermore, the subjective fatigue score significantly decreased in the CSLG ($p=0.009$).

Conclusions

Combining SHE and LEO inhalation could be an effective strategy to enhance sleep latency, subjective sleep quality, and overall wellness, and reduce feelings of fatigue in trained athletes following late-evening resistance training sessions.

Keywords

Sleep, Insomnia, Hygiene, Aromatherapy, Night training

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Boujelbane MA: Resources; **Belgacem A:** Investigation, Writing – Original Draft Preparation; **Kerkeni M:** Investigation; **kerkeni M:** Investigation; **Boukhris O:** Investigation; **Jahrami H:** Writing – Review & Editing; **Glenn J:** Writing – Review & Editing; **Ammar A:** Writing – Review & Editing; **Schöllhorn W:** Writing – Review & Editing; **Chtourou H:** Methodology, Supervision, Writing – Review & Editing

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Introduction

This section should include the aim and objectives of this study in the context of the wider subject area.

Adequate sleep is a crucial component for athletic success, complementing physical and mental training, nutrition, and overall health.¹ However, many athletes are prone to experiencing sleep inadequacies,^{2,3} often characterized by insufficient sleep quantity (<8.2 hrs per night)² and/or poor sleep quality, such as sleep fragmentation and reduced sleep efficiency.⁴

Athletes' sleep is frequently compromised due to various interconnected factors.^{3,4} These factors include early morning training, increased training load, early departure times for traveling, jet lag, exposure to high altitudes, as well as anxiety and stress, especially on the night before an important competition.³

Night-time training and competition sessions can have detrimental effects on both the quantity and quality of sleep.^{3,4} Athletes involved in team sports, who have late-evening matches or training, often experience disrupted sleep.^{5,6} Eagles and Lovell⁷ found that after a twelve-night period involving training and two competitive matches, athletes reported lower sleep quantity and increased sleep latency. The delay in bedtime on competition nights reduces the overall time available for sleep.⁸ Therefore, engaging in training and competition sessions during nighttime, especially within one hour before bedtime, can have a detrimental impact on sleep duration and quality.⁴ This has the potential to negatively affect athletes' overall performance and recovery.

Identifying and evaluating effective strategies to mitigate potential sleep disturbances related to late training and/or competition is crucial for optimizing performance and overall well-being. Previous studies highlight the potential of sleep hygiene education (SHE) to improve sleep quality and quantity among athletes.^{9,10} SHE involves providing a range of recommendations as a simple, accessible, and cost-effective tool to discourage behaviours disrupting normal sleep patterns.¹¹ While initially implemented in clinical populations,¹² SHE has evolved to include other behavioural factors such as limiting technological device usage, creating a dark and cool bedroom environment, and avoiding blue light exposure in nonclinical and healthy individuals.¹³ Educating individuals, including athletes, about sleep and sleep hygiene practices offers strategies to optimize both sleep quantity and quality.¹⁴ For example, one session of SHE improved sleep latency and sleep efficiency in elite rugby players during a 4-week intervention.¹⁵ Similarly, an enhancement in objective sleep latency has been reported one night following a late-evening small-sided-game session in soccer players who attended one session of SHE.¹⁶ SHE also led to improved total sleep time and reduced wake episode duration in elite female netball athletes.⁹ However, in another study among soccer players, SHE was associated with increased wake episodes compared to the control group,¹⁷ Caia, Scott¹⁸ observed earlier bedtime and increased sleep duration in rugby league athletes following a SHE session, although sleep indices returned to baseline after one month. Furthermore, previous studies,^{11,19} examining the effects of SHE on fatigue have consistently shown improvements in fatigue levels following SHE interventions. A more recent study by Biggins, Purtill²⁰ reported that athletes experiencing a sleep problem of clinical importance had a higher tendency to describe poorer sleep habits, increased instances of health-related issues, and disturbances in their mood.

On the other hand, phytotherapy, which involves the use of herbs, herbal preparations, and phytochemicals for medicinal purposes, has received growing interest in alternative medicine in recent years.²¹ Aromatherapy, a branch of phytotherapy, utilizes plant-derived essential oils (EOs) for medicinal, cosmetic, and culinary applications.^{22,23} Aromatherapy has demonstrated effectiveness in reducing stress, improving depression, and enhancing sleep quality in healthy adults by alleviating emotional stress and stabilizing moods.²⁴ Short-term aromatherapy treatments have also shown promising results in improving sleep quality without the need for special equipment.²⁵ These EOs enter the body through the respiratory tract, influencing the limbic system and triggering emotional and physiological responses.²⁵ Various application methods of EOs, such as inhalation, massages, and baths, are reported to have positive effects on sleep quality.^{24,26,27} Inhalation is the most popular and is often associated with EOs,²⁸ Inhaling essential oils is a quick, easy, and safe method.^{29,30} Among the EOs, Lavender essential oil (LEO) is highly recommended due to its potential sleep-promoting effects.²⁸ LEO demonstrates positive effects on various clinical issues (e.g., anxiety, depression, fatigue, stress, and pain), and may potentially improve sleep quality and mood.^{31,32} However, there is a lack of research evaluating the effects of LEO inhalation on sleep quality, mood states, and subjective feelings of recovery, specifically in athletes.

Particularly, there is a paucity of scientific investigations examining the synergistic effects of SHE and LEO inhalation on sleep quality following late-evening resistance training sessions in trained athletes. Evaluating this strategy would not only contribute to the existing literature but also enable coaches to implement effective measures for improving sleep and subsequently enhancing athletes' performance and recovery. Therefore, the purpose of this study was to examine the effects of combining a single SHE session with LEO inhalation during 7 days of late-evening resistance training sessions on sleep quality and mood states in trained athletes. The hypotheses were as follows: (i) an acute SHE session would

enhance both sleep quantity and quality and reduce mood disturbance; (ii) LEO inhalation before bedtime would improve sleep quantity, and quality, and positively impact mood states; and (iii) the combination of an acute SHE session and LEO inhalation before bedtime would result in greater improvements in sleep quality, sleep quantity, and mood states compared to SHE or LEO alone.

Methods

Study design

This study adopted a four-arm, parallel-group randomized controlled trial design. Participants were randomly assigned to one of four groups: a control group (CG), a LEO group (LEOG), a SHE group (SHEG), and a combined SHE + LEO group (CSLG). Randomization was performed using a computer-generated list of random numbers. The CG and LEOG were instructed to maintain their usual lifestyle and sleep habits throughout the intervention period (Figure 1). The SHEG and CSLG were provided with sleep hygiene recommendations to follow for the entire 7-day period (Figure 1). The LEOG and CSLG were asked to inhale the LEO every night before going to sleep for the duration of the 7 days (Figure 1). Sleep patterns were accessed using GT3X actigraphy every night for 7 days (Figure 1). The participants completed the Brunel Mood Scale (BRUMS) and Hooper questionnaires before and after the 7-day intervention period (Figure 1). Furthermore, participants in the LEOG and CSLG were asked to report any potential side effects experienced after inhaling LEO before bedtime during the 7-day intervention period. No participants reported any side effects, such as difficulty breathing, headaches, or dizziness.

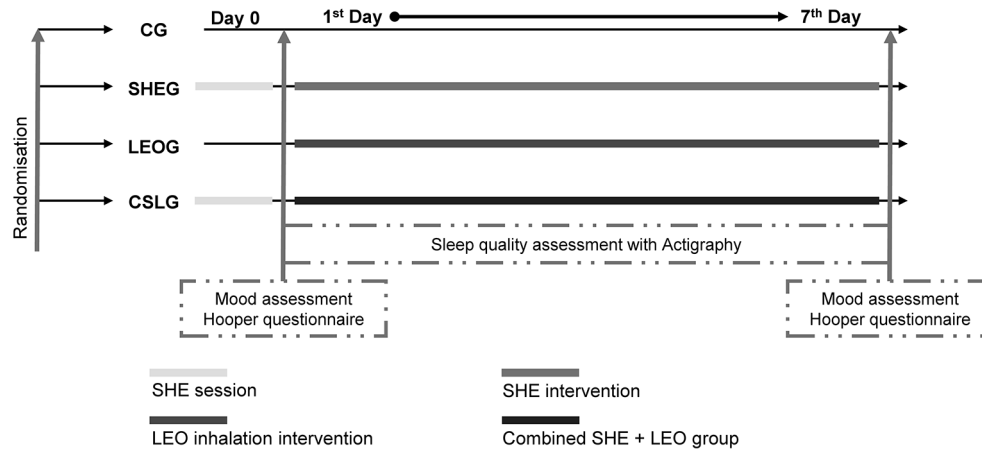


Figure 1. Experimental design of the study.

Participants

The minimum required sample size was calculated using G*power software (version 3.1.9.6; Kiel University, Kiel, Germany). Based on the effect size estimated from the studies by Lee, Lim²⁴ and Vitale, La Torre,¹⁶ a sample size of 32 subjects would be sufficient to detect significant differences (effect size $f = 0.8$, $\alpha = 0.05$) with an actual power of 95.66%. In this study, a total of 42 resistance-trained athletes (27 males and 15 females) voluntarily participated. The inclusion criteria required participants to be: (i) aged ≥ 18 years, (ii) engage in nighttime resistance training for at least 1 hour, four times a week, and (iii) females who were in the follicular phase of their menstrual cycle during the experimentation. All training sessions were scheduled between 21:00 and 23:00. Exclusion criteria were being a morning (M-type) or evening (E-type) chronotype, as assessed using the Horne-Ostberg morningness-eveningness Questionnaire (MEQ),³³ tobacco use, history of lower extremity injury or surgery within the past 6 months, and previous exposure to SHE or LEO, which would potentially interfere with the validity of the study protocol. Additionally, participants who were anticipated to encounter conditions with the potential to disrupt their sleep patterns, such as traveling and jet lag, were excluded from the study. Finally, participants who experienced any adverse effects as a result of LEO inhalation were excluded from the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol received full approval from the Ethical Committee for the Protection of Southern Persons (CPP SUD N° 0520/2023) on 31st May 2023 and was registered at the Pan African Clinical Trial Registry (PACTR202306806244897) on 09th June 2023. Participants were allocated to one of four groups: CG ($n = 11$), SHEG ($n = 11$), LEOG ($n = 10$), or CSLG ($n = 10$). Three participants from the SHEG, one from the LEOG, and one from the CSLG were excluded from the final analysis due to being lost to follow-up for SHE recommendation ($n = 4$) or incomplete use of LEO ($n = 1$) during the intervention period. The flowchart of the study according to CONSORT guidelines³⁴ is illustrated in Figure 2 (Checklist: <https://zenodo.org/records/11368563>).

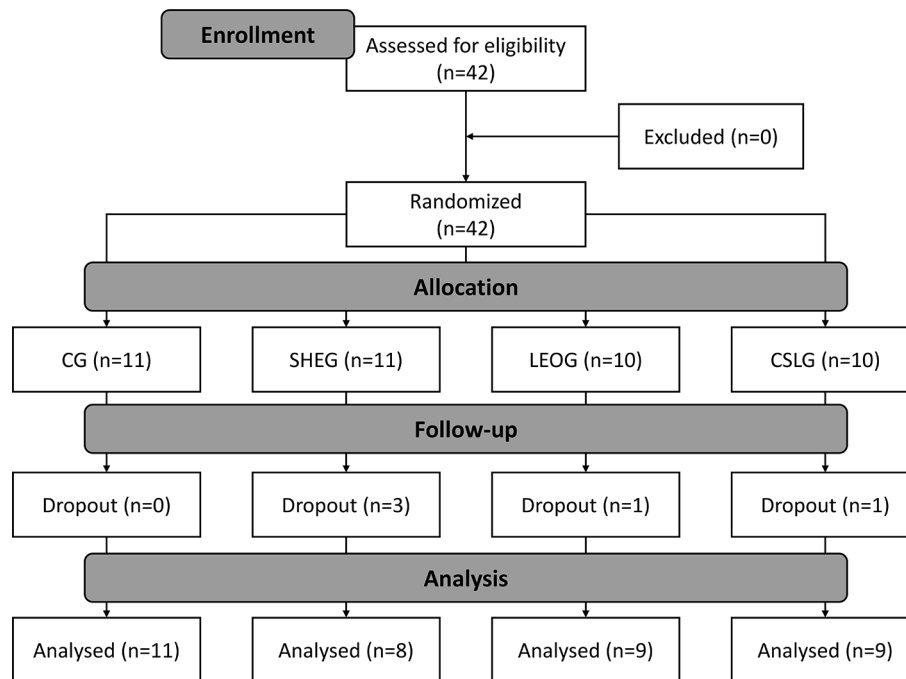


Figure 2. Flowchart of the study.

Aromatherapy

Participants in the LEOG and CSLG were provided with lavender (*Lavandula angustifolia*, of the family Lamiaceae) essential oil (LEO) for inhalation. The LEO was prepared in a laboratory. To use the LEO, as described by Salamati, Mashouf,³⁵ participants were instructed to apply two drops (equivalent to 0.14 mL) of the oil onto a cotton ball. The cotton ball was then placed at a distance of 5 cm from their nose. Participants were asked to inhale the aroma of the LEO for 10 min, engaging in normal breathing, at their convenience prior to bedtime.²⁸

Sleep hygiene education session

All participants attended a SHE session led by a specialist in sleep research and athletic recovery. The session took place one day prior to the start of the study and lasted for approximately 40–45 min. The SHE session focused on practical tips that were evidence-based and recommended by Nédélec, Halson.³⁶ These tips included various recommendations such as taking a post-training shower, ensuring a quiet, cool, and dark bedroom environment, removing the bedroom clock, avoiding the use of light-emitting technology devices at least 1 hour before sleep, refraining from consuming caffeine, alcohol, or other stimulants before sleep, drinking high-electrolyte fluids, such as milk instead of only water, between training cessation and bedtime, and eating a light, high-glycaemic index meal with few proteins. All participants were asked to avoid afternoon naps in order to limit the beneficial effects of napping on their sleep patterns at night. Following the educational session, participants were provided with a leaflet summarizing the sleep hygiene recommendations to follow between training cessation and bedtime. All participants slept in their usual beds at home throughout the study.

Testing procedures

Circadian typology

Circadian typology was assessed using the Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ).³³ MEQ scores were categorized into three groups: morning-type (score ≥ 59), evening-type (score ≤ 41), or neither-type (score 42–58). Based on their MEQ scores, all participants in this study were categorized as neither-type, indicating a lack of strong preference for either morningness or eveningness in their sleep-wake patterns.

Wristwatch actigraphy

Participants were asked to wear the GT3X actigraphy device (Actigraph, FL, USA) on their non-dominant wrist to assess their sleep patterns. The Actilife 6 software was used to analyse the recorded data and calculate various sleep parameters, including in bedtime (IB), out bedtime (OB), sleep latency (SL), sleep efficiency (SE), total time in bed (TTB), total sleep time (TST), wake after sleep onset (WASO), number of awakenings (N° AW), and average awakening (AW). The sleep analysis software categorized each 60-second epoch as either asleep or awake based on the recorded data. By analysing these parameters, the sleep-awake patterns of participants during the night were evaluated.

Hooper questionnaire

The Hooper questionnaire was used to assess signs of pre-fatigue and stress.³⁷ This questionnaire included subjective assessments of sleep quality, fatigue, stress, and muscle soreness. Participants provided their ratings for each of these factors using a seven-point Likert scale, with responses ranging from 1 (very, very good) to 7 (very, very bad) for sleep, and from 1 (very, very low) to 7 (very, very high) for fatigue, stress, and muscle soreness. The responses were then used to calculate the Hooper Index (HI), which represents the total of the four ratings. The HI provides an overall measure of participants' subjective experiences of sleep quality, fatigue, stress, and muscle soreness. A higher score on the HI indicates better well-being and readiness for training or competition, while a lower score suggests a potential decrease in readiness or the presence of factors that may impact performance.³⁸

The Brunel Mood Scale (BRUMS)

The BRUMS³⁹ consists of 32 items assessing mood states. These items are divided into six subscales: anger, tension, depression, vigour, fatigue, confusion, happiness, and calmness. Each item is rated on a 5-point Likert scale, ranging from 0 (not at all) to 4 (extremely). Participants were asked to complete the BRUMS by indicating their current feelings and emotions. The subscale scores are calculated based on four relevant items, with possible scores ranging from 0 to 16. The BRUMS provides a comprehensive assessment of participants' mood states, including both negative and positive aspects, allowing for a multidimensional evaluation of emotional well-being.

Statistical analyses

Descriptive statistics were presented as Mean \pm standard deviation (SD). The normality of the data was checked using the Shapiro-Wilk test. To assess the statistical significance of differences between groups for participants' characteristics and actigraphy-based sleep data, the one-way analysis of variance (ANOVA) (when a parametric test was appropriate) or the Kruskal-Wallis test (when a non-parametric test was appropriate) were performed, followed by a post-hoc pairwise comparison or the Dunn's test, both with the Bonferroni adjustment. To assess the statistical significance of differences between groups and measures times, the two-way ANOVA was performed (when a parametric test was appropriate) or the F1-LD-F1-model was performed (when a non-parametric test was appropriate). This model provides an ANOVA-type statistic for group, time, and the interaction between group and time. When significant main or interaction effects were found, a post-hoc pairwise comparison or the Dunn's test as post-hoc, both with Bonferroni adjustment, were performed. The effect size statistic (η_p^2 and η_H^2) was calculated to assess the magnitude of the difference between age groups using the following criteria: small = 0.01, moderate = 0.06, and large = 0.14.⁴⁰ Standardized effect size (Cohen's d) analysis was used to interpret the magnitude of differences between variables and classified according to Hopkins⁴¹ as: trivial ($d \leq 0.20$), small ($0.20 < d \leq 0.60$), moderate ($0.60 < d \leq 1.20$), large ($1.20 < d \leq 2.0$), very large ($2.0 < d \leq 4.0$), and extremely large ($d > 4.0$). Upper and lower 95% confidence intervals of the difference (95% CI_d) were calculated. For all analyses, significance was assumed a priori at $p < 0.05$. Statistical analyses were conducted using the R programming language.⁴² ANOVAs and post-hoc tests for normally distributed data were conducted with the "afex"⁴³ and "emmeans"⁴⁴ packages, respectively. The Kruskal-Wallis and Dunn's tests were conducted with the "rstatix" package.⁴⁵ The F1-D1-F1 model was performed with "nparLD" package.⁴⁶

Results

Participants characteristics

Participants' characteristics are presented in [Table 1](#). Statistical analysis showed no difference in participant characteristics between the four groups.

Table 1. Participants characteristics.

	CG (n = 11)	SHEG (n = 8)	LEOG (n = 9)	CSLG (n = 9)	p-Value
Age (years)	21.91 \pm 1.51	21.25 \pm 0.89	21.78 \pm 1.39	21.22 \pm 0.83	0.616
Height (cm)	176.91 \pm 11.7	154.1 \pm 62.04	178.44 \pm 10.56	156.54 \pm 58.48	0.913
Weight (kg)	72.45 \pm 14.94	73.5 \pm 13.19	72.38 \pm 14.7	78.22 \pm 14.37	0.795
MEQ-score (points)	49.36 \pm 6.07	50.5 \pm 5.32	49.78 \pm 5.31	51.22 \pm 5.04	0.886
TS/W (n)	4.91 \pm 0.94	4.38 \pm 1.51	4.89 \pm 0.93	4.44 \pm 0.73	0.51
TTH/W (min)	72.27 \pm 22.06	69.55 \pm 21.5	73.73 \pm 23.55	75 \pm 22.25	0.839

CG: Control group; SHEG: Sleep hygiene education group; LEOG: Lavender essential oil group; CSLG: Sleep hygiene education and Lavender essential oil combination group; MEQ-score: Morningness-eveningness questionnaire score; TS/W: Training sessions per week; TH/W: Total training hours per week; n = number.

Table 2. Values of the actigraphy-based sleep indices recorded during the one-week intervention period.

	CG	SHEG	LEOG	CSLG	ANOVA
IB (hh:mm)	23:26 ± 0:46	0:30 ± 0:55	0:01 ± 0:43	0:14 ± 2:02	F (3,33) = 1.31; p = 0.288; $\eta_p^2 = 0.11$
OB (hh:mm)	7:49 ± 0:46	8:01 ± 0:38	7:43 ± 0:52	8:31 ± 1:17	F (3,33) = 1.36; p = 0.273; $\eta_p^2 = 0.11$
SL (min)	1.91 ± 0.98	0.72 ± 0.15 **	1.34 ± 0.4	0.98 ± 0.45 *	F (3,33) = 6.8; p = 0.001; $\eta_p^2 = 0.38$
SE (%)	87.27 ± 5.02	89.57 ± 3.03	85.88 ± 3.98	86.93 ± 4.8	H (3) = 4.28; p = 0.233; $\eta^2_H = 0.04$
TTB (min)	507.2 ± 56.33	451.73 ± 39.29	461.26 ± 57.3	497.4 ± 86.83	H (3) = 5.87; p = 0.118; $\eta^2_H = 0.09$
TST (min)	441.12 ± 55.21	404.34 ± 43.4	397.23 ± 65.55	437.66 ± 95.54	H (3) = 3.36; p = 0.399; $\eta^{2H} = 0.01$
WASO (min)	64.53 ± 25.38	46.73 ± 11.96	62.03 ± 15.49	58.25 ± 19.3	H (3) = 5.42; p = 0.143; $\eta^2_H = 0.07$
N° AW (n)	22.82 ± 6.26	17.45 ± 4.88	20.09 ± 5.01	19.9 ± 5.23	F (3,33) = 1.54; p = 0.222; $\eta_p^2 = 0.12$
AW (min)	2.82 ± 0.49	2.77 ± 0.7	3.15 ± 0.76	2.89 ± 0.56	F (3,33) = 0.67; p = 0.578; $\eta_p^2 = 0.06$

CG: Control group; SHEG: Sleep hygiene education group; LEOG: Lavender essential oil group; CSLG: Sleep hygiene education and Lavender essential oil combination group; IB: In bedtime; OB: Out bedtime; SL: Sleep latency; SE: Sleep efficiency; TTB: Total time in bed; TST: Total sleep time; WASO: Wake after sleep onset; N° AW: Number of awakenings; AW: Average duration of awakening; n: number. * (p = 0.012), ** (p = 0.001); significantly different compared to CG; ANOVA: Analysis of variance; η^2_H : eta2 calculated using H-value of Kruskal-Wallis test.

Table 3. Values of Hooper questionnaire recorded pre- and post-intervention period.

	Time	CG	SHEG	LEOG	CSLG	ANOVA
Sleep (A.U.)	Pre	4.09 ± 1.45	4.13 ± 1.13	4.56 ± 0.88	4.33 ± 0.87	G: F(3,33) = 2.68; p = 0.063; $\eta_p^2 = 0.196$ T: F(1,33) = 66.78 ; p < 0.001 ; $\eta_p^2 = 0.669$ G×T: F(3,33) = 17.98 ; p < 0.001 ; $\eta_p^2 = 0.62$
	Post	4.55 ± 1.37 ^{§§§§§}	2.38 ± 0.92 ^{***}	3.33 ± 1.12 ^{***}	2.11 ± 0.78 ^{***}	
Stress (A.U.)	Pre	3.18 ± 1.99	4.25 ± 1.16	3.78 ± 1.2	3.56 ± 1.74	G: F(3,33) = 1.33; p = 0.28; $\eta_p^2 = 0.108$ T: F(1,33) = 0.92; p = 0.346; $\eta_p^2 = 0.027$ G×T: F(3,33) = 0.65; p = 0.588; $\eta_p^2 = 0.056$
	Post	3.64 ± 1.8	3.63 ± 1.19	3.44 ± 1.33	3.11 ± 1.69	
Muscle soreness (A.U.)	Pre	3.45 ± 1.21	3.75 ± 0.89	4.11 ± 0.78	3.56 ± 1.13	G: F(3,33) = 0.97; p = 0.418; $\eta_p^2 = 0.081$ T: F(1,33) = 3.54; p = 0.069; $\eta_p^2 = 0.097$ G×T: F(3,33) = 2.68; p = 0.063; $\eta_p^2 = 0.196$
	Post	3.55 ± 1.04	3.88 ± 0.99	3.67 ± 1.22	2.78 ± 1.2	
Fatigue (A.U.) [†]	Pre	4.36 ± 1.21	3.63 ± 1.19	4.56 ± 0.88	3.89 ± 1.36	G: ATS_{Mod} (2.89, 32.33) = 2.73 ; p = 0.044 ; $\eta_p^2 = 0.2$ T: ATS (1, ∞) = 9.47 ; p = 0.002 ; $\eta_p^2 = 0.22$ G×T: ATS (2.8, ∞) = 2.58; p = 0.056; $\eta_p^2 = 0.19$
	Post	4.55 ± 1.51	3.13 ± 1.13	4 ± 1.22	3 ± 1.12	
Hooper index (A.U.) [†]	Pre	15.09 ± 4.04	15.75 ± 2.82	17 ± 2.45	15.33 ± 3.5	G: ATS_{Mod} (2.95, 32.89) = 1.06; p = 0.364; $\eta_p^2 = 0.09$ T: ATS (1, ∞) = 41.86 ; p < 0.001 ; $\eta_p^2 = 56$ G×T: ATS (2.08, ∞) = 10.69 ; p < 0.001 ; $\eta_p^2 = 0.49$
	Post	16.27 ± 4.08 [§]	13 ± 2.88 [*]	14.44 ± 3.57	11 ± 3.54 [*]	

[§](p < 0.05), ^{***}(p < 0.001); significantly different compared to pre-intervention.

^{§§}(p = 0.002); significantly different compared to SHEG.

^{§§§}(p = 0.026), ^{§§§§}(p < 0.001); significantly different compared to CSLG; CG: Control group; SHEG: Sleep hygiene education group; LEOG: Lavender essential oil group; CSLG: Sleep hygiene education and Lavender essential oil combination group; **ANOVA**: Analysis of variance.

[†]ANOVA was performed with the F1-D1-F1 model; **ATS**: ANOVA-type test statistic; **ATS_{Mod}**: Modified ANOVA-type test statistic with Box approximation.

Table 4. Values of BRUMS questionnaire recorded pre- and post-intervention period.

	Time	CG	SHEG	LEOG	CSLG	ANOVA
Anger (A.U.)[†]	Pre	4.09 ± 2.88	4 ± 3.02	4.22 ± 3.31	5.33 ± 4.95	G: ATS _{Mod} (2.90, 30.33) = 0.05; p = 0.986; $\eta_p^2 = 0.04$ T: ATS (1, ∞) = 3.49; p = 0.062; $\eta_p^2 = 0.1$ G × T: ATS (2.94, ∞) = 0.81; p = 0.488; $\eta_p^2 = 0.07$
	Post	3.73 ± 3.95	4.13 ± 2.85	3.11 ± 2.62	3.44 ± 4.3	
Tension (A.U.)[†]	Pre	4.45 ± 4.55	3.38 ± 2.5	3.67 ± 2.5	4 ± 4.44	G: ATS _{Mod} (2.76, 29.24) = 0.14; p = 0.924; $\eta_p^2 = 0.01$ T: ATS (1, ∞) = 0.52; p = 0.471; $\eta_p^2 = 0.02$ G × T: ATS (2.54, ∞) = 0.39; p = 0.729; $\eta_p^2 = 0.03$
	Post	3.91 ± 4.41	3.38 ± 2.88	4.22 ± 3.38	2.78 ± 3.11	
Depression (A.U.)[†]	Pre	3.64 ± 3.98	3.63 ± 2.45	2.56 ± 2.6	4.11 ± 5.86	G: ATS _{Mod} (2.84, 29.79) = 0.25; p = 0.85; $\eta_p^2 = 0.2$ T: ATS (1, ∞) = 2.25; p = 0.134; $\eta_p^2 = 0.06$ G × T: ATS (2.79, ∞) = 0.76; p = 0.51; $\eta_p^2 = 0.06$
	Post	3.64 ± 5.68	3.38 ± 4	2.67 ± 2	2.44 ± 3.75	
Vigour (A.U.)	Pre	9.36 ± 5.37	9.75 ± 3.54	8.56 ± 2.35	10.56 ± 4.42	G: F (3, 33) = 0.44; p = 0.729; $\eta_p^2 = 0.04$ T: F (1, 33) = 0.14; p = 0.71; $\eta_p^2 = 0.004$ G × T: F (3, 33) = 0.46; p = 0.712; $\eta_p^2 = 0.04$
	Post	9.91 ± 3.86	9.63 ± 2.97	8 ± 3.64	10.11 ± 5.18	
Fatigue (A.U.)[†]	Pre	7.09 ± 4.01	7.38 ± 3.46	6.22 ± 3.99	10.78 ± 2.49	G: ATS _{Mod} (2.82, 29.62) = 0.85; p = 0.459; $\eta_p^2 = 0.07$ T: ATS (1, ∞) = 9.02 ; p = 0.002 ; $\eta_p^2 = 0.21$ G × T: ATS (2.14, ∞) = 6.57 ; p = 0.001 ; $\eta_p^2 = 0.37$
	Post	8.18 ± 4.67	6.88 ± 3.4	4.78 ± 2.99	4.89 ± 4.62**	
Confusion (A.U.)[†]	Pre	5.09 ± 4.04	5.13 ± 5.22	4.67 ± 3.54	4.56 ± 4.39	G: ATS _{Mod} (2.78, 27.44) = 0.08; p = 0.964; $\eta_p^2 = 0.01$ T: ATS (1, ∞) = 0.98; p = 0.322; $\eta_p^2 = 0.03$ G × T: ATS (2.32, ∞) = 0.1; p = 0.924; $\eta_p^2 = 0.01$
	Post	4.36 ± 3.59	4.38 ± 4.34	5.11 ± 4.34	3.78 ± 4.06	
Happiness (A.U.)[†]	Pre	10.09 ± 4.25	9.5 ± 3s.02	8.44 ± 0.88	10.56 ± 3.36	G: ATS _{Mod} (2.76, 27.49) = 2.04; p = 0.111; $\eta_p^2 = 0.16$ T: ATS (1, ∞) = 0.01; p = 0.91; $\eta_p^2 = 0$ G × T: ATS (2.76, ∞) = 0.25; p = 0.848; $\eta_p^2 = 0.02$
	Post	10.27 ± 2.57	9.13 ± 2.47	8.11 ± 2.93	11 ± 4.3	
Calmness (A.U.)	Pre	10.82 ± 3.6	8.88 ± 3.8	7.89 ± 1.69	9.78 ± 3.77	G: F (3, 33) = 1.32; p = 0.286; $\eta_p^2 = 0.11$ T: F (1, 33) = 0.73; p = 0.4; $\eta_p^2 = 0.02$ G × T: F (3, 33) = 1.51; p = 0.229; $\eta_p^2 = 0.12$
	Post	9.36 ± 4.13	8.13 ± 3.56	7.44 ± 3.78	10.89 ± 4.2	

** (p = 0.009); significantly different compared to pre-intervention. CG: Control group; SHEG: Sleep hygiene education group; LEOG: Lavender essential oil group; CSLG: Sleep hygiene education and Lavender essential oil combination group; ANOVA: Analysis of variance.
[†]ANOVA was performed with the F1-D1-F1 model; **ATS**: ANOVA-type test statistic; **ATS_{Mod}**: Modified ANOVA-type test statistic with Box approximation.

Adherence to sleep hygiene recommendations

Of the initial number of participants in the SHEG and CSLG, four were excluded from the analysis due to not following the sleep hygiene recommendation for more than half of the experimental days. However, the majority of participants in both groups demonstrated a high level of adherence to sleep hygiene recommendations. Specifically, 6 out of 8 participants in the SHEG and 8 out of 9 participants in the CSLG followed all seven sleep hygiene recommendations, achieving a 100% adherence rate (7/7). There were a few participants who did not fully adhere to specific recommendations, such as refraining from consuming caffeine before sleep and avoiding light-emitting technology devices at least 1 hour before sleep. The adherence rate for these participants was 71% (5/7). Overall, total adherence to the sleep hygiene recommendations across both groups was 82%.

Actigraphy-based sleep evaluation

Objective sleep indices are presented in Table 2. Statistical analysis reported a significant effect of group for sleep latency, with higher values in CG compared to SHEG ($p = 0.001$, 95% CI = 0.39 to 2, $d = 1.70$) and CSLG ($p = 0.012$, 95% CI = 0.15 to 1.71, $d = 1.22$). However, there is no significant effect of group for the other indices.

Hooper questionnaire

Hooper scores are presented in Table 3. There was a significant effect of time and an interaction between group and time for sleep scores. Sleep scores significantly improved from pre- to post- 7-days in SHEG ($p < 0.001$, 95% CI = 0.93 to 2.57, $d = 1.69$), LEOG ($p < 0.001$, 95% CI = 1.45 to 2.99, $d = 1.22$), and CSLG ($p < 0.001$, 95% CI = 1.45 to 2.99, $d = 2.69$). Sleep score in CG post- 7-days was significantly higher compared to SHEG ($p = 0.002$, 95% CI = 0.61 to 3.74, $d = 1.86$) and CSLG ($p < 0.001$, 95% CI = 0.92 to 3.95, $d = 2.19$), indicating poorer sleep quality in the CG. There was a significant main effect of time and an interaction between group and time for the HI. HI values significantly decreased in SHEG ($p = 0.048$, 95% CI = -0.3 to 5.8, $d = 0.96$) and CSLG ($p = 0.027$, 95% CI = 0.82 to 7.85, $d = 1.23$) at post-compared to pre-intervention. Additionally, HI in CG post-intervention was significantly higher compared to CSLG ($p = 0.026$, 95% CI = 1.64 to 8.9, $d = 1.4$). Additionally, significant main effects of group and time were found for fatigue scores without an interaction between group and time. Subsequent post-hoc test indicated no statistically significant differences. Furthermore, statistical analysis revealed no significant effect of group, time, or interaction between group for stress and muscle soreness scores.

BRUMS questionnaire

BRUMS scores are presented in Table 4. There was a significant effect of time and an interaction between group and time for fatigue score. Fatigue score significantly decreased from pre- to post-intervention in CSLG ($p = 0.009$, 95% CI = 2.18 to 9.6 A.U., $d = 1.59$). However, statistical analysis showed no significant effect of group, time, or interaction between group and time for the other scores.

Discussion

This study aimed to investigate the effects of a single session of SHE and LEO inhalation over a 7-day period of late-evening resistance training sessions on actigraphy-based sleep quality, well-being, and mood state indices in trained athletes. The main results revealed (i) the objective measure of SL was significantly better in SHEG and CSLG compared to CG, (ii) the subjective sleep quality score improved in SHEG, LEOG, and CSLG after the intervention period, and (iii) the sleep score was significantly worse in CG compared to the other groups after the intervention. Moreover, HI decreased in the SHEG and CSLG after the 7-day period and was higher in the CG vs. CSLG at the post-intervention assessment. Additionally, subjective fatigue scores improved in the CSLG after the intervention.

The results of our study highlight the potential benefits of SHE in improving SL among trained athletes practicing resistance training during the night. SL refers to the time it takes for an individual to fall asleep after getting into bed, and a shorter SL indicates an easier and quicker transition into sleep. In the present study, SL values were significantly lower in both SHEG and the CSLG ($d = 1.7$ and 1.22 , respectively) compared to the CG. These findings suggest implementing SHE, even in a single session, can be an effective strategy for reducing SL in athletes. Furthermore, subjective sleep score significantly improved in the SHEG, LEOG, and CSLG ($1.22 \leq d \leq 2.69$) and was significantly better in SHEG and CSLG ($d = 1.86$ and 2.19 , respectively) compared to CG at post-intervention.

The influence of SHE on sleep quality and quantity has been studied across various populations, although there is limited research specifically focused on athletes.^{47,48} Recently, two studies investigated the effect of SHE on middle-aged swimmers⁴⁹ and youth elite rugby union players.¹⁵ Dunican, Perry⁴⁹ revealed no effect of SHE intervention during 16-week training programme on both sleep quality and quantity for the nights after evening training. Contrarywise, Vachon, Sauvet¹⁵ demonstrated SHE improved sleep quality (i.e., SL and SE), but not quantity. However, previous studies have shown SHE could have the potential to improve sleep duration and subsequently enhance performance in

athletes.^{5,17,50} Nédélec, Halson³⁶ highlighted several factors, such as cognitive features and sleep environment, that are strongly associated with inadequate SH among elite soccer players. Harada, Wada⁵¹ found athletes experienced longer SL and poorer sleep quality during one month of SHE intervention. Conversely, Lastella, Roach¹⁴ emphasized the positive effects of implementing SHE on both sleep quantity and quality in athletes. Furthermore, athletes themselves acknowledged the potential influence of improved sleep guidance on their performance.⁵²

In the context of acute SHE sessions implemented after training or match play, the focus has primarily been on enhancing the quantity of sleep rather than its quality, as observed in various populations and settings.^{53,54} Fullagar¹⁷ conducted a study involving soccer players and investigated the effects of an acute SHE session, which included controlled room temperature, lighting, and restricted use of technological devices before bedtime, following a late-night competition. The study reported a significant improvement in sleep quantity of the players. Similarly, other studies show acute SHE sessions improve TTB and sleep quantity among athletes, with no significant impact on other objective sleep measures such as SL and SE.^{9,55}

These findings from our study partially align with previous research,¹⁶ as we observed significant changes only in SL and not in measures of sleep quality or quantity. The SHE recommendations we used were based on Nédélec, Halson,³⁶ which identified effective strategies for improving sleep in soccer players. We purposely did not enforce a set bedtime to avoid disturbing participants' usual sleep routines. This may be why we did not observe differences in sleep quality between the groups. However, our SHE strategy did have a positive impact on SL, resulting in a 37% lower SL in the SHEG compared to the CG. This finding is supported by a recent study, reporting an acute SHE session enhanced SL but may have sustained effects on other sleep parameters, emphasizing the need for ongoing support and reinforcement of sleep hygiene strategies in athletes.¹⁶ Further, O'Donnell and Driller⁹ found similar results, indicating that most sleep studies using SHE showed similar sleep quality but varied results in SL. SL improvement may be related to the timing of training, as it could have affected athletes' core temperatures, thereby delaying the sleep onset time (SOT) and lowering SE percentages. Contradictory to our results, Caia, Scott¹⁸ demonstrated SL did not improve in professional rugby players across a two-week intervention period involving SHE. They noted that, even though the SHE session encouraged athletes to have an earlier bedtime, the actual SOT was delayed, resulting in a lower percentage of SE.¹⁸

In the present study, no significant effect was observed regarding the influence of inhaling LEO on sleep quality. Our findings suggest the SL value in the LEOG was slightly higher than in the SHEG and CSLG, although the difference was not statistically significant. However, it was also slightly lower than in the CG, again without statistical significance. This suggests any potential effect on SL in the CSLG was likely due to adherence to the SHE recommendations, rather than the LEO inhalation. Moreover, no significant effects of LEO inhalation were found on any of the actigraphy-based sleep indices. These results are consistent with prior research reporting inconclusive findings regarding the effectiveness of EOs in enhancing sleep. Lin, Lee⁵⁶ conducted a meta-analysis on non-patient participants and reported overall heterogeneity between studies, indicating the lack of consistent evidence supporting the effectiveness of aromatherapy in improving sleep. The non-significant findings in our study suggest inhaling LEO may not have a substantial impact on objective sleep measures. It is important to consider individual variability in response to aromatherapy and the complexity of factors influencing sleep quality. Further research is needed to better understand the potential benefits and limitations of using EOs for sleep enhancement, considering factors such as dosage, timing, and individual preferences. The effects of EOs inhalation on sleep quality have been studied in different populations. Several studies conducted on different populations report a reduction in SL and an improvement in overall sleep quality with EO inhalation.^{28,57} Specifically, it has been found that one to three inhalations of EO before bedtime were more effective than continuous indirect inhalation over a 24-hour period.²⁸ Other studies have also explored the positive effects of aromatherapy on sleep quality,^{31,58} although the exact mechanisms of action are not yet fully understood. Further, LEO is often recommended over other EOs due its potential sleep-inducing effects and safety (i.e., low risk of adverse effects).^{28,30} LEO has been found to not only improve sleep quality but also have beneficial effects of LEO on many clinical conditions (e.g., anxiety, depression, fatigue, and stress).^{31,59} In a study examining the effects of LEO inhalation for one night, improvements were observed in sleep quality, TTB, and SE, but not in SL, in healthy participants.⁵⁸

In terms of evaluating the wellness index and mood states before and after the 7-day intervention period, the HI decreased in the SHEG ($d = 0.96$) and CSLG ($d = 1.23$) and was significantly lower in the CSLG compared to the CG post-intervention ($d = 1.4$), suggesting the combined effect of SHE and LEO inhalation had a positive impact on the participants' well-being. Additionally, the fatigue score assessed by the BRUMS questionnaire decreased significantly in the CSLG ($d = 1.59$). Conversely, the SHEG and LEOG did not show significant decreases in fatigue scores, indicating the observed decrease in the CSLG was primarily influenced by the effects of LEO inhalation rather than the SHE intervention.

A previous review showed varied effects of SHE on athlete fatigue levels.⁶⁰ Studies found SHE interventions led to fewer awakenings and lower fatigue levels.¹⁹ SHE also improves sleep architecture, increasing deep and restorative sleep, leading to rejuvenation and reduced fatigue.⁶¹ Moreover, SHE includes strategies for managing stress and anxiety, benefiting both sleep quality and psychological well-being. Irwin, Cole⁶² demonstrated reduced distress and fatigue with SHE interventions.

Moreover, recent studies showed EO inhalation influenced fatigue scores.^{63,64} LEO inhalation can lead to a decrease in fatigue through various mechanisms. Firstly, LEO possesses anxiolytic properties (anxiety-reducing). This can contribute to a decrease in fatigue, as anxiety and fatigue often coexist. LEO inhalation may reduce anxiety and improve mood, promoting relaxation and a sense of calmness.⁶⁵ Additionally, the aromatherapeutic effects of LEO could have a significant impact on fatigue reduction. When inhaled, LEO stimulates the olfactory system, which in turn activates the limbic system in the brain responsible for emotions and mood regulation.⁶⁶ This activation could induce a sense of calmness, relaxation, and overall well-being, thereby reducing fatigue.⁶⁷ Neurophysiologically, LEO modulates the activity of neurotransmitters and receptors in the central nervous system. For example, LEO has been shown to interact with gamma-aminobutyric acid (GABA) receptors, which have an inhibitory effect on the nervous system, promoting relaxation and calmness; animal studies demonstrate LEO inhalation increases the expression of GABA receptors, further supporting its potential fatigue-reducing effects.⁶⁸ Furthermore, the anti-inflammatory properties of LEO may contribute to fatigue reduction. Chronic fatigue is often associated with underlying inflammation, and LEO has been found to possess anti-inflammatory properties.⁶⁹ Inhalation of LEO decreases the production of inflammatory cytokines in human subjects, suggesting its potential for reducing inflammation associated with fatigue.⁷⁰

This study represents a pioneering effort to assess the effectiveness of LEO inhalation on sleep quality in athletes, particularly those who engage in late-evening training sessions. The lack of significant results may be attributed to individual variations in response to EOs. Indeed, it has been previously suggested that the variability in individuals' sensitivities to aromatherapy treatments could potentially impact the outcomes of the study.⁷¹ In this context, a prolonged utilization of aromatherapy has been associated with a potential decrease in olfactory receptor sensitivity, resulting in diminished individual responsiveness and subsequently reducing the therapeutic impact of the aroma.⁷¹ To gain a more comprehensive understanding of the contrasting effects, future research should consider stratifying participants based on their response to EO inhalation.

Considerations when interpreting these results include the study's duration, which may not have been sufficient to capture long-term changes in sleep quality. Additionally, it is important to explore the impact of different training content on physiological parameters such as blood pressure. For instance, investigating the effects of isometric training, dynamic training, and endurance training on blood pressure changes could provide valuable insights into their potential counter effects. The recommended dose of LEO inhalation in this study was two drops (0.14 mL) for a duration of 10 minutes before sleep. It is worth considering that this dosage may not have been sufficient to significantly improve sleep quality. Further research is necessary to fully understand the effects of EOs on sleep in athletes. Future investigations should focus on optimizing EO selection and accounting for individual variations in response. Conducting larger studies with longer intervention periods could yield more conclusive results on the impact of LEO inhalation on athletes' sleep quality. Finally, it is important to explore different doses and timings of EOs. For sleep assessment, the use of polysomnography, which is universally identified as the gold standard method for sleep monitoring, is warranted.⁷²

Conclusion

Combining an acute SHE session with LEO inhalation yielded greater improvements in sleep quality, overall wellness, and fatigue scores compared to using them separately. The findings provided further corroboration for the positive effects of SHE and LEO inhalation on sleep pattern, mood states, and wellness, with the combined intervention showing a greater impact. While the statistical results in this study cannot be generalized, the multiple significant outcomes and their associated effect sizes may have two implications. Firstly, in accordance with Fisher's original statistics,⁷³ the significant findings warrant further research in this direction. Secondly, the synergistic effects of SHE and LEO could potentially serve as a safe and effective strategy for improving sleep quality and well-being indices in athletes following late-evening resistance training sessions.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki, and the protocol received full approval from the Ethical Committee for the Protection of Southern Persons (CPP SUD N° 0520/2023) on 31st May 2023 and was registered at the Pan African Clinical Trial Registry (PACTR202306806244897) on 09th June 2023.

Consent to participate

Prior to their inclusion in the study, all participants received comprehensive verbal and written instructions that explained the procedures and potential risks involved. They were also informed of their right to withdraw from the trial at any point.

Data availability

Zenodo: <https://doi.org/10.5281/zenodo.11066092>.⁷⁴

Data are available under the terms of the [Creative Commons Attribution 4.0 International license \(CC-BY 4.0\)](#).

Extended data

Trial protocol: Zenodo: <https://doi.org/10.5281/zenodo.11575185>.⁷⁵

CONSORT Checklist: Zenodo: <https://doi.org/10.5281/zenodo.11368563>.⁷⁶

CONSORT FlowChart: Zenodo: <https://doi.org/10.5281/zenodo.11577279>.⁷⁷

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Martha J Greenberg 

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This is a very good article on " the effects of a single Sleep Hygiene Education combined with nightly Lavender Essential Oil inhalation for 7 days of late-evening resistance training sessions on sleep quality and mood states in trained athletes."

My two criticisms are:

- The sample size is the very small $n=42$ even though the author states that an n of 32 would be adequate.
- There is no specific section on limitations-I suggest that one be created and populated with them.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Aromatherapy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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