Complementary Therapies in Clinical Practice 43 (2021) 101315

Contents lists available at ScienceDirect

Complementary Therapies in Clinical Practice

journal homepage: http://www.elsevier.com/locate/ctcp

Effects of diaphragmatic deep breathing exercises on prehypertensive or hypertensive adults: A literature review

Katherine Ka-Yin Yau [a], Alice Yuen Loke [b,*]

[a] School of Nursing, Tung Wah College, 31 Wylie Road, Homantin Kowloon, Hong Kong, China
[b] School of Nursing, The Hong Kong Polytechnic University, Hong Kong, China

A R T I C L E I N F O

Keywords:
Deep breathing exercise
Diaphragmatic breathing exercise
Hypertension
Prehypertension
Slow abdominal breathing

A B S T R A C T

Diaphragmatic breathing, a deep breathing technique, has been reported to improve autonomic function by reducing sympathetic activity and increasing baroreflex sensitivity. This literature review aimed to (1) examine the effects of diaphragmatic breathing on physiological and psychological measures in prehypertensive or hypertensive adults and to (2) determine the appropriate length, frequency, and duration of an effective diaphragmatic breathing exercise in the management of prehypertension and hypertension. Relevant studies were searched using electronic databases, and 13 studies that met the inclusion criteria were included. The synthesis of the findings revealed that voluntary diaphragmatic deep breathing resulted in decreased of systolic and diastolic blood pressures, reduced heart rate, a relaxing effect, and reduced anxiety in hypertensive or prehypertensive individuals. It is concluded that 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. The results of this review provide directions for related interventions and future research.

1. Introduction

Hypertension and prehypertension are associated with an increased risk of cardiovascular diseases [1], which result in coronary heart disease, cerebrovascular accidents, and renal failure [2]. Prehypertension or stage I hypertension is categorized as consistently elevated systolic blood pressure (SBP) and diastolic blood pressure (DBP) ranging from 120 to 139 mmHg and from 80 to 89 mmHg [3], respectively, while hypertension is defined when SBP and DBP consistently range from 130 to ≥139 and/or from 80 to ≥89 mmHg [4], respectively. The prevalence of hypertension is on the rise to 22% globally [5].

Early use of antihypertensive drugs and lifestyle changes have been recommended for adults with hypertension and prehypertension, to reduce the morbidity and mortality associated with hypertension. Controlling high blood pressure (BP) can reduce cardiovascular risks [6]. Evidence shows that pharmacological treatment has limitations in the control of high BP and prevention of complications [2,7]. Lifestyle or behavioral modification is an approach that hypertensive and prehypertensive individuals should adopt to reduce BP and prevent cardiovascular diseases [8–10]. Chronic stress is associated with sustained elevation of BP, which leads to hypertension [11,12]. The autonomic sympathetic and parasympathetic nervous systems play important roles in the regulation of BP and heart rate through the baroreflex mechanism [13–15]. Stress control is considered effective for lowering BP [16].

Prehypertensive or hypertensive individuals demonstrate an increase in sympathetic activity, vagal withdrawal, and a decrease in parasympathetic activity when exposed to extended periods of stress [11,12, 17–19]. Under stress, overactivity of the sympathetic nervous system enhances smooth muscle tone, causing increased BP and heart rate [12, 17]. Hypertensive individuals also have a decreased exercise tolerance, with elevated total peripheral resistance and reduced arterial baroreflex sensitivity due to autonomic imbalance [20–22]. Such autonomic dysfunction may contribute to and sustain hypertension [20,22,23]. It is concluded that relaxation techniques, such as diaphragmatic deep breathing exercises, that have been reported to be effective for improving autonomic functions and are recommended for the prevention and management of hypertension [24,25].

Diaphragmatic deep breathing (DDB) is also known as deep breathing or slow abdominal breathing. It is a breathing practice that involves deep and slow rhythmic breathing by increasing the diaphragm contraction length, minimizing the respiration frequency, and deepening the inhalation and exhalation volumes to maximize the amount of

* Corresponding author. GH525, School of Nursing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, HKSAR, Hong Kong, China.
E-mail addresses: kyyau@twc.edu.hk (K.K.-Y. Yau), alice.yuen.loke@polyu.edu.hk (A.Y. Loke).

https://doi.org/10.1016/j.ctcp.2021.101315
Received 22 October 2020; Received in revised form 7 January 2021; Accepted 21 January 2021
Available online 26 January 2021
1744-3881/

oxygen entering the bloodstream [26,27]. DDB has been observed to have a therapeutic effect on both the physiological and psychological health of hypertensive individuals [22,24,27–33].

Over the last decade, studies have indicated that practicing diaphragmatic deep breathing at 6 or ≤10 breaths per minute can lead to arteriolar dilatation by activating pulmonary-cardiac mechanoreceptors and inhibiting sympathetic nerve activities and chemoreflex activation. This increases parasympathetic activity and baroreflex sensitivity, leading to a decrease in SBP and DBP in hypertensive adults [22,24,30,31,34]. Two-minute slow and deep breathing has been shown to reduce SBP and DBP by 8.6 and 4.9 mmHg, respectively, in hypertensive adults [22]. It is postulated that hypertensive adults who practice slow and deep breathing techniques over several weeks will show significant reductions in SBP and DBP compared with those who do not practice deep breathing [31,34].

Practicing slow and deep breathing over several weeks has also been showed to enhance baroreflex sensitivity and significantly increases heart rate variability (HRV) in both prehypertensive and hypertensive individuals [30,31]. During a state of relaxation, HRV, referring to the fluctuation in the time intervals between consecutive heart beats increases [35]. The increase in HRV has been reported to be associated with decreased SBP and improved psychological health [30,31].

Moreover, diaphragmatic deep breathing has been reported to have potential psychological benefits in hypertensive or prehypertensive adults by stimulating parasympathetic nervous system activity [27,32,33,36]. In response to stressors, the sympathetic nervous system releases stress hormones, and the sympathetic tone fails to return to its resting level, which leads to negative emotions during prolonged exposure to stressful conditions [37,38]. DDB in ways of slower, deeper, and more prolonged exhalation could reduce the basal sympathetic tone, which renders people feeling calm and relaxed [36,39]. A study in China reported that practicing DDB could stimulate the vagal nerve, which leads to emotion regulation in healthy adults [27]. Another study in Taiwan also found that a DDB relaxation training program reduced perceptions or symptoms of anxiety [32].

A meta-analysis of randomized controlled studies was conducted to evaluate the effects of the diaphragmatic deep breathing technique on heart rate and BP in patients with cardiovascular diseases [40]. The results showed that SBP, DBP, and resting heart rate (HR) of participants were significantly reduced by 6.36 mmHg, 6.39 mmHg, and 1.7 beats per min, respectively, after practicing diaphragmatic deep breathing without using an assistive device over weeks to months. However, this meta-analysis did not examine the potential beneficial effect of DDB as a relaxation therapy in prehypertensive patients.

Another systematic review with a meta-analysis [41] was conducted on the effects of device-guided deep breathing on controlling BP. The review found that short-term use of devices to achieve slow breathing (device-guided breathing) could lower BP, but it demonstrated no effect on increasing the HR and improving the quality of life over 8–9 weeks. The beneficial effect of long-term use of device-guided breathing on both physiological and psychological health is unclear [42]. Moreover, this review that used devices to slow breathing as an intervention did not include pre-hypertensive patients. It is considered a comprehensive review of the effects of diaphragmatic deep breathing with or without a device on physiological and psychological health outcomes on lowering BP among adults with prehypertension and hypertension should be further examined.

Diaphragmatic deep breathing has been promoted as an alternative approach for controlling BP in prehypertensive and hypertensive individuals. A review of the relevant literature will strengthen the evidence from standalone studies to provide directions for future interventions and research. The specific objectives of this literature review were (1) to examine the potential physiological and psychological effects of DDB on autonomic functions in prehypertensive or hypertensive adults, and (2) to identify the appropriate length, frequency, and duration of an effective DDB pattern in the management of prehypertension and hypertension.

2. Methods

2.1. Search strategies

The search for relevant studies for this review was conducted by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Studies were searched from four electronic databases, namely PubMed, the Cochrane Library, CINAHL Complete, and Embase, which included published studies that cover the fields of biomedicine, health care, psychology, nursing, medicine and health science, health and social sciences, and rehabilitation sciences. The search terms used to identify the relevant articles were "prehypertension" or "hypertension" AND "diaphragmatic breathing exercise" or "deep breathing exercise" or "slow abdominal breathing" AND "intervention" or "randomized control trials" AND "blood pressure" or "pulse rate" or "heart rate" AND "stress level" or "mood status." Studies published in English and only those published from 2010 were included to identify the most updated scientific evidence on the effects of diagrammatic deep breathing exercises. Then, the references of the included studies were searched for identifying additional studies, if appropriate.

2.2. Selection criteria

Studies identified from literature searches that could provide evidence on the topic were screened for eligibility. The inclusion criteria were as follows: (1) studies focused on adults aged ≥18 years who had prehypertension or hypertension, (2) intervention studies or randomized control trials with or without a comparison group; (3) studies that involved diaphragmatic deep breathing or slow abdominal exercise; and (4) studies that evaluated at least one of the following outcomes: BP, pulse rate, HR, stress level, and mood status. Studies that included participants who were pregnant or diagnosed as having cancer, stroke, mental illness, chronic respiratory disease, chronic kidney disease, or malignant hypertension were excluded.

2.3. Study selection process

A total of 1640 studies were identified from the electronic databases. Forty-two studies were excluded because of duplication. The remaining 1598 publications were screened by title and abstract and were excluded. A total of 104 articles remained, and the full texts were further evaluated based on the inclusion and exclusion criteria. A total of 91 studies were further excluded: focused on patients with chronic heart failure, chronic obstructive pulmonary disease, chronic renal failure, cancer, or postoperative or chronic pain syndrome rather than those with hypertension (n = 53); included healthy university students or adults as participants (n = 20); interventions involved yoga, tai chi, mindfulness, or combination with other relaxation therapies but not DDB (n = 12); combined intervention with inspiratory muscle training (n = 2); on the effects of exercise on BP as outcome (n = 2). Two systematic reviews that included papers that were published before 2010 were excluded. Finally, 13 articles were retrieved and included in this review. All were published in English. A flowchart of the literature search and selection process is shown in Fig. 1.

2.4. Assessing the quality of the studies for risk of bias

To assess the quality of the studies for the risk of bias, two reviewers appraised the 13 included studies independently using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) [43]. This tool contains 16 reporting items; however, only 14 items were used to assess the quality of the included studies, as two items are applicable to qualitative studies. The items were evaluated on a scale ranging from

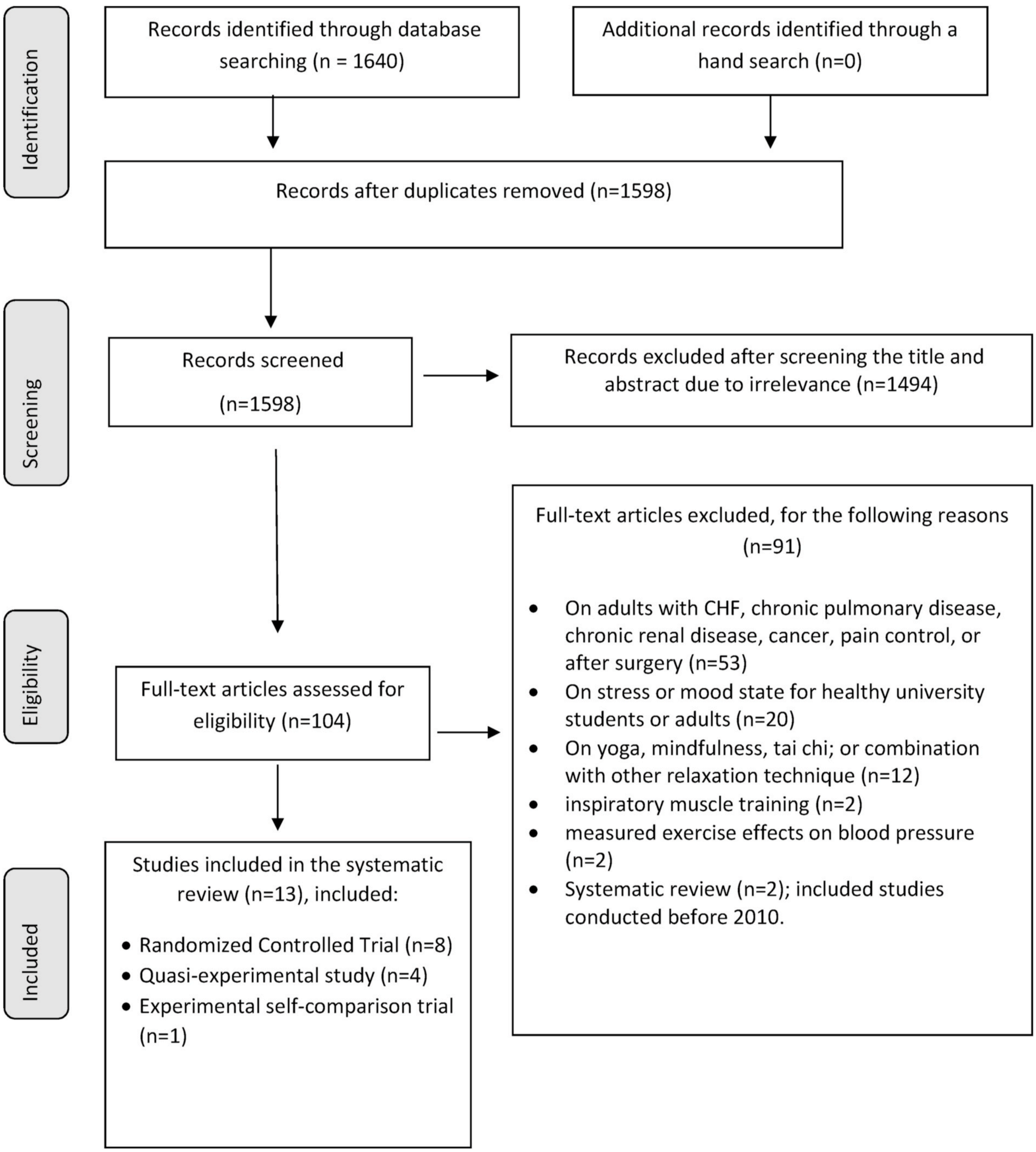

Fig. 1. Flow chart of the literature search process (PRISMA 2009).

0 to 3, with possible scores ranging from 0 to 42. The reviewers followed 14 scoring guidance notes to critique all reviewed studies for the following requirements: (1) inclusion of an explicit theoretical framework, (2) determination of a reasonable sample size for the target group, (3) appropriateness of the study design, (4) reporting of the data collection strategies and outcome measures, (5) explanation and justification of statistical analyses and data collection tools; (6) involvement of a pilot study for study design; and (7) critical appraisal of the findings.

3. Results

3.1. Data extraction

The selected studies were extracted and tabulated according to the authors, year of publication, country where the study was conducted, study design, sample size and characteristics of the participants, description of the diaphragmatic deep breathing intervention, comparison intervention (if any), length, frequency, and duration of the intervention; and timing of the outcome measure (Table 1). The specific physiological and psychological outcomes of the studies are summarized in Table 2.

3.2. Quality assessment

The methodological quality of the included studies was scored using QATSDD and is shown in the last column of Table 1. Three studies with high scores ranging from 30 to 37 of 42 provided a reasonable sample size for the target group, designed an appropriate study setting and

Table 1
Characteristics of the included studies.

Author, Year, Country	Study Design	Sample Size	Criteria for the inclusion of Participants	Deep breathing intervention	Control/Comparator	Length and Frequency	Duration	Intervals for outcome measures	QATSDD Score (0–42)
Anderson, McNeely & Windham, 2010 [50] United State America	Randomized Controlled Trial	n = 40; (male = 21; female = 19) I = 20; C = 20	Mean aged 53; Known prehypertension or mild HTN (SBP 130–160 mmHg; DBP <100 mmHg)	RESPeRATE device guided breathing at <10 breaths/min at home	Natural breathing at home with sitting position & eye closed, legs and hands uncrossed	15 min daily	4 weeks	Clinic BP: 1 & 2 week before intervention & after intervention; 24 h ABPM: daytime every 30 min for 16 h & at nighttime every 60 min for 8 h	26
Amandeep, Preksha, Divya, 2015 [46] India	Quasi-experimental study	n = 60; (male = 31; female = 29) I = 30; C = 30	Aged 30–71; Recruited from a Medicine OPD; Known primary HTN; Willing to join in the study	Slow Abdominal breathing exercise at home	No intervention	10 min twice a day	10 days	Immediate before and after each intervention	26
D'silva, Vinay & Muninarayanappa, 2014 [33] India	Randomized Controlled Trial	n = 45 (male = 30; female = 15) I = 23; C = 22	Aged 40–59; Diagnosed with stable angina or post myocardial infarction with stable condition; Being identified with anxiety or depressive symptoms; Can read and write Kannada, Malayalam or English	Slow and Deep breathing exercise at home; with 2 training sessions in total of 20 min prior to study entry	No intervention	10 min twice a day	2 weeks	Before and after intervention	21
Howorka et al., 2013 [49] Austria	Randomized Controlled Trial	n = 32 (male = 17; female = 15) I = 16; C = 16	Aged 18–78 years; S/S of DM for 3 mo; Hx of HTN on anti-hypertensive drug; BP well controlled below 130/80 mmHg; with sedentary compliance; structured education; capability of self-monitoring & recording the values; understand informed consent	RESPeRATE device guided breathing at <10 breaths/min at home continue usual care of DM and HTN	No intervention but continue usual care of DM & HTN	12 min daily	8 weeks	24 h-ABPM & short-term spectral analysis of HRV measured before & after 8 weeks of interventions	30
Harneet & Saravanan, 2014 [44] India	Quasi-experimental study	n = 45, Did not mention gender;	19–35 years, SBP 120–139 mmHg and DBP 80–90 mmHg, not on antihypertensive drug	Deep breathing at 6 breaths/min Ix3gps: Gp1: BMI 18–24 kg/m2 Gp2: BMI 25–29.9 kg/m2 Gp3: BMI >30 kg/m2	NA	10 min every evening	4 weeks	Before and at the end of 4 week of intervention	25
Jindal & Yogesh, 2019 [23] India	Experimental self-control trial	n = 22 Did not mention gender	Aged 20–40 years; SBP 120–139 mmHg and/or DBP 80–98 mmHg; not on antihypertensive drug	Abdominal breathing at 6 breaths/minute Breathing at 20/minute for 10 min pre & post intervention	NA	10 min	NA	Before, during and after intervention	24
Kow et al., 2018 [47] Malaysia	Randomized Controlled Trial	n = 87 (male = 46; female = 41) I = 42; C = 45	Mean aged 61; Known stage 1 essential HTN (BP of 140–159/90–99 mmHg) 6 months prior to study entry; with or without anti-HTN medication; No change of medication two months prior to study entry and during the study	CD guided breathing at 5 breaths/min; 1:2 inspiration and expiration duration ratio (4s inspiratory; 8s expiratory time) at home with training sessions provided prior to study entry	Listen to CD music only at home	15 min daily	8 weeks	Screening, baseline, week 4, 6, 8.	37
Landman et al., 2013 [51] Netherlands	Randomized Controlled Trial	n = 45; (male = 20; female = 25) I = 21; C = 24	Mean aged 65; Known T2DM & HTN; SBP 140–160 mmHg, with one or more antihypertensive drug; unchanged drug treatment 3 mo prior to study entry	RESPeRATE device guided breathing at <10 breaths/min	Sham device guided breathing (without musical tone) with 14 breaths/min	15 min daily	8 weeks	Office BP measured before and after intervention; Home BP measured on the first day and the last day of the study	30
Lin et al., 2012 [52] China	Randomized Controlled Trial	n = 45 (male = 36; female = 7);	Mean aged 22.3; College student with asymptomatic prehypertension in Zhongshan School of Medicine, Sun Yet-Sen University	HRV-BF gp: abdominal breathing at own RF in 10 sessions HRV-BF training and at home for using a respiratory audio guide	Breath naturally in front of the computer screen during training session and usual care at home	20 min twice a day + 20 min daily	5 weeks & 3-month follow-up	Before, during each session; after & post 3-mouth follow up intervention	28

(continued on next page)

Table 1 (*continued*)

Author, Year, Country	Study Design	Sample Size	Criteria for the inclusion of Participants	Deep breathing intervention	Control/Comparator	Length and Frequency	Duration	Intervals for outcome measures	QATSDD Score (0–42)
		HRV-BF gp = 18; SAB gp = 15; Control gp = 10		SAB gp: Abdominal breathing at 6 cycles/min at home using a respiratory audio guide		in the follow-up periods.			
Modesti et al., 2010 [48] Italy	Randomized Controlled Trial	n = 84 (male = 52; Female = 34); I = 29; Control-M = 26; Control-R = 31	Aged 40–75 years; Known essential HTN, treated with or without anti-hypertensive drugs at least 3 months prior to the study	With music guided abdominal breathing at 4–6 breaths/min; 1:2 inspiration and expiration duration ratio at least 3 h after lunch at home; 2 h training sessions provided prior to study entry, 1 week, 1, 3 and 6 months	Control-M gp: relax to listen slow music Control-R gp: relax to reading a book or magazine	30 min daily	6 months	Office BP measured after 1 week, and after 1, 3, 6 months; 24 h ABPM measured at daytime and nighttime that was programmed 15–20 min intervals	27
Sundaram et al., 2012 [20] India	Randomized Controlled Trial	n = 40 (male = 26; female = 14); I = 20; C = 20	Aged 35–60 years; Known essential or primary hypertension with SBP 140–160 mmHg and DBP 90–100 mmHg; received antihypertensive drug treatment	Slow breathing exercise at 6 breaths/min along with pharmacological treatment in an OPD department	Usual care + pharmacological treatment	2 times Per week	4 weeks	Before and after intervention	26
Vasuki & Sweety, 2017 [29] India	Quasi-experimental study	n = 60; I = 30; C = 30 Did not mention gender	Aged 30–50 years; With SBP > 140 and < 180 mmHg; or DBP> 90 and < 110 mmHg; or using hypertensive medication and BP < 180/110 mmHg.	Deep breathing exercise with training prior to study entry	No intervention	10 min twice a day	12 weeks	Baseline, week 4, 8, 12	20
Vasuki & Sweety, 2017 [45] India	Quasi-experimental study	n = 60 (100% female); I = 30; C = 30	Aged 30–50 years; from an NCD Clinic; Hypertensive patients with SBP >140 and < 180 mmHg and DBP> 90 and < 110 mmHg; or using hypertensive medication and BP < 180/110 mmHg; Pre-hypertensive patients with SBP 120–139 mmHg or DBP 80–89 mmHg	Deep breathing exercise at 6 breaths/min with 1:1 inspiration and expiration duration ration, with 5s deep inspiratory; 5s slow prolonged expiratory time regularly with training prior to study entry	No intervention	10 min twice a day	12 weeks	Baseline, week 4, 8, 12	20

Remark: C, Control group; I, Intervention group; S/S, Sign and Syndrome; CD, Compact Disc; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; HRV-BF, Heart rate variability-biofeedback; SAB, Slow abdominal breathing; HRV, Heart rate variability; HTN, Hypertension; Hx, History; DM, Diabetes Mellitus; T2DM, Type 2 Diabetes Mellitus; RSP, RESPeRATE device pacer; ABPM, Ambulatory blood pressure monitoring; gp, group; NCD, Non-communicable disease; OPD, Out-patient department; H, Hour; 24 h ABPM, 24 h Ambulatory blood pressure monitoring; min, minutes; Control-M, Control-Music; Control-R, Control-Reading; S, Second.

Table 2
Summary of the outcome measures of the included studies.

Reference/Participants	Change in SBP (mmHg)	Change in DBP (mmHg)	Change in Heart rate (bpm)	Change in HRV	Change in stress/mood level	Change in other outcome measures
Voluntary diaphragmatic deep breathing (n = 7)						
Sundaram et al., 2012 [20] Hypertensive middle-aged adults	After 4 weeks, I: reduced by 3.4 C: no change	After 4 weeks, I: reduced by 4 C: no change	After 4 weeks, I: reduced by 1.6 C: no change	NA	NA	After 4 weeks, Resting RR I: reduced by 2.5 bpm C: no change 6 MWD I: no change C: no change
D'silva, Vinay & Muninaraya-nappa, 2014 [33] Middle-aged adult with coronary artery disease	After 2 weeks: I: reduced by 10.5 C: reduced by 10 No significant difference between two gp	After 2 weeks: I: reduced by 7.5 C: no change Reduced by 7.5 compared with control gp	After 2 weeks: I: reduced by 4 C: reduced by 3.1 No significant difference between two gp	NA	Anxiety scored-BDI I: reduced by 16.45 C: reduced by 11.75 Reduced by 4.6 compared with control gp Depression scored-BDI I: reduced by 8.5 C: reduced by 8.2 No significant difference between two gp	NA
Harneet & Saravanan, 2014 [44] Pre-hypertensive adult	After 4 weeks, Normal BMI: reduced by 10.8 Overweight: reduced by 9.8 Obese: no change	After 4 weeks, Normal BMI: reduced by 9.4 Overweight: reduced by 6.6 Obese: no change	After 4 weeks, Normal BMI: reduced by 3.6 Overweight: no change Obese: no change	NA	NA	After 4 weeks, Body weight Normal BMI: no change Overweight: no change Obese: reduced by 1.8 kg
Amandeep, Preksha & Divya, 2015 [46] Hypertensive adults	After 10 days; I: reduced by 15.27 C: reduced by 2.34 Reduced by 12.9 compared with control gp	NA	NA	NA	NA	Significant association of blood pressure with age increase.
Vasuki & Sweety, 2017 [29] Hypertensive middle-aged adults	After 4,8,12 weeks, I: reduced by 5.9, 11 & 15.3, respectively C: reduced by 2, 3.4 & 4.2 respectively	After 4, 8, 12 weeks, I: reduced by 3.6, 7.8 & 11.4 respectively C: no significant change	NA	NA	NA	After 4, 8 & 12 weeks, MAP I: reduced by 4.4, 8.9 & 12.7 respectively C: no significant change
Vasuki & Sweety, 2017 [45] Pre-hypertensive & hypertensive adults	Pre-hypertensive & hypertensive gp After 4 weeks: I: reduced by 2.2 & 5.9 C: reduced by 0.7 & 2.0 After 8 weeks: I: reduced by 2.2 & 11 C: reduced by 2.6 & 3.4 After 12 weeks: I: reduced by 7.6 & 15.3 C: reduced by 2.3 & 4.2	Pre-hypertensive & hypertensive gp: After 4 weeks; I: reduced by 3.1 & 3.6 C: no significant difference After 8 weeks; I: reduced by 4.2 & 7.8 C: reduced by 1.8 & 2.6 After 12 weeks; I: reduced by 7.1 & 11.4 C: reduced by 2.6 & 2.5	NA	NA	NA	NA
Jindal & Yogesh, 2019 [23] Pre-hypertensive adults	After intervention @ 6 breath/min: SBP decreased by 6	After intervention @ 6 breath/min: DBP decreased by 4	NA	HRV- LF: marked significant reduced by 20 n.u during intervention HRV- HF: marked significant increased by 21 n.u during intervention HRV- LF/HF ratio: marked significant reduced by 1.6 during intervention		
Diaphragmatic deep breathing use of device (n = 6)						
	After 8 weeks: I: reduced by 8.3	After 8 weeks: I: reduced by 5.6	After 8 weeks: I: increased by 0.3	NA	NA	After 8 weeks, MAP: I: reduced by 6.5

(*continued on next page*)

Table 2 (*continued*)

Reference/Participants	Change in SBP (mmHg)	Change in DBP (mmHg)	Change in Heart rate (bpm)	Change in HRV	Change in stress/mood level	Change in other outcome measures
Kow et al., 2018 [47] Middle-aged hypertensive adult	C: reduced by10.5 No significant difference between two gp	C: reduced by 5.2 No significant difference between two gp	C: reduced by 1.0 No significant difference between two gp			mmHg C: reduced by 6.8 mmHg No significant difference between two gp
Modesti et al., 2010 [48] hypertensive adults	After 6 months, office, mean 24 h, daytime & nighttime SBP I: reduced by 4.4–7.5 C: no significant difference On average 24-h SBP reduced by 4.6 and 4.1 compared with two control gp	After 6 months, office, mean 24 h, daytime & nighttime DBP I: reduced 3.9–4.3 C: no significant difference On average 24-h DBP, no significant difference compared with between two gp	After 6 months; office, mean 24 h, daytime & nighttime HR I: no significant difference C: no significant difference On average 24-h HR, no significant difference between two gp	NA	QoL by SF-36: After 6 months, no significant difference between gp	No. of drug classes & No. of treated participants: After 6 months, no significant effect on change in anti-HTN treatment between gp
Howorka et al., 2013 [49] Hypertensive diabetic middle-aged adult	After 8 weeks; 24 h. SBP: I: reduced by 2.9 C: no difference Reduced by 2.9 between two gp	After 8 weeks; 24 h DBP: I: no difference C: no difference No significant difference between two gp	NA	After 8 weeks; I: significantly stronger Tx effect in LF and a significant reduction of centroid frequency in the HF band C: no difference in LF/HF No significant differences on treatment effect between two gp		After 8 weeks; 24 h pp: I: reduced by 2.3 mmHg C: no difference reduced by 2.3 compared with control group After 8 weeks; 24 h MAP; I: no difference C: no difference
Anderson, McNeely & Windham, 2010 [50] Pre-hypertensive and hypertensive middle-aged adult	After 4 weeks, resting SBP in clinic & mid-day 24 h SBP in women were greater decreased than in the Control gp; 24 h & nighttime SBP was no difference between gp	After 4 weeks, resting DBP in clinic and mid-day 24 h DBP in women were lower than in the control gp; 24 h & nighttime DBP was no difference between gp	NA	NA	NA	After 4 weeks no change of overnight breathing rate and tidal volume between gp
Landman et al., 2013 [51] Hypertensive adult with type 2 DM	After 8 weeks, Office SBP: I: reduced by 6.03 C: reduced by 8.38 Home SBP: I: reduced by 3,66 C: reduced by 0.64 No significant difference between two gp either measured in office or home	After 8 weeks, Office DBP: I: reduced by 5.92 C: reduced by 3.67 Home DBP: I: reduced by 1.38 C: reduced by 1.48 No significant difference between two gp either measured in office or home	NA	NA	NA	NA
Lin et al., 2012 [52] Pre-hypertensive young adult	After 5 weeks with 3 months follow up: HRV-BF gp: reduced by 13.8 SAB gp: reduced by 7.2 Control gp: no difference Compared with SAB gp, 6.6 lowered in HRV-BF gp Compared with control gp, 7.2 lower in SAB gp	After 5 weeks with 3 months follow up: HRV-BF gp: reduced by 7.4 SAB gp: reduced by 4.4 Control gp: no difference Compared with SAB gp, 3 lowered in HRV-BF gp Compared with control gp, 4 lowered in SAB gp	NA	After 5 weeks with 3 months follow up: HRV- IgSDNN HRV-BF gp: increased by 0.14 ms SAB gp: increased by 0.09 ms Control gp: no difference HRV- IgTP HRV-BF gp: increased by 1 ms2 SAB gp: increased by 0.6 ms2 Control gp: no difference	NA	After 5 weeks with 3 months, BRS HRV-BF gp: increased by 8.8 ms/mmHg; SAB gp: 3.2 ms/mmHg Control gp: no significant changes

Remark: C, Control group; I, Intervention group; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, Pulse pressure; HR, Heart rate; HRV, Heart rate variability; QoL, Quality of life; SF-36, Medical Outcome Study Short-form 36-item Health Survey; MAP, mean arterial pressure; Tx, Treatment; 6 MWD, 6 min walk test; HRV_BF, Heart rate variability-biofeedback; SAB, low abdominal breathing; RF, Resonant frequency; BRS, Baroreflex sensitivity; IgSDNN, log(10)-transformed of the standard deviation of normal to normal beats; IgTP, log(10)-power of spectral density in the range of frequencies between 0 and 0.4HZ (ms2); LF, low frequency power; HF, High frequency power; LF/HF, A ratio of low frequency to high frequency; HTN, Hypertension; Hx, History; DM, Diabetes Melius; ABPM, Ambulatory blood pressure monitoring; PP, Pulse Pressure; RSP, RESPeRATE device pacer RSP; BDI, Beck's anxiety inventory and depression inventory–II.

discussed the strengths and limitations of the study. Seven studies with scores ranging from 24 to 28 out of 42 clearly stated the study objectives and data collection strategies but statistical and critical analyses were not conducted. Three studies scored 20 or 21 of 42. Most of the studies did not provide information on how the target groups were recruited/ selected and did not include information on how the sample size was calculated, how the data were collected, or if measurement tools were validated. Nevertheless, all the studies were rated as moderate to good quality and were included in this review.

3.3. Study characteristics

Of the included articles, half were conducted in India (n = 7), while others were published in China (n = 1), Austria (n = 1), Malaysia (n = 1), the Netherlands (n = 1), Italy (n = 1), and the United States (n = 1). The 13 selected studies included randomized controlled trials (n = 8), quasi-experimental studies (n = 4), and experimental self-comparison trials (n = 1).

A total of 665 participants were included in the 13 selected studies, with the number of participants ranging from 20 to 87 in each study. Of the 665 participants, 259 were women and 279 were men; the sex of the remaining 127 participants was not reported. The participants were adults or older people aged between 18 and 78 years. Of the included studies, five included prehypertensive adults, with SBP ranging from 120 to 139 mmHg and/or DBP ranging from 80 to 98 mmHg without the use of antihypertensive drugs. Eight studies included stable stage I or II hypertensive individuals with SBP 140–160 mmHg and DBP 90–100 mmHg and were receiving prescribed antihypertensive medications.

3.4. Diaphragmatic deep breathing exercise intervention

Of the 13 included studies, seven adopted the voluntary diaphragmatic deep breathing technique, in which participants were instructed to control their respiration rate more slowly and deeply by breath counting. The participants were to concentrate on their respiration rate while performing slow and deep breathing. Six studies adopted device-guided slow breathing exercises, which included used of music (n = 2), a RESPeRATE device (n = 3), and respiratory audio (n = 1).

3.4.1. Voluntary diaphragmatic deep breathing

Of the seven included studies that adopted voluntary diaphragmatic deep breathing, all were conducted in India and rated as moderate-quality studies. Of the seven studies, three instructed participants to breath at 6 breaths per minute for 10 min one time [23], every evening [44] or twice a day [45] in a quiet room with a comfortable temperature [23] during the intervention periods. The participants in one of the three studies were specifically taught to breathe at 6 breaths per minute with a 5-s deep inspiratory time and 5-s slow and prolonged expiratory time [45].

Three other studies instructed participants to perform deep breathing at a slower respiration rate at home for 10 min twice a day during the intervention periods [29,33,46], but these studies did not ask the participants to record the actual respiration rate. In one of the studies, the participants were required to perform diaphragmatic deep breathing at 6 breaths per minute in an outpatient department twice a week [20].

In the seven studies that adopted voluntary diaphragmatic deep breathing, one reminded the participants to perform the breathing exercise in a quiet room to avoid any disturbances [44]. Two studies advised the participants to continue with their existing level of physical activity during the intervention period [29,45]. No specific advice or restriction was provided during the interventions in the other four studies [20,23,33,46]. The participants in three studies were trained by certified therapists on slow and deep breathing techniques before intervention [29,33,45].

3.4.2. Diaphragmatic deep breathing with a device

In the six studies that adopted a device to achieve slow deep breathing, all the participants were well trained by certified therapists on guided breathing technique. Of these six studies, two [47,48] instructed participants to practice deep breathing exercises while listening to music in a quiet room without disturbances. One of the studies required participants to breathe with slow musical rhythm until their respiration rate reached 6 breaths per minute with prolonged expiration [48]. The other study required the participants to follow the bird chirping sound cues to breathe in deeply and stream flowing sound cues to breathe out slowly until their breathing rate reached 5 breaths per minute with prolonged expiration [47]. They practiced such respiration frequency for 15 min daily [48] and 30 min daily [47], respectively.

Three studies utilized a RESPeRATE device to guide slow breathing in hypertensive adults [49–51]. RESPeRATE is an electronic device consisting of a breathing sensor connected to a control box containing a microprocessor, headphones, and a computerized unit. The sensor was placed on the chest of the participants to analyze individual breathing patterns and create a personalized melody of inhale and exhale guiding tones. The participants then listened to the melody through headphones, which guided them to slow their breathing frequency. They were then guided to breathe effortlessly for $<$10 breaths per minute. The device was to be used 12–15 min daily at home during the intervention periods [49–51].

In a study that used respiratory audio [52], participants in the heart-rate variability biofeedback (HRV-BF) group were taught to perform diaphragmatic deep breathing at their own resonant frequency (RF) in the biofeedback training sessions. RF refers to the maximal amplitude of HRV [52]. The participants in the slow abdominal breathing group (SLB) were first taught to control the respiration rate at 6 breaths per minute for 20 min in the training sessions using a pacing stimulus, which guided participants to breathe slowly and deeply. The participants in both groups were then required to practice the guided breathing frequency using a respiratory audio guide for 20 min twice a day at home for 5 weeks and 20 min daily for 3 months during the post-intervention follow-up period [52].

3.5. Duration, length, and frequency of the diaphragmatic deep breathing intervention

Of the 13 included studies, 12 examined the effects of diaphragmatic deep breathing for 10 days to 6 months; only one study examined the effect of only one time of 10 min of voluntary slow and deep breathing [23]. Among the 12 studies, one had an intervention duration of 10 days [46], one had 2 weeks [33], three had 4 weeks [20,44,50] and another three had 4 weeks [47,49,51], two had 12 weeks [29,45] and one had 6 months [48]. One study offered breathing training for 5 weeks in a training center, followed by device-guided breathing for 3 months at home, with a total of 17 weeks of intervention [52].

The length of the deep breathing exercises ranged from 10 to 30 min, once daily to twice weekly. Of the seven studies that adopted voluntary diaphragmatic deep breathing exercises, four asked participants to practice slow and deep breathing for 10 min twice a day [29,33,45,46]; one, to perform regulated breathing for 10 min every evening [44]; and one, to practice 10 min once only [23]. The remaining studies required participants to practice voluntary deep breathing exercises twice per week, but the length of breathing was not reported [20] (Table 1).

Two studies asked participants to practice deep breathing exercises 15 min daily at home, guided by musical rhythm [47] or 30 min daily [48]. Three studies requested participants to practice deep breathing exercises at home guided by the RESPeRATE device 15 min daily [50,51] or 12 min daily [49]. The only study that adopted a respiratory audio device instructed participants to practice slow and deep breathing at home for 20 min twice a day [52]. (Table 1).

3.6. Control-comparison interventions

Of the 13 included studies, all but two did not include a control group for comparison [23,44]. Of the 11 studies with control intervention for comparison, participants in seven studies received no intervention (routine care) [20,29,33,45,46,49,52]. Four studies asked participants to listen to music at home for 15 min daily [47], either listen to slow music or read a book or magazine for 30 min daily at home [48], breathe naturally for 15 min in a sitting position with eyes closed and uncrossed legs and arms [50] or breathe at approximately 14 breaths per minutes for 15 min daily with music guided by an identical device [51].

3.7. Time points of the outcome measures

Of the 13 included studies, all but 4 measured outcomes before and after intervention [20,33,44,49]. One study measured the BPs of the participants in a clinic 1 and 2 weeks before intervention as baseline for eligibility and then reassessed the participants' BPs after intervention, but measured the 24-h ambulatory BP measurement (AMBP) at daytime every 30 min for 16 h and at nighttime every 60 min for 8 h [50]. In two studies of short-term deep breathing intervention, outcome measures were obtained either immediately before and after each intervention [46] or before, during, and after the intervention [23]. Of the two other studies, one assessed all the outcomes before and during each training session and after the 3-month follow-up intervention [52]. Other studies assessed the participants' home BP at the first, third, and sixth months of intervention, with 24-h AMBP was programmed to be measured every 15–20 min during the intervention [48].

Two of the included studies adopted a 12-week deep breathing intervention that assessed the BP and HR of the participants at baseline for eligibility; then, their BP and HR were reassessed after 4, 8, and 12 weeks of intervention [29,45]. While two studies adopted an 8-week intervention, the participants' BP and HR were obtained by a trained assistant in a clinic at baseline for eligibility, and these physiological outcomes were reassessed at the 4th, 6th, and 8th weeks of intervention [47] or their BP was measured in the clinic before and after intervention and measured at home by participants themselves on the first and last days of the study following a standardized protocol [51]. The time points of the outcome measures are summarized in Table 1.

3.8. Outcomes of the diaphragmatic deep breathing interventions

The outcomes of the diaphragmatic deep breathing intervention in the 13 studies included physiological and psychological indices. The main physiological outcomes included SBP and DBP, HR, HRV, pulse pressure (PP), and mean arterial pressure (MAP). Psychological outcomes included anxiety and depression scores as well as quality of life. All are summarized in Table 2.

3.9. Effects of diaphragmatic deep breathing on physiological parameters

3.9.1. Effect on blood pressure (systolic and diastolic)

Of the 13 included studies, all intervention studies measured BP as the primary outcome and reported significant results in lowering BP in prehypertensive and hypertensive adults.

Of the seven studies on voluntary diaphragmatic deep breathing without device, the results showed that 10-min deep breathing at 6 breaths per min produced a decreased in SBP by 6 mmHg and DBP by 4 mmHg in prehypertensive adults [23]. Ten-minute voluntary DDB at 6 breaths per min daily or twice a day for 4 weeks reduced SBP and DBP by 10 mmHg and 6.6–9.4 mmHg [44] or 2.2 mmHg and 3.1 mmHg [45], respectively in prehypertensive participants with normal BMI or overweight participants.

Ten minutes of voluntary DDB twice a day for 10 days showed a remarkable reduction in SBP by 12.9 mmHg in participants who had primary hypertension without antihypertensive medication [46]. Adopting such breathing pattern and frequency could also significantly reduce SBP by 10.5 mmHg and DBP by 7.5 mmHg in participants with coronary artery disease [33]. Whereas regular voluntary DDB for 4 weeks demonstrated a significant reduction in SBP and DBP of 4–5.9 mmHg and 3.6–4 mmHg, respectively, in hypertensive participants with regular antihypertensive medication [20,29,45]. The BP-lowering effect in hypertensive participants was found to be significantly greater after 12 weeks of intervention. The SBP and DBP of hypertensive participants were remarkably reduced by 15.3 and 11.4 mmHg, respectively, after 10-min DDB exercise at 6 breaths per min twice a day for 12 weeks [29, 45].

Of the six included studies that used a device to achieve slow breathing, for interventions lasting weeks to months, all reported that 15–30 min of slow and deep breathing could reduce SBP and DBP by 6–8 mmHg and 4–6 mmHg, respectively, in prehypertensive and hypertensive participants [47–52]. Three of the studies measured the 24-h ambulatory BP and reported a 24-h ambulatory SBP of 3–4.6 mmHg lower than the baseline in hypertensive individuals after 8 weeks of guided breathing, but the 24-h ambulatory DBP demonstrated no significant difference after the 8-week intervention [48,49]. However, a reduction in 24-h ambulatory BP was not observed in prehypertensive or hypertensive participants [50].

In summary, regular diaphragmatic deep breathing at 6–10 breaths per minute for weeks to months with or without using a device can potentially be promoted to manage prehypertension or hypertension.

3.9.2. Effect on heart rate (HR)

HR as an index of the activation of the autonomic nervous system was measured in five of the included studies. Regular voluntary diaphragmatic deep breathing twice a day or twice a week was found to reduce the HR by 2–4 beats per min in both prehypertensive and hypertensive adults even after a 2- or 4-week intervention [20,33,44]. However, 15- to 30-min music-guided deep breathing was reported to be ineffective in lowering the HR in hypertensive adults after 8 weeks or 6 months of intervention [47,48].

In summary, voluntary diaphragmatic deep breathing exercises have inconsistent results on lowering the HR in prehypertensive and hypertensive adults.

3.9.3. Effect on heart rate variability (HRV)

HRV, refers to variation in beat-to-beat intervals, was measured in three of the included studies to judge autonomic nervous system responses.

In these studies, 10-min voluntary diaphragmatic deep breathing was reported to induce a significant increase in high-frequency power of HRV by 21 normalized units (n.u.) in prehypertensive adults after one-time intervention [23]. Twenty-minute diaphragmatic deep breathing guided with a respiratory device daily for 5 weeks increased HRV by 0.09 ms of the standard deviation from normal-to-normal beats and 0.6 ms of the log (10) power of spectral density in frequency ranges between 0 and 0.4 Hz (ms^2) [IgTP] in prehypertensive adults. The efficacy remained for at least 3 months [52]. In addition, 15-min RESPeRATE device-guided breathing for 8 weeks demonstrated an increase in high-frequency power in hypertensive adults with diabetes mellitus [49].

Diaphragmatic deep breathing with or without a device was shown to potentially decrease sympathetic activity and increase parasympathetic activity in adults with prehypertension and hypertension.

3.9.4. Effect on resting pulse pressure (PP) and mean arterial pressure (MAP)

Pulse pressure, defined as subtracting the DBP from the SBP, and mean arterial pressure (MAP), defined as the average arterial pressure, were regulated in maintaining perfusion of vital organs by the arterial baroreflex and autonomic nervous system [53]. Of the included studies, three measured MAP [29,47,49] and one [49] measured PP as outcomes of diaphragmatic deep breathing in hypertensive adults.

Results showed that MAP was significantly reduced by 6.5 mmHg in hypertensive adults on hypertensive medication [47] and reduced by 8.9 mmHg in prehypertensive adults [29] after 8 weeks of regular diaphragmatic deep breathing. The MAP was remarkably reduced to 12.7 mmHg after the 12-week intervention [29]. A study of 12-min RESPeRATE device-guided breathing daily found no significant difference in 24-h MAP in hypertensive diabetic middle-aged adults after 8 weeks of intervention, but the 24-h PP was reduced by 2.3 mmHg [49].

These results suggest that diaphragmatic deep breathing intervention might have consistent effects on reducing sympathetic activity.

3.10. Effects of diaphragmatic deep breathing on psychological response

3.10.1. Effect on anxiety and depression levels

Of the 13 included studies, one study measured the anxiety and depression levels as psychological outcomes by using the Beck's Anxiety Inventory and Depression Inventory II [33]. The study reported that after 10 min of deep breathing exercises twice a day for 2 weeks, the anxiety score of the intervention group decreased by 4.6 points compared with that of the control group, who received usual care. The depression scores of both the intervention and control groups were lower by 8.5 points than the baseline scores [33]. Deep breathing exercise was considered an effective approach in reducing anxiety, but no statistically significant reduction in depression occurred after the intervention.

3.10.2. Effect on quality of life

Only one study that adopted DDB intervention accompanied with music, measured the quality of life of participants by using the Medical Outcomes Study Questionnaire Short Form 36 (MOS–SF–36). The study reported no change in dimensions in the SF-36 questionnaire between the groups during the intervention period [48].

In conclusion, diaphragmatic deep breathing was shown to reduce anxiety in prehypertensive and hypertensive adults, but no effect was observed on improving the quality of life and depression syndrome.

3.11. Confidentiality of the study participants

The fidelity of the studies is of queries. Of the 13 included studies, only one conducted deep breathing exercises in a clinic [23]. All the other 12 studies instructed their participants to practice diaphragmatic deep breathing exercises at home. Participants were asked to record the time and the duration of each session in a log sheet [47], diary card [48], personal diary [44], or the RESPeRATE device [49].

Seven studies did not report participants' compliance with the deep breathing intervention at home [20,29,33,45,46,51,52].

4. Discussion

Diaphragmatic deep breathing exercise as a relaxation approach is recommended as a primary prevention strategy for hypertension to lower BP and reduce stress [24,25,32]. This review found that practicing DDB could have physiological and psychological effects on prehypertensive and hypertensive adults. Diaphragmatic deep breathing was identified as voluntary diaphragmatic deep breathing and diaphragmatic deep breathing with a device.

Of the interventions, voluntary diaphragmatic deep breathing demonstrated the most significant physiological effect on improving automatic function in prehypertensive or hypertensive adults [20,23,29,33,44–46] and demonstrated potential benefits in reducing anxiety in hypertensive participants [33]. The results revealed that practicing voluntary diaphragmatic deep breathing for 6 to <10 breaths per minute twice a week or twice a day for 4 weeks could significantly reduce the resting SBP and DBP in hypertensive adults undergoing antihypertensive medication therapy [20,29,45]. The BP-lowering effect was observed in week 4 in prehypertensive individuals [44,45]. The beneficial effect of voluntary DDB on BP was greater when the practice lasted for 12 weeks in both prehypertensive and hypertensive individuals [29,45].

In addition to the BP-lowering effect, voluntary diaphragmatic deep breathing plays an important role in reducing the HR in prehypertensive and hypertensive adults [20,33,44]. A study found that the 10-min voluntary diaphragmatic deep breathing at 6 breaths per minute daily for 4 weeks significantly reduced the HR by 3.6 beats per minute in prehypertensive adults with normal BMI. However, HR demonstrated no changes in participants who were overweight or obese due to autonomic dysfunction associated with obesity [44]. The results showed that diaphragmatic deep breathing was not associated with a decrease in HR in obese prehypertensive individuals.

MAP was measured in three studies to check the resistance of individual' blood vessel after DDB intervention [29,47,49]. A significant decreased in mean arterial pressure was found in hypertensive participants after eight-week DDB guided device with music [47] and twelve-week voluntary DDB [29], respectively. As reduction in mean arterial pressure and pulse pressure were said as increase in blood flow to vital organ of individual in every cardiac cycle, DDB demonstrated the potential benefit in reducing risk of cardiovascular disease in hypertensive patients.

In this review, two studies observed that the effect of diaphragmatic deep breathing was associated with changes in BP and HRV in prehypertensive adults [23,52]. A significant treatment effect was shown on HRV after 10 min of voluntary diaphragmatic deep breathing and 20 min of respiratory audio device-guided breathing in prehypertensive adults [23,52]. HRV should be further observed for the beneficial effect of diaphragmatic deep breathing.

Depression as an important risk factor for recurrent cardiac events, was found a significant correlation with anxiety on the effect of DDB in patients with coronary artery disease [33]. This review found that 10-min voluntary DDB twice a day for two weeks could reduce anxiety level in hypertensive adults with coronary artery disease. The results provided preliminary evidence for the positive association between diaphragmatic deep breathing and reduced levels of anxiety among hypertensive individuals.

4.1. Implications for practice

Diaphragmatic deep breathing has been practiced as a relaxation approach for lowering BP [54,55]. The American Heart Association clearly elucidated the mechanism by which slow and deep breathing lowered BP and recommended device-guided breathing as an alternative approach to lowering BP. Researchers have suggested providing more clinical evidence on the effectiveness of slow breathing without the use of devices and long-term device-guided breathing intervention [42]. In this review, the short-term physiological and psychological beneficial effects of slow and deep breathing without a device were observed in prehypertensive and hypertensive adults who were taking antihypertensive medication.

Given the evidence of difficulty in adherence to lifestyle strategies and the cost-effectiveness of pharmacological therapy, diaphragmatic deep breathing without a device may provide a practical option for individuals with prehypertension and an alternative approach among adults with hypertension on BP control [42]. As diaphragmatic deep breathing has been proven to have little to no side effects, health-care providers may promote this approach as part of the initial treatment of stage I hypertension or resistant hypertension to achieve a BP-lowering effect in individuals with medication intolerance and noncompliance.

4.2. Recommendations for future research

Diaphragmatic deep breathing has been established to have short-term effectiveness in lowering BP and HR and a potential effectiveness for reducing the level of anxiety of patients in the management of hypertension. It is recommended that the researchers conduct clinical studies to demonstrate the long-term health benefits of diaphragmatic deep breathing on HR, mood state, and stress in prehypertensive and hypertensive adults. Voluntary diaphragmatic deep breathing can be compared with other relaxation approaches to establish strong evidence of their clinical effects. Both the physiological and psychological impacts of SBP, DBP, HR, mood states, and anxiety levels, which reflect the stress-relieving effects of DDB exercises, should be measured to examine the potential health benefits of such practice on the treatment of hypertension. Measurements can be obtained at baseline, before and after the intervention, and at 3-month follow-up for longer effects.

4.3. Limitations

Although this review observed that diaphragmatic deep and slow breathing exercises had positive therapeutic effects on prehypertensive and hypertensive adults, it still has several limitations. First, only studies on DDB interventions published in English were examined; those in other languages were not identified, which could lead to bias. Second, conference proceedings and dissertations of interest on this topic were not retrieved for this review. The included published articles may be a potential source of bias. Half of the included studies have been conducted in India, and thus may limit the generalizability of the results to populations with different cultural backgrounds.

5. Conclusions

This review concluded that diaphragmatic deep breathing could significantly improve autonomic dysfunction in patients with prehypertension and hypertension by lowering BP and HR. Such a breathing technique may produce a beneficial psychological effect on prehypertensive and hypertensive adults. Clinical trials are required to provide definitive evidence. The results of this review suggested that an intervention study should be conducted to examine the possible benefits in adults with prehypertension or hypertension.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgements

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ctcp.2021.101315.

Author contributions

Katherine Yau & Alice Lok: Conceptualization, Katherine Yau: Methodology; Investigation; Writing- original Draft; Alice Loke: Writing-Review & Editing.

Funding

This research received no grant from any funding agency.

Ethical statement

This research did not require an ethical approval as it does not involve any human or animal experiment.

Data availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

References

[1] J. Li, H. Zheng, H.B. Du, X.P. Tian, Y.J. Jiang, S.L. Zhang, et al., The multiple lifestyle modification for patients with prehypertension and hypertension patients: a systematic review protocol, BMJ Open 4 (2014), e004920.

[2] O'Brien E The Lancet Commission, The Lancet Commission on hypertension: addressing the global burden of raised blood pressure on current and future generations, J. Clin. Hypertens. 19 (2017) 564–568.

[3] American Heart Association, Newsroom. High Blood Pressure Redefined for First Time in 14 Years: 130 Is the New High, American Heart Association/American College of Cardiology guidelines, 2017. https://newsroom.heart.org/news/high-blood-pressure-redefined-for-first-time-in-14-years-130-is-the-new-high?preview=06e4. (Accessed 26 November 2019).

[4] American Heart Association, Understand blood pressure readings. https://www.heart.org/en/health-topics/high-blood-pressure/understanding-blood-pressure-readings, 2019. (Accessed 2 June 2020).

[5] World Health Organization, Hypertension. Hypertension prevalence by WHO region, Website, https://www.who.int/health-topics/hypertension/#tab=tab_1, 2019. (Accessed 24 June 2020).

[6] C. Sierra, A. De La Sierra, Early detection and management of the high-risk patient with elevated blood pressure, Vasc. Health Risk Manag. 4 (2008) 289–296.

[7] L.J. Appel, C.M. Champagne, D.W. Harsha, L.S. Cooper, E. Obarzanek, P.J. Elmer, et al., Effects of comprehensive lifestyle modification on blood pressure control: main results of the PREMIER clinical trial, J. Am. Med. Assoc. 289 (2003) 2083–2093.

[8] Z. Wang, Z. Chen, L. Zhang, X. Wang, G. Hao, Z. Zhang, et al., Status of hypertension in China: results from the China hypertension survey, 2012-2015, Circulation 137 (2018) 2344–2356.

[9] Y. Zhang, A.E. Moran, Trends in the prevalence, awareness, treatment, and control of hypertension among young adults in the United States, 1999-2014, Hypertension 70 (2017) 736–742.

[10] J.N. Booth III, J. Li, L. Zhang, L. Chen, P. Muntner, B. Egan, Trends in prehypertension and hypertension risk factors in US adults: 1999-2012, Hypertension 70 (2017) 275–284.

[11] F. Sparrenberger, F.T. Cichelero, A.M. Ascoli, F.P. Fonseca, G. Weiss, Berwanger, et al., Does psychosocial stress cause hypertension? A systematic review of observational studies, J. Hum. Hypertens. 23 (2009) 12–19.

[12] A. Steptoe, Psychophysiological stress reactivity and hypertension, Hypertension 52 (2008) 220–221.

[13] P. Pavithran, R. Mithun, M. Jomal, H. Nandeesha, Heart rate variability in middle-aged men with new-onset hypertension, Ann. Noninvasive Electrocardiol. 13 (2008) 242–248.

[14] J. Amerena, S. Julius, The role of the autonomic nervous system in hypertension, Hypertens. Res. 18 (1995) 99–110.

[15] S. Julius, Abnormalities of autonomic nervous control in human hypertension, Cardiovasc. Drugs Ther. 8 (suppl 1) (1994 March 1) 11–20.

[16] American Heart Association, Stress management. https://www.heart.org/en/healthy-living/healthy-lifestyle/stress-management, 2019. (Accessed 7 July 2020).

[17] J.S. Wu, F.H. Lu, Y.C. Yang, T.S. Lin, J.J. Chen, C.H. Wu, et al., Epidemiological study on the effect of pre-hypertension and family history of hypertension on cardiac autonomic function, J. Am. Coll. Cardiol. 51 (2008) 1896–1901.

[18] A.R. Sales, B.M. Silva, F.J. Neves, N.G. Rocha, R.F. Medeiros, R.R. Castro, et al., Diet and exercise training reduce blood pressure and improve autonomic modulation in women with prehypertension, Eur. J. Appl. Physiol. 112 (2012) 3369–3378.

[19] S.R. Mangala Gowri, V. Gurushanthappa, Cardiac autonomic functions in hypertensive and normotensive subjects: a comparative study, Med. Sci. 4 (2016) 320.

[20] B. Sundaram, P.J. Maniyar, V.P. Singh, Slow breathing training on cardio-respiratory control and exercise capacity in persons with essential hypertension—a randomized controlled trial, Indian J. Physiother Occup. Ther. 6 (2012) 17–21.

[21] K. Sevre, J.D. Lefrandt, G. Nordby, I. Os, M. Mulder, R.O. Gans, , et al.I. Os, M. Mulder, R.O. Gans, et al., Autonomic function in hypertensive and normotensive subjects: the importance of gender, Hypertension 37 (2001) 1351–1356.

[22] C.N. Joseph, C. Porta, G. Casucci, N. Casiraghi, M. Maffeis, M. Rossi, et al., Slow breathing improves arterial baroreflex sensitivity and decreases blood pressure in essential hypertension, Hypertension 46 (2005) 714–718.

[23] N. Jindal, S. Yogesh, Acute effect of slow abdominal breathing on heart rate variability in pre-hypertensive, Int. J. Sci. Res. 8 (2019) [11].

[24] J. Srinivasa, P.A. Mr, Respiratory sinus arrhythmia (RSA): noninvasive measure of parasympathetic cardiac control in newly diagnosed hypertensives and the influence of abdominal breathing, Kharkiv Karazin's National University Bulletin. Medicine 545 (2002) 80–85.

[25] S.S. Patil, R.H. Taklikar, A comparative study of heart rate variability during deep breathing in normotensive and hypertensive subjects, Int. J. Med. Health Sci. 4 (2015) 421–425.

[26] Gale Encyclopedia of Medicine, Deep breathing, July 92020, https://medical-dictionary.thefreedictionary.com/Deep+breathing, 2008.

[27] X. Ma, Z.Q. Yue, Z.Q. Gong, H. Zhang, N.Y. Duan, Y.T. Shi, et al., The effect of diaphragmatic breathing on attention, negative affect and stress in healthy adults, Front. Psychol. 8 (2017) 874.
[28] N.K. Subbalakshmi, P. Adhikari, P. Shanmugavel Jeganathan, Comparative study on cardiac autonomic modulation during deep breathing test and diaphragmatic breathing in type 2 diabetes and healthy subjects, J Diabetes Investig 5 (2014) 456–463.
[29] G. Vasuki, L.M. Sweety, The study of usefulness of deep breathing exercise (non-pharmacological adjunct) on blood pressure in hypertensive patients, J Dent and Med Sci (ISOR_JDMS) 16 (2017) 59–62.
[30] S.Z. Wang, S. Li, X.Y. Xu, G.P. Lin, L. Shao, Y. Zhao, et al., Effect of slow abdominal breathing combined with biofeedback on blood pressure and heart rate variability in prehypertension, J. Alternative Compl. Med. 16 (2010) 1039–1045.
[31] W.J. Elliott, J.L. Izzo, W.B. White, D.R. Rosing, C.S. Snyder, A. Alter, et al., Graded blood pressure reduction in hypertensive outpatients associated with use of a device to assist with slow breathing, J. Clin. Hypertens. 6 (2004) 553–559.
[32] Y.F. Chen, X.Y. Huang, C.H. Chien, J.F. Cheng, The effectiveness of diaphragmatic breathing relaxation training for reducing anxiety, Psychiatr. Care 53 (2017) 329–336.
[33] F. D'silva, H. Vinay, N.V. Muninarayanappa, Effectiveness of deep breathing exercise (DBE) on the heart rate variability, BP, anxiety and depression of patients with coronary artery disease, Nitte Univ. J. Health Sci. 4 (2014) 35.
[34] M. Mourya, A.S. Mahajan, N.P. Singh, A.K. Jain, Effect of slow- and fast-breathing exercises on autonomic functions in patients with essential hypertension, J. Alternative Compl. Med. 15 (2009) 711–717.
[35] F. Shaffer, J.P. Ginsberg, An overview of heart rate variability metrics and norms, Front Public Health 5 (2017) 258.
[36] S. Chen, P. Sun, S. Wang, G. Lin, T. Wang, Effects of heart rate variability biofeedback on cardiovascular responses and autonomic sympathovagal modulation following stressor tasks in prehypertensives, J. Hum. Hypertens. 30 (2016) 105–111.
[37] T.M. Spruill, Chronic psychosocial stress and hypertension, Curr. Hypertens. Rep. 12 (2010) 10–16.
[38] H.C. Chen, M.B. Lee, Psychosomatic aspects of relaxed breathing training, Taiwan. J. Psychiatry 16 (2002) 177–192.
[39] P.M. Lehrer, R. Gevirtz, Heart rate variability biofeedback: how and why does it work? Front. Psychol. 5 (2014) 756.
[40] Y. Zou, X. Zhao, Y.Y. Hou, T. Liu, Q. Wu, Y.H. Huang, et al., Meta-analysis of effects of voluntary slow breathing exercises for control of heart rate and blood pressure in patients with cardiovascular diseases, Am. J. Cardiol. 120 (2017) 148–153.
[41] K.R. Mahtani, D. Nunan, C.J. Heneghan, Device-guided breathing exercises in the control of human blood pressure: systematic review and meta-analysis, J. Hypertens. 30 (2012) 852–860.
[42] R.D. Brook, L.J. Appel, M. Rubenfire, G. Ogedegbe, J.D. Bisognano, W.J. Elliott, et al., Beyond medications and diet: alternative approaches to lowering blood pressure: a scientific statement from the American Heart Association, Hypertension 61 (2013) 1360–1383.
[43] R. Sirriyeh, R. Lawton, P. Gardner, G. Armitage, Reviewing studies with diverse designs: the development and evaluation of a new tool, J. Eval. Clin. Pract. 18 (2012) 746–752.
[44] K. Harneet, S. Saravanan, Effect of slow breathing on blood pressure, heart rate and body weight in prehypertensive subjects of varying body mass index, Int. J. Sci. Eng. Res. 3 (2014) 863–867.
[45] G. Vasuki, L.M. Sweety, The study of usefulness of deep breathing exercise on blood pressure in pre-hypertensive and hypertensive patients, Indian J. Clin. Anat Physiol. 4 (2017) 400–403.
[46] K. Amandeep, M. Preksha, S. Divya, Effectiveness of abdominal breathing exercise on blood pressure among hypertensive patients, Int J Ther Appl 24 (2015) 39–49.
[47] F.P. Kow, B. Adlina, S. Sivasangari, N. Punithavathi, K.K. Ng, A.H. Ang, et al., The impact of music guided deep breathing exercise on blood pressure control-A participant blinded randomized controlled study, Med. J. Malaysia 73 (2018) 233–238.
[48] P.A. Modesti, A. Ferrari, C. Bazzini, G. Costanzo, I. Simonetti, S. Taddei, et al., Psychological predictors of the antihypertensive effects of music-guided slow breathing, J. Hypertens. 28 (2010) 1097–1103.
[49] K. Howorka, J. Pumprla, J. Tamm, A. Schabmann, S. Klomfar, E. Kostineak, et al., Effects of guided breathing on blood pressure and heart rate variability in hypertensive diabetic patients, Auton. Neurosci. 179 (2013) 131–137.
[50] D.E. Anderson, J.D. McNeely, B.G. Windham, Regular slow-breathing exercise effects on blood pressure and breathing patterns at rest, J. Hum. Hypertens. 24 (2010) 807–813.
[51] G.W. Landman, I. Drion, K.J. van Hateren, P.R. van Dijk, S.J. Logtenberg, J. Lambert, et al., Device-guided breathing as treatment for hypertension in type 2 diabetes mellitus: a randomized, double-blind, sham-controlled trial, JAMA Intern Med 173 (2013) 1346–1350.
[52] G. Lin, Q. Xiang, X. Fu, S. Wang, S. Wang, S. Chen, et al., Heart rate variability biofeedback decreases blood pressure in prehypertensive subjects by improving autonomic function and baroreflex, J. Alternative Compl. Med. 18 (2012) 143–152.
[53] E.A. Wehrwein, M.J. Joyner, Regulation of blood pressure by the arterial baroreflex and autonomic nervous system, Handb Clin Neurol Elsevier 117 (2013) 89–102.
[54] L. Bernardi, P. Sleight, G. Bandinelli, S. Cencetti, L. Fattorini, J. Wdowczyc-Szulc, et al., Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study, BMJ 323 (2001) 1446–1449.
[55] M.J. Irvine, D.W. Johnston, D.A. Jenner, G.V. Marie, Relaxation and stress management in the treatment of essential hypertension, J. Psychosom. Res. 30 (1986) 437–450.