Effects of Four Foundations of Mindfulness-Based Intervention (FFMBI) on Salivary Cortisol Levels, Body Composition, Blood Pressure and Pulse Rate, and Brain Waves of Practitioners

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This study examines the effects of the *Four Foundations of Mindfulness-Based Intervention* (FFMBI) on physiological and psychological markers, including salivary cortisol, body composition, blood pressure, pulse rate, and brain waves. A mixed-methods approach involved interviews with 12 Vipassanā meditation masters and Buddhist scholars to develop the FFMBI program, followed by a 7-day retreat with 30 volunteers. Results showed significant reductions in self-reported stress (SPST-20 scores from 32.07 to 23.00) and improvements in brainwave alpha/beta ratios (highest scores from 54.84 to 79.82; average scores from 6.16 to 9.80), indicating enhanced mental relaxation. Body weight, BMI, and obesity levels improved, though heart rate and blood pressure changes were not significant. Unexpectedly, salivary cortisol levels increased, suggesting the need for further investigation. Overall, the findings highlight the positive impacts of FFMBI on both physical and mental well-being.

← *Photography by Martin Dojčár, 2025.*

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1 Introduction

Mindfulness-based interventions have gained significant attention in recent years due to their potential to improve mental and physical well-being (Goldberg *et al.* 2018; Goyal *et al*. 2014, 357; Pascoe *et al*. 2017, 156). The *Four Foundations of Mindfulness-Based Intervention* (FFMBI) is a comprehensive approach that integrates mindfulness practices with four key domains: mindfulness of the body, feelings, mind, and phenomena. This approach, rooted in Theravada Buddhist traditions, offers a structured framework for cultivating awareness and insight (Payutto 2021).

While there is a growing body of research on the effects of mindfulness-based interventions, limited studies have investigated the specific impact of FFMBI on various physiological markers. This study aims to address this gap by examining the effects of FFMBI on salivary cortisol levels, body composition, blood pressure, pulse rate, and brain waves of practitioners.

Salivary cortisol levels have been widely used as a biomarker to measure stress and the body's physiological response to stressors (Clow 2010, 97). High levels of cortisol have been associated with various adverse health outcomes, including anxiety, depression, cardiovascular diseases, and impaired immune function. Understanding the effects of FFMBI on salivary cortisol levels can provide insights into its stress-reducing capabilities and potential benefits for overall health.

Body composition, including measures such as body mass index (BMI), body fat percentage, and muscle mass, is crucial for assessing overall health and risk of chronic diseases. Mindfulness practices have been suggested to influence eating behaviors, physical activity, and body awareness, potentially leading to changes in body composition (Ruffault *et al.* 2017, 90). Examining the effects of FFMBI on body composition can provide insights into its role in promoting healthy lifestyles and weight management.

Blood pressure and pulse rate are important physiological indicators of cardiovascular health. Chronic stress and elevated blood pressure are significant risk factors for cardiovascular diseases. Mindfulness-based interventions have shown promise in reducing blood pressure and pulse rate, indicating their potential as non-pharmacological interventions for hypertension and stress management (Babak *et al.* 2022, 127).

Brain waves, as measured by *electroencephalography* (EEG), reflect the electrical activity of the brain and offer valuable information about cognitive processes and mental states. Different patterns of brain waves, such as alpha, beta, theta, and delta waves, are associated with distinct states of consciousness, attention, and relaxation. Investigating the impact of FFMBI on brain waves can help elucidate the neural mechanisms underlying mindfulness practices and their effects on mental states.

This study seeks to bridge the gap in current knowledge by providing a comprehensive examination of FFMBI's effects on multiple physiological and psychological markers. The research employs a mixed-methods approach, combining quantitative measurements with qualitative interviews to gain a holistic understanding of the intervention's impact.

The Four Foundations of Mindfulness, as described by Somdet Phra Buddhaghosacariya (Payutto 2021), encompass the "contemplation of the body" (Pi. *Kāyānupassanā Satipaṭṭhāna*), "feelings" (Pi. *Vedanānupassanā Satipaṭṭhāna*), "mind" (Pi. *Cittānupassanā Satipaṭṭhāna*), and "mind-objects" (Pi. *Dhammānupassanā Satipaṭṭhāna*). This ancient practice, rooted in Buddhist traditions, has been adapted into a structured intervention program for this study, aiming to explore its effects on modern physiological and psychological measures.

Previous research has shown promising results in related areas and found that brief mindfulness meditation training led to lower cortisol responses to social stress tasks (Creswell *et al*. 2014, 1). and demonstrated decreased cortisol levels following intensive meditation training and mindfulness-based stress reduction programs, respectively (Jacobs *et al*. 2011, 664; Jaremka *et al.* 2013, 1089).

In terms of body composition, improvements in binge and impulsive eating following mindfulness training were observed (Ruffault *et al*. 2017, 90), as well as significant reductions in body weight, BMI, and body fat percentage in participants who received a mindfulness-based diet and exercise intervention (Mason *et al*. 2016, 86).

Regarding cardiovascular health, systematic reviews have shown associations between meditation interventions and reductions in blood pressure and heart rate (Hilton *et al*. 2017, 453; Pascoe *et al*. 2017, 152). These findings suggest potential benefits for cardiovascular health through mindfulness practices. Brain wave studies have highlighted the impact of meditation on increased alpha and theta waves, associated with relaxed and focused states of consciousness (Cahn and Polich 2006, 180), and found that mindfulness meditation was associated with increased activation in brain regions involved in attentional control and emotional regulation (Zeidan *et al.* 2014).

The present study aims to extend this body of research by specifically examining the effects of FFMBI on a comprehensive set of physiological and psychological markers. By investigating salivary cortisol levels, body composition, blood pressure, pulse rate, and brain waves, this research seeks to provide a multifaceted understanding of FFMBI's impact on practitioners' well-being.

The study's objectives are threefold:

1. *Design and Development:* To systematically develop a *Four Foundations of Mindfulness-Based Intervention* (FFMBI) by integrating insights from Buddhist scholars and *Vipassanā* meditation masters, in accordance with the concepts of the *Four Foundations of Mindfulness* practice in the *Satipaṭṭhāna Sutta*.

2. *Implementation and Feasibility:* To implement the FFMBI in a controlled setting with a cohort of experienced practitioners, assessing the feasibility, adherence, and practical application of the intervention.

3. *Physiological and Psychological Impact Assessment:* To quantitatively evaluate the effects of FFMBI on key physiological markers (salivary cortisol levels, body composition, blood pressure, and pulse rate) and neurophysiological parameters (brainwave activity), alongside psychological outcomes (self-reported stress levels).

Based on the existing literature and the objectives of this study, we propose the following research hypotheses:

1. *The Four Foundations of Mindfulness-Based Intervention* (FFMBI) will result in a significant decrease in salivary cortisol levels and a significant reduction in stress among practitioners after receiving the intervention compared to their baseline levels.

2. FFMBI will lead to a significant improvement in brain wave patterns associated with relaxation (e.g., increased alpha wave activity) among practitioners after receiving the intervention compared to their pre-intervention measurements.

3. FFMBI will result in a significant improvement in body composition, indicated by reduced body fat percentage and increased muscle mass, among practitioners after receiving the intervention compared to their initial measurements.

4. FFMBI will lead to a significant decrease in blood pressure and pulse rate among practitioners after receiving the intervention compared to their pre-intervention measurements, indicating improved cardiovascular health and relaxation.

These hypotheses predict that FFMBI will have a positive impact on multiple physiological and psychological parameters, including salivary cortisol levels, brain wave patterns, body composition, blood pressure, and pulse rate. The intervention is expected to result in decreased stress levels, improved relaxation, positive changes in body composition, and enhanced cardiovascular health among the practitioners.

By employing a quasi-experimental design with a one-phase embedded model, this research aims to provide both quantitative data on physiological changes and qualitative insights into participants' subjective experiences. The study will be conducted at Wat Bhaddanta Asabharam in Chonburi Province, Thailand, offering an appropriate setting for mindfulness training and meditation practices.

2 Literature Review

2.1 Four Foundations of Mindfulness

The Four Foundations of Mindfulness, or "cattaro satipaṭṭhānā" in Pāli (Buddhaghosa 2010), are described in the *Mahāsatipaṭṭhāna Sutta* (MN 10). These four foundations include the "mindful contemplation of the body" (Pi. *Kāyānupassanā Satipaṭṭhāna*), "feelings" (Pi. *Vedanānupassanā Satipaṭṭhāna*), "states of mind" (Pi. *Cittānupassanā Satipaṭṭhāna*), and "mind-objects" (Pi. *Dhammānupassanā Satipaṭṭhāna*). The practice of these Four Foundations focuses on cultivating awareness of the body, feelings, mind, and mental objects. These teachings were given by the Buddha as the only path to purify oneself, transcend the suffering of existence, and achieve Nibbāna, as stated in the *Dīghanikāya* (DN 22):

> *The one and only path, Bhikkhus leading to the purification of beings, to passing far beyond grief and lamentation, to the dying-out of ill and misery, to the attainment of right method, to the realization of Nirvana, is that of the Fourfold Setting up of Mindfulness.*

The practice of the *Four Foundations of Mindfulness* involves observing one's experiences without judgment, leading to mental clarity to see things as they really are. By understanding how phenomena arise, exist, and cease, one can cultivate wisdom. The Four Foundations deepen one's awareness of the impermanent nature of existence, aligning with The Universal law of the "Three Common Characteristics" (Pi. *Tilakkhana*). This principle highlights that things (phenomena) are "impermanent and subject to change" (Pi. *Anicca*), inherently "unsatisfactory" (Pi. *Dukkha*), and "beyond one's control" (Pi. *Anattā*).

For instance, in the contemplation of the body, practitioners are instructed to observe and be mindful of breathing, abdomen movements, postures, and the body's impermanence. In the contemplation of feelings, one observes pleasant, unpleasant, or neutral sensations without attachment. The contemplation of the mind involves recognizing various mental states, while the contemplation of mind-objects includes examining the hindrances to meditation and the factors of enlightenment. In Buddhism, this practice aims to cultivate mindfulness and awareness, leading to a deeper understanding of the nature of reality and ultimately, the cessation of suffering.

2.2 Modern Applications and Benefits

In recent years, mindfulness practices derived from these Buddhist traditions have gained significant attention in Western psychology and neuroscience. Mindfulness-based interventions have shown promise in reducing stress, improving mental health, and enhancing overall well-being (Goldberg *et al.* 2018; Goyal *et al.* 2014, 357; Pascoe *et al.* 2017, 156).

The practice of mindfulness has been associated with numerous benefits. Mindfulness can lead to stress reduction, improved memory, increased happiness, enhanced creativity, and positive effects on genes and immune function (Sutton 2020). Moreover, recent neuroimaging research indicates that mindfulness meditation is associated with long-lasting changes in brain network topology – particularly in the hippocampus – suggesting neuroplastic adaptations that may underlie personal growth (Lardone *et al.* 2018).

In clinical settings, mindfulness-based interventions have been applied to various conditions. For instance, a *mindfulness-based stress reduction* (MBSR) program significantly lowered awakening salivary cortisol levels in individuals receiving treatment for substance abuse (Marcus *et al.* 2003, 63). This suggests that mindfulness practices may have a measurable impact on physiological stress markers.

2.3 Salivary Cortisol as a Biomarker of Stress

Salivary cortisol has emerged as a valuable biomarker in stress research, offering insights into the activation of the *hypothalamic-pituitary-adrenal* (HPA) axis. Cortisol, the primary glucocorticoid produced by the adrenal cortex, plays a crucial role in various physiological processes, including stress response, energy metabolism, and immune function (Gatti *et al.* 2009, 1205).

The measurement of salivary cortisol provides several advantages over serum cortisol. It reflects the levels of biologically active, non-protein bound cortisol in serum and follows the circadian variation of serum cortisol (King 2002, 92). Moreover, salivary cortisol collection is non-invasive and can be easily performed by participants at home or in various settings.

Several studies have demonstrated the utility of salivary cortisol in assessing stress levels. For instance, salivary cortisol levels could help identify groups with impaired stress responses (Bani-Issa *et al.* 2020). Similarly, workers without stress had significantly lower cortisol levels compared to those experiencing acute stress (Amer *et al.* 2018, 56).

2.4 Body Composition and Health Assessment

Body composition analysis has become an essential tool in assessing overall health and nutritional status. Unlike simple metrics such as *Body Mass Index* (BMI), body composition measurements provide a more nuanced understanding of an individual's physical makeup, differentiating between fat mass, lean mass, and bone density (Toomey *et al.* 2015, 16).

The importance of body composition in health assessment stems from its ability to provide insights into various health conditions and risks. For instance, excess adiposity is associated with increased risk of cardiovascular diseases and metabolic disorders, while insufficient lean mass can indicate malnutrition or sarcopenia. BMI alone tends to misclassify at the individual level and has low sensitivity in determining excess adiposity, highlighting the need for more comprehensive body composition assessments (Okorodudu *et al.* 2010, 791).

Various methods exist for measuring body composition, each with its advantages and limitations. These include *bioelectrical impedance analysis* (BIA), *dual-energy x-ray absorptiometry* (DXA), and anthropometric measurements such as skinfold thickness. The choice of method often depends on the specific clinical or research context, balancing factors such as accuracy, practicality, and cost-effectiveness.

2.5 Blood Pressure and Pulse Rate

Blood pressure and pulse rate are fundamental physiological parameters that provide crucial information about cardiovascular health. Blood pressure, measured in millimeters of mercury (mm Hg), represents the force exerted by blood against artery walls during the cardiac cycle. It is typically expressed as two numbers: systolic pressure (when the heart contracts) and diastolic pressure (when the heart relaxes).

The American College of Cardiology and American Heart Association guidelines (Whelton 2017) define normal blood pressure as less than 120/80 mm Hg, with hypertension diagnosed at 130/80 mm Hg or higher. These guidelines emphasize the importance of maintaining healthy blood pressure levels to prevent cardiovascular diseases.

Pulse rate, or heart rate, measures the number of times the heart beats per minute. The American Heart Association defines a normal sinus heart rate as between 60 and 100 beats per minute (Mason *et al.* 2007, 228). Both blood pressure and pulse rate can be influenced by various factors, including stress, physical activity, and overall health status.

2.6 Brain Waves and EEG

Electroencephalography (EEG) has emerged as a powerful non-invasive tool for studying brain activity. EEG measures the electrical activity of the brain by recording voltage fluctuations resulting from ionic current flows within neurons (Olejniczak 2006, 186). This technique has been widely used in both clinical settings and neuroscience research to investigate various aspects of brain function.

Brain waves, as measured by EEG, are typically categorized into different frequency bands, each associated with specific mental states or cognitive processes. These include:

1. **Delta waves** (0.5–3 Hz): Associated with deep, dreamless sleep and the release of growth hormone.
2. **Theta waves** (4–7 Hz): Linked to dreaming sleep (REM), increased creativity, and deep meditation.
3. **Alpha waves** (8–13 Hz): Indicative of relaxation, light meditation, and pre-sleep states.
4. **Beta waves** (13–30 Hz): Associated with alert wakefulness, concentration, and cognitive processing.

Research has suggested that certain patterns of brain wave activity may be associated with improved cognitive performance and well-being. For instance, increases in alpha waves and decreases in beta waves have been linked to enhanced learning, memory retention, and improved cognitive performance (Keune *et al.* 2017, 1746; Young 2011, 75).

In the context of mindfulness and meditation research, EEG has been instrumental in elucidating the neurophysiological correlates of these practices. Studies have consistently shown that meditation is associated with increased alpha and theta wave activity, reflecting states of relaxed alertness and internalized attention (Cahn and Polich 2006, 180).

The integration of EEG measurements in mindfulness research provides objective data to complement subjective reports, offering a more comprehensive understanding of the effects of mindfulness practices on brain function. This approach aligns with the growing trend towards using multimodal assessment methods in studying the impact of mindfulness-based interventions on both psychological and physiological parameters.

In conclusion, by examining salivary cortisol levels, body composition, blood pressure, pulse rate, and brain waves, researchers can gain a more holistic understanding of the effects of mindfulness practices on overall health and well-being. This integrative approach paves the way for more comprehensive investigations into the mechanisms underlying the benefits of mindfulness and its potential applications in healthcare and personal development.

3 Materials and Methods

3.1 Research Design

This study employed a mixed-methods approach to investigate the effects of *Four Foundations of Mindfulness-Based Intervention* (FFMBI) on various physiological and psychological parameters. The research was conducted in two phases: a qualitative phase followed by a quantitative phase.

3.2 Qualitative Research

The qualitative phase aimed to develop a comprehensive *Four Foundations of Mindfulness-Based Intervention* (FFMBI) and inform the design of the intervention for the quantitative phase. This included an extensive literature review of primary sources, such as English translations of the *Tipiṭaka* related to the *Four Foundations of Mindfulness*, as well as secondary sources, including commentaries, research articles, and Buddhist journals. In addition to the literature review, in-depth, in-person interviews were conducted with 12 key informants, including Vipassanā meditation Masters and Buddhist scholars.

The primary aim of these interviews was to gather expert insights on structuring and organizing the FFMBI. This qualitative phase played a crucial role in shaping the intervention design, ensuring that it was both practically effective and aligned with the *Four Foundations of Mindfulness* practice in accordance with the principles of the *Satipaṭṭhāna Sutta*. The interviews were conducted by the lead researcher, a scholar with a PhD in Buddhist Studies and an MA in Buddhist Psychology, as well as a dedicated practitioner with extensive experience in the Four Foundations of Mindfulness meditation. This background ensured an in-depth data collection process. Each interview lasted between one and two hours, providing ample time for key informants to share their perspectives on the optimal duration, structure, and supplementary activities of the FFMBI.

Semi-structured interview questions were designed to encourage open reflection, focusing on areas such as:

1. The appropriate duration of FFMBI to induce physical and mental changes in practitioners.

2. The ideal structure and balance between sitting meditation, walking meditation, other meditation postures, and the contemplation of minor activities.

3. Supplementary activities such as Dhamma talks and meditation interview sessions.

4. Factors that support meditation practice during the retreat.

All interviews were audio-recorded and transcribed verbatim. The qualitative data were analyzed through a reflective thematic approach, where recurring ideas and key themes were identified organically based on the experts' narratives. Rather than applying a rigid coding framework, the analysis emphasized capturing the depth and nuances of the informants' experiences and insights, which were inherently tied to spiritual and traditional practices. Themes that emerged – such as the importance of tailored instruction for beginners, and the role of Dhamma talks – were directly integrated into the intervention design.

To ensure credibility, the emergent themes and their application in the program design were periodically reviewed in discussions with other researchers familiar with mindfulness-based interventions, allowing for cross-validation of interpretations while respecting the non-mechanistic nature of the spiritual insights provided.

3.3 Quantitative Research

The quantitative phase employed a quasi-experimental design with a one-group pretest-posttest approach. Thirty participants were recruited based on specific inclusion criteria: voluntary participation with signed consent, Thai nationality, ability to participate in the entire retreat, age of 20 years or older, prior experience in practicing mindfulness according to the *Four Foundations of Mindfulness*, ability to practice Walking and Sitting Meditation for a minimum of 30 minutes per session, good health with no chronic illnesses or mental health issues, and no significant loss of a family member within the past 6 months. Exclusion criteria were the inverse of these inclusion criteria.

The minimum sample size was calculated using G*Power software version 3.1.9.4, assuming an effect size of 0.8, α value of 0.05, and power of 80%. The calculated minimum sample size was 15, which was increased to 30 to accommodate potential incomplete tests.

3.4 Research Instruments

The study utilized several instruments to measure the effects of FFMBI. Salivary cortisol levels were assessed using Salivette tubes for sample collection, with analysis performed on the Elecsys 2010 analyzer. This method employed a competitive polyclonal antibody immunoassay with magnetic separation and electrochemiluminescence quantitation.

Body composition was analyzed using a TANITA DC360 Body Composition Analyzer, which measures body fat percentage, fat mass, fat-free mass, muscle mass, and bone mass using *Bioelectrical Impedance Analysis* (BIA). Blood pressure and heart rate were measured using the TM-2657P Fully Automatic Blood Pressure Monitor.

For brainwave measurement, the study employed the Se-Mind EEG system from the Faculty of Medical Technology, Mahidol University. This system was used to assess relaxation conditions by analyzing the ratio between alpha and beta EEG signals.

To evaluate participants' stress levels, the Suanprung Stress Test 20 (SPST-20) was employed. This standardized questionnaire, developed by the Department of Mental Health, Ministry of Public Health, Thailand, consists of 20 self-administered questions. The SPST-20 score defines four levels of stress: mild (0–24), moderate (25–42), high (43–62), and severe (over 63). Participants completed this questionnaire both before and after the intervention. The reliability of the SPST-20 was assessed using Cronbach's Alpha Coefficient, yielding a value of 0.7, indicating acceptable internal consistency.

3.5 Experimental Procedure

The experiment took place at Wat Bhaddanta Arsabharam in Chonburi Province, Thailand, during a 7-day meditation retreat. Before the meditation retreat, researchers conducted orientation for the 30 participants and collected baseline data, including salivary cortisol tests, body composition analysis, blood pressure and heart rate measurements, EEG recordings, and stress level assessments.

The measurement process was conducted under consistent conditions to ensure data reliability. Prior to the experiment, the pre-meditation measurements were conducted in the morning, the day before participants began the meditation retreat to receive the FFMBI intervention. These included a saliva cortisol test, body composition analysis, blood pressure and heart rate measurement, EEG for brainwave activity, and a stress level test. After the pre-meditation measurements, the participants took part in the 7-day meditation retreat.

The day began at 03:30 a.m. with a wake-up bell. This was followed by alternating sessions of walking and sitting meditation, interspersed with mindful eating meals and periods for contemplation of minor daily activities, such as taking a shower and mindful drinking. Participants engaged in meditation interviews, Dhamma talks, and evening chanting to support mindfulness practice. The day concluded with a final meditation session and a mindful approach to sleep at 9:00 p.m. This rigid schedule ensured that all participants experienced similar physical, cognitive, dietary and environmental conditions, thereby controlling for variability in daily routines.

Post-meditation measurements were taken on the last day of the meditation retreat, following the same protocol as the pre-meditation tests by the same research team to ensure consistency. Measurements were conducted simultaneously. However, for the saliva cortisol test, participants self-collected samples upon waking at 3:30 a.m. to align with the meditation schedule before breakfast. Efforts were made to maintain consistency in environmental conditions, measurement times, and participant dietary intake to ensure accuracy in data comparison. Additionally, in depth interviews with the practitioners were held to gather qualitative data on participants' experiences and perceptions of the intervention.

The venue of the 7-day retreat (Wat Bhaddanta Arsabharam) was a setting conducive to mindfulness practices, which helped control for environmental variables. To ensure a controlled environment, participants stayed in individual residences. Additionally, they were asked not to use their mobile phones for the entire duration of the program and practiced noble silence (only speaking with the meditation master during meditation progress interview sessions). To control physiological variables, all participants followed the same schedule, including mealtimes, meditation sessions, and rest periods, to minimize variations in daily routines that could influence the outcomes.

3.6 Data Collection

Quantitative data collection was divided into body and mind measurements. For body measurements, saliva samples were collected using Salivette devices, with participants gently chewing the swab for about 2 minutes to saturate it with saliva. Samples were then centrifuged and analyzed using the Elecsys Cortisol assay. Body composition measurements were taken with participants standing barefoot on the Tanita DC360 scale. Blood pressure and heart rate were measured after participants had been seated quietly for 3–5 minutes, with their arms stretched out, palm upward.

For mind measurements, EEG recordings were taken with participants seated comfortably, eyes closed, for 15 minutes. The scalp was cleaned with 70% alcohol, and conductive gel was applied before electrode placement. The MU team analyzed the EEG results, focusing on alpha and beta brain waves and their ratio. Qualitative data was collected through in-depth interviews, focusing on participants' experiences and perceptions of their body and mind after receiving the FFMBI intervention.

3.7 Data Analysis

Quantitative data was analyzed using descriptive statistics, including percentages, means, and standard deviations. Paired t-tests were employed to investigate significant differences between pre- and post-intervention measurements. Qualitative data from the interviews was transcribed, coded, and analyzed using thematic analysis to identify recurring themes and patterns related to participants' experiences and perceptions of the intervention.

3.8 Ethical Considerations

This study was reviewed and approved by the Research Ethics Committee of the Researcher's Institution under the certificate approval code R.263/2024 on 9th May 2024. All participants provided written informed consent before participating in the study. Participants were informed of their right to withdraw from the study at any time without consequence. All data collected was kept confidential and used solely for research purposes.

3.9 Integration of Findings

The quantitative and qualitative findings were integrated during the interpretation phase to provide a comprehensive understanding of the effects of FFMBI on the targeted variables. This mixed-methods approach allowed for a holistic perspective on the research objectives, combining objective physiological measurements with subjective experiences of the participants.

4 Results

4.1 Demographic Information

The study included 30 participants, with a significant gender imbalance: 96.7% female and 3.3% male. The age range was 36–75 years, with the largest group (34.0%) aged 66–70 years. All participants had prior experience with Vipassanā meditation, with 80.0% having practiced continuously for more than 7 days.

Figure 1
Age Distribution of Participants

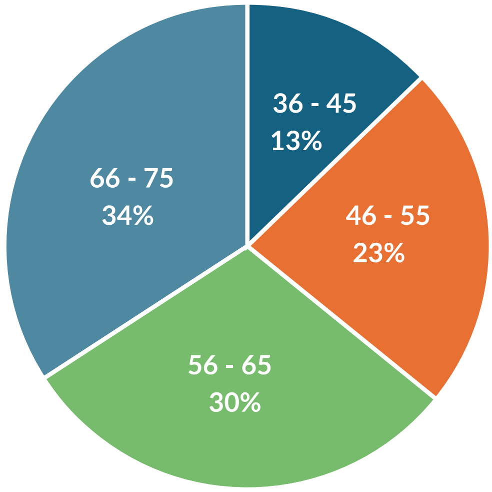


Table 1
Summary of the Demographic Information and Prior Mediation Experience of the Respondents

Demographic Information	Frequency	Percentage
Gender		
Male	1	3.3%
Female	29	96.7%
Age		
36–45	4	13.3%
46–55	7	23.3%
56–65	9	30.0%
66–75	10	33.3%
Previous meditation experience	**Frequency**	**Percentage**
Having Experience with Vipassanā meditation	30	100.0%
Practiced continuously for 7 days	2	6.7%
Practiced continuously for more than 7 days	24	80.0%
Practiced continuously for 5 days	2	6.7%
Practiced continuously for 4 days	1	3.3%
Practiced 1 day	1	3.3%

Table 2
Comparison of Pre- and Post- Intervention Blood Pressure, Pulse Rate, Body Composition, Cortisol Levels, Brain Wave Measurement and Stress Assessment

Parameters	Pre-Intervention	Post-Intervention	p-Value**
Systolic Blood Pressure	124.43±21.62	124.27±21.61	0.946
Diastolic Blood Pressure	75.43±13.64	73.67±12.67	0.254
Heart Rate	71.83±10.49	69.90±9.75	0.078
Body Composition			
Weight (kg)	54.28±10.63	53.84±10.29	0.001
BMI	22.00±3.46	21.84±3.31	0.008
Fat (%)	30.17±6.21	30.04±0.67	0.668
Fat Mass (kg)	16.85±6.38	16.55±5.81	0.128
FFM (kg)	37.43±5.45	37.29±5.72	0.409
Muscle Mass (kg)	35.34±5.06	35.21±5.30	0.418
TBW (kg)	25.71±4.57	25.68±4.85	0.864
TBW (%)	47.66±3.44	47.86±3.49	0.548
Bone Mass (kg)	2.09±0.41	2.08±0.44	0.380
Metabolic Age	44.33±10.89	43.63±9.76	0.219
Visceral Fat Rating	6.03±2.73	5.87±2.45	0.057
Degree of Obesity (%)	0.05±15.73	−0.70±15.02	0.008
Hormone			
Cortisol (µg/dL)	0.11±0.05	0.40±0.24	0.000
Brain Wave (Alpha/Beta Ratio Score)			
The highest Alpha/Beta Ratio Score	54.85±31.58	79.82±60.13	0.008
The average Alpha/Beta Ratio Score	6.16±3.22	9.80±7.16	0.002
Stress Level			
Stress	32.07±13.81	23.00±12.01	0.001

*Data are presented as mean ± SD
** Using the Paired t-Test

4.2 Body Composition Measurements

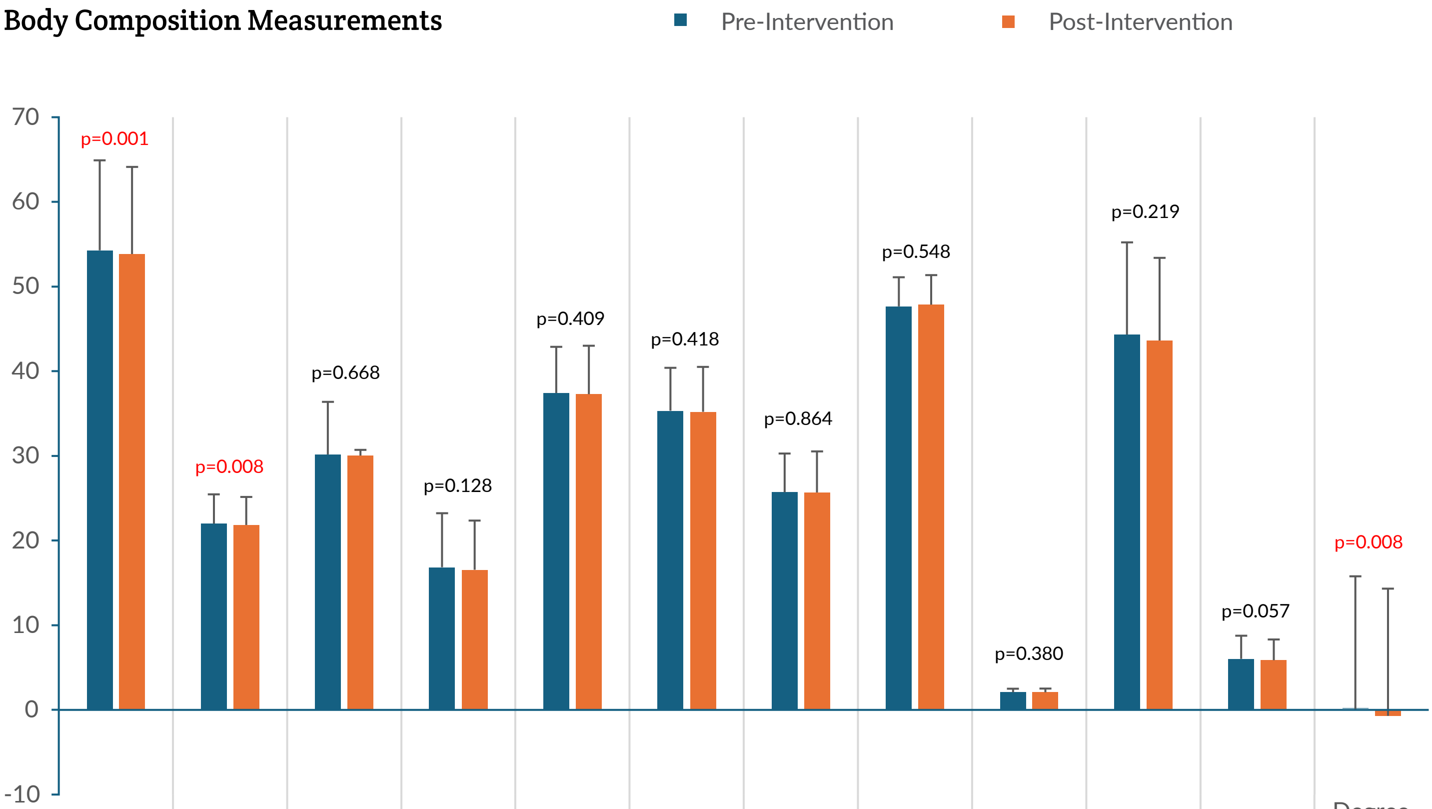
Following the *Four Foundations of Mindfulness-Based Intervention* (FFMBI), several changes in body composition were observed.

There was a statistically significant decrease in body weight from 54.28 kg to 53.84 kg (p<0.05), accompanied by a significant reduction in BMI from 22.00 to 21.84 (p<0.05). Total body fat percentage showed a slight, non-significant decrease from 30.17% to 30.04% (p=0.668), while fat mass decreased marginally from 16.85 kg to 16.55 kg (p=0.128).

Fat-Free Mass (FFM) and muscle mass showed minor, non-significant decreases. FFM decreased from 37.43 kg to 37.29 kg (p=0.409), and muscle mass from 35.34 kg to 35.21 kg (p=0.418). Total body water (TBW) in kilograms decreased slightly from 25.71 kg to 25.68 kg (p=0.864), while TBW percentage increased marginally from 47.66% to 47.86% (p=0.548).

Bone mass showed a slight, non-significant decrease from 2.09 kg to 2.08 kg (p=0.380), and metabolic age decreased from 44.33 to 43.63 years (p=0.219). The visceral fat rating decreased from 6.03 to 5.87 (p=0.057). Notably, the degree of obesity showed a significant change, moving from 0.05% to −0.70% (p<0.05).

Figure 2
Body Composition Measurements



	Weight (kg)	BMI	Fat (%)	Fat Mass (kg)	FFM (kg)	Muscle Mass (kg)	TBW (kg)	TBW (%)	Bone Mass (kg)	Metabolic Age	Visceral Fat Rating	Degree of Obesity (%)
■ (Pre-Intervention)	54.28	22.00	30.17	16.85	37.43	35.34	25.71	47.66	2.09	44.33	6.03	0.05
■ (Post-Intervention)	53.84	21.84	30.04	16.55	37.29	35.21	25.68	47.86	2.08	43.63	5.87	-0.70

4.3 Blood Pressure and Heart Rate Measurements

Changes in cardiovascular parameters were observed, though none reached statistical significance. Systolic blood pressure decreased from 124.43 mmHg to 124.27 mmHg (p=0.946), while diastolic blood pressure decreased from 75.43 mmHg to 73.67 mmHg (p=0.254). Heart rate showed the most pronounced change, decreasing from 71.83 beats per minute to 69.90 beats per minute (p=0.078).

4.4 Stress Assessment

Participants experienced a substantial and statistically significant reduction in stress levels following the FFMBI. The mean self-assessed stress score, as measured by the Suanprung Stress Test 20 (SPST-20), decreased from 32.07 to 23.00 (p<0.05). This reduction indicates a marked improvement in perceived stress following the intervention.

4.5 Brainwave Measurement

The results of the brainwave measurements demonstrated significant enhancements in both the highest and average alpha/beta ratio scores. The highest alpha/beta ratio score increased substantially from 54.85 to 79.82 (p<0.05), indicating a marked improvement in relaxation and cognitive state. Additionally, the average alpha/beta ratio score rose from 6.16 to 9.80 (p<0.05), further corroborating the positive effects of the FFMBI on brain activity related to relaxation and mental calmness.

Figure 3
Changes in Blood Pressure and Heart Rate

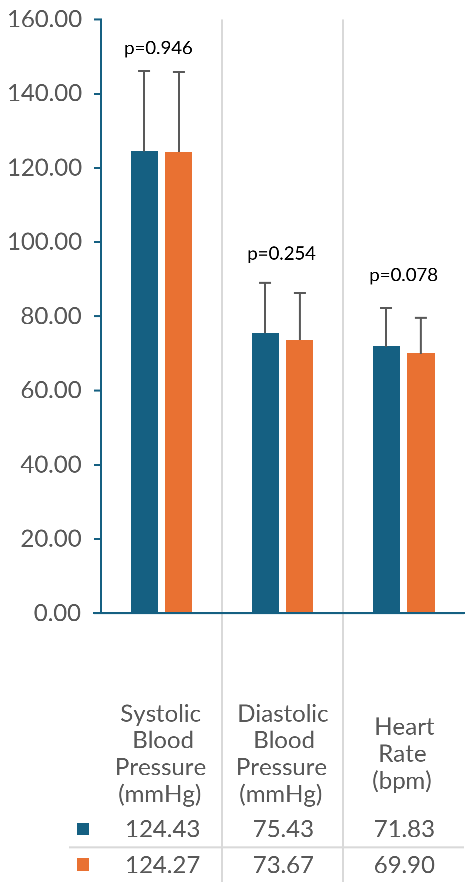


Figure 4
Change in Stress

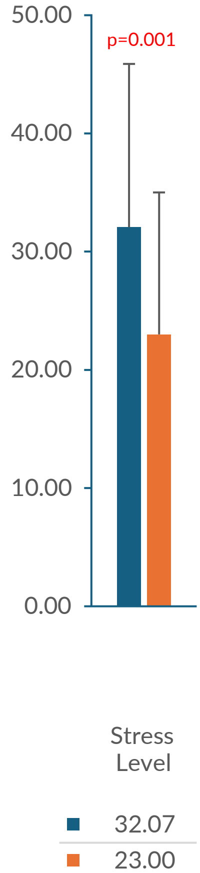
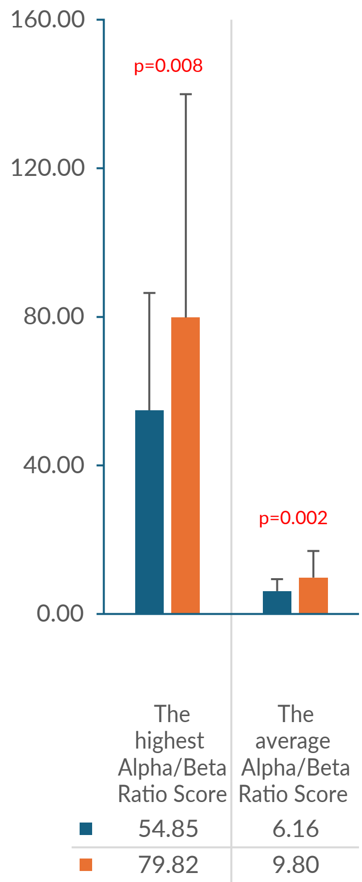


Figure 5
Changes in Brainwave Measurements



4.6 Cortisol Levels

Contrary to the expected outcome, salivary cortisol levels showed a significant increase from 0.106 μg/dL to 0.405 μg/dL ($p<0.05$). It's important to note that despite this increase, cortisol levels remained within the reference morning range (<0.69 μg/dL).

4.7 Hypotheses Testing

The study tested four main hypotheses regarding the effects of the FFMBI:

1. *Salivary cortisol levels:* The hypothesis was not supported, as levels increased significantly. However, results showed a significant reduction in self-reported stress scores.

2. *Brain wave patterns:* The hypothesis was supported, with significant improvements in alpha/beta ratios.

3. *Body composition:* The hypothesis was partially supported, with significant improvements in weight, BMI, and degree of obesity, but non-significant changes in body fat percentage and muscle mass.

4. *Blood pressure and pulse rate:* The hypothesis was not supported, as changes were not statistically significant.

4.8 Participant Feedback and Experiences

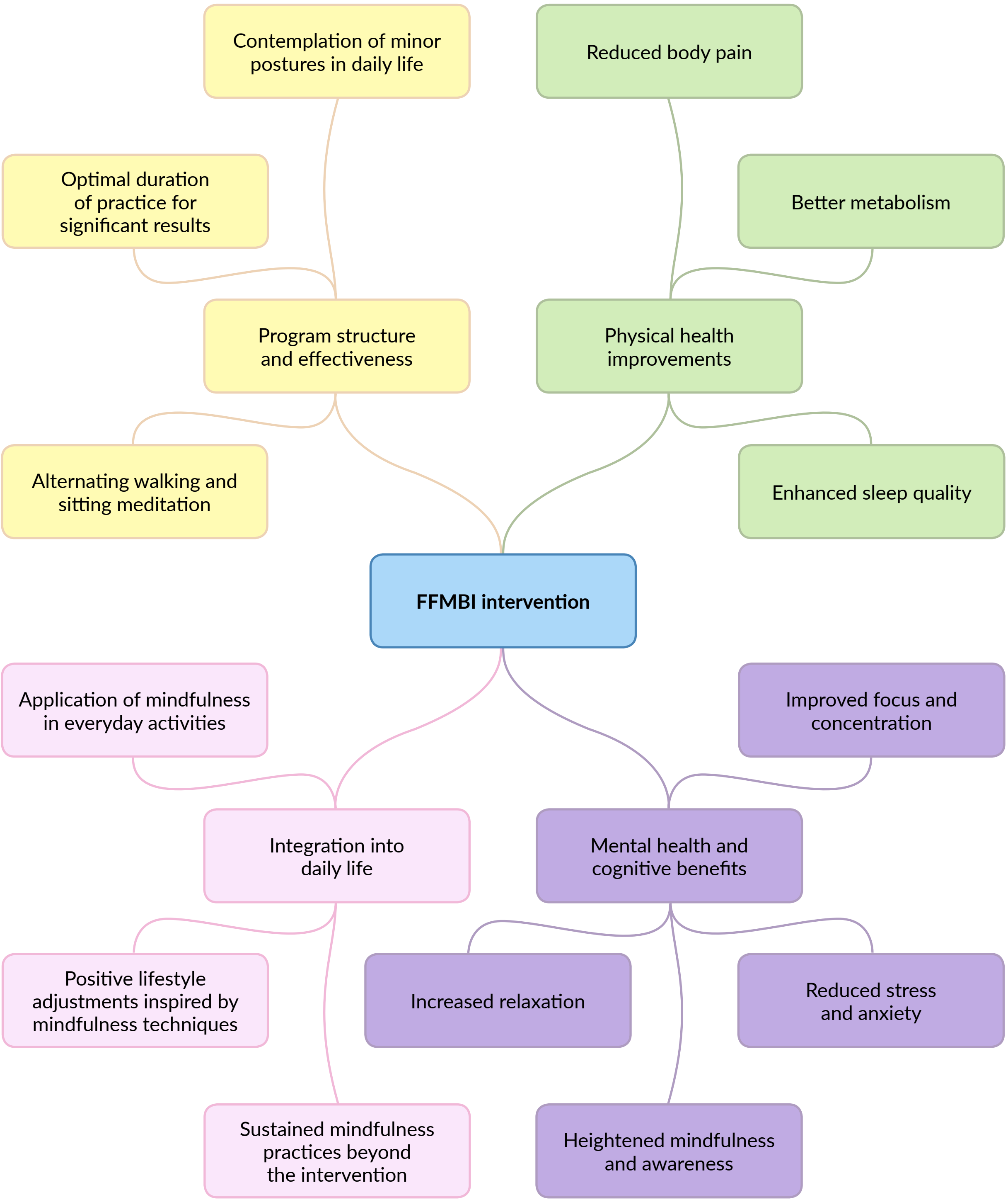
Qualitative data collected through interviews revealed positive experiences in three main areas:

1. *Physical changes:* Participants reported improvements in metabolism, reduced body pain, and enhanced sleep quality.

2. *Mental changes:* Participants experienced increased relaxation, better focus on daily activities, and a noticeable reduction in stress and anxiety. One participant noted, "*There is an increase in tranquility, which is very useful in my daily life.*"

3. *Application to daily life:* Participants expressed a strong intention to integrate the mindfulness techniques into their daily routines. One participant shared, "*I use it every day and share it with friends to reduce stress and anxiety*."

Figure 6
Thematic Map illustrating key themes derived from qualitative interviews with key informants (yellow) and participants (green, pink, and purple). Themes include program structure and effectiveness, physical and mental health improvements, and the integration of mindfulness practices into daily life.



4.9 Satisfaction Scores

Participants reported high satisfaction with various aspects of the FFMBI program. The overall average satisfaction score was 4.52 out of 5, with 90.38% of participants rating their experience as 4 or 5. Notably, all participants (100%) expressed interest in joining a future 15-day meditation course for the research project.

In summary, the FFMBI program demonstrated significant positive effects on perceived stress levels, brainwave patterns associated with relaxation, and certain body composition measures. While some physiological parameters showed unexpected results or non-significant changes, the qualitative feedback from participants was overwhelmingly positive, indicating substantial perceived benefits and a high likelihood of continued practice.

Table 3
Summary of Satisfaction Scores for Various Aspects of the FFMBI Program

Item	Average Satisfaction	Percentage	S.D.	Evaluation
Suitable location: peaceful, clean, and not crowded	4.60	92.00	0.56	Excellent
Suitable transportation	4.20	84.00	0.66	Good
Suitable conversations: discussing only good topics	4.57	91.33	0.68	Excellent
Suitable people: knowledgeable individuals, teachers, and good friends guiding in the right direction	4.77	95.33	0.50	Excellent
Suitable food	4.37	87.33	0.72	Good
Suitable weather: fresh, shady, cool, not too hot or cold	4.50	90.00	0.63	Good
Suitable posture: areas arranged for comfortable standing, sitting, and walking	4.63	92.67	0.49	Excellent
Overall satisfaction	**4.52**	**90.38**		**Excellent**

5 Discussion

5.1 Demographic Characteristics and Participant Engagement

The demographic profile of our study participants provides valuable insights into the *Four Foundations of Mindfulness-Based Intervention* (FFMBI) program. The overwhelming female representation (97%) in our sample raises important questions about gender differences in seeking mindfulness-based interventions. This skew towards female participants is consistent with previous research on mindfulness and meditation programs, which often report higher female engagement (Katz and Toner 2013, 318). The wide age range of participants (36–75 years) demonstrates the broad appeal of FFMBI across different life stages, with higher representation in the 51–75 age brackets. This finding aligns with research indicating that older adults often show more interest in mindfulness practices for managing age-related stressors and improving overall well-being (Geiger *et al*. 2016, 296).

These demographic findings have important implications for the design and implementation of future mindfulness-based interventions. They highlight the need for targeted outreach to underrepresented groups, particularly men and younger adults, to ensure that the benefits of such programs are accessible to a more diverse population.

5.2 Cardiovascular Effects of FFMBI

The results from our blood pressure and heart rate measurements following the FFMBI program, while not statistically significant, warrant careful consideration. The marginal nature of these changes could be attributed to the relatively short duration of the intervention (7 days) and the fact that participants' baseline blood pressure readings were already within the normal range. The trend towards a decrease in heart rate, approaching the threshold of significance ($p=0.077$), suggests a potential effect of FFMBI on autonomic nervous system function.

It's important to note that the lack of statistical significance in these cardiovascular measures does not necessarily negate their clinical relevance. Small changes in blood pressure and heart rate, if sustained over time, can have meaningful impacts on long-term cardiovascular health (Cook *et al.* 1995, 701). These findings highlight the need for longer-term studies with larger sample sizes to better elucidate the cardiovascular effects of FFMBI.

5.3 Body Composition Changes

The observed changes in body composition provide valuable insights into the physiological effects of FFMBI. The statistically significant reductions in body weight, BMI, and degree of obesity suggest that FFMBI has a positive impact on overall body composition. These changes could be attributed to increased body awareness and improved eating behaviors associated with mindfulness practices (Tapper 2017).

A key factor contributing to these outcomes was the structured meal schedule followed during the intervention. Participants consumed two daily meals – breakfast at 6:30 a.m. and lunch at 10:30 a.m. – and engaged in mindful eating practices throughout. This process involved mindfulness practice to each stage of eating: eating slowly and being fully aware of the eating process. This practice included observing the food, taking a portion, placing it in the mouth, noticing the taste and smell, being aware of jaw movement while chewing, swallowing, and then repeating the process with each spoonful until finishing the meal. Such practices have fostered healthier eating habits, leading to improved weight regulation.

Additionally, the stress-reducing effects of FFMBI may have played a role in mitigating stress-related eating and enhancing metabolic regulation.

The significant improvement in BMI and degree of obesity reinforces the potential of FFMBI as a tool for weight management, aligning with emerging research suggesting that mindfulness-based interventions can be effective adjuncts to traditional weight loss programs (Carrière *et al.* 2018, 164). The trending decrease in visceral fat rating, approaching statistical significance, is particularly noteworthy given the association between visceral fat and metabolic health risks (Shuster *et al.* 2012, 1).

However, these findings should be interpreted with caution. While statistically significant, the observed changes were relatively modest, and the study's short duration limits the ability to assess long-term effects or sustainability. Although no specific dietary restrictions were imposed, all participants adhered to the Buddhist precept of abstaining from food after noon. Consequently, all caloric intake occurred before midday, with meals consisting of a vegetable-based diet that included eggs but excluded meat. This consistent dietary pattern helped minimize variability in nutritional intake. Nevertheless, the fasting period after noon may have influenced fluctuations in body weight and BMI, necessitating further investigation into its long-term impact.

5.4 Stress Response and Brainwave Activity

The significant reduction in self-assessed stress levels aligns with the well-established stress-reducing effects of mindfulness practices (Khoury *et al.* 2015, 519). This decrease suggests that FFMBI was effective in helping participants manage their perceived stress, which could have far-reaching implications for mental health and overall well-being. The magnitude of this reduction over a relatively short intervention period is particularly noteworthy and speaks to the potential efficacy of FFMBI as a stress management tool.

The brainwave measurements provide compelling evidence for the neurophysiological impact of FFMBI. The significant increases in both the highest and average alpha/beta ratios indicate a shift towards a more relaxed and focused mental state. Higher alpha/beta ratios are associated with increased relaxation, improved attention, and enhanced cognitive processing (Putman *et al.* 2014, 782). These findings suggest that FFMBI may not only reduce subjective feelings of stress but also induce measurable changes in brain activity conducive to improved mental functioning.

5.5 Cortisol Response

The cortisol results present an unexpected finding. The significant increase in salivary cortisol levels seems to contradict the observed reductions in stress and improvements in brainwave patterns. However, it's crucial to consider the complex nature of cortisol function and its diurnal rhythm (Adam *et al.* 2017, 25). The timing of sample collection may have influenced these results, with pre-intervention samples collected between 9 a.m. and 10 a.m., and post-intervention samples collected just after 3 a.m. This discrepancy in collection times likely contributed to the observed increase in cortisol levels.

Future research should aim to clarify the relationship between subjective stress reduction, brainwave changes, and cortisol responses in the context of mindfulness practices. Longitudinal studies with more frequent cortisol sampling throughout the day could provide a more comprehensive understanding of how FFMBI affects the entire diurnal cortisol rhythm.

5.6 Participant Feedback and Experiences

The qualitative insights from participant interviews offer a deeper understanding of the FFMBI program's impact. Participants reported improvements in physical health, including better metabolism, reduced body pain, and enhanced sleep quality, aligning with the quantitative findings of slight but significant reductions in body weight and BMI. These physical benefits contribute to the overall well-being of participants and support the program's potential to foster a positive mind-body connection.

The mental benefits reported by participants, including increased relaxation, better focus, and reduced stress and anxiety, reinforce the significant reductions in self-assessed stress levels and the enhancements in brainwave activity observed in the study. These improvements in mental clarity, emotional stability, and mindfulness indicate that the FFMBI program effectively promotes mental well-being.

Importantly, participants expressed a strong intention to integrate mindfulness techniques into their daily lives, highlighting the program's sustainability and practical applicability. This intention is crucial for maintaining the benefits of mindfulness interventions over the long term and underscores the program's real-world applicability and potential for sustained impact.

5.7 Limitations and Future Directions

While this study provides valuable insights into the effects of FFMBI, several limitations should be acknowledged. The short duration of the intervention and the relatively small sample size limit the generalizability of our findings. The gender imbalance in our sample also restricts our ability to draw conclusions about the effectiveness of FFMBI across different demographic groups.

Future research should address these limitations by conducting longer-term studies with larger, more diverse samples. Additionally, investigating the mechanisms underlying the observed changes would be valuable, particularly examining the relationships between mindfulness, stress reduction, eating behaviors, and metabolic processes. Exploring the potential therapeutic applications of FFMBI in clinical populations, such as individuals with hypertension or obesity, could provide insights into its efficacy as a complementary treatment approach.

In conclusion, this study provides evidence for the multifaceted impact of FFMBI on both physiological and psychological parameters. The findings suggest that FFMBI has potential benefits for stress reduction, cognitive function, and body composition. However, the mixed results, particularly regarding cortisol levels, underscore the complexity of mindfulness interventions' effects on the body and mind. These results lay the groundwork for future investigations into the mechanisms and applications of FFMBI in promoting holistic health.

Ethics Statement

This study was approved by the Research Ethics Committee of the Buddhist Research Institute, Mahachulalongkornrajavidyalaya University, under case #R.263/2024 on May 9, 2024.

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The authors report there are no competing interests to declare.

6 Conclusion

This study provides compelling evidence for the multifaceted effects of the *Four Foundations of Mindfulness-Based Intervention* (FFMBI) on both physiological and psychological parameters. The findings demonstrate significant improvements in perceived stress levels, brainwave patterns associated with relaxation and cognitive function, and certain aspects of body composition. These results suggest that FFMBI has the potential to be an effective tool for stress management, cognitive enhancement, and overall well-being.

The observed reductions in body weight, BMI, and degree of obesity, although modest, indicate that FFMBI may have positive implications for weight management and metabolic health. The significant improvements in brainwave activity, particularly the increased alpha/beta ratios, provide objective evidence of the intervention's impact on mental states conducive to relaxation and focused attention.

While some findings, such as the increase in cortisol levels, were unexpected and warrant further investigation, they highlight the complex nature of mind-body interventions and the need for more comprehensive, long-term studies. The qualitative feedback from participants further supports the beneficial effects of FFMBI, emphasizing improvements in both physical and mental well-being, and indicating a strong likelihood of continued practice.

However, the limitations of this study, including its short duration and gender imbalance in the sample, underscore the need for more extensive research. Future studies should aim to include larger, more diverse samples over longer periods to better understand the long-term effects and sustainability of FFMBI benefits.

In conclusion, this research contributes valuable insights to the growing body of evidence supporting mindfulness-based interventions. The FFMBI program shows promise as a holistic approach to improving both mental and physical health. As we continue to face increasing stress and health challenges in modern society, interventions like FFMBI may play a crucial role in promoting overall well-being and quality of life. Further research in this area has the potential to refine our understanding of mindfulness practices and their applications in both clinical and non-clinical settings.

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