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Impact of combined high-intensity bodyweight interval training and breathing exercise on cardiometabolic health in normal-weight middle-aged adults with hypertension

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Abstract

Background High-intensity interval training and breathing exercises alone have well-documented health benefits in people with hypertension. This study aimed to investigated the effects of combining the two methods on physical health among adults with hypertension.

Methods Ninety-six adults (59.4 ± 9.1 years; 84% female; BMI 22.7 ± 1.6 kg/m^2) with hypertension were randomized into one of four groups: Breathing Exercise (BE), High-Intensity Bodyweight Interval Training (HIBIT), Combined Exercise (CE), or a Non-Exercise Control (CON) group. The intervention lasted 10 weeks, with all exercise groups having the same total training time of 3 days per week (BE: 30 min/day; HIBIT: 60 min/day; CE: BE 30 min/day plus HIBIT 60 min/day). Resting heart rate, resting blood pressure, hand grip strength, cardiorespiratory fitness assessed using 6-Minute Walking Test (6MWT) and blood lipids were measured pre- and post-intervention.

Results The BE group showed the greatest reduction in systolic blood pressure (SBP) compared to CON, although differences among the exercise groups were not statistically significant. The increase in 6MWT values in the combined exercise group differed significantly compared to the other three groups ($p = 0.000$ and effect size = 0.296). The combined exercise group showed significant reductions in total cholesterol, LDL and triglyceride levels compared to the control group. The average reduction in total cholesterol levels was 20.8 mg/dL (95% C: -41.9 – 0.4) with an effect size of 0.103. Meanwhile, the decrease in LDL and triglyceride levels was 20.1 mg/dL (95% CI: -37.6—-2.5; $p = 0.014$) and -40.4 mg/dL (95% CI: -82.1—1.3; $p = 0.04$) with effect sizes of 0.118 and 0.101.

Conclusions In conclusion combined exercise for 10 weeks could lower systolic and diastolic blood pressure, increase CRF, and improved lipid profile. As a clinical implication, the results of this study can be an alternative or complementary approach to treatment for hypertension, potentially reducing the need for medications and their associated side effects.

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Trial registration TCTR20230707003 (http://www.clinicaltrials.in.th/) registered on 28 January 2023.

Keywords High intensity bodyweight interval training, Breathing exercise, Combined exercise, Physical health, Hypertensive adults

Background

Hypertension is a major public health problem worldwide and is the most frequent risk factor for cardiovascular disease and is not optimally controlled worldwide [1]. Hypertension kills nearly 8 billion people each year worldwide and nearly 1.5 million people each year in the East-South Asia region. About one-third of adults in East-South Asia suffer from hypertension [2]. The prevalence of hypertension at the age of ≥ 18 years in Indonesia is 34.1%. Of this prevalence, 13.3% of people diagnosed with hypertension do not take medication and 32.3% do not regularly take medication (Ministry of Health of the Republic of Indonesia, 2018). This shows that most hypertensive patients do not know that they have hypertension so they do not receive treatment [3].

Enhanced cardiorespiratory fitness (CRF) is strongly associated with a reduced risk of developing hypertension. Individuals with higher CRF levels have a 36% lower risk of hypertension compared to those with lower fitness levels [4]. A meta-analysis further supports this, revealing that individuals with elevated CRF exhibit a 37% reduced risk of hypertension relative to those with diminished CRF. Notably, each 1 MET (metabolic equivalent) improvement in fitness is linked to an 8% reduction in hypertension risk [5].

Dyslipidemia, characterized by abnormalities in blood cholesterol and triglyceride levels, is a well-established risk factor for atherosclerotic cardiovascular disease [6]. The co-occurrence of dyslipidemia and hypertension is frequently observed in clinical settings [7, 8]. Elevated levels of total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and non-high-density lipoprotein cholesterol (non-HDL-C), along with reduced high-density lipoprotein cholesterol (HDL-C), have been identified as contributing factors to increased hypertension risk [9]. Effective management of these lipid abnormalities is crucial for preventing and controlling hypertension, particularly among middle-aged populations.

Regular aerobic exercise plays a vital role in both the prevention and management of hypertension and is considered the first-line non-pharmacological intervention for hypertension control [10, 11]. Despite its proven benefits, many individuals do not fully recognize the importance of physical activity for cardiovascular health. Low engagement in exercise within the community can be attributed to factors such as poor health literacy, inadequate infrastructure, and limited support from family members and healthcare professionals [12].

High-intensity interval training (HIIT) has been reported to be equal or even superior in deriving health benefits compared to moderate-intensity continuous training (MICT) [13, 14].

High-Intensity Interval Training enhances myocardial VEGF protein levels, resulting in increased capillary density and reduced interstitial fibrosis.r [15]. HIIT has also been found to improve endothelial function [16, 17], markers of sympathetic activity [18], as well as blood glucose and lipid levels [19]. HIIT can be performed either using body weight alone or with external weights for additional resistance. Bodyweight training use an individual's body weight as resistance to enhance strength, flexibility, and balance. This exercise is both accessible and beneficial for a diverse array of persons, as it necessitates no equipment or specific techniques, enabling it to be performed anywhere—at home, at the park, or while travelling [20]. HIIT using body weight (HIBIT) has been proven to be safe for those with hypertension across all ages [21, 22]. In addition, HIIT has shown higher adherence rates and similar levels of enjoyment compared to MICT [23]. Community-based group exercise interventions for the elderly have shown better compliance outcomes with adherence rates between 69.1–75% [24].

Another therapeutic approach in the management of hypertension that has gained attention recently is breathing exercises. Recently, it was found that deep breathing exercise (DBE) to have therapeutic effects on the physiological and psychological health of hypertensive individuals [25–29]. Effective breathing techniques enhance parasympathetic tone, counteracting the elevated sympathetic activity associated with stress and anxiety. Respiratory entrainment of cerebral rhythms provides an alternative mechanism by which respiration might affect neuronal circuit dynamics, cognition, and mood [30, 31]. Consistent research shows that breathing less than 10 times the usual rate of 16.6 ± 2.8 times/min at periodic intervals for at least 15 min a day leads to a reduction in BP [25]. Diaphragmatic breathing performed 20 sessions over 15 min over 8 weeks reduced negative influences (i.e., negative emotions and expressions) and physiological markers of stress (i.e., salivary cortisol), but did not alter positive influences (i.e., positive emotions and expressions) in healthy adults [27]. Further physiological adaptations to DBE encompass modifications in autonomic function, enhanced heart rate variability, greater baroreflex sensitivity, and improved ventilatory efficiency [32].

Although HIIT and breathing exercises have been independently investigated for their effects on hypertension, no studies have examined the combined effects of these two interventions. HIIT is well-documented as a potent stimulus for central cardiovascular adaptation and metabolic stress. High-Intensity Interval Training (HIIT) is an efficient workout method designed to enhance cardiometabolic health and cardiovascular endurance [33]. Simultaneously, Diaphragm Deep Breathing has demonstrated therapeutic benefits for the psychological well-being of hypertensive individuals [27–29], baroreflex sensitivity (BRS) and autonomic nervous system (ANS) function [34]. The combination of HIIT with breathing exercises provides a comprehensive method for hypertension management. This technique emphasizes not only the reduction of blood pressure but also the improvement of cardiovascular health, stress relief, and overall fitness improvement. Applying this combination consistently can serve as a beneficial technique for hypertensive people to achieve better health outcomes. This study aims to explore how the integration of these two methods can reduce blood pressure, CRF, and lipid profile compared to using either method alone. The results of this study provide valuable knowledge in the field of hypertension management, which has the potential to lead to more effective and holistic treatment strategies for patients. We hypothesized that combining both exercises would lower BP, improve cardiorespiratory fitness and lipid profile compared to HIBIT or DBE alone.

Methods

Study design and setting

This was a 10-week, single-blind randomized controlled trial that was conducted in the Posyandu Community Health Center Kartasura, Sukoharjo, Jawa Tengah, Indonesia. Prior ethical clearance was obtained from the Ethics Committee of Universiti Kebangsaan Malaysia (JEP-2019–461) and the Ethics committee of Universitas Muhammadiyah Surakarta (2494.2022). Written informed consent was obtained from each individual by the researcher after the individual has received a sufficient explanation and period of time in which to make a thoughtful decision. This study protocol has been registered at Thai Clinical Trial Registry (TCTR20230707003) on the 28 January 2023.

Participants

Ninety-six (females = 88, males = 8) hypertensive participants with a mean age of 59.5 ± 9.2 years voluntarily participated in this study. Inclusion criteria were: 1) having diagnosed with hypertension; systolic blood pressure (SBP) > 130 mmHg and/or diastolic blood pressure (DBP) > 80 mmHg, 2) had not participated in any type of regular exercise for at least 3 months prior to this study, and 3) having a body mass index (BMI) between 18.5 to 25 kg/m^2. The exclusion criteria were: 1) those with uncontrolled hypertension, 2) having chronic health conditions e.g., heart disease, diabetes, renal disease, exercise-induced asthma, and cancer, 3) having orthopedic conditions that affect the ability to participate in exercise programs, and 4) on medications that can interfere with the parameters of the study. All participants signed and received informed consent in accordance with the recommendations of the Declaration of Helsinki for Human Research.

Sample size

The sample size was calculated following a priori power analysis [35] by using G*power 3.1. Calculation was based on F test ANOVA repeated measure within-between interactions. The type 1 error rate was set at 5% (alpha-level 0.05) and type II error rate at 5% (95% power). As there was no published literature on the effect of size for a similar study on local population, the convention developed by Cohen [35] was adopted, whereby the effect size F is 0.25 (medium effect size). From the G-power output, at least 60 participants were required. Taking into account for a maximum 50% drop out and equal distribution for each group, a total sample size of 96 hypertensive individuals were recruited for this study.

Randomization and allocation

Ninety-six participants were randomly by taking a sealed envelope containing the intervention allocation, divided into four groups: control group (CON, $n = 24$), breathing exercise group (BE, $n = 24$), HIIT body weight exercise group (HIBIT, $n = 24$), and combined exercise group (CE, n = 24).

Intervention

All exercise groups completed 10 weeks of training, three days per week for 60 min per session, supervised by the researchers. The control group did not participate in the exercise intervention. They were instructed to carry out their usual activities and not engage in any additional physical activity during these 10 weeks. The CE group performed HIBIT and BE on different days. Attendance for each session was recorded and each participant was provided with a logbook to record their exercise session and progression. Participants were excluded from this study once failed to attend three times in a row or total attendance was less than 75%.

Deep Breathing Exercise (BE)

Under our direct supervision, exercise sessions were held three times a week for 15 min in the morning and evening. The breathing protocol was set at a respiratory rate of six breaths per minute using the following steps: 1) Participants sat as comfortably as possible before instructing them to relax their neck and shoulder muscles. 2) Participants placed his or her right hand on the chest wall and his or her left hand over the navel. 3) Participants took a deep breath slowly for 4 s, and inhale through the nose. They were told to notice that during the inhalation, the abdomen was inflated, while the chest did not move. 4) Participants exhaled slowly for 6 s through his/her mouth. These steps were repeated for up to 15 min, with each 10 breaths followed by a 1-min rest pause.

High Intensity Bodyweight Interval Training (HIBIT)

The HIBIT protocol consisted of 8 types of exercises that targeted major muscle groups. The selected exercises were jumping jacks, squats, high knees, lunges, side lunges, butt kicks, lateral walks, and split squats. The exercise protocol began with a 5-min warm-up followed by a 30-min HIBIT. In the first 2 weeks, participants were asked to do as many repetitions as possible for 20 s of each individual exercise (RPE 15–17) followed by a walking exercise (RPE 10–12) while performing breathing exercise for 40 s. At weeks 3 to 10, the intensity was increased to 30 s of high-intensity exercise and 30 s of walking. The entire sequence of exercise as repeated in three sets with 2-min intervals between sets. All training sessions were actively conducted and supervised by investigators. The exercise continued with a 5-min cool-down period at the end of the session. A pulse oximeter (Oxy-5-Plus Oximeter) was placed on the participants' index finger during exercise to monitor their exercise HR. After a 1-week familiarization period, the HIBIT group underwent 9 weeks of HIBIT (3 times per week on an alternating basis excluding weekends). Indications for termination of exercise sessions were in accordance with ACSM guidelines. It was not possible to blind participants or therapists, as they were both aware of the type of intervention received and delivered, but outcome assessors were blinded to control for detection bias.

Before the exercise session, the participant's BP and pulse rate were measured using an automated digital blood pressure monitor (OMRON SEM-1). If the resting BP was more than 180/110 mmHg, the participant was not allowed to participate in the exercise. To prevent delayed onset muscle soreness (DOMS) and to acclimatize to the exercise regimen for physically inactive participants in all exercise groups, a 1-week familiarization period was provided with a total of 3 exercise sessions on different days.

Combined Exercise (CE)

CE consisted of HIBIT and Breathing exercises that have been done on different days. HIBIT consisted of 8 types of exercises: jumping jacks, squats, high knees, lunges, side lunges, butt kicks, lateral walks, and split squats with the same intensity as previously described. On another day, participants had done breathing exercises for 15 min twice a day, in the morning and evening. The intensity of breathing exercises was the same as that described earlier.

Outcome measurements

BP, HR, cardiorespiratory fitness, muscle strength, and serum lipids were measured prior to the commencement of the 10-week intervention, and again in the same way after intervention ended. The post-intervention measurements were carried out no more than 72 h after the last exercise session.

Blood Pressure (BP) and Heart Rate (HR)

Participant's BP and heart rate were measured from the brachial artery using an automated digital BP monitor (OMRON SEM-1) after 5 min of relaxed chair rest. Each participant's arm was supported on a table at heart level, and both SBP and DBP were measured 3 times with a 5-min interval between each measurement to obtain the most accurate results. These measurements were performed at an integrated health care centers by clinicians blinded for group allocation.

Cardiorespiratory Fitness

Cardiorespiratory fitness was measured using the 6-min walk test (6MWT). The categorization of cardiorespiratory fitness (CRF) based on the 6-min walk test (6MWT) distance is valid when compared to maximal oxygen consumption ($\dot{V}O2max$), particularly for identifying persons with poor CRF [36]. The 6MST appears to be a dependable and valid method for evaluating cardiorespiratory fitness in individuals at risk of cardiovascular disease across various clinical environments [37]. The 6MWT was completed by all participants on a flat and comfortable surface. Participants were told to (a) wear comfortable shoes/footwear and clothing, (b) rest for 10 min before the test (at which time their HR and BP were recorded and probable contraindications were evaluated by the researcher), and (c) walk for 6 min. Participants were given the required information, including walking pace, stopping time, and guidance on potentially harmful sensations such as weariness, cramps, chest pain, and dyspnea. Supervisors used standard phrases of encouragement (e.g., you're doing fine) recommended by the American Thoracic Society.

Muscle strength

The handgrip test was used to measure upper body strength, using an electronic dynamometer (Camry Electronic Handgrip Dynamometer). Participants were asked to stand with her feet hip-width apart and her toes pointed forward, her arms slightly abducted but not touching their bodies. The dynamometer was placed between the fingers and palm, near the base of your thumb, and was required to press the dynamometer with their hands during the test, the dynamometer should not touch the body or other items. During the test, participants did not hold their breath, inhaled before starting the squeeze, then exhale the air during it. Highlight the squeezing motion's speed and hardness (with a slightly shaking fist). Each test was performed three times with a one-minute break between tests. The highest value obtained was recorded for analysis.

Serum lipids

Total cholesterol (TC), triglyceride (TG), high density lipoproteins (HDL), and low-density lipoproteins (LDL) were determined using automated spectrophotometry. Blood samples were collected in the morning after 8 h of fasting, from the antecubital vein, then centrifuged to separate the serum at 3000 rpm for 15 min. The serum was then aliquoted and stored at -20˚C until analysis.

Statistical analysis

Statistical analysis was performed using the SPSS software package (SPSS Statistics 25.0, IBM, Ehningen, Germany) for participants who achieved at least 75% exercise adherence. Data were first tested with the Shapiro–Wilk normality test. Mixed ANOVA was used to compare differences between groups (CON vs BE vs HIBIT vs CE) and time group interactions (baseline values and post training values) for all parameters. Statistically significant results were indicated by $p < 0.05$. Descriptive statistics of all data are presented as arithmetic mean ± standard deviation.

Results

Sociodemographic characteristics

Figure 1 shows the participant flow from recruitment to follow-up. Of the 96 randomized individuals, 87 (91%) completed the 10-week intervention, while 9 individuals (9%) were unable to complete all exercise sessions due to attendance rates of less than 75%. These individuals were excluded from analysis. The average exercise attendance was 92%. On average, the BE group completed 100 ± 9%

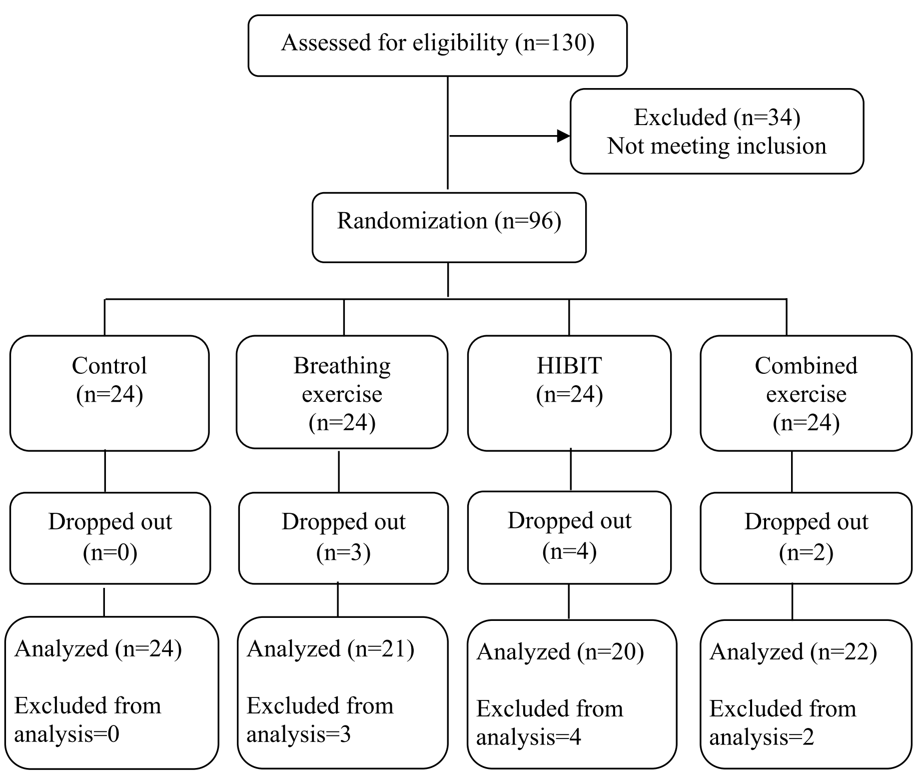

Fig. 1 Participant Flow chart

of the prescribed number of exercises. Participants in the HIBIT group completed 100 ± 10% of the prescribed sets, and combined exercise participants completed 100 ± 5% of the prescribed number of exercises. In the entire exercise session, no adverse events occurred in any of the intervention groups.

At the start of the study, participants were 59 ± 4 years old, 87.5% female, 12.5% male, and had a body mass index of 22.7 ± 1.6 kg/m^2. Baseline resting SBP was 156 ± 14 and DBP was 91 ± 10 mmHg. There were no differences in the baseline parameters between the 4 groups (Table 1).

Table 2 showed the data for changes in BP and heart rate pre- and post-intervention. After 10 weeks, all exercise groups (BE, HIBIT, CE) observed significantly reduced BP and heart rate compared to pre-intervention values. The BE group reduced SBP the most by -21 mmHg. However, no significant differences were observed in resting BP and heart rate when comparing BE, HIBIT, and CE to control group.

Outcome measures for cardiorespiratory fitness, muscle strength, and serum lipids are summarized in Table 3. The increase in 6MWT values in the combined exercise group differed significantly compared to the other three groups ($p = 0.000$ and effect size = 0.296). The combined exercise group showed significant reductions in total cholesterol, LDL and triglyceride levels compared to the control group. The average reduction in total cholesterol levels was 20.8 mg/dL (95% C: -41.9 – 0.4) with an effect size of 0.103. Meanwhile, the decrease in LDL and triglyceride levels was 20.1 mg/dL (95% CI: -37.6—-2.5; $p = 0.014$) and -40.4 mg/dL (95% CI: -82.1—1.3; $p = 0.04$) with effect sizes of 0.118 and 0.101.

Figure 2 shows the change in outcomes before and after the intervention in all groups. SBP and DBP in all groups decreased, except for the control group. HR, total cholesterol, LDL, and triglycerides showed a downward trend in all groups, while CRF, MS, and HDL were on the rise in all groups.

Discussion

The purpose of this study was to determine the effectiveness of combining HIBIT and BE in lowering BP, improving cardiorespiratory fitness, increasing muscle strength, improving total cholesterol, LDL, HDL, and triglyceride levels among hypertensive patients. The study also ensured that the total exercise time was consistent across exercise groups to make it more applicable to the general population and help determine the effectiveness of each type of exercise.

The main finding of the study was that combined exercise provided a significant improvement in cardiorespiratory fitness than the other 3 groups. It also reduced LDL and triglyceride levels significantly compared to the control group. Although participants in the breathing

Table 1 Baseline participants characteristics

Variable	All	CON	BE	HIBIT	CE
N	87	24	21	20	22
Age, years	59.6 ± 9.2	60.2 ± 10.7	58.9 ± 8.9	59.1 ± 10.4	60.1 ± 6.9
Women, n (%)	84	21	19	22	22
BMI (kg/m^2)	22.7 ± 1.6	22.7 ± 1.7	22.6 ± 1.8	23.2 ± 1.2	22.3 ± 1.3
Medication consumption	No	No	No	No	No
Categories of hypertension					
prehypertension	17	7	4	5	1
Stage 1	37	9	10	5	13
Stage 2	33	8	7	10	8
Resting SBP (mmHg)	156 ± 13	151 ± 11	159 ± 11	160 ± 17	155 ± 9
Resting DBP (mmHg)	90 ± 10	86 ± 7	93 ± 9	96 ± 11	88 ± 8
Resting HR (bpm)	90 ± 7	86 ± 7	93 ± 5	91 ± 7	90 ± 6
6MWT (m)	304.1 ± 65.2	280.4 ± 55.2	286.7 ± 54.6	298.5 ± 72.4	351.8 ± 55.9
Handgrip strength (kg)	16.4 ± 3.4	16.8 ± 3.4	16.7 ± 3.7	16.4 ± 3.1	16.4 ± 3.4
Total cholesterol (mg/dL)	204.7 ± 30.9	208.6 ± 35.5	199.1 ± 32.3	217.9 ± 32.6	193.8 ± 15.9
LDL cholesterol (mg/dL)	138.9 ± 25.6	144.7 ± 31.0	131.1 ± 26.5	146.4 ± 24.4	133.5 ± 15.5
HDL cholesterol (mg/dL)	69.8 ± 9.4	72.5 ± 10.8	69.0 ± 9.1	71.6 ± 9.1	66.1 ± 7.5
Triglycerides (mg/dL)	197.0 ± 60.4	217.3 ± 66.2	180.1 ± 57.6	211.2 ± 66.4	178.0 ± 40.5

SBP Systolic blood pressure, *DBP* Diastolic blood pressure, *HR* Heart rate, *BE* Breathing exercise group, *HIBIT* High intensity Bodyweight interval training, *BP* Blood pressure, *6MWT* Six minutes walking test, *MS* Muscle strength, *HDL* High-density lipoprotein, *LDL* Low-density lipoprotein

Data presented as mean ± SD for continuous variables or number of participants (%) for categorical variables

Table 2 Resting BP and heart rate (pre-intervention vs. post-intervention)

Intervention group	*n*	Mean ± SD		MD (95% CI)			
		Baseline (pre-intervention)	Post-intervention	Within-group change	*p*-value	Change vs control group	*p*-value vs control group
SBP (mm Hg)							
CON	24	151 ± 11	151 ± 12	0 (-2, 2)	0.949	-	-
BE	21	159 ± 11	136 ± 11	23 (18, 27)	0.000†	-4 (-12,5)	0.693
HIBIT	20	160 ± 17	141 ± 14	18 (12,24)	0.000†	0 (-9,8)	0.999
CE	22	155 ± 9	137 ± 6	18 (14, 21)	0.000†	-5 (-14,4)	0.412
DBP (mm Hg)							
CON	24	86 ± 7	86 ± 7	0 (-3, 2)	0.679	-	-
BE	21	93 ± 9	83 ± 6	10 (5,14)	0.000†	2 (-3,7)	0.793
HIBIT	20	96 ± 11	82 ± 6	13 (9,17)	0.000†	3 (-2,8)	0.494
CE	22	88 ± 8	80 ± 3	7 (4, 11)	0.000†	-2 (-7,3)	0.726
Resting Heart Rate (mm Hg)							
CON	24	86 ± 7	84 ± 7	2 (0, 5)	0.057	-	-
BE	21	93 ± 5	84 ± 9	9 (5, 13)	0.000†	4 (-1,8)	0.251
HIBIT	20	91 ± 7	84 ± 9	7 (3, 12)	0.004†	3 (-2,7)	0.553
CE	22	90 ± 6	84 ± 7	6 (2, 9)	0.001†	2 (-3,7)	0.715

All values were adjusted for age, sex, and baseline values. *CON* Control group, *BE* Breathing exercise group, *HIBIT* High intensity Body weight interval training group, *CE* Combine group

* The mean difference is significant at the .05 level ($p < 0.05$), † $p < 0.01$ vs. control group

exercise and HIBIT groups received benefits from the exercises performed, the combined group experienced more cumulative benefits as indicated by the sig score (Table 2). This study supports the 2008 Physical Activity Guidelines recommendation that individuals can receive greater and more complete CVD health benefits by performing both aerobic exercise and resistance training. This indicates that physicians can implement a coordinated strategy by incorporating these improvements via education, counselling, and support. When utilized alongside pharmaceutical therapy, it will demonstrate better efficacy than monotherapy or standard treatments.

The study revealed no differential reductions in blood pressure among the intervention groups; however, each intervention group individually achieved significant reductions in blood pressure, with the exception of the control group. The BE group reduced systolic blood pressure more than the other two exercise groups (MD: 23 mmHg, CI 95%: 18–27; p: 0.000). BE and HIBIT can reduce blood pressure through distinct processes; BE induces a relaxing effect that alleviates stress-induced hypertension, while HIBIT presents a robust method for enhancing physical fitness and cardiovascular performance.

This study has shown that HIBIT and breathing exercises independently contribute to lowering blood pressure. The combination of these interventions can lead to synergistic effects, resulting in a better reduction in systolic and diastolic blood pressure. This is especially important for hypertensive patients, as effective blood pressure management can reduce the risk of cardiovascular events. This is in line with the Meta-analysis and previous studies have reported a reduction in SBP after aerobic exercise or resistance exercise alone or in combination [38]. Previous studies have also shown that sixteen-week programs of high-intensity interval training (20 min per session) have demonstrated a reduction in systolic blood pressure of − 8 mmHg in hypertensive individuals [39], four weeks of exercise five times a week reduced SBP by 13.4% and DBP by 8.51% [40]. The decrease in BP in the three types of exercise was not significantly different, but it can be seen that the largest decrease occurred in the breathing exercise group (21 + 12 mmHg).

Cardiorespiratory fitness (CRF) in the CE group shown a substantial enhancement relative to the control group ($p = 0.000$). High-Intensity Interval Training (HIIT) is extensively documented for its efficacy in enhancing cardiorespiratory fitness by elevating VO_2 max and overall aerobic capacity [41]. Breathing workouts enhance this by augmenting lung function and optimizing breathing efficiency. Collectively, they can enhance oxygen transport to muscles during physical exertion, hence boosting total exercise performance and endurance.

This combined exercise, if done regularly in the long term, can provide benefits to the health of the body. This

Table 3 Cardiorespiratory fitness, muscular strength and serum lipids (pre-intervention vs. post-intervention)

Intervention group	*n*	Mean ± SD		MD (95% CI)			
		Baseline (pre-intervention)	Post-intervention	Within-group change	*p*-value	Change vs control group	*p*-value vs control group
6MWT (m)							
CON	24	280.4 ± 55.2	300.8 ± 58.7	-20.4 (-30.7, -10.1)	0.000†	-	-
BE	21	286.7 ± 54.6	337.1 ± 54.1	-50.5 (-74.6, -26.4)	0.000†	21.3 (-21.9,64.5)	0.545
HIBIT	20	298.5 ± 72,4	310.0 ± 60.9	-11.5 (-43.8, 20.8)	0.465	13.6 (-30.1, 57.4)	0.834
CE	22	351.8 ± 55.9	403.2 ± 55.2	-51.4 (-66.7, -35.9)	0.000†	86.9 (44.2, 129.5)†	**0.000**†
Muscle strength (kg)							
CON	24	16.8 ± 3.4	17.7 ± 3.9	-0.9 (-1.4, -0.3)	0.003†	-	-
BE	21	16.7 ± 3.7	17.8 ± 3.9	-1.0 (-1.6, -0.5)	0.001†	0 (-2.8,2.8)	1.000
HIBIT	20	15.7 ± 3.5	16.8 ± 3.7	-1.1 (-1.9, -0.3)	0.007†	-1.0 (-3.8,1.8)	0.766
CE	22	16.4 ± 3.1	17.4 ± 3.2	-1.0 (-1.9, 0.1)	0.064	-0.3 (-3.1, 2.4)	0.987
Total cholesterol (mg/dL)							
CON	24	208.6 ± 35.5	197.9 ± 31.7	10.7 (0.6, 20.8)	0.039*	-	**-**
BE	21	199.1 ± 32.3	186.3 ± 32.3	12.8 (5.4, 20.2)	0.002†	-10.5 (-31.9, 10.9)	0.547
HIBIT	20	217.9 ± 32.6	189.7 ± 23.9	28.2 (14.7, 41.7)	0.021*	0.5 (-21.2, 22.3)	1.000
CE	22	193.8 ± 15.9	171.0 ± 17.6	22.8 (16.1, 29.5)	0.000†	-20.8 (-41.9, 0.4)*	**0.046***
LDL (mg/dL)							
CON	24	144.7 ± 31.0	137.5 ± 28.6	7.2 (1.2, 13.2)	0.021*	-	-
BE	21	131.1 ± 26.5	117.9 ± 24,8	13.3 (6.4, 20.2)	0.001†	-16.6 (-34.3, 1.2)	0.064
HIBIT	20	146.4 ± 24.4	116.3 ± 16.5	30.1 (19.5, 40.7)	0.000†	-9.7 (-27.7, 8.3)	0.466
CE	22	133.5 ± 15.5	108.5 ± 12.4	25.0 (18.5, 31.6)	0.000†	-20.1 (-37.6, -2.5)*	**0.014***
HDL (mg/dL)							
CON	24	72.5 ± 10.8	79.3 ± 9.7	-6.8 (-9.6, -3.9)	0.000†	-	-
BE	21	69.0 ± 9.1	75.5 ± 8.7	-6.5 (-10.2, -2.7)	0.002†	-3.7 (-10.2, 2.9)	0.438
HIBIT	20	71.6 ± 9.1	78.3 ± 7.2	-6.8 (-10.2, -3.3)	0.001†	-0.9 (-7.6, 5.7)	0.980
CE	22	66.1 ± 7.5	77.1 ± 7.3	-10.9 (-13.3, -8.5)	0.000†	-4.3 (-10.7, 2.2)	0.286
Triglyceride (mg/dL)							
CON	24	217.3 ± 66.2	197.9 ± 53.5	19.5 (9.3, 29.7)	0.001†	-	-
BE	21	180.1 ± 57.6	162.9 ± 42.9	17.1 (5.1, 29.2)	0.007†	-36.1 (-78.3, 6.1)	0.104
HIBIT	20	211.2 ± 66.4	181.9 ± 56.3	29.4 (19.8, 38.9)	0.000†	-11.1 (-53.8, 31.7)	0.897
CE	22	178.0 ± 40.5	156.4 ± 36.6	21.5 (12.2, 30.8)	0.000†	-40.4 (-82.1, 1.3)*	**0.04***
		Mean ± SD			Mean ± SD		

All data presented as mean ± Standard deviation and adjusted for age, sex, and baseline value of each outcome measure

6MWT Six minutes walking test, *LDL* Low density lipoprotein, *HDL* High low density, *CON* Control group, *BE* Breathing exercise group, *HIBIT* High intensity Body weight interval training group, *CE* Combine group

* The mean difference is significant at the .05 level ($p < 0.05$), † $p < 0.01$ vs. control group

is also supported by previous research which states that hybrid training that combines aerobic and resistance-based exercise with an average weekly exercise volume of ~ 100 min with a net exercise time of 6.5–24.0 min/session (total duration/session 23–41 min) and its intensity maintained at 73–87% MHR with an RPE of 14–16 for 5 months has been shown to improve cardiometabolic health aspects and antioxidant status in inactive and overweight women body and obesity [42]. Another study states that multicomponent exercise combining bodyweight training and resistance-based alternative modes performed over 1 year was shown to improve several musculoskeletal fitness indicators in sedentary middle-aged adults with overweight/obesity [43].

In our study, significant reductions in LDL and triglyceride levels occurred in the BE and combined exercise groups. This is in line with previous studies that HIIT is superior to MICT in reducing LDL, total cholesterol, and triglyceride concentrations [44, 45]. The intensity of exercise exhibits a substantial positive link with the levels of

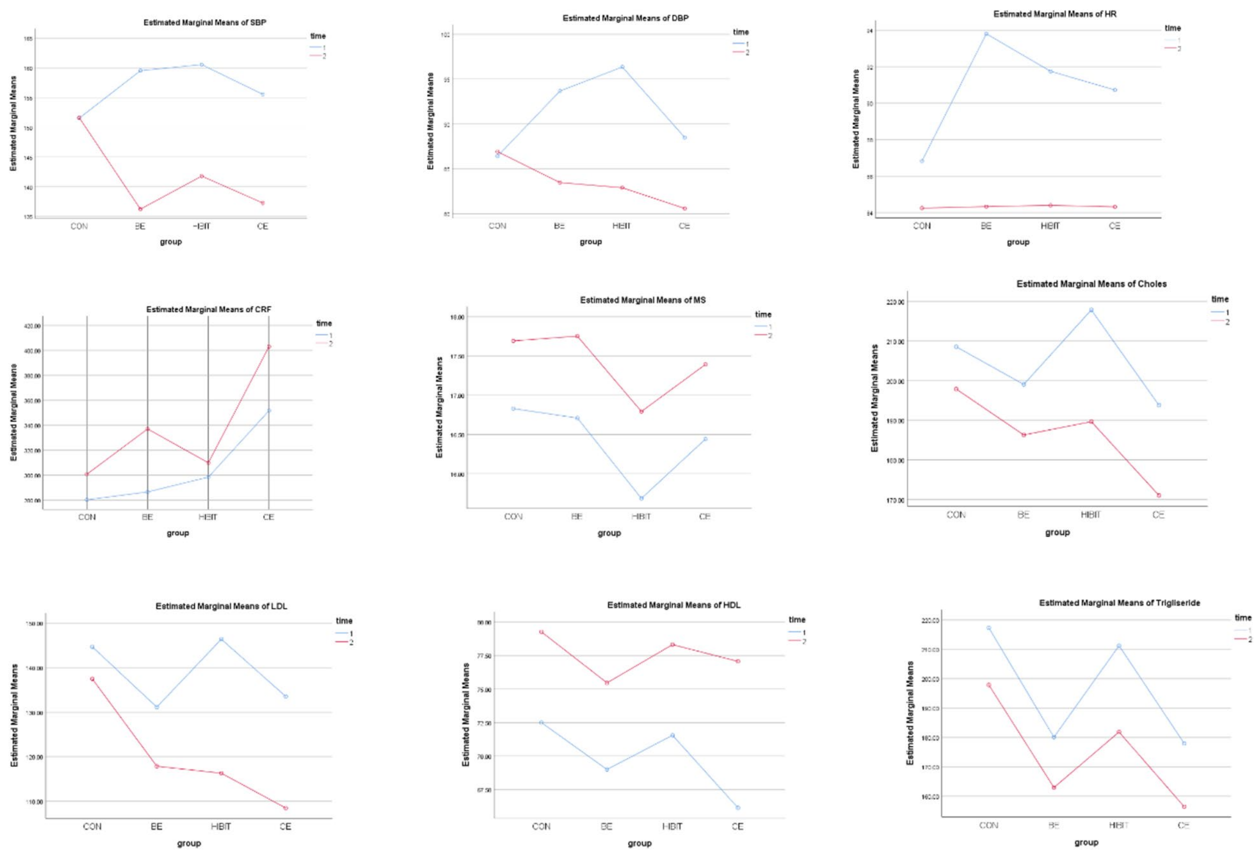

Fig. 2 Graph of changes in outcomes before and after the intervention SBP systolic blood pressure; DBP diastolic blood pressure; HR heart rate; CRF cardiorespiratory fitness; MS muscle strength; Choles total cholesterol; LDL low density lipoprotein; HDL high low-density lipoprotein; time 1 pre intervention; time 2 post intervention

growth hormone, epinephrine, and fat oxidation. Growth hormone and epinephrine have lipolytic effects, and an augmented fat oxidation might beneficially influence lipid levels in individuals [46]. Given that HIIT exhibits a superior exercise intensity compared to MICT, it is plausible that the resultant elevation in growth hormone, epinephrine, and fat oxidation associated with HIIT will influence the lipid profile distinctively from MICT.

In this study, LDL and triglyceride levels experienced a significant decrease in the BE group. These findings are supported by Antonelli et al. [47] who state that breathing exercises in meditation in adults lower cholesterol levels by an average of about -14 mg/dL, triglyceride levels by -33 mg/dL, and LDL, by an average of about -8 mg/dL [47]. This effect can be attributed to changes caused by breathing exercises in the activity of the autonomic nervous system, characterized by an increase in ventral vagal tone and a decrease in adrenergic activity [48, 49]. Autonomic dysfunction is associated with prehypertension and is intricately connected to alterations in systolic blood pressure and lipid metabolism [50]. In addition, stress-induced adrenergic hyperactivation can result in the release of abnormal and prolonged stress hormones such as cortisol, thereby stimulating lipid metabolism and leading to increased levels of circulating fat [51]. As a result, interventions aimed at reducing stress-induced disorders or diseases caused by autonomic dysregulation can exert a positive influence on serum lipid levels [47].

Breathing exercises carried out in conjunction with physical exercise also have a role in improving the lipid profile. Previous research stated that after three weeks of yoga practice consisting of breathing exercises, physical exercises (Asanas) and meditation, there was a significant decrease in Total Cholesterol, Trigliceride and Very LDL levels. A further reduction in levels was seen after six weeks of training. A better ability to cope with stress can be cited as a possible mechanism for the improvement of lipid profile [52]. The reduction in TG, total cholesterol, and LDL, and the elevation HDL, may be attributed to yoga interventions, particularly deep breathing, stretching, and flexibility exercises, which enhance metabolism and the utilisation of blood lipids and lipoproteins for energy production [53, 54]. On the other hand, yoga improves LDL-C receptor sensitivity, receptor-mediated endocytosis, and receptor recycling [55]. Also, the regulatory effects of yoga on HDL-C are mediated through a reverse cholesterol transport mechanism that includes the removal of macrophage cholesterol in the arteries [55].

Voluntary diaphragmatic breathing at < 10 or 6 breaths per minute for 10 min twice a day for 4 weeks was effective in producing positive outcomes [56]. Performing diaphragmatic deep breathing at 6 or ≤ 10 breaths per minute can lead to arteriolar dilation by activating the heart's pulmonary mechanoreceptors and inhibiting sympathetic nerve activity and chemoreflex activation. This increases parasympathetic activity and baroreflex sensitivity, leading to a decrease in SBP and DBP in hypertensive adults [26]. Practicing twice a week or twice a day for 4 weeks can significantly reduce SBP and resting DBP in hypertensive adults undergoing antihypertensive drug therapy [28]. The effect of lowering BP was observed at week 4 in prehypertensive individuals [28].

Diaphragmatic breathing practice for nine months shown a sustained positive impact on reducing stress, as assessed by the DASS-21 subscale self-report instrument. The research indicated a beneficial impact of diaphragmatic breathing on stress alleviation, as evidenced by respiratory rate and cortisol levels [57].

These findings suggest that this exercise regimen may serve as an alternate therapy for those with pre-hypertension and hypertension, augmenting existing treatments to mitigate additional harm from elevated blood pressure. This exercise combination offers shorter workouts to sustain physical and cardiorespiratory fitness, hence facilitating lifestyle changes through consistent physical activity.

Strengths of this study include randomization that ensured participants were comparable at the start of the study in key confounding factors (e.g., age, gender), orientation sessions to minimize potential drop-outs leading to high attendance and adherence. In addition, this study combined bodyweight exercises with a variety of easy-to-perform movement variants to modify HIIT for all age groups. The participants in this study were divided into four groups to compare the findings among the four groups and provide a more comprehensive understanding of the cardioprotective effects of different forms of exercise.

This study also has several limitations. Exercise instructors and the participants were not blinded due to the nature of the setting where it was impossible to do. Another key limitation of our study is the absence of body composition assessment, which restricts our ability to fully evaluate the physiological impact of the exercise intervention on individuals with hypertension. Body composition, including metrics such as body fat percentage, lean muscle mass, and visceral fat distribution, plays a significant role in cardiovascular health and exercise response. Without these measurements, we are unable to determine whether improvements in blood pressure were influenced by changes in fat mass, muscle gain, or other compositional adaptations. Future research should include detailed body composition assessments to better elucidate the mechanisms through which exercise contributes to blood pressure regulation in hypertensive individuals. The participants' dietary intake may also play an important role in controlling BP, as it was not possible to directly observe and monitor their adherence to the Dietary Approaches to Stop Hypertension (DASH) and sodium restriction. Therefore, future studies with a larger sample size, longer duration of intervention, and strict control of the DASH diet plan are highly recommended.

While these findings are promising, additional research is needed to determine the optimal load and intensity required for people with hypertension and other chronic diseases. Future study using the combination of breathing exercise and HIBIT with a selection of body weight training movements tailored to respondents' conditions, and varying exercise intensities to get the optimal dose. In addition, future intervention studies should also report measures of intervention fidelity, such as adherence to specific intensity.

Conclusion

Combining HIBIT and BE presents a promising non-pharmacological intervention for managing hypertension. The study found that combined exercise for 10 weeks could lower systolic and diastolic blood pressure and increase CRF. This combination of exercises not only targets blood pressure but also addresses other cardiovascular risk factors such as total cholesterol, LDL and triglyceride levels. As a clinical implication, the results of this study can be used as a non-pharmacological intervention, which offers an alternative or complementary approach to pharmacological treatment for hypertension, potentially reducing the need for medications and their associated side effects.

Abbreviations

HIIT	High-intensity Interval Training
DBE	Deep Breathing Exercise
BE	Breathing Exercise
HIBIT	High Intensity Bodyweight Interval Training
CE	Combined Exercise
BP	Blood Pressure
HR	Heart Rate
TC	Total Cholesterol
TG	Triglyceride
HDL	High Density Lipoproteins
LDL	Low Density Lipoproteins
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure

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Authors' contributions
Isnaini Herawati (IH) & Arimi Fitri Mat Ludin (AF) conceptualized the study with critical input from Ismarulyusda Ishak (IYI), Mutalazimah Mutalazimah (MM) and Nor M.F. Farah (NF). IH carried out the intervention and data collection. AF & NF verified the data analysis and interpretation. IH wrote the initial draft of the manuscript with critical input from NF & AF. AF, NF, IYI & MM supervised the overall study. All authors read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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Data availability
All the data generated and analysed throughout this study are included in this published article. Individual participants data re available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Prior ethical clearance was obtained from the Ethics Committee of Universiti Kebangsaan Malaysia (JEP-2019–461) and the Ethics committee of Universitas Muhammadiyah Surakarta (2494.2022). Written informed consent was obtained from each individual by the researcher after the individual has received a sufficient explanation and period of time in which to make a thoughtful decision.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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