



Clinical trial

Effects of aromatherapy on stress, fructosamine, fatigue, and sleep quality in prediabetic middle-aged women: A randomised controlled trial

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ABSTRACT

Introduction: Although there has been an overall increase in life expectancy, the rise in chronic diseases poses a threat to healthy life expectancy. In particular, individuals with chronic diseases such as diabetes, stress, fatigue, postmenopausal accumulation of abdominal fat, insulin resistance, and insomnia are likely to have a poorer quality of life. This study aimed to investigate whether aromatherapy (inhalation and massage) could affect levels of stress, blood glucose, fatigue, and sleep quality in middle-aged prediabetic women.

Methods: This was a randomized controlled trial. In this study, prediabetic middle-aged women, aged 40–65-years old, with a fasting blood glucose or HbA1c level of 100 mg/dL–126 mg/dL or 5.5–6.4%, respectively, were included. The experimental treatment consisted of direct inhalation of aroma essential oil and self-massage with 3% massage oil for two weeks, as prescribed by an international aromatherapist. To determine the effects of treatment, subjective stress, objective stress index, fructosamine, fatigue, and sleep quality were measured. Differences in stress response, sleep quality, and fatigue over time and between the two groups were analysed using repeated measures ANOVA and Student's t-tests.

Results: Subjective stress did not significantly differ between the two groups after one week but became significantly different after two weeks ($t = -3.78, p = .001$). After the treatment, there were significant changes in fructosamine ($t = -3.53, p = .001$), fatigue ($t = -4.12, p = .001$), and sleep quality ($t = 6.27, p < .001$).

Conclusion: The study suggests that aroma inhalation and self-abdominal massage may help manage blood sugar, fatigue and improve sleep quality in pre-diabetic women.

1. Introduction

As life expectancy has increased with increased standard of living and advances in medicine, there is a growing interest in the quality of life [1]. According to a 2014 report, life expectancy in the Republic of Korea has been consistently rising annually, with a projected mean expected age of 79.8 years for men and 86.3 years for women by 2030. However, with a concomitant rise in chronic diseases, this life expectancy increase does not necessarily mean increase healthy life expectancy. Midlife management of health is critical for a healthy life in late adulthood.

Stress refers to a nonspecific body response caused by factors that pose a physical burden [2]. Midlife in particular is a period characterized by substantial changes, where middle-aged women experience menopause and various mental and physical symptoms [3,4].

Middle-aged women perceive such environmental changes as stress, which increases their stress index [5], and stress symptoms tend to increase with increasing subjective stress perception [5]. Stress is also known to be associated with metabolic syndrome. Particularly, it is one of the cardio-cerebrovascular risk factors in middle-aged women [6]. In middle-aged women, the prevalence of metabolic syndrome increases as they experience menopause, which is attributable to the accumulation of abdominal fat and insulin resistance [7]. In a study that explored the factors that diminished quality of life in middle-aged women, stress, hypsomnia, and metabolic syndrome were associated with a low quality of life [7].

Stress has a direct impact on fatigue and may result in sleep disorders in middle-aged women [8]. In middle-aged women, fatigue increases with an increasing stress score. Further, middle-aged women may develop sleep disorder caused by physical and mental changes as

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they undergo neuroendocrine changes during menopause [8]. Stress is one of the factors that have the greatest impact on fatigue, and sleep quality is related to fatigue. Further, stress is associated with blood glucose and sleep quality [8], and thus, stress, blood glucose, fatigue, and sleep quality are mutually related in middle-aged women. Therefore, measures to lower stress, blood glucose, and fatigue while enhancing sleep quality are crucial for maintaining health in middle-aged women.

Aromatherapy is one of the several treatment modalities that could be used to improve sleep quality. Aromatherapy has been reported to reduce stress [9] and fatigue while boosting sleep quality. This study aimed to investigate the effects of specific essential oils known to alleviate stress, improve sleep, and lower blood glucose. Aromatherapy was administered through inhalation and abdominal massage to prolong its effects. Lavender, geranium, cinnamon, grapefruit, neroli, and ylang ylang were chosen as the essential oils for aromatherapy. Lavender has stabilization and sedation effects [10], and geranium has hormone-regulating effects [11]. Cinnamon regulates blood glucose [12], and grapefruit facilitates diuretic effects [13]. Neroli alleviates stress [14], and ylang ylang treats palpitations and reduces high blood pressure [15].

Women are physiologically exposed to menopause at middle age and experience various mental and physical symptoms. These changes act as stressors and result in various consequences in the organism through internal processes. Increasing stress is known to increase cortisol and eventually glucose. In diabetic patients, it acts as a factor that can worsen blood glucose. Although there are many studies of stress and cortisol, studies that measure stress and glucose have been difficult to find. Therefore, a study was conducted to reduce stress and to observe the changes in blood glucose through aromatherapy intervention. It is highly challenging to understand and measure the relationship between stress and blood glucose levels because these levels are altered by several factors, including stress situation, diet, and changes in circadian rhythm. In particular, although it is possible to determine blood glucose levels using glucose monitors or serum tests, these measured levels are affected by multiple factors, and it is difficult to determine continuous blood glucose levels. Thus, the American Diabetes Association (ADA) suggests that fructosamine may be a useful alternative in the absence of a reliable glycated haemoglobin measurement [16]. A fructosamine test can be performed 2–3 weeks after treatment to test the mean blood sugar level [17]. Unlike glycated haemoglobin, which represents the average blood glucose concentration during a period of two to three months [16], glycated plasma proteins, such as fructosamine, represent the average glucose concentration during a 2–3 week period [18]. The aim of this study was to verify the effects of aromatherapy on stress, fructosamine, fatigue, and sleep quality in prediabetic middle-aged women, with an ultimate goal to explore whether such a nursing intervention may be an option to maintain a healthier mid-adulthood.

2. Method

The study was approved by the institutional review board (IRB) at Eulji University Hospital before the study was conducted (IRB No: EMC2018-05-009-002).

2.1. Study design

This study was a randomized controlled trial and conducted as shown in Fig. 1.

2.2. Study participants

The inclusion criteria of the subjects were middle-aged women aged 40 to 65 years, who met the pre-diabetic level, and the pre-diabetic criteria were fasting glucose 100 mg / dL to 126 mg / dL or HbA1c 5.5

to 6.4% [19]. The exclusion criteria were those who were taking medications that could affect sleep quality and fatigue, those who have had side effects from aroma essential oils, those who have been diagnosed with diabetes and who are currently being given diabetes oral drugs and insulin injections.

The sample size was computed using the G-Power 3.1.9 software (<http://www.gpower.hhu.de/>, Heinrich Heine university, Düsseldorf, Germany) after entering significance level, power, and effect size. For *t*-test for two groups with a significance level α of 0.05, power (1- β) of .80, and effect size of 0.726, the required sample size was 31 for the intervention group and 31 for the control group. Effect size was computed based on the results of a previous study on aroma oil inhalation in middle-aged women. Considering a 10% dropout rate, we recruited 68 participants. The candidates were recruited through the recruitment announcement, and the recruitment announcement was approved by the Institutional review board. Before the public announcement, it was approved by Eulji University Hospital belonging to the researcher and attached to the designated bulletin board. The announcement period was maintained for two weeks and the total number of applicants was 68. One participant was excluded for taking diabetes medication, and two were excluded for having a HbA1c of 6.5% or higher. Sixty-five participants were randomly assigned and for the randomization, excel function was used to generate random numbers, and participants were randomized according to the order of recruitment. During the study, one participant in the intervention group withdrew due to discomfort with blood drawing, and two participants were withdrawn for not attending their 1-week follow-up appointment. Thus, there were a total of 31 participants in the intervention group and 31 in the control group. The study flow diagram is shown in Fig. 2.

2.3. Outcomes

2.3.1. Primary outcomes

2.3.1.1. Subjective stress. Subjective stress level was measured using the numeric rating scale (NRS). The NRS is a horizontal line with 0 (no stress at all) on the leftmost side and 10 on the rightmost side (extremely high stress). The intervals in between 0 and 10 are consistent, and the subjective stress score refers to participants' reported level of stress on the NRS. A higher score indicates a higher degree of stress.

2.3.1.2. Objective stress index. Objective stress index was measured using an autonomic nervous system monitor known as Canopy 9 RSA (IEMBIO, Gangwondo, Korea). The level of stress according to autonomic nervous balance was quantified via standard lead based on the measured heart rate variability. From an index of 1–10, a higher score indicates a higher level of stress.

2.3.1.3. Fructosamine. Blood was sampled (3 ml) into serum separator tubes, centrifuged, and submitted to the G laboratory for analysis. The analytical reagent used for the fructosamine test was “Fruc”, and the “Modular analytics (manufacturer: Roche, Germany)” was used for the analysis. Enzyme colorimetry was performed. The specimens, sent to the G laboratory for analysis, were stored for two weeks following analysis before being discarded. For tests that examined the average blood glucose levels in a short period, the reference value for non-diabetics is 205–285 $\mu\text{mol/L}$ [17]. An increase indicates an elevation of average blood glucose levels and a decrease in value indicates a reduction of average blood glucose levels.

2.3.2. Secondary outcomes

2.3.2.1. Fatigue. Fatigue was quantified using the NRS. The NRS consisted of a line with 0 in the left end (No fatigue) to 10 in the right end (Extremely high fatigue). A higher score indicates a higher level of fatigue.

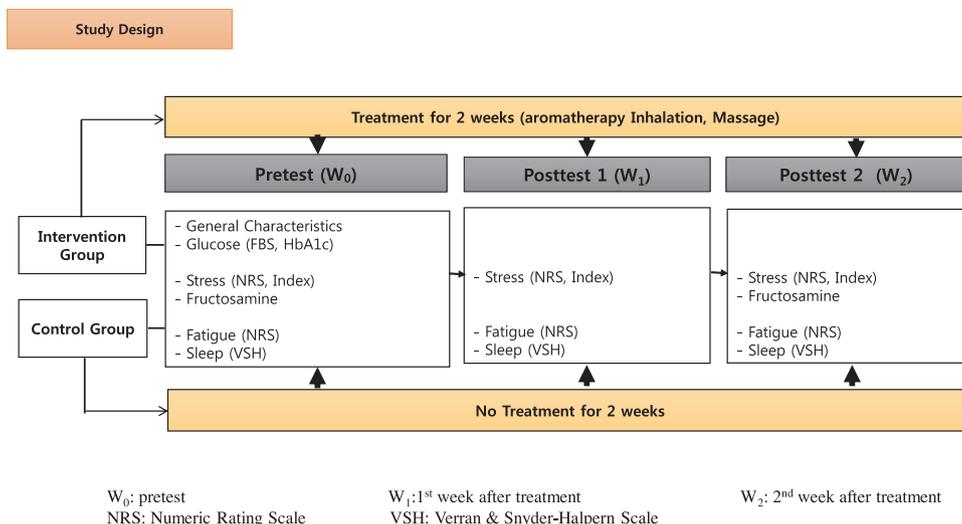


Fig. 1. Study design.

2.3.2.2. *Sleep quality.* In the present study, sleep referred to the perceived quality of sleep, and it was measured using the Korean version of the Verran & Snyder-Halpern Scale (VSH). Permission to use VSH was obtained from professor Verran Joyce, the developer, via e-mail. The VSH is an eight-item scale in four domains, with each item rated on a 10-point scale. The total score ranges from 0–80. A higher score indicates a higher quality of sleep. The Cronbach's α was .82 for the reliability of the instrument at the time of VSH development [20].

The reliability of the tool as measured with Cronbach's α in this study before experimental treatment, one week after treatment, and two weeks after treatment were .827, .828, and .888, respectively.

2.4. Experimental treatment

The experimental treatment consisted of aromatherapy. The details of the treatment are described below.

2.4.1. Research assistant preparation

One research assistant was in charge of each of the following: random allocation of subjects, blood sampling and measuring vital signs, and video production to train subjects about essential oil inhalation and self-abdominal massage. The research assistants were instructed to familiarize themselves with the pre-experimental procedures and precautions prior to the study. The research assistant in charge of instructing subjects about inhalation and massage participated in the

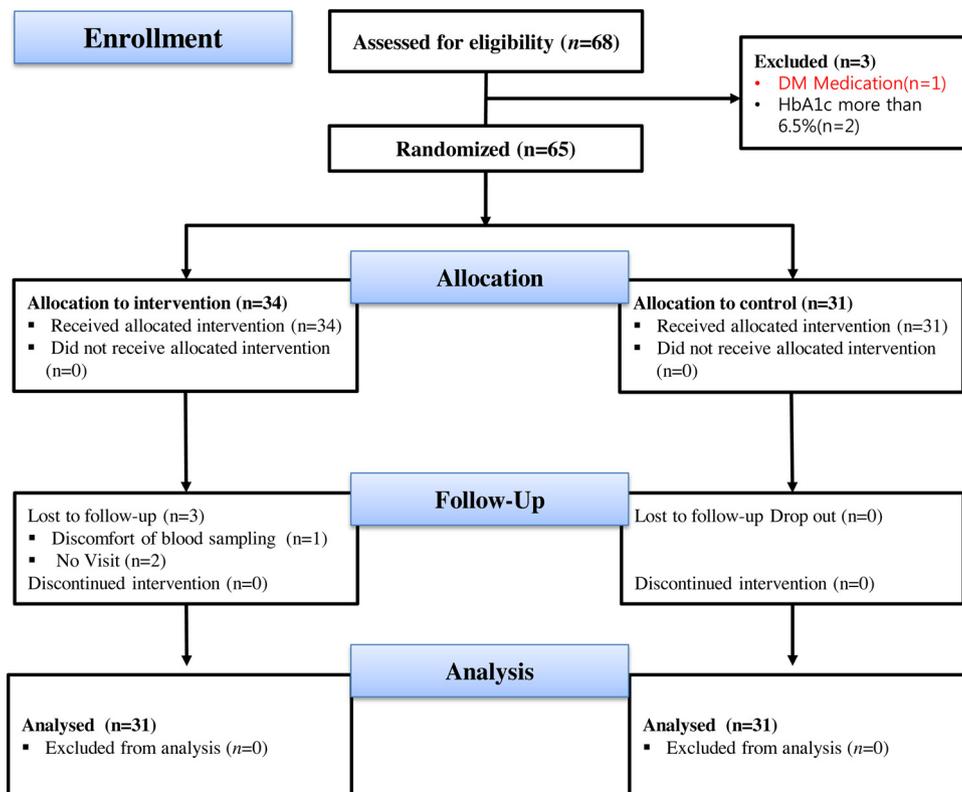


Fig. 2. Flow diagram of the study.

production of the self-abdominal massage video. Research assistants were also taught about the purpose and rationale, experimental treatments and precautions, completion of questionnaires, instructions for the participants, potential adverse events and subsequent actions, and consent forms.

2.4.2. Aroma essential oil preparation

Aroma oil used in this study was prescribed by an international aromatherapist and professor with extended research experience in aromatherapy. The blending of the prepared oils was carried out at the Eulji University Hospital's education room, considering that there are windows, which are well ventilated, and where there is little human travel. In order to minimize the exposure of oil, this researcher and one research assistant were blended, and after blending, they were subdivided into the shading bottle and labeled for inhalation and massage.

Per the prescription, lavender, geranium, cinnamon, grapefruit, neroli, and ylang ylang were blended in a 6:3:3:3:1:3 ratio for inhalation. For abdominal massage, the same essential oil (30 ml) was blended in 970 ml of almond oil to prepare a 3% massage oil. We used organic aroma oil by Neumond (Raisting, Germany, website: <https://www.neumond.de/>) to ensure safety for participants.

2.4.3. Administration of experimental treatment

The intervention consisted of essential oil inhalation and self-abdominal massage. After the pre-test, explanations were provided on how to perform the inhalation and self-abdominal massage, and participants watched the instructional video. The intervention group performed inhalation and self-abdominal massage every day for two weeks, as this has been shown to be effective [21]. The intervention duration of two weeks was based on the findings that clary sage oil inhalation reduced stress in middle-aged women [22] and that abdominal essential oil massage effectively reduced abdominal fat [23].

An aroma necklace for day and night inhalation to prevent fatigue among participants was used. This necklace is portable and close to the nose, enabling continuous inhalation.

2.4.3.1. Aroma essential oil inhalation. We used lavender and ylang ylang oil for stress- and fatigue-relieving effects and cinnamon oil, which is known to be involved in blood glucose and lipid metabolism. The oils were blended per the prescription and stored in a refrigerator until use. For inhalation, the aroma necklace was used during the day and night. The necklace was filled with the blended oil using a dropper, and the necklace was refilled after one or two weeks if needed. The volume of the initial fill was about 1 ml.

Because the one inhalation of essential oil persists only for about 3–6 h after inhalation, we instructed the patients to wear the necklace throughout the day. The length of the necklace was designed to be 20 cm based on the previous study that a 20-cm necklace was effective for lowering stress in nursing students [24]. The participants were taught how to adjust the length of the necklace. The intervention group inhaled essential oil, while the control group did not.

2.4.3.2. Aroma essential oil self-abdominal massage. The intervention group performed self-abdominal massage, and the control group maintained their routine activity. The abdominal massage was designed as a 9-step massage. An instructional video and pictures for a detailed explanation of each step were provided via a QR code. The participants were able to watch the video at home using the QR code.

Participants were instructed to perform massage once a day, preferably before going to bed, and not to take a shower or bath after the massage. The massage was designed to last for 15–20 min based on a previous finding that a 20-minute abdominal essential oil massage effectively reduced abdominal fat [23].

Essential oil for the abdominal massage was diluted to 3% and about 20 drops of oil were used for each abdominal massage. A 10 ml brown bottle was filled with a suitable volume to last for about 1 week and

given to the participants. They were asked to return with the bottle to refill and a self-recorded massage diary to ensure compliance. Education to ensure safe use of aroma oil included information about storage, relevant precautions, especially avoiding eye contact, potential adverse reactions, and remedies.

2.5. Data collection

Data were collected from August 1 to October 31, 2018. Participants were recruited through a recruitment announcement. For random allocation of subjects, random numbers were created, using the excel function, and placed in a covered envelope. The participants were randomly allocated in the order of recruitment. Participants who agreed to participate filled out the informed consent form and were informed that they needed to provide consent voluntarily and that they could withdraw from the study at any point. Per the inclusion criteria, fasting glucose and HbA1c measurements were taken to screen for prediabetic women. As a part of the pre-test, the objective stress level was measured using the Canopy 9 (IEMBIO, Gangwon-do, Korea). Vital signs (blood pressure and pulse) were taken and subjective stress (NRS), fatigue (NRS), and sleep quality (VSH) were measured using a questionnaire. Blood was sampled to measure blood glucose.

Post-test was performed for both groups twice; 1 week and 2 weeks after the experimental treatment. Blood samples were only taken 2 weeks after the intervention to measure blood glucose level. Objective stress was measured using Canopy 9 RSA, and stress, fatigue, and sleep quality were measured.

It is difficult to control these exogenous variables because changes in glucose are sensitive to diet and activity. Therefore, we tried to measure the average blood sugar level for 2 weeks, so we measured the fructosamine. Among the dependent variables, stress and blood collection were maintained at the same time as the pre-measured time, and measured after 10 min of stability to maintain a stable state before measurement. The place was measured in the training room at the time when there was no education.

After all measurements, the participants were given their pre-intervention HbA1c and blood glucose readings and, if desired, the laboratory test report was provided. After the study, the control group was also taught about the same aromatherapy and was provided the aroma oil and instructional materials.

2.6. Data analysis

The collected data were statistically processed using the SPSS software for window version 24.0. Participants' demographics were analysed with real number, percentage, mean, and standard deviation. Homogeneity of the general characteristics between the two groups before the intervention was analysed with *t*-test, Chi-square test, and Fisher's exact test. Homogeneity of the dependent variables between the two groups before the intervention was analysed with the *t*-test. Internal consistency of the VSH was analysed using Cronbach's α . The differences in stress response, sleep quality, and fatigue over time in the intervention and control groups were analysed with repeated measures ANOVA. The results of the ANOVA were tested for the assumption of sphericity and homogeneity of variance. If they were not satisfied, multivariate analysis of variance (MANOVA) was performed to check for Wilk's lambda. The effects size of the experimental treatment was assessed using partial η^2 . Differences in fructosamine after the intervention in both groups were analysed with the *t*-test. Statistical significance (p-value) was set at 0.05 for all analyses.

3. Results

3.1. Characteristics of participants

A total of 62 participants were enrolled in this study; 31 in the

Table 1
Homogeneity test of General Characteristics between two Groups (N = 62).

Characteristics	Intervention Group (n = 31) Mean ± SD or n (%)	Control Group (n = 31) Mean ± SD or n (%)	t or χ^2	p
Age (yr)	50.39 ± 6.17	51.39 ± 5.97	0.81	0.422
Educational level				
High school	15 (48.4)	12 (38.7)	1.89	0.424
University	9 (29.0)	7 (22.6)		
Graduate school	7 (22.6)	12 (38.7)		
Menopause				
Yes	16 (51.6)	17 (54.8)	0.06	0.799
No	15 (48.4)	14 (45.2)		
HbA1c(%)	5.58 ± 0.22	5.70 ± 0.61	-1.07	0.287
FBS(mg/dl)	104.74 ± 10.23	105.23 ± 7.54	-0.21	0.833
Stress				
Subjective Stress (NRS)	6.65 ± 1.49	6.42 ± 1.78	0.54	.591
Objective Stress (Index)	7.03 ± 2.21	7.90 ± 1.81	-1.69	.095
Fructosamine ($\mu\text{mol/L}$)	245.35 ± 18.80	254.74 ± 24.82	-1.68	.098
Subjective Fatigue (NRS)	7.03 ± 1.42	6.39 ± 1.64	1.64	.104
Sleep (VSH)	45.38 ± 14.43	45.96 ± 12.30	-0.17	.865

Mean ± SD = Mean ± Standard Deviation. FBS = Fasting Blood Sugar

intervention group and 31 in the control group. The mean ages were 50.39 and 51.39 years for the intervention and control group, respectively. There were no significant differences in age, education, menopause status, pre HbA1c, and pre fasting blood sugar between two groups (Table 1).

A *t*-test was performed to check for homogeneity of dependent variables between the two groups. There were no significant differences in subjective stress, objective stress, subjective fatigue, sleep quality, and serum fructosamine between the two groups (Table 1).

3.2. Effects of aromatherapy on stress

For the intervention group, the subjective stress score was 6.65 ± 1.49 , 6.00 ± 1.63 , and 5.65 ± 1.53 , before, one week after, and two weeks after the intervention, respectively. For the control group, the subjective stress score was 6.42 ± 1.78 , 6.26 ± 1.59 , and 7.23 ± 1.74 , before, one week after, and two weeks after the intervention, respectively. The two groups differed in subjective stress only after two weeks of intervention ($t = -3.78$, $p = .001$). There was a significant time and group interaction effect ($F = 8.324$, $p < .001$), the effect size of aromatherapy essential oil on stress, the partial η^2 was 0.122.

For the intervention group, the objective stress score was 7.03 ± 2.21 , 6.81 ± 2.19 , and 6.65 ± 1.83 before, one week after, and two weeks after the intervention, respectively. For the control group, the objective stress score was 7.90 ± 1.81 , 7.19 ± 1.75 , and 7.52 ± 2.04 , respectively. The time and group interaction effect were not significant (Table 2)

3.3. Effects of aromatherapy on serum fructosamine

Significant differences in serum fructosamine levels at 2 weeks after intervention were observed; $236.06 \pm 18.17 \mu\text{mol/L}$ and $256.19 \pm 26.07 \mu\text{mol/L}$ for the intervention and control groups, respectively ($t = -3.53$, $p = .001$). There was a significant time and group interaction effect ($F = 6.618$, $p = .013$) (Table 2). Subgroup analysis according to menopause showed significant difference in fructosamine between intervention group and control group (Table 2). The effect size of aromatherapy essential oil on fructosamine, the partial η^2 was 0.099.

3.4. Effects of aromatherapy on fatigue

A significant difference in fatigue at 2 weeks after intervention was observed; 5.52 ± 1.36 and 7.10 ± 1.64 for the intervention and control groups, respectively ($t = -4.12$, $p = .001$). There was a significant time and group interaction effect ($F = 9.594$, $p = .001$) (Table 2). The effect size of aromatherapy essential oil on fatigue, the partial η^2 was 0.138.

3.5. Effects of aromatherapy on sleep quality

A significant difference in sleep quality at 2 weeks after intervention was observed; 60.41 ± 9.13 and 45.10 ± 9.70 for the intervention and control groups, respectively ($t = 6.27$, $p < .001$). There was a significant time and group interaction effect ($F = 15.430$, $p < .001$) (Table 2). The effect size of aromatherapy essential oil on sleep quality, the partial η^2 was 0.343.

4. Discussion

This study investigated the effects of aromatherapy on stress, serum fructosamine, fatigue, and sleep quality in middle-aged prediabetic women, to provide foundational data for the application of aromatherapy as a nursing intervention in practice. Based on these results, the effects of nursing intervention and relevant implications are discussed below.

4.1. Effects of aromatherapy on stress response

The subjective stress level, objective stress index were measured and analysed before, 1 week after, and 2 weeks after the intervention. The two groups significantly differed in subjective stress, but not in objective stress index.

Homogeneity of the baseline stress level was established prior to the intervention. The two groups significantly differed in subjective stress only at two weeks after the intervention, with the intervention group having a significantly lower subjective stress score than the control group. However, objective stress parameters, namely stress index, were not significantly different between the two groups regardless of the intervention duration. The stress reduction effect was effective only after two weeks, and was inconsistent with the results of the objective indicators, thus limiting the results in this paper. Therefore, essential oil inhalation and self-abdominal massage were helpful in relieving subjective stress, although its effects on objective stress could not be confirmed. Some reports have shown aromatherapy is effective alleviating job stress [25], mental health [26], however, other studies have reported no significant changes.

We conclude that positive expectations for aromatherapy may influence its effects since only subjective stress was reduced. Furthermore, it is predicted that the effects of aromatherapy would differ according to the essential oils used, but we could not identify enough literature evidence to support this assumption.

Lavender and ylang ylang oils are known to have relaxing and sedating effects and can lower neural tension [26]. The linalool in lavender oil and ylang ylang's sedative properties seem to have contributed to reducing subjective stress. The active ingredients of lavender are linalyl acetate of the ester and linalool of monoterpene alcohol [10]. Linalool acts on the cerebral cortex to sedate brain cells and stabilize the brainwave meditation index, thereby effectively relieving stress [27]. Inhalation of aroma essential oil contributes to stabilizing and maintaining brain functions, as it decreases gamma waves, which are activated when the brain is stimulated, while increasing alpha waves, which are activated when the brain is at rest [28]. The familiar and pleasant scent of lavender likely contributed to the reduction in subjective stress reported by subjects.

Table 2
Comparison of stress, fructosamine, fatigue and sleep between two groups.

variable	Intervention Group (n = 31) Mean ± SD	Control Group (n = 31) Mean ± SD	t	p	F (p)	Sphericity test W(p)
Subjective Stress (NRS)						
Pre Stress Score (W ₀)	6.65 ± 1.49	6.42 ± 1.78	0.54	.591	Time 1.687 (.189)	0.933 (.129)
Post Stress Score (W ₁)	6.00 ± 1.63	6.26 ± 1.59	-0.63	.531	Group 2.823 (.098)	
Post Stress Score (W ₂)	5.65 ± 1.53	7.23 ± 1.74	-3.78	.001	G*T 8.324 (<.001)	
Objective Stress Index						
Pre Stress Index (W ₀)	7.03 ± 2.21	7.90 ± 1.81	-1.69	.095	Time 1.651 (.196)	0.985 (.637)
Post Stress Index (W ₁)	6.81 ± 2.19	7.19 ± 1.75	-0.77	.447	Group 3.280 (.075)	
Post Stress Index (W ₂)	6.65 ± 1.83	7.52 ± 2.04	-1.76	.083	G*T 0.515 (.599)	
Fructosamine(μmol/L)						
Pre Fructosamine (W ₀)	245.35 ± 18.80	254.74 ± 24.82	-1.68	.098	Time 3.524 (.065)	1.000 (>.999)
Post Fructosamine (W ₂)	236.06 ± 18.17	256.19 ± 26.07	-3.53	.001	Group 7.902 (.007)	
					G*T 6.618 (.013)	
Subgroup analysis(W ₂) < pre menopause >	226.27 ± 18.42	248.71 ± 28.38	-2.54	.001		
Subgroup analysis(W ₂) < post menopause >	245.25 ± 12.55	262.35 ± 23.02	-2.62	.001		
Fatigue (NRS)						
Pre Fatigue Score (W ₀)	7.03 ± 1.42	6.39 ± 1.64	1.64	.104	Time 1.746 (.179)	0.924 (.097)
Post Fatigue Score (W ₁)	6.10 ± 1.79	6.48 ± 1.69	-0.87	.386	Group 2.457 (.122)	
Post Fatigue Score (W ₂)	5.52 ± 1.36	7.10 ± 1.64	-4.12	.001	G*T 9.594 (.001)	
Sleep (VSH)						
Pre Sleep Score (W ₀)	45.38 ± 14.43	45.96 ± 12.30	-0.17	.865	Time 13.089 (<.001)	0.710 (<.001)
Post Sleep Score (W ₁)	54.69 ± 11.07	44.80 ± 9.94	3.69	<.001	Group 10.247 (<.002)	
Post Sleep Score (W ₂)	60.41 ± 9.13	45.10 ± 9.70	6.27	<.001	G*T 15.430 (<.001)	

Mean ± SD = Mean ± Standard Deviation.

4.2. Effects of aromatherapy on fructosamine

Changes in blood glucose levels were followed by measuring fructosamine levels for over two weeks after the intervention. Serum glycosylated proteins like fructosamine better reflect blood glucose levels in 2–3 weeks because they are metabolized faster than haemoglobin [17]. The baseline fructosamine levels were in the normal ranges (i.e., 205–285 μmol/L) for both the intervention and control groups.

The two groups did not significantly differ in their baseline fructosamine levels, but they did significantly differ in the post-test measurements. The intervention group had a fructosamine decrease of 9 μmol/L after the intervention. We selected cinnamon oil for its blood sugar-reducing effects [15], geranium for its hormone-regulating effects [11], and lavender, neroli, grapefruit, and ylang ylang oils for their stress-regulating properties. We chose cinnamon oil based on the findings that cinnamon cassia extracts regulate the Hypothalamic-Pituitary-Adrenal Axis [29], and cinnamon intake lowers HbA1c and fasting blood glucose in people with type 2 diabetes, prediabetes, and obesity [12,30]. In a rat study, Cinnamon extracts increased insulin secretion and improved blood glucose [31]. Cinnamon-derived components increased insulin activity, increased glucose utilization, and increased insulin receptor [32,33].

No previous study has examined the changes in blood glucose after aromatherapy; few studies have examined blood glucose changes after cinnamon extract intake, however, and the conclusions are conflicting. In a study involving 96 type 2 diabetics with HbA1c of ≥7.0%, cinnamon intake led to a reduction of HbA1c in patients who were unable to regulate their blood glucose [29]. Further, in another study involving 60 type 2 diabetics, cinnamon cassia supplement reduced fasting serum glucose (18–19%) [34]. However, other reports have shown that cinnamon intake does not improve HbA1c levels and fasting blood glucose in patients with types 1 and 2 diabetes [35,36].

As shown here, most studies examined the effects of oral cinnamon intake, not an essential oil. Therefore, our study could be the first suggesting the effects of lavender, geranium, cinnamon, grapefruit, neroli, and ylang ylang essential oil inhalation.

Women begin to accumulate body fat around 40 years of age due to changes in hormones related to menopause [6], during which they undergo metabolic changes leading to insulin resistance [37]. When stress is detected, insulin resistance causes cortisol to maintain an appropriate glucose level in the brain and muscles [38]. Middle-aged women may develop metabolic disorders after menopause due to insulin resistance caused by abdominal fat accumulation [37,39] and hormonal changes [40]. Several studies have reported that postmenopausal hormonal changes induce metabolic disorders [40], while others argued that aging-related changes, as opposed to menopause, is the major cause of metabolic disorder [37]. One common finding is that aging is associated with menopause and metabolic syndrome [7].

Therefore, we predicted that blood glucose variability would differ in relation to menopause in middle-aged women and, thus, performed a sub-group analysis for women according to menopause. The results showed that there were large changes in fructosamine levels in the intervention group among pre-menopausal women, but no significant changes in fructosamine levels among the postmenopausal women. However, we only had a small sample for this subgroup analysis, so additional studies with larger samples are needed to substantiate these results.

4.3. Effects of aromatherapy on fatigue and sleep quality

Participants' fatigue and sleep quality were measured three times; at baseline, 1 week, and 2 weeks after the intervention. After the intervention, the intervention group had a significant reduction of fatigue and a significant improvement of sleep quality compared with the control group.

These findings are in line with previous reports that foot reflexology significantly lowered fatigue score in elderly females [41]. Foot reflexology using lavender, peppermint, and pine significantly lowered fatigue in the intervention group among middle-aged women in rural areas [41], and that lavender and sweet orange oils reduced fatigue in patients undergoing haemodialysis [42]. Aromatherapy improved chronic pain and sleep score in community older adults [43]. Lavender

oil alleviated sleep disorder in middle-aged women [21], and lavender, marjoram, and ylang ylang inhalation reduced sleep disorder, while lavender improved sleep in patients with essential hypertension [44].

Linalool, a component of lavender, has sedative properties and has been used to relieve stress and sleep abnormalities for years [45]. Esters such as linalyl acetate, geraniol acetate and eugenol acetate found in aromatherapy essential oils have spasmolytic, muscle relaxation, and central nervous system stabilizing effects [10]. In the present study, the interaction between these two ingredients seems to have improved sleep quality.

Inhalation is the fastest method for absorbing oil into the body [13], and massage facilitates blood and lymph circulation by stimulating and relaxing muscles [26]. Most aroma essential oils warm the skin and can readily penetrate the blood because they are dissolved in fat [10]. Self-abdominal massage promotes blood circulation and metabolism, and the sedative and relaxing properties of lavender and ylang ylang help relieve psychological tension. Further, a massage before going to bed relaxes the body, thereby enhancing the quality of sleep.

In conclusion, we believe that inhalation and self-abdominal massage with essential oils, including lavender oil, have the potential of effective nursing interventions that reduce subjective stress and fatigue and improve sleep quality in pre-diabetic women.

A prolonged life expectancy and growing interests in life after mid-adulthood, the prevalence of chronic diseases is also consistently rising. Middle-aged women undergo various mental and physical changes as they age; therefore, this is a period requiring aggressive management. Active prevention is the best treatment for all diseases. Our study is meaningful in that it has identified the possibility of practical and feasible interventions that can be used routinely by pre-diabetic middle-aged women.

From a nursing research perspective, this study verified the effects of aromatherapy on subjective responses as well as blood glucose based on fructosamine levels. We substantiated the effects on high-risk pre-diabetic middle-aged women while maintaining their routine daily environment. Hence, our findings can be used as a nursing intervention.

From a nursing practice perspective, aroma oil inhalation and massage have been shown to improve sleep quality while reducing stress, blood sugar and fatigue. Therefore, our findings suggest that aromatherapy can be used as an active intervention for pre-diabetic middle-aged women to manage stress and fatigue, improve sleep quality, and prevent diabetes.

There were some limitations associated with the design and conduct of this study. First of all, the experimental treatment was self-massage, and although the performance was determined, the complete homogeneity of the experimental treatment could not be maintained. In addition, the influence of confounding variables such as daily stress and job stress could not be completely controlled, and complete concealment was impossible due to the nature of aromatherapy intervention. The physiological measurement time, which is a dependent variable, was attempted to maintain the same time zone as possible, but this was a limitation of this study because there was a case in which the same time was not maintained. Fortunately, glucose was used as an indicator to measure the average blood sugar for 2 weeks and was reflected in the results.

5. Conclusion

This study applied aromatherapy, with a blend of lavender, geranium, cinnamon, grapefruit, neroli, and ylang ylang oils in a 6:3:3:3:1:3 ratio, through inhalation and self-abdominal massage in middle-aged prediabetic women and found that their subjective stress, fructosamine, and fatigue were reduced, while sleep quality was improved. Based on these results and discussion, we make the following suggestions for subsequent studies examining the effects of aromatherapy in middle-aged women:

Various types and blending ratios of essential oils should be used.

Also, a standardized aroma essential oil regimen should be established.

Subsequent studies should examine the changes in dependent variables in relation to menopause in middle-aged women, and use a placebo group to eliminate the Hawthorne effect.

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CRedit authorship contribution statement

Myung-Haeng Hur: Conceptualization, Formal analysis, Funding acquisition, Writing - original draft. **Jun Hwa Hong:** Conceptualization, Data curation, Formal analysis, Writing - original draft. **SeongHee Yeo:** Conceptualization, Formal analysis, Funding acquisition, Writing - original draft.

Declaration of Competing Interest

The authors declare they have no conflict of interest.

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