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Effects of Yoga on Heart Rate Variability and Depressive Symptoms in Women: A Randomized Controlled Trial

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Abstract

Objectives: The purpose of the study was to investigate the effects of a 12-week yoga program on heart rate variability (HRV) and depressive symptoms in depressed women.

Methods: This was a randomized controlled trial. Twenty-six sedentary women scoring ≥14 on the Beck Depression Inventory-II were randomized to either the yoga or the control group. The yoga group completed a 12-week yoga program, which took place twice a week for 60 min per session and consisted of breathing exercises, yoga pose practice, and supine meditation/relaxation. The control group was instructed not to engage in any yoga practice and to maintain their usual level of physical activity during the course of the study. Participants' HRV, depressive symptoms, and perceived stress were assessed at baseline and post-test.

Results: The yoga group had a significant increase in high-frequency HRV and decreases in low-frequency HRV and low frequency/high frequency ratio after the intervention. The yoga group also reported significantly reduced depressive symptoms and perceived stress. No change was found in the control group.

Conclusions: A 12-week yoga program was effective in increasing parasympathetic tone and reducing depressive symptoms and perceived stress in women with elevated depressive symptoms. Regular yoga practice may be recommended for women to cope with their depressive symptoms and stress and to improve their HRV.

Keywords: yoga, heart rate variability, depression, women's health, stress

Introduction

Depression is a serious mental disorder throughout the world. According to the Global Burden of Disease Study, depression is a leading cause of disease burden and is ranked the 11th highest cause of disability-adjusted life years in the world.[1] In Taiwan, the estimated lifetime prevalence of major depressive disorder (MDD) is 1.2%, and the 12-month prevalence is 0.6%.[2] Additionally, women are around twice as likely as men are to suffer from a depressive disorder.[2] The Global Burden of Disease Study also showed that depression is the fourth leading cause of disease burden in women but ranks seventh in men.[3] Consequently, it is especially important for women to acquire effective strategies to cope with their depressive symptoms and to improve and maintain their psychological well-being.

Yoga has received considerable attention for its therapeutic benefits over the past few decades.[4] Previous reviews also suggested that yoga may be an effective intervention for treating anxiety and depression.[5,6] In women, yoga has been shown to relieve stress in those who are pregnant,[7] those with mental distress,[8] and those with restless leg syndrome.[9] Yoga was also found to reduce depressive symptoms in women with depression,[10] breast cancer,[11] and menopausal symptoms.[12] Collectively, these findings suggest that yoga may be an effective strategy for women to adopt to cope with stress and the symptoms of depression.

Chronic stress and the failure to resolve negative emotional states can generate imbalance between the sympathetic and the parasympathetic nervous systems and result in reduced heart rate variability (HRV), a measure of cardiac autonomic activity.[13] Studies have revealed an association

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between depression and autonomic dysfunction, including elevated heart rate and reduced HRV.[14,15] High-frequency HRV (HF-HRV) measures parasympathetic influences, and low-frequency HRV (LF-HRV) measures both sympathetic and parasympathetic influences on the heart. The LF/HF ratio is a measure of sympatho-vagal balance,[16] although Billman[17] suggested LF/HF may not accurately quantify cardiac sympatho-vagal balance. In previous studies, depressed patients were shown to have reduced HF-HRV and higher LF-HRV and LF/HF when compared with healthy controls.[18,19] Reduced HRV indicates high sympathetic and low parasympathetic activity, and has been linked to increased cardiovascular morbidity and mortality.[20] Thus, individuals with depressive symptoms may be prone to have reduced HRV, which increases their risk of cardiovascular disease.

Yoga practice is thought to modulate HRV (i.e., reduce sympathetic and increase parasympathetic nervous system activity).[21] Yoga breathing provides a useful tool for adjusting imbalances in the autonomic nervous system and thereby influencing a broad range of both mental and physical disorders.[22] Studies have shown that a single session of yoga can acutely improve HRV in experienced yoga practitioners[23,24] and non-experienced office workers.[25] It is, however, unclear whether regular yoga training will result in positive adaptations in HRV, as previous findings have been inconsistent. A study of pregnant women showed no changes in HRV after 16 weeks of yoga training,[7] while another study of healthy adults showed an increase in LF/HF after a 10-week yoga intervention.[26] Only one study with a single-group design has examined the effect of yoga on HRV in individuals with depression. The results showed a significant reduction in LF-HRV after 8 weeks of training.[19] In a recent systematic review and meta-analysis of randomized controlled trials (RCTs), the authors reported that due to substantial heterogeneity of the study populations, yoga classes, control interventions, and HRV indexes in the reviewed RCTs, the effectiveness of yoga training in modulating HRV remains inconclusive.[27] Collectively, data about whether yoga training can result in improved HRV are limited. As women with depressive symptoms may be predisposed to dampened HRV, further investigation of the long-term effects of yoga on HRV in this population is warranted. Moreover, while a number of studies have examined the effects of yoga on depression, few have included measures of HRV. The inclusion of this physiological measure is important, as it can provide objective markers of the effectiveness of the intervention.

The main purpose of this study was to examine the effects of a 12-week yoga program on HRV and depressive symptoms in depressed women. The secondary purpose was to examine the effect of yoga training on perceived stress. It was hypothesized that there would be improvements in HRV and a reduction in symptoms of depression and perceived stress after the yoga intervention.

Method

Participants

All participants were volunteers recruited from a university and the surrounding community. To enroll in this study, participates had to be women, aged between 18 and 50 years old, have a body mass index (BMI) of $<30\,kg/m^2$, and have mild to moderate depressive symptoms (a score of 14–28 on the Beck Depression Inventory-II [BDI-II]). If a volunteer's score indicated that she had severe depressive symptoms (a score >28 on the BDI-II), written permission from her psychiatrist had to be obtained before she could enroll in the study. Participants also had to be sedentary (exercising fewer than three times per week for <20 min per session, as assessed by interviewing the participants using the Godin Leisure-Time Exercise Questionnaire[28]) and could not be involved in any yoga practice. Participants were excluded if they were pregnant or nursing or had physical contraindications to exercise (e.g., orthopedic problems or heart disease).

Participants were required not to take any medication or receive psychotherapy or other therapies for treating depression during the course of the study. However, if participants had been taking antidepressant medication for >3 weeks before study entry, they could enroll in this study and report any change in antidepressant use during the course of the study to the primary investigator. Since ectopic or missed beats may influence the analysis of HRV,[16] only participants without ectopic or missed beats during electrocardiogram (ECG) assessment were eligible for the study.

The sample size of 21 participants per group was calculated with an alpha level of 0.05, a power of 0.80, and an effect size of 0.89. The effect size was calculated using the means ± standard deviations (yoga: 7 ± 13; control: -5 ± 14) of the changes in high-frequency HRV (in normalized units) derived from a pilot study, which was conducted in 12 women (six per group) with elevated depressive symptoms. The G*Power was used for these calculations.[29] The study protocol was approved by the Kaohsiung Medical University Chung-Ho Memorial Hospital Institutional Review Board. Informed written consent was received from all participants.

Measures

All outcome measures were collected and analyzed at baseline (week 0) and 12 weeks later (week 13) by a qualified experimenter blinded to the group assignment. HRV analysis was derived from continuous heart rate recording at a sampling rate of 1024 Hz using an ECG system (MP 150; BIOPAC Systems, Goleta, CA). During the assessment, the experimenter first placed the electrodes at participants' midclavicular points bilaterally and a third electrode 1 cm above the left lower costal margin. Next, participants were instructed to relax in a supine position with no other tasks or stimulation for 20 min while the ECG was recording. The last 5 min of the ECG recording was analyzed for HRV. The standard deviation of normal-to-normal intervals (SDNN; estimate of overall HRV) was computed, and the HRV power spectrum was obtained via a fast Fourier transformation algorithm using an appropriate software program (HRV Analysis for Windows; Biosignal Imaging Group and Analysis, University of Kuopio, Kuopio, Finland). The energy in the specific frequency bands of HRV was expressed as normalized units for the two frequency bands: low frequency (LF; 0.04–0.15 Hz) and high frequency (HF; 0.15–0.40 Hz).[16]

Depressive symptoms were measured using the Beck Depression Inventory-II (BDI-II). The BDI-II is a self-report inventory with 21 items assessing the behavioral and cognitive symptoms of depression.[30] Each item consists of four statements numbered from 0 to 3, with a higher number indicating more severe depressive symptoms. Participants were asked to circle the statement that best described their symptoms in each item. The circled number from each item was summed to obtain a total score, which can range from 0 to 63. Scores of 0–13 indicate minimal depression, 14–19 indicate mild depression, 20–28 indicate moderate depression, and 29–63 indicate severe depression.[30] This inventory has demonstrated acceptable internal consistency, with Cronbach's alphas ranging from 0.92 to 0.93.[30]

Perceived stress was measured by the 14-item Perceived Stress Scale (PSS).[31] Participants were instructed to answer the PSS by indicating how often they felt or thought a certain way. The scale has a five-point scoring system, ranging from 0 to 4, with reverse scoring for seven positive items (i.e., items 4, 5, 6, 7, 9, 10, and 13). The final score is a sum of the scores for all 14 items. This scale has demonstrated acceptable internal consistency, with Cronbach's alphas ranging from 0.84 to 0.86.[31]

Procedures

All eligible participants were randomly assigned to the yoga group or the control group via a computer-generated random allocation sequence by simple randomization. The yoga group engaged in a yoga program in a group of three to five participants for 12 weeks. All yoga classes were offered twice per week and were led by the same instructor. The control group was instructed not to engage in any yoga practice and to maintain their usual level of physical activity during the course of the study. For both pretest and post-test, participants were requested to come to the laboratory between 7:00am and 11:00am and were instructed to avoid exercise one day before their lab visit and abstain from caffeinated food and beverages on the day of their visit. After completing the post-test, participants in the control group were provided a free 12-week yoga program.

Yoga program

The yoga program was group based and was led by an experienced yoga instructor blinded to the research questions. Each 60-min session consisted of 5 min of pranayama (breathing exercises), 5 min warm up, 40 min of asana (yoga pose) practice, and 10 min of savasana (meditation/relaxation). Yoga props, such as blocks and belts, were used in accordance with each participant's particular body type and needs in order to help participants achieve precise yoga postures safely and comfortably. Examples of yoga poses practiced were Mountain Pose, Downward Facing Dog, Warrior I, Triangle Pose, Tree Pose, Cat Pose, Child's Pose, and Corpse Pose. Not all poses were practiced in each session, and some more advanced poses (e.g., Warrior III, Plow Pose) were introduced later into the program as training progressed. Participants were instructed to maintain their concentration and synchronize their breaths with movements during the yoga session.

Statistical analyses

This study had a two-group, pre–post design. Descriptive statistics were performed for baseline characteristics of the participants. The baseline values were checked for matching between the groups by the independent samples *t*-test and the chi-square test. Intent-to-treat analysis of all participants was conducted. Missing data were imputed by carrying forward the last recorded observation. Pre–post differences within groups and between groups were checked using separate repeated-measures analyses of variance (ANOVA). Age and baseline BDI-II score were added as covariates in all ANOVAs for HRV. The significance level (α level) was set at 0.05, and partial eta squared (η^2) was used as an indicator of effect size. All data analyses were performed with the IBM SPSS Statistics for Windows v19 (IBM Corp., Armonk, NY).

Results

A total of 40 individuals volunteered for the study. Of these, 26 were found to be eligible and were randomized to either the yoga or the control group. Six participants dropped out during the course of the study for the reasons stated in Figure 1. There were no differences between those who dropped out of the study and those who completed the study with regard to any demographics, HRV, or psychological variables at baseline.

Baseline characteristics

Descriptive statistics for the 26 participants are presented in Table 1. At baseline, there was no significant difference between the yoga and control groups in any of the characteristics presented. The mean score of Godin Leisure-Time Exercise Questionnaire increased significantly ($p=0.001$) from baseline to post-test in the yoga group. This increase was mainly due to participation in the yoga program. On the other hand, no change was found in the control group, suggesting that the control group has maintained their usual physical activity level during the course of the study.

Four participants reported a diagnosis of MDD and were all taking antidepressant medication for >6 months. None of the participants had received any psychotherapy before study entry. Besides depression, other major health problems reported included sleep disturbance, chronic fatigue, and anxiety. For the yoga group, the average attendance rate was 81.3%, ranging from 67% to 100%. No adverse events or change in antidepressant use were reported during the course of the study.

All outcome measures are presented in Table 2. At baseline, there was no significant difference between the two groups in any of the HRV and psychological variables. No ectopic or missed beats were observed during ECG assessments. Nine participants in each group had a BDI-II score indicating mild to moderate depressive symptoms. The other four participants in each group had severe depressive symptoms, and all provided written permission from their psychiatrists to be enrolled in this study.

Effect of yoga intervention on HRV and heart rate

There were significant group–time interaction effects for HF-HRV, LF-HRV, and LF/HF after controlling for age and

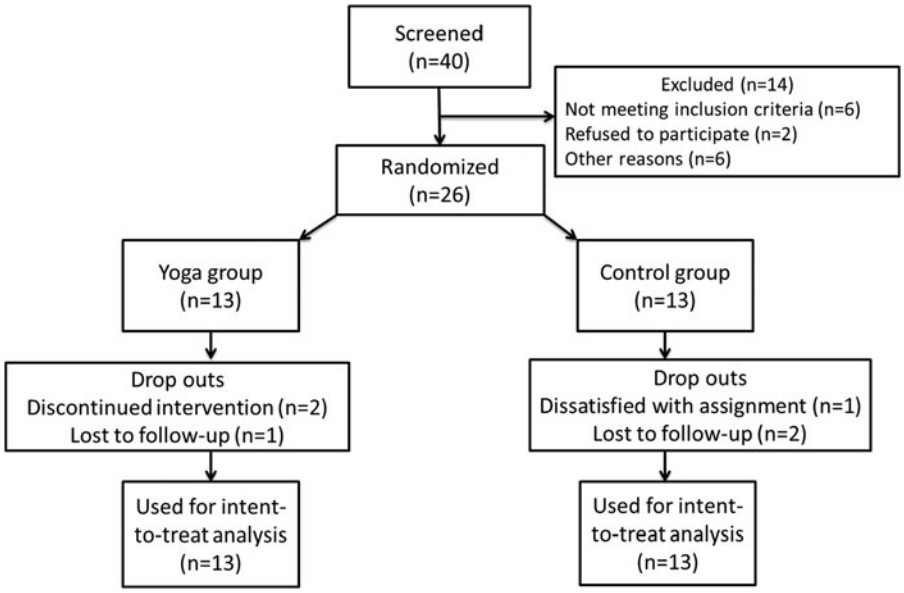

FIG. 1. Flow of participants.

baseline BDI-II scores (Table 2). The yoga group had a significant increase in HF-HRV ($F[1, 12] = 4.95$, $p = 0.046$) and decreases in LF-HRV ($F[1, 12] = 5.39$, $p = 0.039$) and LF/HF ($F[1, 12] = 5.60$, $p = 0.036$), while no significant change was found in the control group. The SDNN was shown to increase in the yoga group and decrease in the control group, yet both changes did not reach statistical significance. Both groups also showed no changes in heart rate after the intervention.

Effect of yoga intervention on psychological variables

For depressive symptoms, there was a significant group–time interaction effect for BDI-II scores. The yoga group reported significantly reduced BDI-II scores ($F[1, 12] = 11.59$, $p = 0.005$). Of the 10 participants who completed the 12-week yoga program, six had a BDI-II score of <14, indicating minimal depression. The control group, on the other hand, showed no changes in BDI-II scores. For perceived stress, the yoga group also reported significantly decreased PSS scores ($F[1, 12] = 13.57$, $p = 0.003$), while the control group showed no changes. The group–time interaction effect for PSS scores did not reach statistical significance.

Table 1. Baseline Characteristics

Characteristic	*Yoga group* (n = *13*)	*Control group* (n = *13*)
Age (years)	33.08 ± 9.11	32.38 ± 8.27
Body weight (kg)	51.36 ± 4.51	53.00 ± 5.29
Height (cm)	157.46 ± 5.04	161.31 ± 6.06
Body mass index (kg/m^2)	20.70 ± 1.26	20.35 ± 1.42
GLEQ baseline	4.77 ± 5.36	3.77 ± 4.90
GLEQ post-test	8.46 ± 4.77*	4.92 ± 4.65
Major depressive disorder diagnosis (*n*)	2	2
Antidepressant use (*n*)	2	2
Sleep disturbance (*n*)	10	9
Chronic fatigue (*n*)	5	6
Anxiety (*n*)	3	5

Data are presented as mean ± standard deviation unless otherwise stated.
*Significantly different from baseline.
GLEQ, Godin Leisure-Time Exercise Questionnaire.

Discussion

This study investigated the effect of yoga training on HRV, depressive symptoms, and perceived stress in depressed women. The results suggest that a 12-week yoga program prescribed twice a week for 60 min per session was effective in increasing HF-HRV and reducing symptoms of depression and perceived stress.

To the authors' knowledge, the present study was the first RCT to investigate the effect of yoga on HRV in women with depressive symptoms. The results revealed that a 12-week yoga program was effective in increasing HF-HRV and decreasing LF-HRV and LF/HF. The findings are similar to the results of previous studies using conventional treatments in a depressed population. Both pharmacologic treatments[15] and psychotherapy[32] were shown to be effective in improving depressive symptoms as well as HRV in individuals with depression.

Yoga training may increase HRV through the practice of pranayama. Pranayama are forms of voluntarily controlled breathing.[21] While practicing pranayama, participants are instructed to focus on their breathing and the sensations it produces in the body. It has been shown that by controlling breathing patterns during yoga practice, one may adjust imbalances in cardiac autonomic nervous system and increase HRV.[22] McCall[33] also suggested that the respiratory effects of pranayama, calming techniques in meditation, and physical movement in asanas may reduce sympathetic activation. In Field's review,[34] the increase in HRV after yoga training may be attributed to the stimulation of dermal and/or subdermal pressure receptors that are innervated by parasympathetic afferent fibers. Although this potential

Table 2. Changes in Outcome Measures in Both Groups

Outcome measure	*Yoga group* (n = *13*)		*Control group* (n = *13*)		*Time–group* p	*Effect size* η^2
	Baseline	*Post-test*	*Baseline*	*Post-test*		
Heart rate (bpm)	69.22 ± 6.24	71.08 ± 7.44	69.01 ± 7.06	68.83 ± 8.55	0.556	0.015
HRV						
HF (nu)	51.39 ± 18.80	59.66 ± 13.55*	52.84 ± 11.92	44.38 ± 20.89	0.012	0.255
LF (nu)	41.92 ± 19.99	32.99 ± 14.79*	41.98 ± 13.51	51.25 ± 20.16	0.007	0.284
LF/HF	1.13 ± 0.95	0.67 ± 0.63*	0.90 ± 0.51	1.80 ± 1.59	0.007	0.286
SDNN (ms)	43.05 ± 11.10	47.08 ± 22.38	53.39 ± 21.33	47.75 ± 20.02	0.228	0.065
Psychological measures						
BDI-II	29.77 ± 14.98	16.85 ± 9.51*	23.62 ± 8.86	21.15 ± 11.28	0.020	0.205
PSS	35.46 ± 5.90	27.62 ± 9.91*	32.77 ± 5.81	29.62 ± 8.53	0.155	0.083

Data are presented as mean ± standard deviation.
*Significantly different from baseline.
BDI-II, Beck Depression Inventory II; HF, high frequency; HRV, heart rate variability; LF, low frequency; LF/HF, low-to-high frequency ratio; nu, normalized units; PSS, perceived stress scale; SDNN, standard deviation of RR interval.

mechanism has not yet been tested, the author suggested that the practice of asanas may stimulate pressure receptors that lead to increased parasympathetic activity.

It is important to note that respiratory parameters (i.e., respiration rate, tidal volume) can alter HRV independent of changes in cardiac autonomic regulation.[17,35] In other words, changes in breathing patterns as a result of yoga training may contribute to changes in HRV at post-test. As breathing was not controlled during the ECG assessment, it was unclear whether the breathing pattern had changed in the yoga group and whether this change (if any) would have influenced the results of HRV. Future research should include assessments of breathing pattern to control for its influence on HRV in yoga training studies.

The SDNN was not affected by yoga intervention. Although SDNN was shown to increase in the yoga group, this increase was not significant. In Papp et al.'s pilot study, a non-significant increase in SDNN was also reported in a small sample of nine healthy adults after 8 weeks of hatha yoga.[36] On the other hand, this study showed a significant increase in HRV at night (between 2.00am and 4.00am) on pNN50% after yoga intervention. As SDNN was rarely reported in yoga training studies, the effect of yoga training on this HRV parameter remains unclear and warrants further investigation.

In agreement with previous studies that examined the effect of yoga training in women,[7–12] the present study showed significant reductions in symptoms of depression and perceived stress after the yoga program. The average BDI-II score in the yoga group decreased from 29.77 to 16.85. This amount of reduction is comparable to findings in older patients[37] and women[38] with depression after aerobic exercise training. Accordingly, the findings suggest that yoga may be an effective strategy for coping with depressive symptoms in women.

The strengths of this study were the RCT study design and the inclusion of both psychological and physiological measures. One limitation of this study was the small sample size. Although the participant recruitment period was extended for another 12 months, it was still not possible to reach the goal of 21 participants per group. Many volunteers could not enroll in this study due to time constraints. Two volunteers were excluded because they refused to be referred to a psychiatrist (BDI-II scores >28). This low recruitment rate may also be attributed to the very low prevalence of MDD in Taiwan (lifetime prevalence 1.2% in Taiwan vs. 19.2% in United States), which may be explained by cultural stoicism and social stigma.[2] Nonetheless, the data analysis showed that the sample size provided adequate power (0.746–0.809) to detect differences between the yoga and control groups. Future studies may consider providing one-on-one yoga sessions, more flexible class schedules, or home yoga sessions to reduce time constraints for the participants and improve recruitments.

Another limitation was that only four participants in the present study reported a diagnosis of MDD. Thus, the results may not be generalized to individuals with clinical depression. Nevertheless, as the reduction in BDI-II score found in the present study was comparable to previous study in clinically depressed population,[37] yoga may still be recommended as a viable adjunct therapy for clinically depressed women. Furthermore, since yoga sessions were performed in a group setting, it is possible that the social interaction of study participants during yoga sessions may have had some beneficial effects. Previous studies on individuals with depression have reported a placebo effect from social interaction during intervention.[38,39] Another potential placebo effect is participant expectations of benefits from yoga training.[40] Future research should include both control and placebo groups to control for these potential placebo effects and to understand better the true effect of yoga on psychological outcomes.

Conclusions

A 12-week yoga program prescribed twice a week for 60 min per session was effective in increasing parasympathetic tone and reducing depressive symptoms and perceived stress in women with elevated depressive symptoms. Regular yoga practice may be recommended for women to cope with their depressive symptoms and stress and to improve their HRV and reduce the risk of developing cardiovascular disease.

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Author Disclosure Statement

No competing financial interests exist.

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