Effects of Lemongrass (*Cymbopogon citratus*) Essential Oil Inhalation on Cognitive Performance and Mood in Healthy Women

นิพนธ์ต้นฉบับ

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Original Article

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บทคัดย่อ

วัตถุประสงค์: เพื่อประเมินผลของการสูดดมน้ำมันหอมระเหยตะไคร้ต่อการรู้คิดและภาวะอารมณ์ในอาสาสมัครหญิงที่มีสุขภาพดี **วิธีการศึกษา:** ผู้ร่วมทดลองกลุ่มละ 30 คนสูดดมน้ำมันหอมระเหยตะไคร้หรือน้ำมันหลอก (inactive control oil) เป็นเวลา 5 นาที โดยที่มีการประเมินการรู้คิดโดยใช้ชุดแบบทดสอบทางคอมพิวเตอร์และภาวะอารมณ์โดยใช้แบบประเมินให้คะแนนด้วยตนเอง รวมทั้งวัดความดันโลหิตและอัตราการเต้นของหัวใจทั้งก่อนและหลังการสูดดมน้ำมันหอมระเหย ความแตกต่างของคะแนนการรู้คิด ภาวะอารมณ์ ระดับความดันโลหิตและอัตราการเต้นของหัวใจได้รับการวิเคราะห์และทดสอบด้วย independent *t*-test **ผลการศึกษา:** หลังการสูดดมน้ำมันหอมระเหยตะไคร้ ผู้ร่วมทดลองมีคะแนนของการรู้คิดดีขึ้นในด้านความต่อเนื่องของความสนใจและคุณภาพของความจำ (*P*-value = 0.013 และ 0.026 ตามลำดับ) ส่วนภาวะอารมณ์ในแง่ความตื่นตัวและความสงบก็มีคะแนนเพิ่มขึ้นเมื่อเปรียบเทียบกับกลุ่มควบคุม (*P*-value = 0.001 และ 0.035 ตามลำดับ) อย่างไรก็ตามการเปลี่ยนแปลงความดันโลหิตและอัตราการเต้นของหัวใจไม่แตกต่างกันในทั้งสองกลุ่ม **สรุป:** การสูดดมน้ำมันหอมระเหยตะไคร้ช่วยเพิ่มการรู้คิดและภาวะอารมณ์ของผู้หญิงที่มีสุขภาพดีโดยที่ไม่มีผลต่อสภาวะทางสรีรวิทยา อย่างไรก็ตามควรมีการศึกษาเพิ่มเติมเกี่ยวกับกลไกการออกฤทธิ์ของน้ำมันหอมระเหยตะไคร้ที่ให้ผลบวกนี้ต่อไป

คำสำคัญ: *Cymbopogon citratus,* ตะไคร้, น้ำมันหอมระเหย, การรู้คิด, ภาวะอารมณ์

Abstract

Objective: To evaluate the effects of inhalation of lemongrass (*Cymbopogon citratus*) essential oil on the cognitive function and mood in healthy female volunteers. **Methods:** All 30 participants of each group were required to inhale either lemongrass essential oil or a placebo (inactive control oil) for five minutes. Before and after the 5-minuite inhalation period, their cognitive function was assessed with a computerized battery of tests and the mood with a self-rated visual analogue; the blood pressure and heart rate were also measured. Differences in the cognitive function, mood, blood pressure and heart rate between the two groups were analyzed and tested using an independent *t*-test. **Results:** After the inhalation, the lemongrass essential oil enhanced their cognitive performance for the domains of the continuity of attention and the quality of memory (*P*-value = 0.013 and 0.026, respectively), whereas the mood in terms of alertness and calmness was also increased (*P*-value = 0.001 and 0.035, respectively). However, no significant change in the blood pressure and heart rate was observed. **Conclusion:** The lemongrass essential oil inhalation could improve the cognitive function and modulate mood of healthy women with no effect on the physiological status. However, the underlying mechanisms of these positive effects still require further studies.

Keywords: *Cymbopogon citratus,* lemongrass, essential oil, cognitive performance, mood

Introduction

Recently, alternative strategies to improve life performance have come to the fore. A number of complementary therapies, especially aromatherapy, are currently employed in the management of various medical conditions including anxiety, depression, insomnia and stress-related disorders. Aromatherapy uses essential oils in various applications including inhalation, massage and baths to alter mood, cognition, and psychological and/or physical well-being. The sense of smell begins when odor molecules bind to the olfactory receptors in the nasal passage. Nerve impulses pass along the olfactory nerve to the olfactory bulb, primary olfactory cortex and limbic system, particularly the hippocampus and amygdaloid body. It is interesting to note that the hippocampus as well as amygdaloid body are brain areas that are related to cognitive performance, emotion and emotional memory.[1] Animal studies indicated that some essential oils produce pharmacological effects on behavior, effects similar to those of central nervous system drugs.[2-4] It is also well known that aroma inhalation causes physiological and psychological alterations in humans.[5] Previous studies have demonstrated that different types of aroma produce significant changes in brain waves, blood pressure, heart rate and respiratory rate.[6,7] In addition, accumulating lines of evidence have reported that some essential oils such as lavender and rosemary exert beneficial effects on cognitive function and mood.[8,9]

Lemongrass (*Cymbopogon citratus*), a plant of Poaceae family, has long been used in Thailand for cooking and medical purposes. This plant exerts beneficial properties such as anti-inflammatory, antifungal,[10] antinociceptive[11] and antioxidant effects.[12] Animal studies show that lemongrass essential oil has anti-anxiety, sedative and anticonvulsive effects.[13,14] A recent human study demonstrated that lemongrass essential oil inhalation exerts anxiolytic effects and reduces subjective tension in male participants who are exposed to an experimental anxiogenic situation.[15] However, the effects of lemongrass essential oil inhalation on the nervous system, particularly as a cognitive enhancer and mood modulator in young female participants, have not been studied. Therefore, we set up this experiment to elucidate this issue. Specifically, we aimed to compare cognitive functions (power of attention, continuity of attention, quality of memory, and speed of memory), mood (alertness, calmness and contentment), and physiological function (diastolic blood pressure, systolic blood pressure, and heart rate) between those inhaling lemongrass essential oil and placebo oil post-inhalation.

Methods

Participants

Sixty healthy female volunteers (mean age ± SD: 20.52 ± 0.60, age range: 20 – 22 years) took part in this experiment, all of whom provided written informed consent. This study was approved by the Human Ethics Committee of the University of Phayao (5701040001). Participants were excluded if they had significant visual impairment, motor impairment, cognitive impairment, or underlying health problem (e.g. allergy, respiratory tract infection, sinusitis, a cold, hypertension or cardiac disorder). Participants with a history of drug abuse, alcohol abuse or prescribed/non-prescribed drug regimen(s) were excluded. In addition, participants who regularly consumed nutraceutical compounds known to influence the function of the nervous system were also excluded. If a participant was with her menstruation, she was asked to wait until her period was passed before participating. All participants were asked not to consume caffeine or alcohol for 12 hours before participating.

Preparation of lemongrass essential oil and placebo oils

The lemongrass essential oil was purchased from Botanicessence, Bangkok, Thailand. It was extracted from lemongrass fresh leaves using a hydrodistillation method. As verified by our preliminary study (data not shown), extra virgin coconut oil obtained from a drug store was used as the placebo. Before testing, one drop (50 µL) of lemongrass essential oil or coconut oil was placed in an amber glass bottle containing sterilized cotton. The bottle was then promptly closed and remained closed until the experimental procedure began.

Analysis of the lemongrass essential oil component

The organic compounds of the lemongrass essential oil were analyzed using gas chromatography–mass spectrometry (GC–MS) which was provided by the Scientific and Technological Instruments Center of Mae Fah Luang University. The GC–MS analysis was performed according to the following conditions. The capillary column (HP-5 ms) was used with the flow rate of 1 ml/min. The oven temperature of the gas chromatograph was set at 40 – 240 °C. Hexane was used as the solvent. The temperature of the injector and detector was set at 250 °C and 230 °C, respectively. The mass spectrometer was set to determine a molecular weight range of 20 – 300. The components were identified by their fragmentation patterns of mass spectra compared with data from the National Institute of Standards and Technology Mass Spectra database (NIST08). The identified constituents of the lemongrass essential oil determined by GC–MS are shown in Table 1. The two main chemical components of the lemongrass essential oil were geranial (28.31%) and neral (26.15%). The other compounds that were found are in a lesser amount.

Procedures

Participants in this double-blinded study were assigned to the lemongrass or placebo group using randomized numbers generated by a computer. The evaluation of cognition was assessed using a cognitive computerized battery of tests while mood state was assessed using a self-rated mood visual analogue scale. The assessments of cognitive function and mood state were performed prior to the trial and immediately after completing the 5-minuite inhalation period. After being randomly assigned to the lemongrass or placebo group, each participant inhaled lemongrass essential oil or a placebo for 5

minutes in a quiet experimental room. Immediately after the 5-minute duration, the cognitive performance and mood state of the participants were assessed again. In addition, the alterations of blood pressure and heart rate were monitored before (baseline) and after the 5-minuite inhalation period. The age, bodyweight, height, body mass index (BMI) and grade point average (GPA) of all participants were also recorded.

Table 1 Main chemical constituents of lemongrass essential oil determined by GC–MS.

Identified constituents	Area (%)	Retention time (min)
Geranial	28.31	20.36
Neral	26.15	19.50
2,6-Octadiene, 1,1-diethoxy-3,7-dimethyl	10.26	24.33
2-Butenoic acid	7.66	23.68
Geraniol	2.86	22.75
Bicyclo hexan-3-ol	2.48	17.03
Linalool	2.28	14.63
Naphthalene	1.80	26.03
Geranyllinalool	1.59	36.32
Geranylgeraniol	1.23	36.79
3-Cyclopentene-1-acetaldehyde, 2,2,3-trimethyl	1.05	11.16
Caryophyllene oxide	1.04	27.71
Camphene	0.92	9.90
Citronellal	0.78	16.10
Phenol	0.66	24.58
Cyclohexanemethanol	0.64	26.89
Bicyclo[2.2.2]octane	0.59	16.47
3-Methyl-2-butenal	0.58	18.16
Eucalyptol	0.56	12.39
4-Nonanone	0.49	13.66

Cognitive computerized battery of tests

The cognitive computerized battery of tests used in this study was modified from the cognitive drug research computerized test battery that has been widely used to assess the cognitive function. This test is comprised of a battery of cognitive tasks sensitive to the effect of psychopharmacological substances. All tasks in the battery were computer-controlled and displayed on high-resolution monitors. The responses were recorded via yes/no buttons. The participants completed the selected battery in approximately 20 minutes. The cognitive tests were administered in the following order.

1) Word presentation: Fifteen words were presented consecutively on the monitor, each for 1 second, with an inter-stimulus interval of 1 second. The participants were required to memorize these words.

2) Picture presentation: Twenty pictures were presented consecutively on the monitor at a rate of 1 every 3 seconds, with an inter-stimulus duration of 1 second. The participants were required to memorize these pictures.

3) Simple reaction time: The word ‘yes’ was presented on a monitor with an inter-stimulus interval at a random rate between 1 and 3.5 seconds. The participants were instructed to press the ‘yes’ button as quickly as possible when they observed the word ‘yes.’ Their reaction time was recorded in milliseconds.

4) Digit vigilance task: A target digit was randomly selected between 0 and 9. It was persistently displayed on the right side of a monitor. A series of other random digits (also between 0 and 9) were then displayed in the center of the screen at the rate of 80 digits per minute. The participants were instructed to press the ‘yes’ button as quickly as possible every time the digit in the random series matched the target digit. The task lasted approximately 1 minute and there were 15 stimulus matches. The reaction time in milliseconds and the accuracy percentage were recorded.

5) Choice reaction time: Either the word ‘yes’ or ‘no’ was displayed on a monitor. The participants were required to press a ‘yes’ or ‘no’ button as quickly as possible when a stimulus ‘yes’ or ‘no’ appeared on the monitor. There were 50 trials during which the stimulus ‘yes’ or ‘no’ was randomly displayed (with equal probability). The inter-stimulus interval randomly varied between 1 and 3.5 seconds. The reaction time in milliseconds and the accuracy percentage were recorded.

6) Spatial working memory: A graphical representation of a house was presented on a screen with four of its nine windows lit. The participants were instructed to memorize the position of the illuminated windows. In 36 subsequent presentations of the house, one of the windows was illuminated and the participants had to decide whether or not the lit window was one of the lit windows in the original presentation. The participants made their response by pressing a ‘yes’ or ‘no’ button as quickly as possible. The mean reaction times in milliseconds and the accuracy percentage were recorded.

7) Numeric working memory: Five numbers were presented on the monitor at a rate of one number per second. A series of 30 numbers were then presented. The participants

had to decide if each of the 30 numbers was in the original series of five numbers as quickly as possible. Their responses were recorded with a 'yes' or 'no' button. The mean reaction time in milliseconds and the accuracy percentage were recorded.

8) Delayed word recognition: Fifteen words that were originally presented to the participants (see 1 above) were again presented to the participants. However, this time these words were randomly mixed with 15 new words. For each word in the newly created set of 30 words, the participants were asked to indicate if each one was included in the original set by pressing a 'yes' or 'no' button as quickly as possible. The mean reaction time in responding to all 30 words was recorded. The accuracy percentage (percentage of a score on 30) was also recorded.

9) Delayed picture recognition: Fourteen original pictures that were originally presented to the participants (see 2 above) were again presented to the participants. However, this time they were randomly mixed with six new pictures. For each picture in the newly created set of 20 pictures, the participants were asked to indicate if each one was included in the original set by pressing a 'yes' or 'no' button as quickly as possible. The mean reaction time in responding to all 20 pictures was recorded. The accuracy percentage (percentage of a score on 20) was also recorded.

To minimize any learning effect in assessing working memory, the set of words and pictures to which participants were exposed before the inhalation were different from those after inhalation. However, it was insured that the difficulty level of the words and pictures for each participant was comparable.

As demonstrated by Peth-Nui and colleagues,[16] we grouped the various outcomes of cognitive functions listed above into four domains, namely, power of attention, continuity of attention, quality of memory, and speed of memory. **Power of attention** is defined as attention and psychomotor/information processing speed measured by summing reaction times in milliseconds of three attentional tasks including digit vigilance, simple reaction time, and choice reaction time. **Continuity of attention** is a prolonged focus measured by summing the accuracy percentage of digit vigilance and choice reaction time. More specifically, 100 percent accuracy across the two tasks would result in a maximum score of 200. **Quality of memory** is defined as the capability to accurately recall various stimuli measured by summing the accuracy percentage of delayed word recognition, delayed picture recognition, spatial working memory, and numeric working memory. One hundred percent accuracy across the four tasks would generate a maximum score of 400. **Speed of memory** is the response speed in milliseconds to various stimuli measured by summing the reaction times of the delayed word recognition, delayed picture recognition, numeric working memory and spatial working memory tasks.

Mood visual analogue scale

This questionnaire is a subjective measurement consisting of 16 items each on a 10-cm visual analog scale with antonyms anchoring the endpoints of each scale. Participants responded by indicating a subjective position between the antonyms on the scale. The obtained mood scores were separated into three factors specifically alertness, calmness and contentment.[17] The alertness factor consisted of the following items: alert–drowsy, attentive–dreamy, lethargic–energetic, muzzy–clearheaded, well coordinated–clumsy, mentally slow–quick witted, strong–feeble, interested–bored and incompetent–proficient. Items of calmness factor included calm–excited and tense–relaxed. Finally, the contentment factor included contented–discontented, troubled–tranquil, happy–sad, antagonistic–friendly and withdrawn–sociable.

Physiological assessment

The blood pressure and heart rate of each respondent were measured using an automatic blood pressure monitor (Omron HEM-7200^{TM}) at the baseline and immediately after essential oil inhalation.

Statistical analysis

Data were presented as mean $\pm$ SD. An independent t-test was used to compare each measure of cognitive function, mood and physiological function between the placebo and lemongrass-treated groups at pre- and post-inhalation. Statistical significance was regarded at P-value < 0.05.

Results

Characteristics of participants

The personal information of participants in both groups is shown in Table 2. No significant differences in mean age,

bodyweight, height, BMI and cumulative GPA between the groups were observed.

Table 2 Demographic information of participants (N = 60).

Characteristic	Mean ± SD by groups		*t*-test	*P*-value
	Placebo (n = 30)	Lemongrass (n = 30		
Age (years)	20.53 ± 0.63	20.50 ± 0.57	0.215	0.831
Bodyweight (kg)	55.90 ± 14.22	56.20 ± 12.45	-0.087	0.931
Height (cm)	160.03 ± 5.71	160.17 ± 5.50	-0.092	0.927
BMI (kg/m^2)	21.76 ± 5.00	21.81 ± 4.13	-0.041	0.968
Cumulative GPA	2.39 ± 0.23	2.42 ± 0.262	-0.346	0.731

Note: GPA = grade point average; BMI = body mass index.

Effect of lemongrass essential oil inhalation on cognitive performance

There was no cross-group significant difference found in any of the cognitive function baseline measures. The baseline and post-inhalation scores of cognitive performance measurements are presented in Table 3. The results revealed that immediately after completing 5-minute inhalation, participants who inhaled lemongrass essential oil performed better than the placebo group in the domains of continuity of attention and the quality of memory with statistical significance (*P*-value = 0.013 and 0.026, respectively). However, the lemongrass inhalation failed to produce a significant difference in the domains of power of attention and speed of memory.

Table 3 Effects of lemongrass essential oil inhalation on cognitive function assessed by cognitive computerized assessment battery test (N = 60).

Cognitive domain	Time	Mean ± SD by groups		*t*-test	*P*-value
		Placebo (n = 30)	Lemongrass (n = 30)		
Power of attention	Baseline	1804.77 ± 240.70	1836.47 ± 262.20	-0.488	0.628
	After	1735.03 ± 218.23	1768.07 ± 215.73	-0.590	0.558
Continuity of attention	Baseline	195.70 ± 4.56	196.33 ± 3.33	-0.615	0.541
	After	196.60 ± 3.29	198.53 ± 2.52	-2.559	**0.013**
Quality of memory	Baseline	367.60 ± 21.30	368.87 ± 26.69	-0.203	0.840
	After	373.27 ± 15.10	380.63 ± 8.99	-2.295	**0.026**
Speed of memory	Baseline	5136.83 ± 1017.88	5040.30 ± 576.28	0.452	0.653
	After	4500.90 ± 734.72	4453.40 ± 661.56	0.263	0.793

Effect of lemongrass essential oil inhalation on mood

Scores obtained from the mood visual analogue scale are presented in Table 4. Scores of each mood index at baseline of the two groups were statistically different. After the inhalation, however, participants who inhaled lemongrass essential oil reported significantly higher scores on alertness and calmness (*P*-value = 0.001 and 0.035, respectively) but not contentment.

Table 4 Effects of lemongrass essential oil inhalation on mood assessed by mood visual analogue scale (N = 60).

Mood index	Time	Mean ± SD by groups		*t*-test	*P*-value
		Placebo (n = 30)	Lemongrass (n = 30)		
Alertness	Baseline	6.24 ± 0.78	6.30 ± 0.81	-0.267	0.790
	After	6.34 ± 0.84	7.01 ± 0.64**	-3.486	**0.001**
Calmness	Baseline	6.27 ± 0.98	6.03 ± 0.87	0.975	0.334
	After	6.33 ± 0.82	6.72 ± 0.50*	-2.176	**0.035**
Contentment	Baseline	7.57 ± 0.56	7.51 ± 0.58	0.364	0.717
	After	7.47 ± 0.85	7.57 ± 0.61	-0.557	0.580

Effect of lemongrass essential oil inhalation on physiological status – blood pressure and heart rate

Blood pressure and heart rate were assessed as a baseline (pre-dose) and immediately after the essential oil inhalation. As shown in Table 5, there were no significant changes in both systolic and diastolic blood pressures between groups both at baseline and after inhalation. In addition, no significant differences of heart rate were found between the two groups at both time points.

Table 5 Effects of lemongrass essential oil inhalation on the alterations of blood pressure and heart rate (N = 60).

Measures	Time	Mean ± SD by groups		*t*-test	*P*-value
		Placebo (n = 30)	Lemongrass (n = 30)		
Systolic pressure (mmHg)	Baseline	106.57 ± 8.68	108.90 ± 9.36	-1.001	0.321
	After	105.17 ± 9.29	106.53 ± 9.13	-0.575	0.568
Diastolic pressure (mmHg)	Baseline	68.93 ± 8.38	66.97 ± 9.17	0.867	0.390
	After	68.70 ± 8.80	66.20 ± 6.88	1.226	0.225
Heart rate (beats/min)	Baseline	85.87 ± 7.38	84.73 ± 8.94	0.536	0.594
	After	85.30 ± 10.43	84.73 ± 7.81	0.238	0.813

Discussions and Conclusion

In this study, we focused on cognitive enhancement, mood modulation and physiological effects of lemongrass essential oil inhalation compared with placebo in healthy female adolescents. The results showed that lemongrass essential oil improved cognitive function in the domains of the continuity (or accuracy) of attention and the quality of memory, both evaluated via a cognitive computerized assessment battery test. The participants who inhaled the lemongrass essential oil also reported higher self-alertness and calmness assessed via

mood visual analogue scale. However, no significant difference was found between the two groups regarding the physiological parameters, i.e., blood pressure and heart rate.

The sense of smell starts when odor molecules bind to olfactory receptors. The chemical signals are then transduced into electrical signals and sent to areas of the brain through the olfactory bulb. The sense of smell is transmitted from the olfactory bulb to the amygdala and entorhinal cortex.[18] The prefrontal cortex of the brain, particularly the orbitofrontal cortex, and the limbic system, particularly the hypothalamus, amygdala and hippocampus have pivotal roles in cognitive function.[19] Functional magnetic resonance imaging (fMRI) evidence indicates that the amygdala and hippocampus are the areas of the brain that are responsible for emotional memory and odor-evoked memory.[20] Previous studies suggested that the prefrontal cortex plays an important role with respect to working memory.[21] Working memory is a process of the brain that allows for both the temporary storage and use of a limited amount of information for cognitive tasks. Working memory involves a central executive system that controls attention, manipulates visual images as well as stores and rehearses speech-based information.[22] Interestingly, it was demonstrated that working memory is associated with dopamine in prefrontal neurons.[23] Dopamine is a neurotransmitter that helps working memory. It was also found that prefrontal dopamine levels gradually increase when participants perform a working memory task.[24] In addition, other neurotransmitters including norepinephrine,[25] serotonin,[26] and acetylcholine[27] also play a role on working memory. Taken together, the cognitive enhancing effect of lemongrass essential oil inhalation may occur due to two possible mechanisms including (1) the strengthening of neural connection between the prefrontal cortex and related brain areas, and/or (2) the enhancement of neurotransmitters mentioned earlier. However, we left the identification of which mechanism for future researchers.

Even though there are protocols outlining the use of essential oil to improve mood, there is scant scientific information regarding the effect of lemongrass on mood. The results of mood in the present study showed that lemongrass essential oil inhalation increased calmness, a similar outcome to a previous study reporting that lemongrass essential oil inhalation reduced anxiety and subjective tension in male volunteers.[15] However, the proportion of subject gender in our study and the previous works was different. Additionally, the outcome measurements of the previous works were focused on psychological parameters (state anxiety, subjective tension, tranquilization, and sedation) and physiologic parameters (heart rate and gastrocnemius electromyogram activity) but not on cognitive performance.

One study demonstrated that the oral administration of lemongrass essential oil produced a sedative effect in mice.[14] Since a sedative effect is related to calmness,[5] we anticipated that lemongrass essential oil would exert a calming effect on our participants. Nevertheless, our study adds value to the literature regarding the effects of lemongrass since our subject pool, method of administrating lemongrass and dependent variables are different from previous research.

In addition, the participants who inhaled the lemongrass essential oil reported an increased level of alertness. Alertness is an aroused state that includes sustaining attention as well as orienting a response.[28] Therefore, we suggested that alertness induced by lemongrass essential oil inhalation would be related to the mechanisms that control arousal such as the sleep-waking system and the hormonal system, particularly hypothalamo–pituitary–adrenal axis.

Previous studies have also demonstrated that the improvement of mood is associated with improved cognitive functioning.[8,29] Ashby and colleagues reported that positive mood is associated with increased brain dopamine levels and influences olfaction as well as working memory.[30] In addition, Mitchell and Phillips suggested that the prefrontal cortex plays an important role in integrating mood with the executive function.[31] The amygdala both receives the olfaction signal from the olfactory bulb and plays a role in emotion as well as affective cognition.[32] Thus, increased alertness and calmness might modulate cognitive function partly due to the strengthening of neurotransmitter levels in the prefrontal cortex and neural connections with the amygdala. However, this possible mechanism remains to be investigated.

Our results are in accordance with the study of Tildesley and coworkers,[8] they found that the oral administration of sage *(Salvia lavandulaefolia)* exerted the acute modulation of mood and cognition in healthy young adults. Specifically, *Salvia lavandulaefolia* essential oil enhanced “speed of memory” and “quality of memory,” and also improved all mood factors (alertness, calmness and contentment). Although the cognitive results of the present study showed inhaling lemongrass essential oil enhanced the cognitive performance in the domains of “continuity of attention” and “the quality of memory”

but failed to improve the domains of “power of attention” and “speed of memory.” In addition to cognitive results, the inhalation of lemongrass essential oil improved self-alertness and calmness but not contentment. However, the routes of administration and the observation time of our work and the previous work are different.

It is well known that the inhalation of an aroma leads the body to respond in at least two different ways. First, a pharmacological effect involves the interaction between an aroma molecule and its receptor. Second, a psychological effect involves a subjective experience to the aroma.[5] Due to the activation on the nervous system, particularly the autonomic nervous system, both pharmacological and psychological effects can alter one’s physiological status. The physiological effect of an aroma can be assessed using measurements such as blood pressure and heart rate. An increase in blood pressure and heart rate indicates a stimulating effect whereas a decrease in blood pressure and heart rate indicates a sedative effect of the autonomic nervous system.[33] We did not find that the inhalation of lemongrass essential oil had either one of these effects. It is interesting to note that such effects were reported using lavender and rosemary oils.[6,7,34] However, the simultaneous recording system used to measure the effects of lavender and rosemary was more sophisticated than the simple automatic apparatus used in this study. Therefore, the assessment method could have limited our ability to identify any physiological effect. Recently, Kamkean and coworkers reported that participants between 18 – 75 years old who received a massage with lemongrass oil in a 3-week program showed a greater reduction in diastolic blood pressure.[35] However, the routes of essential oil administration, age range of participants and the time of assessment in the previous study and the present study are different. Therefore, these three factors might explain the difference between our results and those of Kamkean.

The pharmacological effect of an essential oil requires the absorption of volatile compounds into the bloodstream, resulting in the stimulation of neurons. However, we did not investigate the absorption of an essential oil in this study. Nevertheless, the data obtained from GC–MS analysis showed that the lemongrass essential oil was composed mainly of geranial and neral. This chemical composition is similar to that found in a previous study on lemongrass tea, in which the tea exerted an anxiolytic and sedative effect in mice.[14] We suggest further investigation to clarify whether the active components in lemongrass oil that produce positive effects in this study are geranial and neral.

It is well recognized that female sex hormones (especially estrogen) play an important role on cognitive function.[36] In order to avoid the effect of estrogen on cognitive performance in female participants, we performed the test when the participants were not having their menstrual period. This concern is one advantage of our study. In addition, we were also concerned about the difference in the individual intelligence of participants. The reason we set the desired cumulative GPA threshold between 2.00 - 2.50 was because we wanted to limit our sample of participants to those who could demonstrate improved cognitive performance. Gender and age may also influence cognitive function. More specifically, previous studies have demonstrated that in adulthood, males are superior at visuospatial and motor tasks whereas females are better in social cognition and recognition memory.[37,38] It is also well known that older adults have poorer cognitive function than young adults.[39] However, to reduce error in the experiment, we focused on young healthy female adults. We also determined the effects of lemongrass essential oil inhalation on three essential parameters including pharmacological (cognitive function), psychological (mood) and physiological (blood pressure and heart rate) effects. These various parameters are important to include because they help clarify the types of odors that have either an advantageous or disadvantageous effect on physiological function. Even though a simple automatic tool used in evaluating blood pressure is not as accurate or reliable as sphygmomanometer and stethoscope in auscultatory method, the cognitive computerized assessment battery test and mood visual analogue scale are suitable to test cognitive function and mood state as implemented by previous studies.[8,9,16,17,29]

In conclusion, lemongrass essential oil improved cognitive performance and modulated mood in healthy female participants. This study provides a scientific basis for further research on the use of lemongrass essential oil as a cognitive enhancer and mood modulator.

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