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Effect of breathing exercises with biofeedback on blood pressure in pre-hypertensive women: a randomised controlled trial

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Abstract

Introduction. Pre-hypertensive women are significantly more likely to develop hypertension or serious cardiovascular disease (CV). Autonomic nervous system abnormalities, such as sympathetic overactivity and parasympathetic withdrawal, are most likely the earliest functional changes in hypertension. The objective of this study was to determine the effect of breathing exercises with biofeedback on blood pressure (BP), heart rate variability (HRV), respiratory rate (RR), and skin galvanic response (SGR).
Methods. Thirty middle-aged women with pre-hypertension (120/80–139/89 mm Hg) were recruited from Ain Shams University. They were divided randomly into two equal groups, with ages ranging from 30 to 40: study group (group A) who performed slow abdominal breathing (six cycles/minute) combined with frontal electromyography (EMG) biofeedback training (3 days per week for 10 sessions) and a control group (group B) who performed slow abdominal breathing (six cycles/minute, 3 days per week for 10 sessions). All subjects were assessed by measuring systolic blood pressure (SBP), diastolic blood pressure (DBP), HRV, RR, and SGR levels before and after the intervention.
Results. SBP, DBP, RR, and SGR mean values showed a statistically significant decline; however, group A's HRV post-treatment increased significantly compared to pre-treatment ($p = 0.001$). In group B, there was no significant difference in DBP or SGR; however, there was a substantial drop in SBP and HRV ($p = 0.001$) and a significant rise in RR ($p = 0.001$). Following therapy, there was a significant difference between the two groups in terms of DBP, HRV, RR, and SGR ($p = 0.001$), favouring group A.
Conclusions. As a result, it is possible to infer that breathing exercises combined with biofeedback were beneficial in lowering BP in middle-aged pre-hypertensive women.
Key words: pre-hypertensive women, blood pressure, breathing exercise, biofeedback

Introduction

Blood pressure (BP), the pressure in the body's arterial system, is regarded as normal when it measures 120 mm Hg systolic (the highest pressure recorded during a ventricular contraction) and 80 mm Hg diastolic (the lowest pressure recorded just before the subsequent contraction) [1]. Stage 1 hypertension ranges from 130 to 139 mm Hg systolic or 80 to 89 mm Hg diastolic, while stage 2 hypertension includes values at or above 140 mm Hg systolic or 90 mm Hg diastolic. These classifications should be based on two or more (averaged) measurements taken on at least two different days rather than just one BP reading [2].

The Joint National Committee on Preventing, Diagnosing, Evaluating, and Treating Hypertension's seventh report, or JNC-7, was released in 2003, defining pre-hypertension (PHT) as a BP range within the new category of 120/80 to 139/89 mm Hg. PHT was found in 31% of American adults, and it was also common in Asians [3].

It is generally recognised that PHT increases the risk of cardiovascular illness and hypertension later in life, which elevates the possibility of cardiac illness and death [4].

Many variables, including genetics, hormones, age, way of life, psycho-physiological elements, and metabolic elements, have an impact on the pathophysiology of PHT [4].

In females, sex-specific risk factors may be an important indication for the development of PHT. In menstruating females, the BP rises with the onset of menstruation in both normotensive and hypertensive women. Both physical and psychological stresses are usually corresponding to this increase in BP [5].

Yet, it is now understood that psycho-physiological stress is among the most significant risk variables for the beginning and development of high BP. Patients with hypertension or PHT are more vulnerable to cardiovascular issues as a result of stress due to the fact that acute tension alters endothelial function and causes transient increases in arterial pressures and heart rate (HR) [4].

The autonomic nerve system and the hypothalamic-pituitary-adrenal axis are deeply linked, according to mechanistic research, which is impacted by both acute and persistent stress. This results in increased sympathetic cardiovascular activity, which raises BP or causes arrhythmias. Additionally, a growing body of research shows that pre-hypertensive individuals and individuals who are stressed out exhibit autonomic dysregulation, it also includes a rise in sympathetic tone, a fall in HRV, and an increase in baroreflex sensitivity [4].

Non-pharmacological and lifestyle management strategies are mandatory for all people diagnosed with elevated BP. These include instructions about weight control, salt restriction, aerobic exercise, breathing, and biofeedback [6]. Studies have shown a link between slow, deep breathing exercises at six to ten breaths every minute and a drop in SBP and DBP [7].

Evidence also suggests that when combined with biofeedback, breathing exercises can help with hypertension

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management. Breathing relaxation activates the parasympathetic nervous system, which lowers sympathetic parameters like HR, respiratory rate (RR), BP, and SGR through diaphragmatic stretch and subsequent vagal stimulation. SGR was chosen for biofeedback because it is a sensitive indication of sympathetic nervous system activity [8].

There are few studies showing that slow abdominal breathing exercises with biofeedback have been used and shown to be effective for lowering BP, but till now, there was no previous study illustrating its effect specifically on PHT in middle-aged women. Consequently, this study will be the first in this field. As a result, this study will aid medical care organisations and add to the body of knowledge held by physical therapists in the scientific community.

Hypothesis: It was hypothesised that breathing exercises with biofeedback will have a positive effect on BP in pre-hypertensive middle-aged women.

Subjects and methods

Study design and sites

This prospective pretest-posttest randomised controlled clinical experiment was undertaken at Ain Shams University from August 2022 to December 2022.

Sampling procedure and recruitment

Initially, a sample of middle-aged women with PHT was assessed for qualifying criteria. Following the screening procedure, women who participated in the research must meet the following requirements. A physician diagnosis of PHT using a digital sphygmomanometer (SBP ranges from 120 to 139 mm Hg and/or DBP is between 80 and 89 mm Hg) [9], they were under 30 kg/m^2 in regards to body mass index (BMI), and every participant experienced regular menstruation. Women were excluded if they had taken any hypertensive medicines in the month preceding the start of the trial, if they had cardiovascular, cerebrovascular, pulmonary, or autoimmune disorders, diabetes, neuropathy and other autonomic neuropathies, or if they used any type of relaxation method.

An independent person randomly selected numbers from a sealed envelope to divide the participants into two equal groups: study group (group A) who performed frontal EMG biofeedback training in conjunction with slow abdominal breathing (six cycles per minute, 3 days per week for 10 sessions) and a control group (group B) who performed slow abdominal breathing (six cycles/minute, 3 days per week for 10 sessions). Figure 1 depicts a representation showing patient retention and randomisation throughout the research. According to the graph, 40 individuals were first assessed, and 30 patients were found to be qualified to participate in the research following the screening procedure.

Before taking part in this trial, all participants were given a thorough description of the evaluation and therapy methods, and each subject signed an informed consent form.

Anthropometric measures

Each participant in the two groups had her weight and height measured using a weight-height scale. By dividing the weight in kilograms by the square of the height in square metres, the BMI was computed.

Outcome variables

Blood pressure

BP was monitored using a Granzia digital sphygmomanometer before and after therapy for each woman in both groups as it is reliable and valid in assessing the BP in accordance with Muntner et al. [9]. Before each measurement, the research subject was calm for at least 10–15 min and sitting with their legs uncrossed, back properly supported, and arms

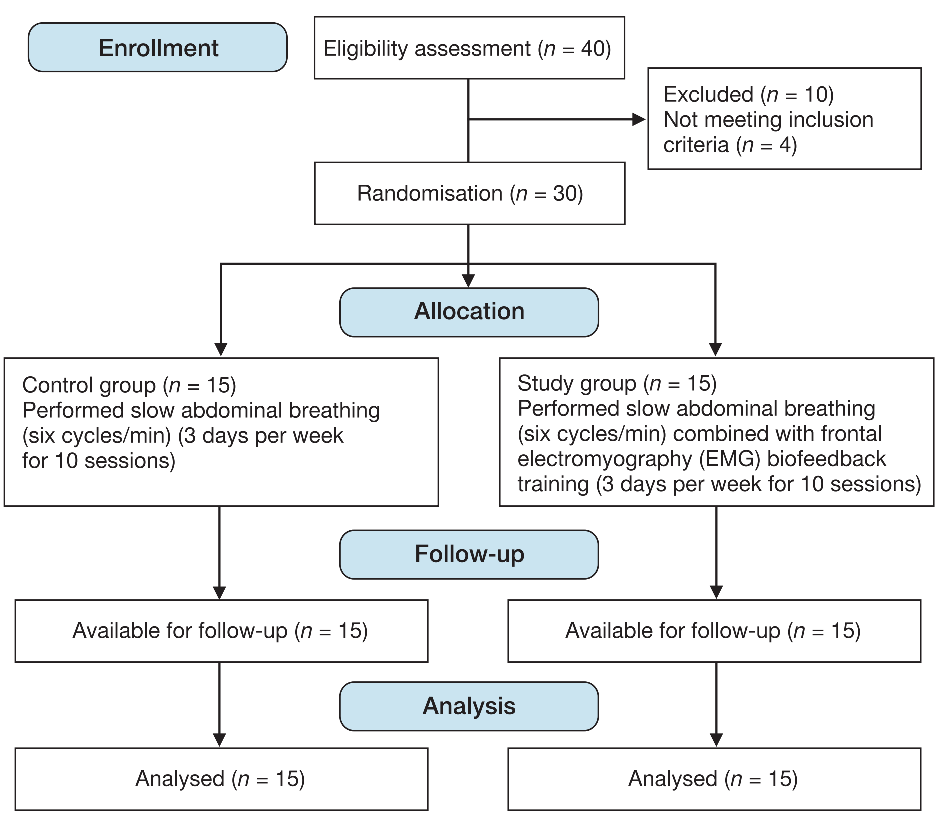

Figure 1. Flowchart outlining the study's experimental strategy

supported at heart level. Cuffs of various sizes were utilised. Each participant's BP was tested twice at 30-second intervals, and the average of the two values was recorded on a data input form.

Heart rate variability

Each woman in groups A and B had her HRV measured using an electrocardiogram (ECG, NeXus-10 biofeedback and neurofeedback system) before and after treatment. When evaluating HRV, the NeXus-10 biofeedback and neurofeedback system exhibits a high level of performance, reliability, and validity according to Wang et al. [10]. After being amplified by a preamplifier, a computer recorded the ECG (lead II) signal at a sampling rate of 1 kHz. The pre-treatment data included an ECG obtained during the first 5 min of the first session. As post-treatment data, 5 min of the tenth session's final ECG was recorded [6].

Skin galvanic response

Electrodermal activity (sweat gland activity) was monitored using a skin sensor connected to the NeXus-10 biofeedback and neurofeedback system before and after the treatment program for each woman in groups A and B. The NeXus-10 biofeedback and neurofeedback system is valid and reliable in assessing SGR, according to Lin et al. [3]. The skin sensor was connected around the participant's index and ring finger to assess the activity of the sweat glands and the quantity of perspiration on the skin, alerting the subject to anxiousness.

Respiratory rate

Each woman in groups A and B had her RR assessed using the NeXus-10 biofeedback and neurofeedback system before and after the treatment program as it represents a high level of performance, accuracy, reliability and validity in assessing the RR according to Lin et al. [3]. To evaluate the participant's breathing patterns and RR, bands with respiratory sensors were placed around their abdomens.

Independent variables

Before the beginning of the study:

– Each woman received information on the advantages of breathing exercises before the start of the trial to elicit her participation.

– The participants were instructed the day before each appointment not to consume any alcohol, caffeine, tea, or spicy meals.

– Twenty minutes of relaxation were advised for all participants before each session so that their bodies could acclimate to the lab setting. The procedure was carried out in a calm lab with preset relative humidity levels of 60% to 70% and air temperatures of 24°C to 26°C.

– All participants received incremental instruction in abdominal breathing to help them develop the requisite skills. To perceive each breathing pattern as abdominal breathing, an inductive belt around the participant's abdomens was connected to a computer and was instructed to be worn while they were lying supine. Also, they were told to touch their chests and abdomens with their hands. They were then instructed to breathe through their abdomen, gradually lowering their breathing frequency to a rate of six times per minute and raising their respiratory amplitude. To assist the participants in modifying their breathing patterns and frequencies, a screen was used to display the amplitude and frequency of abdominal movements (respiration biofeedback).

– The study proceeded to the following step when subjects acquired the calm abdominal breathing basics.

Breathing training program with biofeedback for group A

Participants were asked to lie down comfortably while a biofeedback device with three electrodes (one reference electrode and two recording electrodes) were fixed over the frontal muscle (1 mm above their eyes). The subjects were then asked to slowly relax their frontal, mimetic, masseter, shoulder, and limb muscles while performing the six cycles per minute abdominal breathing mentioned above (with respiration biofeedback). Their frontal EMG signal amplitude was decreasing, as displayed on the biofeedback machine (the feedback signal), as a result. They were instructed to visualise their arms and legs getting heavy and limp, as well as their hands and feet increasingly warmer and warmer. The session was repeated three times a week for ten sessions, each lasting 20 min.

Breathing training program for group B

The members of this group were instructed to lie down in a relaxed manner. Afterwards, for ten sessions totalling 20 min each, the abdominal breathing exercises described above were practised by the participants (six cycles/minute, independently counted without respiratory biofeedback).

Data analysis

Using G*POWER statistics (G*power version 3.1), sample size calculations were done to establish the needed sample size for both groups. Utilising data from [11], with a mean difference between groups of 4 seconds. A two-sided *t*-test was performed with an error probability of 5%, a power of 80%, and an effect size of 0.97, yielding a sample size of 15 participants per group. Calculations were performed with $\alpha = 0.05$, $\beta = 0.8$, effect size = 0.97, and allocation ratio of N2/N1 = 1.

Statistical design

Data was presented as means ± *SD*. To compare between subjects, an unpaired *t*-test utilised traits that distinguish the two groups. Kolmogorov–Smirnov and Shapiro–Wilk tests were employed to check the normality of the data distribution. For parametric variables (SBP, DBP, HRV, and RR), MANOVA was used to examine effects within and between groups and Wilcoxon and Mann–Whitney tests were used for non-parametric variables (SGR). The statistical package for the social sciences computer program (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA) was used to analyse the data. A *p-value* of 0.05 or less was considered to be significant.

Results

Demographic data of the subjects

Thirty pre-hypertensive women participated in this study and were split into two equal groups: group A (study), consisting of 15 women who received frontal EMG biofeedback training along with slow abdominal breathing, and group B (control group), consisting of 15 women who received slow abdominal breathing only. The mean age and BMI of the two groups were not statistically different from one another, as indicated in Table 1 (p = 0.723 and 0.534, respectively).

Table 1. Demographic data of the subjects of both groups

Demographic data	Group A (study group) mean ± *SD*	Group B (control group) mean ± *SD*	*p*-value	*t*-value
Age (years)	33.9 ± 2.3	34.3 ± 2.7	–0.358	0.723
BMI (kg/m^2)	25.9 ± 1.7	26.3 ± 1.8	–0.630	0.534

BMI – body mass index

Normality test

Data were examined for the presence of extreme scores, homogeneity of variance, and assumptions. Kolmogorov–Smirnov and Shapiro–Wilk tests for normalcy revealed that SBP, DBP, HRV and RR variables were normally distributed, while the SGR variable was not normally distributed.

The impact of EMG biofeedback training on SBP and DBP

SBP in group A had a mean ± *SD* of 135 ± 2.3 and 129.9 ± 3.4 mm Hg, respectively, before and after treatment. The SBP in group A dropped by 3.8% post-treatment compared to pre-treatment, which was statistically significant (p = 0.001). The mean and standard deviation of group A's DBP before and after treatment were 83.5 ± 1.6 and 80 ± 1.6 mm Hg, respectively. Compared to pre-treatment, group A's DBP dropped 4.2%, which was statistically significant (p = 0.001).

The mean and standard deviation of group B's SBP before and after treatment were 134.9 ± 1.5 and 131.7 ± 1.8 mm Hg, respectively. SBP dropped 2.4% less in group B post-treatment compared to pre-treatment (p = 0.001), which was statistically significant. The mean and standard deviation of group B's DBP before and after treatment were 84.3 ± 1.9 and 83.9 ± 1.8 mm Hg, respectively. Change as a percentage was 0.5%. Between the pre- and post-treatment measurements of DBP in group B, there was no statistically significant difference (p = 0.167, Table 2).

Table 2. Mean ± *SD* for SBP, DBP, HRV, and RR pre- and post-treatment in both groups

Measured variables	Group A (study group) mean ± *SD*	Group B (control group) mean ± *SD*	*F*-value	*p*-value	η^2
SBP (mm Hg)					
pre-treatment	135 ± 2.3	134.9 ± 1.5	0.036	0.851	0.001
post-treatment	129.9 ± 3.4	131.7 ± 1.8	3.3	0.080	0.106
mean difference	5.1	3.2			
% of change	↓3.8%	↓2.4%			
p-value	0.001*	0.001*			
DBP (mm Hg)					
pre-treatment	83.5 ± 1.6	84.3 ± 1.9	1.58	0.219	0.053
post-treatment	80 ± 1.6	83.9 ± 1.8	40.14	0.001*	0.589
mean difference	↓3.5	↓0.4			
% of change	4.2%	0.5%			
p-value	0.001*	0.167			
HRV (ms)					
pre-treatment	14.4 ± 2.2	15.8 ± 2.9	2.006	0.168	0.067
post-treatment	17.2 ± 2.3	12.5 ± 3.1	21.76	0.001*	0.437
mean difference	–2.8	3.3			
% of change	↑19.4%	↓20.9%			
p-value	0.001*	0.001*			
RR (breath /min)					
pre-treatment	18.6 ± 2.5	17.3 ± 2.9	1.76	0.195	0.059
post-treatment	16.1 ± 2.7	19.9 ± 2.4	15.95	0.001*	0.363
mean difference	↓2.5	–2.6			
% of change	13.4%	↑15%			
p-value	0.001*	0.001*			

SBP – systolic blood pressure, DBP – diastolic blood pressure, HRV – heart rate variability, RR – respiratory rate
* significant

The mean SBP post-treatment values between the two groups did not differ statistically significantly, according to MANOVA ($p = 0.080$); however, the mean DBP post-treatment values did differ significantly in favour of group A ($p = 0.001$, Table 2).

The impact of EMG biofeedback training on HRV and RR

Group A's mean and standard deviation for HRV pre- and post-treatment were 14.4 ± 2.2 and 17.2 ± 2.3 ms, respectively. Compared to pre-treatment, group A's HRV increased by 19.4% in a statistically significant way ($p = 0.001$). The mean and standard deviation of group A's RR before and after therapy were 18.6 ± 2.5 and 16.1 ± 2.7 breaths per minute, respectively. Compared to before treatment, group A's RR dropped by 13.4%, which was statistically significant ($p = 0.001$).

Group B's HRV pre- and post-treatment mean ± *SD* values were 15.8 ± 2.9 and 12.5 ± 3.1 ms, respectively. In group B, the post-treatment HRV was statistically significantly lower than the pre-treatment HRV by 20.9% ($p = 0.001$). The mean and standard deviation of group B's RR before and after therapy were 17.3 ± 2.9 and 19.9 ± 2.4 breaths per minute, respectively. Compared to before treatment, group B's RR rose 15% ($p = 0.001$, Table 2). According to MANOVA, group A was statistically significantly better than group B in terms of post-treatment mean values of HRV and RR ($p = 0.001$, Table 2).

The impact of EMG biofeedback training on SGR

The median interquartile range (IR) of SGR pre- and post-treatment of group A was 2 (1–2) and 1 (1–1) microsiemens, respectively. There was a statistically significant decrease in SGR by 50% in group A post-treatment compared to pre-treatment ($p = 0.007$). The median IR of SGR pre- and post-treatment of group B was 2 (2–2) and 2 (2–2) microsiemens, respectively. There was no statistically significant difference in SGR between pre- and post-treatment in group B ($p = 0.317$). Mann–Whitney tests revealed that there were statistically significant differences in the median values of SGR post-treatment between both groups ($p = 0.001$) in favour of group A (Table 3).

Table 3. Median (IR) of skin galvanic response (SGR) pre- and post-treatment for both groups

Skin galvanic response (microsiemens)	Group A median (IR)	Group B median (IR)	Mann–Whitney test	
Pre-treatment	2 (1–2)	2 (2–2)	*z*-value	*p*-value
Post-treatment	1 (1–1)	2 (2–2)	–0.479	0.632
% of change	50%	0%	–3.23	0.001*
p-value (Wilcoxon test)	0.007*	0.317		

IR – interquartile range, * significant

Discussion

PHT is a separate risk indicator for heart and brain arterial disease, according to numerous studies. After correcting for other cardiovascular risk factors, they have also shown that pre-hypertensive patients are more likely to experience total cardiac vascular events, myocardial infarctions, and strokes. Furthermore, past studies have connected microalbuminuria, atherosclerosis, and left ventricular hypertrophy to target organ damage caused by PHT [12]. This study's objective was to determine how breathing exercises with biofeedback affected BP in pre-hypertensive women.

The findings of our research revealed that:

Following treatment, SBP considerably decreased in both groups compared to baseline. However, there was no statistically significant distinction between the two groups' post-treatment values ($p = 0.080$), but the percentage of decrease was greater in group A (3.8%) compared to group B (2.4%). This can be explained by the activation of pulmonary-cardiac mechanoreceptors, slow abdomen breathing causing arteriolar dilation while suppressing sympathetic nerve activity, and chemoreflex activation. A decrease in SBP is the outcome of raising parasympathetic activity and baroreflex sensitivity [7].

Using biofeedback-assisted training, a method that is often employed for relaxation training, trainees can immediately recognise changes in their physiological signals thanks to real-time visualisation improving training effectiveness and skills. Training in relaxation techniques with biofeedback has been more effective than breathing alone in treating hypertension [10].

Our results agreed with those of Wang et al. [10], who claimed that biofeedback and slow-breathing exercises worked better together to lower BP than each of them alone ($p < 0.05$). Moreover, our findings matched those of Lin et al. [3], who found that heart rate variability-biofeedback (HRV-BF) considerably reduced SBP throughout the follow-up period, persisting for at least 3 months.

In terms of DBP, group A experienced a statistically significant decrease in DBP of 4.2% from pre- to post-treatment ($p = 0.001$); however, group B experienced no statistically significant change in DBP between pre- and post-treatment ($p = 0.167$). There was a statistically significant difference in the mean values of DBP post-treatment ($p = 0.001$) in favour of group A when comparing post-treatment values.

The improvement in DBP in group A can be attributed to a combination of slow abdominal breathing and biofeedback, which activated the baroreflexes and then "exercised" them in a way that could increase baroreceptor sensitivity more efficiently than simply slow breathing alone [3].

This result agrees with Elavally et al. [8], who looked into how nurse-led home biofeedback affected BP and discovered that the mean SBP and DBP of the research group participants significantly decreased. However, the participants in the control group's mean systolic and diastolic BP levels marginally increased between the pretest and posttest.

These findings conflict with a study carried out by New York et al. [13], who investigated how guided timed breathing biofeedback affected BP and found that participants experienced a decrease in mean SBP following the intervention ($p = 0.002$); however, there was no statistically significant decline in DPB.

The explanation why DBP did not improve in group B post-treatment can be explained by the absence of complementary feedback signals during slow abdominal breathing that reflect the state of the body as well as the comparatively brief practice period. Participants were unable to adjust appropriately to achieve a greater level of relaxation without the feedback signals, which resulted in a comparatively less effective reduction in BP [10].

These findings matched those of Wang et al. [10], who asserted that doing slow abdominal breathing exercises significantly reduced SBP by 4.3 mm Hg ($p < 0.05$) but did not affect DBP ($p > 0.05$).

From pre-treatment to post-treatment, group A's HRV increased significantly by 19.4% ($p = 0.001$). This can be explained by the requirement of respiratory sinus arrhythmia (RSA) biofeedback, also known as HRV-BF, to slow breathing to a frequency at which the amplitude of HRV is maximised. Resonant frequency (RF) is the term used to describe this frequency [3]. Numerous studies have shown that essential hypertensive patients showed a drop in HRV, an increase in sympathetic activity, and a decrease in parasympathetic activity of the autonomic nervous system even in the early stages of the disease. According to studies by Lehrer and Gevirtz [14], HRV-BF may boost HRV and lower BP in persons with hypertension.

This result agreed with Wang et al.'s findings [10], which showed that the R-R interval significantly increased after training compared to the control group.

In contrast, group B showed a statistically significant reduction in HRV of 20.9% between pre- and post-treatment ($p = 0.001$). This can be explained by the fact that six cycles per minute of slow abdominal breathing increased the NN intervals' standard deviation while having no impact on the R-R interval. The R-R interval changes increased arterial baroreflex sensitivity, which reduces sympathetic activity and chemoreflex sensitivity (due to the Hering-Breuer reflex being activated by the increased tidal volume), respectively, both of which are induced by the R-R interval changes, which enhance arterial baroreflex sensitivity. The inefficiency of slow abdominal breathing in increasing HRV may also be caused by a lack of feedback signals that match and represent the body's situation. Without the feedback signals, participants would not have been able to reach a deeper state of relaxation. To get the best results, slow breathing exercises should be paired with another procedure that can provide feedback signals, like EMG biofeedback [10].

This agrees with research done by Joseph et al. [15], slow breathing decreased systolic and diastolic pressures as well as the RR interval ($p < 0.05$).

In group A, there was a statistically significant reduction in the RR of 13.4% from pre-treatment to post-treatment ($p = 0.001$), as biofeedback is an additional therapy focused on self-regulation that helps patients restore mental and emotional control over their bodies. This is accomplished by providing feedback on people's unconsciously occurring physiological activities and helping them to manage them consciously while reducing autonomic nervous system activity. So when breathing exercises paired with biofeedback can aid in the control of stretching the diaphragm and stimulating the vagus nerve, which results in a decrease in sympathetic indices, including HR, RR, and BP [14].

While in group B, RR increased by 15% post-treatment compared to pre-treatment, which is statistically significant ($p = 0.001$). This can be explained by RR being negatively correlated with HRV [16]. Even though earlier research revealed that lower respiratory frequencies were associated with more vagal activation, it is also possible that lower respiratory frequencies are associated with more thorough acetylcholine hydrolysis. This idea states that since acetylcholine hydrolysis is a rather slow process, it is more complete at slower RRs before the subsequent breath prevents acetylcholine expression. As a result, the higher RSA at lower respiratory frequencies wouldn't necessarily indicate more vagal traffic [17].

These results came in contrast to Lin et al. [3], who established that there is no significant impact of either biofeedback or breathing on RR. This discrepancy may be due to differences in age in both studies, as in our study, the age ranged from 30–40 years, whereas in Lin et al., the mean age was 22.3 years.

SGR was 50% lower in group A post-treatment compared to pre-treatment, which was statistically significant ($p = 0.007$). However, in group B ($p = 0.317$), there was no statistically significant difference in SGR between pre- and post-treatment. This can be explained by the fact that a major contributing component to the development of hypertension is an increase in sympathetic tone. Slow abdominal breathing combined with biofeedback may have a greater modulatory effect on relaxation and reduced sympathetic arousal than simple-paced breathing at 6 cycles per minute [3]. This could be the result of the fact that abdominal breathing doesn't provide the same physiological reaction, which stops learners from making the appropriate adjustments based on their physiological feedback's apparent manifestations [10].

This result was consistent with Lin et al. [3], who reported that the post-intervention study of anthropometric indices revealed that SGR was significantly decreased ($p < 0.01$) in the HRV-BF group compared to the slow abdominal breathing group.

The study's shortcomings include the short length of therapy and the lack of follow-up beyond 3 months to assess the long-term effects.

Conclusions

Our data shows that breathing exercises combined with biofeedback were beneficial in lowering BP in middle-aged pre-hypertensive women.

Availability of data and materials

The datasets used in this study will be made available by the corresponding author upon reasonable request.

Acknowledgement

The study would not have been feasible without the participants' dedication, thus, the authors are grateful to everyone who took part.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Cairo University's Faculty of Physical Therapy's Research Ethics Committee (approval No.: P.T.REC/012/003687) and is registered on PACTER (No. 202207676593752).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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