ORIGINAL ARTICLE

The Effects of Anapana Meditation Training Program Monitored by Skin Conductance and Temperature (SC/ST) Biofeedback on Stress in Bachelor's Degree Students

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Background: Stress was the major psychological problem affecting physical and mental health among undergraduate students.

Objective: To determine the effectiveness of a meditation training program (MTP) for stress reduction measured by biofeedback (BB) machine.

Material and Methods: The present study was a quasi-experimental study conducted in Faculty of Dentistry, Thammasat University, Thailand. The study period was between August and December 2023. Participants were first-year Dentistry students. MTP was concentration meditation (Anapana meditation). Stress measurement was evaluated by using Thai version of Perceived Stress Scale (T-PSS-10) performed at one week before study, 14 and 18 weeks. Stress evaluation by biofeedback machine using skin conductance (SC), and skin temperature (ST) were performed at one week before the study, and at week 4, 8, 14, and 18. Data from T-PSS-10 and SC/ST biofeedback were collected and analyzed.

Results: Twenty-eight subjects were recruited. The mean age of participant was 18.4 years old. Two-third (19/28) were female. Stress reduction from MTP was detected in the fourth and eighth weeks by STBB and SCBB, respectively. T-PSS-10 scores before MTP, 14, and 18 weeks were 17.7±5.4, 9.8±3.1, and 8.4±3.1 with statistical significance.

Conclusion: Meditation training program could reduce stress measured by SC/ST biofeedback.

Keywords: Stress; Meditation; Biofeedback; Student

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Bachelor's students face the transitional period from childhood to adulthood. Changes of the environment from high school to university need adaptation in both mental and physical health. Stress from this critical change could affect mental and physical health[1]. Half of university students reported low self-esteem, little optimism, and sense of self-efficacy[2]. Academic performance, pressure to succeed and post-graduation plans are the major potential factors of depression, anxiety, and stress in university students[3]. Teenagers in university especially female were exposed to excessive stress, anxiety, and suicidal ideation from mental health problems[4-6]. Adverse academic and health problems are associated with increased drug use among college students[7]. Age, feeling of exclusion, and verbal aggression are the major predictors of depressive mood and sleep disturbance in college students[8,9].

According to previous literature, depressive mood of health science students such as students studying in the medical, dental, and pharmacy fields, was higher compared to students from other faculties[10-14]. The nature of health science work requires knowledge and integration of biological sciences for clinical work based on live human. Overall suicidal ideation of dental students ranged from 13% to 48.2%[10,15,16]. From studies, dental practice and environment significantly correlate with stress, depression, and anxiety as reported among dental students[17-21].

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Meditation practices were shown to reduce stress and enhance forgiveness among university students[22]. Dalpati reported in 2022 that the practice of yoga and meditation could boost university students' performance and assisted them to maintain physical and mental health during stressful conditions[23]. Meditation scripts and biofeedback devices were utilized to support the mindfulness-based intervention, biofeedback, and self-regulation for stress reduction for university students who self-identify as highly stressed[24]. Ratanasiripong from Thailand reported in 2015 that the practice of mindfulness meditation was found to reduce anxiety and stress level in nursing students[25]. Stress reduction after mindfulness meditation was explained by the significantly increased average early morning cortisol, diurnal dehydroepiandrosterone (DHEA), and melatonin after mindfulness meditation from Nagendra's work[26]. Dental students perceived stress from both clinical and educational environment. However, the majority reported depression, anxiety, and stress at the level of normal to moderate level[27]. Most previous studies conducted for stress or anxiety reduction usually monitored the effect of intervention by pre and post intervention questionnaire[22,24,25].

The current study aimed to investigate the effectiveness of meditation training program (MTP) for stress reduction in dental students. The authors believed that meditation would significantly decrease stress or anxiety among participants. The result of stress from the Thai version of Perceived Stress Scale (T-PSS-10) questionnaire and biofeedback machine readout, which monitor the skin conductance (SC) and the skin temperature (ST), would be compared. The result from the present study could be used in designing student mental support.

Materials and Methods

Participants of the present study were the first-year bachelor's degree Thai students in dental studies both in regular and bilingual degree programs during the study period of August to December 2023. This quasi-experimental study was approved by the Ethical Committee of Faculty of Nursing, Thammasat University, Pathumthani, Thailand (COA. 110/2565). The flow of the study is presented in Figure 1. Inclusion criteria were the first year Thai dental students aged more than 18 years old at the time of the test with the self-identified of mild to moderate stress (T-PSS-10 between 1 and 26 points). The exclusion criteria were subjects having major psychiatric disorder confirmed by psychiatrist. The

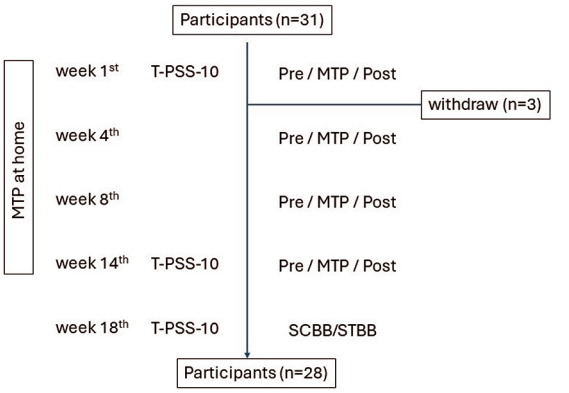

Figure 1. Flow of study.

T-PSS-10: Thai version of Perceived Stress Scale, SCBB: skin conductance biofeedback, STBB: skin temperature biofeedback; MTP: meditation training program, Pre: SCBB/STBB before MTP, Post: SCBB/STBB after MTP

scope of the work was explained to all and those who participated signed consent forms.

The sample size was calculated using G*Power program, version 3.1.9.4 (UCLA, LA, USA), with a power analysis of 0.80 and a confidence level of 95%. An effective size of 0.25 was chosen with alpha errors set at 0.05 level. Repeated measures ANOVA and MANOVA were selected as the statistical measurement, resulting in a sample size of 28 cases. An additional 10% was added to account for potential data loss, resulting in the total sample size of 31 cases. The ratio of participants in regular and bilingual programs was 3:2.

The qualitative data were collected from the questionnaire. The T-PSS-10 was used for evaluation of subjects' stress[28]. The T-PSS-10 consisted of ten items. Each item had a 5-point Likert scale ranging from zero for never, one for almost never, two for sometimes, three for often, and four for very often. This indicated the frequency of the subjects' thought within the previous month. The questions consisted of both positive and negative aspects. The Cronbach's alfa coefficient at level 0.76 was confirmed in the present study.

The biofeedback was of galvanic skin resistance measurement type (GSR/TEMP2, Thought Tech, Canada). This machine could be used to measure both SC and ST. The scale was ranging from –1 to 1. When the subject relaxed, the scale would show the negative number while the increasing stress level would result in the positive read out. The scale is shown in Figure 2A. The skin conductance biofeedback (SCBB) tool was used to measure sweat gland function which reflects levels of body's response

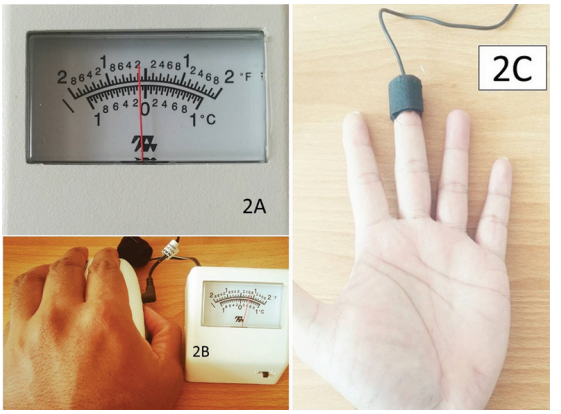

Figure 2. Biofeedback machine. (2A) GSR: galvanic skin resistance, (2B) SCBB: Skin conductance biofeedback, (2C) STBB: skin temperature biofeedback.

to stress. Participants were asked to place their left hands on the galvanic skin response (GSR) machine, which was connected to a device displaying stress levels and numerical results as shown in Figure 2B. Lower numbers indicated increased stress while higher numbers suggested relaxation. The results were analyzed after the session. Furthermore, the skin temperature biofeedback (STBB) tool measured ST changes showing stress levels. Increased stress caused blood vessel constriction and decreased ST in hands and feet. Participants placed a temperature sensor on their middle fingers while the machine was connected to a GSR machine and a pointer signal device, as shown in Figure 2C. Relaxation led to increase ST and was reflected in an increased number on the screen and a leftward shift of the pointer.

The meditation effect on participants measurement was conducted using questionnaires administered at the first, fourteenth, and eighteenth weeks. Anapana meditation in the current study consisted of walking and sitting meditation steps. The walk took around thirty minutes. The walking step consisted of walking slowly around ten meters, turning back, and repeating for thirty minutes. During the walk, the participants slowly inspired and exhaled. The participants' concentration focused on forehead, heart, and central part of their body, the umbilicus. At the same time, the participants focused on the mind of a single mantra, Budho, by silently repeating this word. This is part of the Anapana meditation. During the sitting meditation, participants sit cross-legged in the quiet place with a comfortable weather. The meditation was performed in the same manner as during the walking portion. The details of the meditation could be accessed via YouTube®[29].

Table 1. Demographic character of participants

Sex; n (%)	
Female	19 (67.9)
Male	9 (32.1)
Age (year); mean±SD	18.4±0.5
Program; n (%)	
Thai	17 (60.7)
English	11 (39.3)
Status; n (%)	
Learning	26 (92.9)
Combine	2 (7.1)
Residence; n (%)	
Dormitory	17 (60.7)
Home	11 (39.3)

SD=standard deviation
Thai: Thai dentistry program, English: bilingual dentistry program, Learning: only learning status, combine working, and learning status

Participants were assigned to a daily 60-minute MTP downloaded from the internet for 14 weeks[29]. At the end of the first, fourth, eighth and fourteenth weeks, participants were instructed to meditate at the Faculty of Dentistry so that data could be recorded from the GSR machine. Measurements were taken before and after the 45 minutes meditation using both SCBB and STBB tools. On the eighteenth week, the questionnaires were administered again alongside measurements from both SCBB and STBB tools.

Statistical analysis was performed by using IBM SPSS Statistics, version 28.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed by percentage, mean and standard deviation. Stress level from questionnaire was analyzed by ANOVA with repeated measurements. While MANOVA with repeated measurements was used to analyze the stress-level recorded by the SCBB and STBB machines.

Results

Twenty-eight participants completed the program out of 31 participants recruited. Two-thirds (19/28) of the participants were female. The mean age of the participants was 18.4 years old. Most of the participants actively registered for the regular program and stayed at the dormitory, as shown in Table 1. The level of stress as read from SCBB at pre- and post-MTPs showed a significant reduction in stress levels at the eighth and fourteenth weeks compared to the fourth week. Meanwhile, the stress level recorded by STBB decreased significantly in the fourth and fourteenth week. However, on the eighth week, the stress level from STBB showed

Table 2. Level of stress from SCBB and STBB at pre and post meditation training program

Week	SCBB; mean±SD				STBB; mean±SD			
	Pre	Post	d	p-value	Pre	Post	d	p-value
1	0.52±0.20	0.51±0.20	0.05	0.69	0.52±0.18	0.53±0.14	−0.06	0.70
4	0.46±0.14	0.47±0.15	−0.07	0.72	0.38±0.18	0.48±0.17	−0.57	<0.001
8	0.49±0.14	0.60±0.17	−0.71	<0.001	0.46±0.18	0.51±0.15	−0.30	0.05
14	0.50±0.16	0.60±0.17	−0.61	<0.001	0.44±0.13	0.56±0.14	−0.89	<0.001

SCBB=skin conductance biofeedback; STBB=skin temperature biofeedback; SD=standard deviation
Pre: before meditation, Post: after meditation, d: effect size by Cohen's d

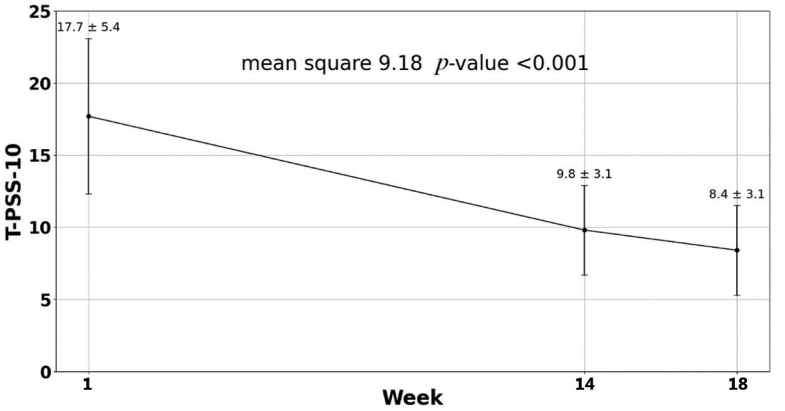

Figure 3. Analysis of stress reduction (T-PSS-10 questionnaire) by Greenhouse-Geisser.

T-PSS-10: Thai version of Perceived Stress Scale

stress reduction without statistically significant. The results are shown in Table 2. In Figure 3, the stress reduction from the T-PSS-10 questionnaire by Greenhouse-Geisser was analyzed. The graph results showed a significant decrease in stress levels ($p<0.001$). The analysis of stress reduction from SCBB and STBB were conducted through MANOVA with repeated measures, in which the results showed a significant decrease, which it is important to note that an increased value indicated stress reduction, at the fourteenth and eighteenth week as shown in Figure 4.

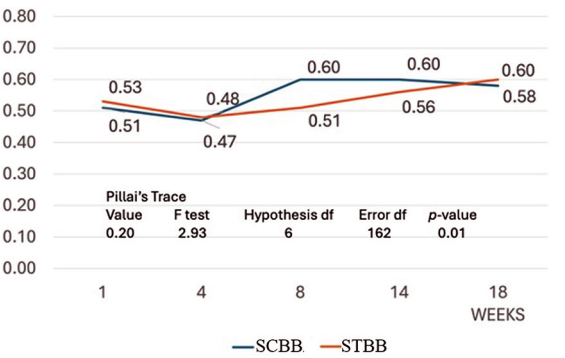

Figure 4. Analysis of stress reduction (SCBB/STBB) by MANOVA with repeated measure.

SCBB: skin conductance biofeedback, STBB: skin temperature biofeedback

Discussion

The participants recruited for the present study were dental students currently enrolled in their first year. The average age was 18.4 years old similar to the previous study conducted by Sakakibara[30]. In that study, the participants were Japanese students who engaged in 20 minutes of daily meditation to assess stress reduction levels. Attar et al.'s study had an average age of 20.6 years old[31]. In that study, the participants were not students, but the age group was similar. A study conducted by Lin et al. also recruited participants who were college students that self-identified as experiencing chronic stress at Southwestern University in the USA. Their average age was 24.1 years old, which is higher than in the present study[24]. Although there is a variance in the educational system between Thailand or USA, the meditation could reduce stress with statistical significance. This makes it reasonable to compare the outcomes of Lin's research with this present study. Additionally, Lee et al.'s and Brinkmann et al.'s research also recruited volunteer participants of

Table 3. Comparison of meditation for stress reduction with biofeedback to the previous literatures

	Present	Lin	Lee	Attar	Brinkmann	Sakakibara
Country	Thailand	USA	Korea	USA	GmbH	Japan
Year	2024	2021	2024	2021	2020	2022
Age (years)	18.4	24.1	49.1	20.6	44.1	Student
Meditation						
Per day (minutes)	30	20	24	5	20	20
Time (weeks)	14	2	2		6	
Subject (n)	28	39	38	15	69	17
Questionnaire						
STAI		Y	Y			Y
PSS-10	Y		Y	Y		
Biofeedback	E	NE	E	E	E	E
GSR	Y					
ST	Y					
EEG			Y	Y		
ECG				Y	Y	Y
RSA		Y				

STAI=State-Trait Anxiety Inventory; PSS-10=Perceived Stress Scale; GSR=galvanic skin response (skin conductance and temperature); ST=skin temperature; NE=no effective result of biofeedback; E=effective result of biofeedback; Y=yes; EEG=electroencephalogram; ECG=electrocardiogram; RSA=respiratory sinus arrhythmia

adult age, with average ages of 49.1 and 44.1 years old, respectively[32,33]. Regarding stress from different origin, the result of the current study supported the previous study that meditation could reduce stress.

In previous literature, meditation was typically practiced with no connection with any religion belief. The process focused on finding a quiet place, achieving calmness, and utilizing breathing techniques, often lasting around 20 minutes. The measurements of Lin et al.'s, Lee et al.'s, Attar et al.'s, and Sakakibara's works relied on self-filling questionnaires including State-Trait Anxiety Inventory (STAI) and PSS-10[24,30-32]. In the present research, the results from the self-filling questionnaires for all techniques demonstrated a reduction in stress levels, which correlated with the results from the previous studies.

Stress is a process that can cause a decrease in an individual's ability to work or learn, leading to psychological and biological changes[34]. Stress can activate both the sympathetic and parasympathetic nervous systems, resulting in observable reactions in the individual's body, such as changes in heart rate (HR), salivation, and body temperature[31]. Biofeedback was chosen for the present research due to its non-invasive nature, good compliance for monitoring, and the availability of uncomplicated and inexpensive equipment. Biofeedback equipment is available in several types, including HR, blood pressure (BP), GSR, respiratory sinus arrhythmia (RSA), and ST. In the current study, GSR and ST were selected to monitor individuals' perceptual levels of stress. The results showed that a 20-minute daily meditation could effectively reduce the individuals' stress levels as seen in both GSR (SCBB) and ST (STBB) results. Previous studies suggested that the reduction in stress through meditation could be observed within the first two weeks[24,32]. However, the present study using GSR detected the stress level at the eighth week, whereas the use of ST detected the stress reduction at the fourth week. Furthermore, stress levels could not be detected by ST at the eighth week significantly ($p=0.05$), due to the small participant numbers. However, by the fourteenth week, ST successfully revealed significant stress levels reduction. When GSR and ST results were compared, the reduction of stress level was shown using ST and GSR at the fourth and eighth week, respectively. Comparison of the current work to the previous literatures is summarized in Table 3.

The strength of the present study lies in its prospective study, which enhances the reliability of the findings. Additionally, the study was conducted in dental students which is known for its high stress prevalence, further increased the study's reliability. However, the small sample size was identified as a limitation of the study.

In conclusion, meditation proved effective in reducing stress levels as assessed through both self-report questionnaires and biofeedback mechanisms.

Questionnaire's data analyses might be time-consuming and complex. Biofeedback data offered convenient, affordable, and easily accessible data for stress detection analysis. Previous studies suggested that electrocardiogram (ECG) could provide faster outcomes in stress level detection, but it is expensive and requires sophisticated handling[31,32]. Conversely, GSR and ST measurements were simpler to use compared to ECG in routine practice and the measurement were easier for participants to independently manage. Despite the slower detection speed of GSR and ST measurement tools, the ease of use make them valuable tools in stress management practices.

What is already known on this topic?

Bachelor's students were teenagers and faced stress from the transitional period from childhood to adulthood. Stress can affect mental and physical health. Stress could increase sweating and decrease ST. The effects of stress reduction could be measured by biofeedback machine both SC and ST. Meditation practices were shown to reduce stress and enhance forgiveness. T-PSS-10 questionnaire was widely used to evaluate the stress level.

What does this study add?

Meditation effectively reduces stress levels, as shown by self-reporting questionnaires and biofeedback mechanisms. The use of biofeedback can serve as an alternative tool for stress monitoring and measuring stress levels reduction from meditation.

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Conflict of interest

The authors declare that there is no conflict of interest.

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