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Effect of aromatherapy through inhalation of lavender oil on Heart Rate Variability and Perceived Stress Levels in Young Adults

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ABSTRACT

Introduction: Stress is a conserved physiological process which is essential for maintaining homeostasis amid environmental challenges. Chronic stress may disrupt autonomic balance and contributes to numerous physical and mental health disorders. Aromatherapy, particularly with lavender oil, is a promising non-pharmacological approach for stress reduction. Despite subjective reports of benefit, objective physiological evidence assessing autonomic modulation remains limited. This study explores the effects of 30 days inhalational lavender oil aromatherapy on autonomic function and perceived stress among adults with moderate stress.

Material and Methods: The study enrolled 34 participants with moderate stress. Participants underwent baseline assessment of perceived stress via questionnaires and HRV analysis was used to evaluate autonomic nervous system function. Participants then completes a 30 day period of lavender oil inhalation. Post-intervention evaluations of stress and HRV parameters were conducted. Statistical analyses compared pre- and post-intervention data to determine significant changes ($p < 0.05$ considered significant).

Results: Following aromatherapy, significant reductions in perceived stress scores were observed. Time-domain HRV parameters indicated increased parasympathetic activity, with significant increases in PNN50 and mean RR interval. Frequency-domain measures showed marked increases in high-frequency (HF) power and decreases in very low-frequency (VLF) absolute power. Moderate correlations between HRV parameters and stress scores at baseline were attenuated post-intervention, suggesting improved autonomic regulation and subjective stress alleviation.

Conclusion Thirty days of inhalational lavender oil aromatherapy effectively reduced perceived stress and enhanced autonomic nervous system function in adults with moderate stress. The intervention promoted parasympathetic dominance and improved HRV indices, representing a safe and promising non-pharmacological strategy for stress management. Further randomized controlled studies are warranted to confirm these findings.

KEYWORDS: Correlations Between HRV and Stress, Reduction in Perceived Stress.

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INTRODUCTION

Stress represents a basic and highly conserved physiological process which has evolved since time, enabling organisms to adapt, survive and sustain internal equilibrium also known as homeostasis even amidst extreme environmental changes. [1] This function remains vital for survival. The foundation of stress was first articulated by Claude Bernard in 1865, who introduced the term “milieu intérieur", translating to stable internal environment which is necessary to support optimal cellular and organ function. The theory emphasised on different variables such as temperature, nutrition and other environmental factors should remain constant for efficient physiological performance of the human body. Any changes in stability can disrupt essential life processes. Bernard’s contribution laid the groundwork for the scientific understanding that organisms are equipped with complex mechanisms to defend this stability.[2]

The modern conceptualization of stress as a distinct physiological and psychological response to real or perceived threats was crystallized by Hans Selye in 1936, who is widely regarded as the father of stress research. Selye’s definition of stress as “the non-specific response of the body to any demand for change” highlighted the universality of the stress response, regardless of the nature of the stressor.[3]

Given the profound impact of chronic stress on physical and mental health, there is a growing recognition of the need for effective, safe, and sustainable stress management interventions. Chronic stress is implicated in the pathogenesis of a myriad of conditions,

including hypertension, metabolic syndrome, depression, anxiety disorders, and immune dysregulation. While pharmacological agents such as anxiolytics, antidepressants, and beta-blockers offer symptomatic relief, their use is frequently associated with side effects, tolerance development, and potential dependency, rendering them unsuitable for long-term preventive application in healthy or moderately stressed individuals.[4]

As a result, non-pharmacological interventions including aromatherapy, psychological counseling, cognitive-behavioral therapy (CBT), physical exercise, yoga, time management training, and dietary modification are increasingly promoted as first-line strategies to enhance resilience, emotional well-being, and autonomic balance. These interventions target both the cognitive and physiological domains of stress, aiming to recalibrate the stress response systems without adverse effects.[5]

Within this context, aromatherapy, a branch of phytotherapy, has emerged as a popular and promising complementary modality for stress reduction. Aromatherapy involves the therapeutic application of essential oils (EOs) highly concentrated volatile extracts derived from aromatic plants which are administered via inhalation, topical application, or rarely, ingestion. These oils are complex mixtures of terpenes, alcohols, esters, aldehydes, and ketones, which possess various biological activities.[6]

Upon inhalation, the volatile constituents of EOs stimulate olfactory receptors located in the nasal cavity. These sensory neurons transmit signals directly to the olfactory bulb, which projects to the limbic system, particularly the amygdala, hippocampus, and hypothalamus brain regions critically involved in emotion processing, memory formation, and autonomic regulation. As such, EOs can potentially modulate neuroendocrine and autonomic responses, influencing stress perception and physiological reactivity.

Among the numerous essential oils studied, lavender oil (from Lavandula angustifolia) has demonstrated the most consistent anxiolytic, sedative, and stress-reducing effects in both experimental models and clinical populations. The principal active compounds responsible for these effects are believed to be linalool and linalyl acetate, which exhibit GABAergic activity modulation enhancing inhibitory neurotransmission in the brain and reducing central nervous system excitability.[7]

These compounds have also been shown to attenuate sympathetic nervous system activity, as evidenced by reductions in heart rate, blood pressure, and cortisol levels following lavender oil inhalation. The net result is a shift toward parasympathetic (rest-and-digest) dominance, promoting relaxation, reduced arousal, and improved autonomic function.

A robust and growing body of research including randomized controlled trials supports the efficacy of lavender oil in ameliorating symptoms of anxiety, depression, sleep disturbances, and perceived stress. For instance, inhalational lavender has been associated with reduced preoperative anxiety, improved sleep quality in patients with insomnia, and optimized cognitive performance under stress.[8]

Despite these promising findings, there remains a paucity of studies assessing the direct impact of lavender oil on objective physiological measures, such as those derived from AFT parameters. Most existing studies have focused on subjective self-reports or psychometric scales, which, although valuable, are susceptible to placebo effects, reporting bias, and individual variability. Consequently, there is an unmet need for well-designed trials that integrate subjective stress assessments with objective autonomic measurements, such as HRV, Valsalva ratio, and orthostatic responses, to elucidate the true physiological effects of aromatherapy.[9]

MATERIAL AND METHODS:

Study design: Single-group Pretest-Posttest Design
Study setting:
The study was conducted in Dept. of Physiology, Geetanjali Medical College, Udaipur, Rajasthan, India.
Study period:
The study was conducted from July 2022 to December 2023.
Study population:
Consenting adults aged 18 years or more and residents of Udaipur.

Inclusion Criteria:

- Individuals ≥ 18 years of age.
- Individuals with stress score between 14-26, obtained through perceived stress score
- Able to communicate in Hindi or English.

Exclusion Criteria:

- Participants who did not provide consent for the study.
- Those who had problems with olfactory function.
- Subjects with Systemic diseases like hypertension, endocrinal disorders, coronary artery disease
- Subjects with known allergies to aroma oils
- Subjects already on any kind of stress management therapies

Sample Size: 34 subjects

Sampling technique: It was a lab-based study with experimental design among adults who scored in the range of 14 to 26 on

Perceived stress score questionnaire.

RESULTS:

The majority of the participants were young adults and a slightly higher percentage of females were present in the study group as compared to males as mentioned in Table 1.

Participants receiving lavender oil aromatherapy had a mean age of 27.18 years and the mean BMI was also under normal range. This strengthens the validity of subsequent comparisons and ensures that observed effects can be confidently attributed to the aromatherapy intervention rather than pre-existing conditions (Table 2).

Effects on Heart Rate Variability (HRV): Aromatherapy led to a statistically significant improvement in several HRV parameters. Time domain HRV parameters reflected increased parasympathetic activity after aromatherapy with a significant increase in PNN50 and prolongation of mean RR interval. Frequency domain HRV indices also demonstrated a marked increase in HF power, a reduction in absolute VLF power and an increase in LF percent power (Table 3 - 5).

Correlations Between HRV and Stress

Prior to aromatherapy, stress scores showed moderate associations with certain HRV metrics (e.g., positive correlations with PNN50 and SDNN, and negative with LF/HF ratio), indicating that higher stress perception was loosely linked to greater variability and more balanced autonomic function, possibly reflecting compensatory mechanisms in moderately stressed adults. After the intervention, these relationships became weaker and less pronounced, with only mild associations remaining. This reduction in correlation strength suggests that aromatherapy may decouple subjective stress perception from physiological stress markers, reflecting a normalization of stress responses and better autonomic balance (table 6).

Reduction in Perceived Stress

Aromatherapy resulted in a pronounced decrease in perceived stress scores, underscoring the subjective benefits of lavender oil inhalation. This finding is strongly supported by clinical literature, which attributes lavender's anxiolytic and calming effects to both direct modulation of central neurochemical pathways and improvements in autonomic regulation (Table 7).

The majority of participants were young adults (18–30 years) and there was a slightly higher proportion of females than males, reflecting the typical demographic at risk for moderate stress in many clinical and occupational populations. This distribution supports the generalizability of findings, as young adults and women often report higher stress levels and may benefit disproportionately from non-pharmacological interventions.

Table 1: Distribution of participants according to age and gender

		Frequency	Percentage
Age Groups	**18 to 30 years**	21	61.76%
	30 to 40 years	11	32.35%
	>40 years	2	5.89%
Gender	**Male**	15	44.12%
	Female	19	55.88%

Table 2: Distribution of participants according to mean values of Age, Body Mass Index (BMI) and Stress score

Mean values	**Group L (n = 34)**
Age	27.18 ± 8.27
BMI	23.50 ± 3.26

Table 3: Distribution of participants according to Time-domain Heart rate variability (HRV) Before and after aromatherapy of the participants

	After Aromatherapy	**Before Aromatherapy**	**p value**
SDNN	22.00 ± 2.7	29.86 ± 5.28	<0.01**
PNN50	129.22 ± 10.31	125.56 ± 7.72	0.04*

*represents p<0.05, **represents p<0.01

Table 4: Distribution of participants according to Mean RR interval Before and after aromatherapy of the participants

	After Aromatherapy	Before Aromatherapy	p value
Mean RR interval	709.20 ± 115.64	640.66 ± 149.40	0.04*

*represents p<0.05

Table 5: Distribution of participants according to Time-domain Heart rate variability (HRV) Before and after aromatherapy of the participants

		After Aromatherapy	Before Aromatherapy	p value
VLF	**% POWER**	56.63 ± 12.21	52.55 ± 24.69	0.51 NS
	ABS. POWER	2770.91± 1314.76	3883.11 ± 2166.58	0.01*
LF	**% POWER**	31.67 ± 17.67	24.18 ± 6.14	0.02*
	ABS. POWER	2852.30 ± 1469.83	2338.02 ± 2256.34	0.27 NS
HF	**% POWER**	17.93 ± 16.38	7.46 ± 2.49	0.00007**
	ABS. POWER	630.56 ± 378.06	389.31 ± 206.08	0.001**

*represents p<0.05, **represents p<0.01

Table 6: Correlation between heart rate variability (HRV) parameters PNN50, SDNN, LF/HF ratio and perceived stress score before and after aromatherapy.

		PNN50	SDNN	LF/HF	Stress score
Before Aromatherapy	**PNN50**	1	-0.118 NS	0.0345 NS	0.132**
	SDNN	-0.1178 NS	1	-0.397 NS	0.296**
	LF/HF	0.0345 NS	-0.397*	1	-0.143**
	Stress score	0.1323 NS	0.296 NS	-0.1427 NS	1
After Aromatherapy	**PNN50**	1	0.1917 NS	0.0774 NS	0.20057 NS
	SDNN	0.1917**	1	0.1047 NS	0.03588 NS
	LF/HF	0.0774**	0.1047 NS	1	0.06688 NS
	Stress score	0.2006**	0.0359 NS	0.0669 NS	1

Table 7: Perceived stress score before and after lavender oil aromatherapy

	Stress Score	p value
Before Aromatherapy	21.62 ± 5.05	<0.01*
After Aromatherapy	11.35 ± 3.41	

DISCUSSION

The present study demonstrated that inhalation of lavender oil over a 30 day period produces substantial improvements in both subjective and objective indicators of stress among adults with moderate perceived stress score.

Taken together, the results reinforce the view that inhalation of lavender oil is effective in reducing stress related markers in adults. In the present study, participants with moderate stress were included. Aromatherapy was able to improve HRV parameters and perceived stress score suggesting enhanced autonomic stability and a favorable shift towards parasympathetic dominance, which are widely regarded as predictors of cardiovascular and mental health. The attenuation of relationships between stress score and HRV after lavender oil inhalation may indicate deeper neurobiological integration of relaxation beyond conscious perception. Lavender oil is documented to act via the olfactory limbic pathway, leading to central GABAergic modulation and a downregulation of sympathetic activity. It was observed that HF power was increased and RR intervals were prolonged, supporting the hypothesis that lavender oil aromatherapy fosters parasympathetic predominance and autonomic stability. This is in agreement with extant research suggesting that lavender oil inhalation can lower heart rate, blood pressure, and stress hormone (cortisol) levels, thereby promoting the "rest-and-digest" physiological state rather than an anxiogenic stress response.

The reduction in perceived stress scores following aromatherapy is both statistically and clinically meaningful. Given the well-established links between chronic psychological stress, autonomic dysregulation, and the development of disorders such as hypertension, metabolic syndrome, and depression, interventions that normalize HRV and suppress sympathetic overactivity have clear relevance for preventive medicine. Notably, the substantial increase in PNN50 and HF% following lavender oil use highlights its potential to improve cardiovascular health and enhance resilience to daily stressors.

Integration of Subjective and Objective Outcomes

A unique strength of this study lies in its comprehensive outcome assessment. Not only did participants report subjective relief from stress, but these self-reports were corroborated by multiple objective physiological improvements in autonomic function. This aligns with the growing recognition that non-pharmacological interventions can yield measurable neurobiological benefits, supporting their utility as first-line strategies in stress management, especially for individuals for whom drug treatment is inappropriate due to adverse effects or risk of dependency.

Shift in HRV-Stress Correlation

Prior to intervention, moderate correlations were noted between HRV indices and perceived stress, perhaps reflective of a compensatory autonomic balance in coping with ongoing psychological demand. After the intervention, these associations became less pronounced, indicating a decoupling of physiological stress response from conscious stress perception. This could signify a deeper integration of relaxation at the neurobiological level, as participants no longer experience the same autonomic-psychological coupling under persistent moderate stress.

Several studies have supported the findings of our study such as:

Reference	Observations similar to the present study
Ghavami et al., 2022[10]	Lavender aromatherapy significantly reduced perceived stress and anxiety, improved sleep quality, and showed both subjective and physiological stress reductions.
Field et al., 2005[11]	Inhaled lavender oil reduced acute anxiety and improved mood in a clinical setting.
Sebastian and Kear, 2024[12]	Aromatherapy led to a reduction in blood pressure and heart rate implying that aromatherapy may be a useful stress management tool for cardiac rehabilitation patients.
López et al., 2017[13]	Mechanistic review highlighted GABAergic modulation, HPA axis inhibition, and direct autonomic effects of lavender's main constituents (linalool, linalyl acetate).
Takagi et al., 2019[14]	The results showed that aromatherapy with lavender oil helped in reducing stress by acting on the immune and autonomic nervous systems in healthy volunteers.
Donelli et al., 2019[15]	Lavender inhalation can significantly reduce anxiety levels but it did not have any significant effect on blood pressure.

Broader Implications and Future Directions

This study contributes to the body of evidence advocating for integrative and holistic approaches to stress management. Lavender oil, a widely accessible and well-tolerated agent, shows promise for improving both psychological well-being and autonomic health. Such interventions may ultimately reduce the burden of stress-related disorders, diminish reliance on medication, and empower individuals with practical, effective tools for self-care.

Further investigation into the neurobiological mechanisms underlying aromatherapy, the generalizability across diverse populations, and long-term efficacy remain important next steps. Combining HRV and other autonomic parameters with neuroimaging or neuroendocrine markers could offer deeper insight into the pathways by which lavender exerts its benefits.

In conclusion, 30 days of inhalational lavender oil aromatherapy confers measurable benefits in stress reduction and autonomic rebalancing among adults with moderate stress. These findings support the greater adoption of non-pharmacologic, evidence-based interventions for stress relief in both clinical and community settings.

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