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Effectiveness of diaphragmatic breathing for reducing physiological and psychological stress in adults: a quantitative systematic review

Susan I. Hopper[1,2] • Sherrie L. Murray[1,2] • Lucille R. Ferrara[1,2] • Joanne K. Singleton[1,2]

[1]College of Health Professions, Pace University, New York, USA, [2]The Northeast Institute for Evidence Synthesis and Translation (NEST): a Joanna Briggs Institute Center of Excellence

ABSTRACT

Objective: The objective of this review was to evaluate the effectiveness of diaphragmatic breathing for reducing physiological and psychological stress in adults 18 years and over.

Introduction: Stress has reached epidemic proportions globally. Unidentified sequela of physiological and psychological stress can result in anxiety, depression, heart disease, cancer, immunologic conditions and death. There is a high cost associated with the treatment of stress related health conditions in the United States and worldwide. Many treatments are pharmacologic and cannot be self-initiated. Therefore, it is critical to identify evidence-based, low-cost, non-pharmacologic, self-administered interventions that can mitigate physiological and psychological stress.

Inclusion criteria: This review considered adults 18 years and over engaged in diaphragmatic breathing as an isolated intervention to reduce physiological and psychological stress. There were no exclusions based on physical or psychological conditions. The comparator was no treatment or usual treatment, which may constitute ordinary breathing.

Methods: The comprehensive literature search included published and unpublished studies in English from the beginning of the databases through January 2018. The databases searched included: PubMed, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL), Embase, PsycINFO, ProQuest Nursing and Allied Health and Health Source: Nursing/Academic Edition. The recommended JBI approach to critical appraisal, study selection, data extraction and data synthesis was used.

Results: Three studies met the criteria for review: one randomized controlled trial and two quasi-experimental studies. Statistical pooling was not possible due to clinical and methodological heterogeneity of interventions and outcome measures of the included studies. All three studies demonstrated the effectiveness of diaphragmatic breathing on reducing stress. One study showed improvement in the biomarkers of respiratory rate and salivary cortisol levels, one showed improvement in systolic and diastolic blood pressure, and one study showed an improvement in the stress subscale of the Depression Anxiety Stress Scales-21 (DASS-21) after implementation of a diaphragmatic breathing intervention. Although there were limitations across the studies, such as sample size, and length and duration of the intervention over time, ranging from one 20-minute intervention to nine months, the studies demonstrated that diaphragmatic breathing had a positive effect on lowering physiological and psychological stress.

Conclusions: The evidence suggests that diaphragmatic breathing may decrease stress as measured by physiologic biomarkers, as well psychological self-report tools. Given the benefits of diaphragmatic breathing on stress reduction, ongoing research is needed to continue to establish the evidence-base for this self-administered, low-cost, non-pharmacologic intervention.

Keywords Deep breathing; diaphragmatic breathing; physiological stress; psychological stress; stress

JBI Database System Rev Implement Rep 2019; 17(9):1855–1876.

Correspondence: Susan I. Hopper, sh31363n@pace.edu

The authors declare no conflict of interest.

DOI: 10.11124/JBISRIR-2017-003848

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Summary of Findings

Diaphragmatic breathing compared to ordinary breathing for stress reduction in adults

Bibliography: Hopper SI, Murray SL, Ferrara LR, Singleton JK, Effectiveness of diaphragmatic breathing for reducing physiological and psychological stress in adults: a quantitative systematic review. JBI Database System Rev Implement Rep 2019; 17(9):1855-1876.

Outcomes	Impact	№ of participants (studies)	Certainty of the evidence (GRADE)
Diastolic blood pressure (DBP) Assessed with: sphygmomanometer	In group comparison in the experimental group showed diaphragmatic breathing had a statistically significant effect on lowering diastolic blood pressure, $p \leq 0.01$. No significant effect was seen in the control group.	80 (1 quasi-experimental study)	⨁⨁◯◯ LOW [a,b]
Systolic blood pressure (SBP) Assessed with: sphygmomanometer	In group comparison in the experimental group showed diaphragmatic breathing had a statistically significant effect on lowering systolic blood pressure, $p \leq 0.01$. No significant effect was seen in the control group.	80 (1 quasi-experimental study)	⨁⨁◯◯ LOW [a,b]
Salivary cortisol Assessed with: cortisol assay	A simple effect measurement showed a statistically significant decrease in salivary cortisol concentration after intervention over time, $p \leq 0.05$. There was no similar effect in the control group, $p \geq 0.05$.	39 (1 randomized controlled trial)	⨁⨁◯◯ LOW [a,b]
Rate of breathing (RR) Assessed with: counting the rate	Diaphragmatic breathing had a statistically significant decrease in the respiratory rate when compared to resting breathing, $p \leq 0.05$.	39 (1 randomized controlled trial)	⨁⨁◯◯ LOW [a,b]
Depression Anxiety Stress Scales-21 (DASS-21) self-perceived stress Assessed with: DASS-21	Diaphragmatic breathing had a statistically significant effect on perceived stress level within and between comparison groups over time, $p \leq 0.01$.	761 (1 quasi-experimental design)	⨁⨁⨁◯ MODERATE [a]

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanation
a. indirect measure of stress
b. small sample size

Introduction

Stress is a global epidemic. In 2011, the World Health Organization (WHO) developed guidelines to support primary care providers in the care of their patients who experience stress.[1,2] A 2016 global assessment by WHO recognized that sources of stress varied internationally and identified that 350 million people were affected by stress worldwide.[2] Stress is the process where environmental demands result in detrimental outcomes to a person's physical and/or mental health.[3,4] When a person experiences stress they have both physiological and psychological responses. The physiologic responses to stress arise from activation of the sympathetic nervous system (SNS) through the secretion of cortisol.[5] An increase in respiratory rate, heart rate, and systolic and diastolic blood pressure result from stress. The stress response can be immediate or delayed, acute or long term.[4] Sympathetic nervous system activity increases in response to psychological stress and are pro-inflammatory leading to the development of mental and physical disease states.[4,5]

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Stress is a major risk factor for the development of many chronic diseases, both physiologic (cancer, cardiovascular disease) and psychological (anxiety, and depression).[6]

Environmental sources of stress include catastrophic events such as floods and earthquakes, inadequate food and water sources, and poor living conditions.[2] Additional triggers of stress include work, school, finances, family and social interactions, and expectations.[7,8] In a study of over 115 million people conducted in the United States (US) by the Robert Wood Johnson Foundation in conjunction with National Public Radio and the Harvard School of Public Health, over half of all adults surveyed acknowledged that they had a major stressful event in the past year.[9] Seventy-two percent of those surveyed regularly experienced financial stress and 60% reported job-related stress.[10]

In work and college environments stress can lead to cardiovascular disease, hypertension, depression, anxiety, social dysfunction, drug and alcohol abuse, and in extreme cases can result in death.[11-14] The International Labour Organization's (ILO) 2016 report on workplace stress identified that global workplace stress is only beginning to be quantified.[15] The study reported €272 billion in lost productivity from work-related stress and €242 billion in healthcare costs in Europe.[15] In addition, Australian estimates in 2008/2009 for lost productivity related to stress were AUD5.3 billion annually.[15] In the US, the cost of stress to employers has been reported to be over US$300 billion (€273 billion).[10] The overall financial burden of stress reported globally is staggering.[2] The high costs of stress is well documented.[6-16] In a study on anxiety and depression by the WHO, increasing future worldwide treatment from 2016 to 2030 using psychosocial counseling and medication is estimated to cost US$141 billion (€119.67 billion).[17] Identifying evidence-based stress reduction interventions that are low cost and easy to use, and that can be self-administered is essential to the overall treatment and management of this global health issue. An intervention that may meet these criteria and is the intervention of interest in this review is diaphragmatic breathing.

Diaphragmatic breathing involves breathing deeply and expanding the lungs into the diaphragm rather than using the abdomen or ribcage alone.[18,19] Diaphragmatic breathing techniques focus on the breath and slowing the breath rate by using a process such as counting the breaths while expanding the abdomen and inhaling deeply through the nose, pausing, followed by contracting the abdomen and exhaling slowly and completely through the mouth.[18-20] This type of deep breathing technique includes developing a pattern of inhalation and exhalation to decrease respiratory rate.[19-23] Deep breathing assists in blood flow, lowering the pulse rate and blood pressure by improving vagal activity and reducing the sympathetic reaction.[18] Diaphragmatic breathing needs no equipment or specific setting, and it can be easily taught and learned, making it cost effective. Further, diaphragmatic breathing can be self-administered when a person identifies a stress trigger, making it a readily available treatment for the management of stress. Diaphragmatic breathing has been identified as a benefit to both physical and mental health.[22]

The intervention of diaphragmatic breathing was considered in this review, independent of other complementary or mindfulness-based therapies, in order to provide supporting evidence of its efficacy in reducing physiological and psychological stress in the absence of any interventions framed by spiritual or religious beliefs. If diaphragmatic breathing can be shown to provide physiological and psychological stress reduction, it may be a cost-effective means for improving health outcomes. Therefore, this review aimed to evaluate the effectiveness of diaphragmatic breathing for reducing physiological and psychological stress in adults 18 years and over. A search of PubMed, Cumulative Index of Nursing and Allied Health Literature (CINAHL), *JBI Database of Systematic Reviews and Implementation Reports,* and the Cochrane Database of Systematic Reviews was performed, and no existing or ongoing systematic review on this topic was identified.

Review question

What is the effectiveness of diaphragmatic breathing for reducing physiological and psychological stress in adults 18 years and over?

Inclusion criteria

Participants

This review considered studies that included adults 18 years and over. There was no exclusion based on

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physical or psychological diagnosis. There was no exclusion based on acute or chronic disease states.

Intervention

This review considered studies that included diaphragmatic breathing of any regimen or duration. Diaphragmatic breathing involves breathing deeply and expanding the lungs into the diaphragm rather than using the abdomen or ribcage alone.[18,19] The intervention of interest was considered when teaching was demonstrated by either researcher or designee in person or by compact disc recording (CD). Studies will be excluded if diaphragmatic breathing is paired with any intervention that may have religious or spiritual implications, such as yoga, meditation or mindfulness.

Comparator

This review considered studies that compared the intervention of diaphragmatic breathing to no treatment or usual treatment. This review also considered, as comparators, other stress reduction interventions such as progressive muscle relaxation and mindfulness techniques if measured independently and if they do not have religious or spiritual implications. ''Mindfulness is defined as the awareness that emerges through purposefully paying nonjudgmental attention to present moment experiences.''[12(p.349)]

Outcomes

This review considered studies that included the following outcomes: physiological and psychological stress. This review examined studies that used physiological measurements such as respiratory rate (RR), blood pressure (BP) and cortisol levels; and self-report instruments that measured participants stress as measured by the Depression Anxiety Stress Scales-21 (DASS-21)-stress subscale.[7,19,22] In one study the BP was measured by the use of an automatic sphygmomanometer; in another study, respiratory rate was recorded using a breathing monitor, and the DASS-21 was used as a self-report tool to measure perceived stress.[7,19,22] Outcome measures were considered from any period after the delivery of the intervention.

Types of studies

This review considered both experimental and quasi-experimental study designs including randomized controlled trials, non-randomized controlled trials, before and after studies and interrupted time-series studies.

Methods

This systematic review was conducted in accordance with the JBI Reviewers' Manual.[24] This review was conducted and specified in advance and documented according to an *a priori* protocol.[25]

Search strategy

The search strategy aimed to find both published and unpublished studies. A three-step search strategy was utilized in this review. An initial limited search of PubMed and CINAHL was undertaken followed by analysis of the text words contained in the title and abstract and the index terms used to describe the article. A second search using all the identified keywords and index terms was undertaken across the following databases from the inception of each database through January 2018; only studies published in English were considered for inclusion: PubMed, CINAHL via EBSCOhost, Cochrane Central Register of Controlled Trials (CENTRAL) via Wiley Online Library, Embase via Elsevier, PsycINFO via EBSCOhost, ProQuest Nursing & Allied Health Database and Health Source: Nursing/Academic Edition via EBSCOhost. The search strategies used for the databases searched are detailed in Appendix I. The search for unpublished studies/gray literature included: ProQuest Dissertations and Thesis A&I, New York Academy of Medicine Library, Virginia Henderson Global Nursing e-Repository and Google Scholar. Finally, the reference lists of all reports and articles selected for critical appraisal were searched for additional studies. In addition, subject matter experts were contacted to attempt to identify other potentially relevant studies. A confirmatory search conducted on May 1, 2018 of PubMed and CINAHL to include individual outcomes of interest did not yield any additional studies of relevance; this supplemental search narrowed the results.

Study selection

Following the search, all identified citations were collated and uploaded into EndNote X7.7 (Clarivate Analytics, PA, USA) and duplicates were removed. Titles and abstracts were screened by two

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independent reviewers for assessment against the inclusion criteria for the review. The full texts of potentially eligible studies were retrieved and assessed in detail against the inclusion criteria by two independent reviewers. Details of studies that met the inclusion criteria were imported into the JBI System for the Unified Management, Assessment and Review of Information (JBI SUMARI) (Joanna Briggs Institute, Adelaide, Australia). Full-text studies that did not meet the inclusion criteria were excluded, and reasons for exclusion are provided in Appendix II. Any disagreements that arose between the reviewers were resolved through discussion.

Assessment of methodological quality

Studies meeting the inclusion criteria were assessed by two independent reviewers for methodological validity prior to inclusion in the review using standardized critical appraisal instruments from JBI for randomized controlled trials and quasi-experimental studies.[24] Any disagreements that arose between the reviewers were resolved through discussion. All studies regardless of their methodological quality underwent data extraction and synthesis.

Data extraction

Data were extracted from studies included in the review by two independent reviewers using the standardized data extraction tool JBI SUMARI.[24] The data extracted included specific details about the interventions, populations, study methods and outcomes of significance to the review question. Any disagreements that arose between the two reviewers were resolved through discussion. Authors of papers were contacted to request missing or additional data where required.

Data synthesis

Statistical pooling for a meta-analysis was not possible due to the clinical and methodological heterogeneity of interventions and outcome measures of the included studies. Therefore, the results are presented in narrative form.

Assessing certainty in the findings

A Summary of Findings was created using GRADEpro software (McMaster University, ON, Canada). The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach for grading the quality of evidence was followed.

Results

Study inclusion

A comprehensive search of the literature revealed 766 potentially relevant papers were obtained. There were 744 articles excluded by duplicates and title. Records screened were 22 of which six were excluded on reading of the abstracts. Sixteen articles were retrieved for full text review. Thirteen articles were excluded for not meeting the inclusion criteria after full text review. Studies were excluded when diaphragmatic breathing was not examined, independent of other stress reduction techniques. Appendix II lists the excluded articles with the rationale for exclusion. Figure 1 outlines the stages of identification and retrieval of studies for inclusion in this systematic review.[26] The reviewers contacted the authors of published studies to obtain unpublished results and other raw or pertinent data.

Methodological quality

Three studies meeting the inclusion criteria were appraised for methodological quality. Based on the limited number of articles identified that met the inclusion criteria for this review and guidance by Tufanaru *et al.*,[27] all studies were included, and any risk of bias was considered during data synthesis and presentation of the results and implications. Randomization in the Ma *et al.* study was by the best means possible and done by alternating registration and considering gender, but it was not blinded. In addition, there may also have been attrition bias in this study, as the follow-up for all participants was not documented.[22] The author of the Joshi *et al.*[7] study was contacted to clarify the participation numbers and allocation via email (A. Joshi, 2018, personal communication). The author stated that students were randomized in sequence of their obtained consent. Participants were allocated to experimental and control groups, and each group comprised 40 subjects. There may have been a risk of selection bias, as it is unclear why there were 123 respondents and only 80 were selected for inclusion in the study.[7] Sundram *et al.* may have had a risk of attrition bias, as documented.[19] A large number of participants did not complete the study in the intervention group. The author commented in the discussion section that due to effect size there was a decreased risk of bias.

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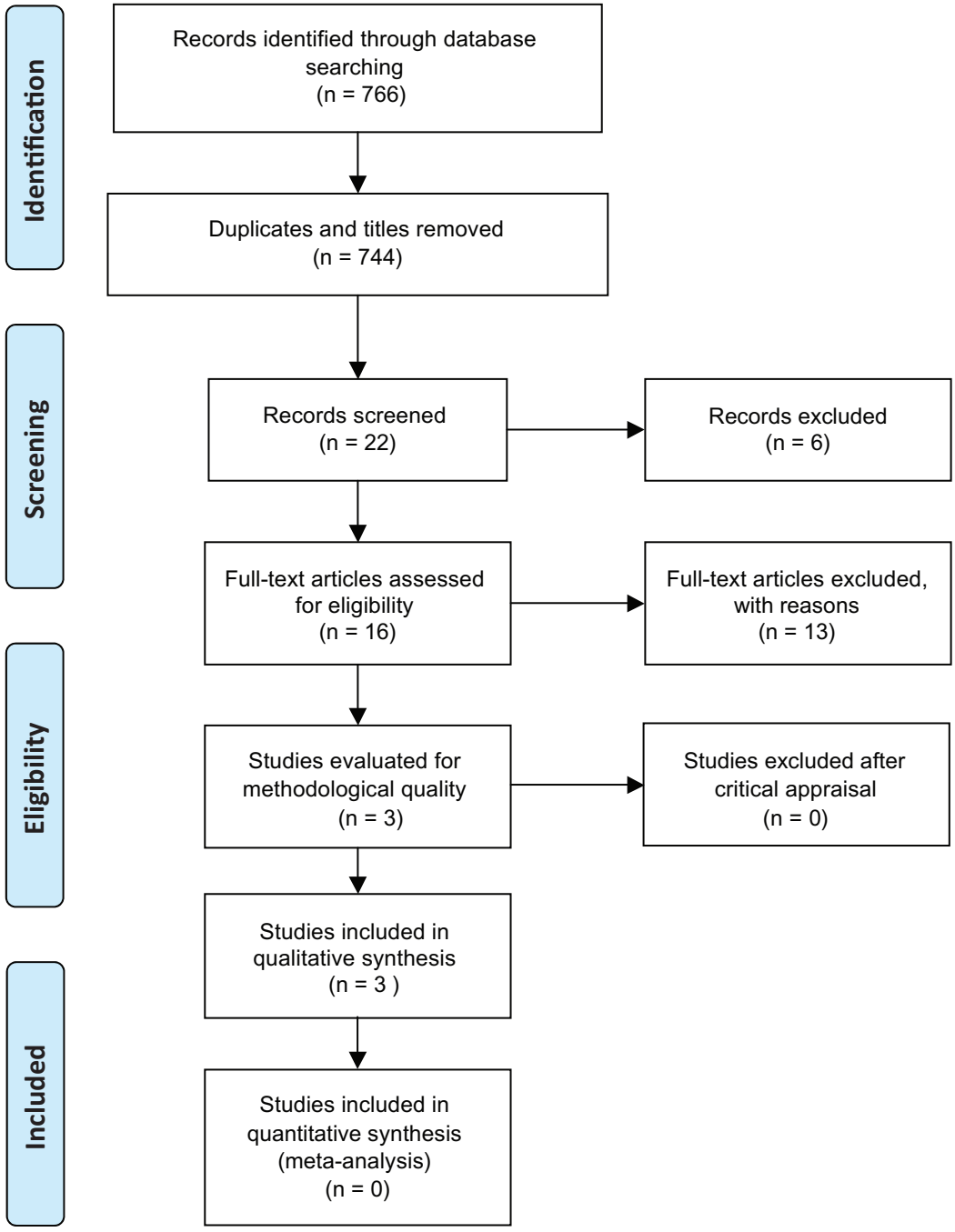

Figure 1: PRISMA flow diagram of study selection and inclusion process[26]

However, if all participants completed the study, there would have been a concern that there was attrition bias as he may not have obtained the same statistically significant results. All reviewed studies held the potential of either bias of attrition or selection bias. There was poor generalizability to the greater population due to a lack of homogeneity in the sample populations studied. In addition, there was not enough information given on the training and background of the individuals introducing diaphragmatic breathing to the experimental groups (see critical appraisal Tables 1 and 2 below).

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Table 1: Critical appraisal results for quasi-experimental studies

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Joshi A, 2016[7]	Y	Y	Y	Y	Y	N	Y	Y	Y
Sundram BM, 2014[19]	Y	Y	Y	Y	Y	Y	Y	Y	Y
%	100	100	100	100	100	50	100	100	100

Y = Yes, N = No
JBI critical appraisal checklist for quasi-experimental studies: Q1 = Is it clear in the study what is the 'cause' and what is the 'effect' (i.e., there is no confusion about which variable comes first)? Q2 = Were the participants included in any comparisons similar? Q3 = Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest? Q4 = Was there a control group? Q5 = Were there multiple measurements of the outcome both pre and post the intervention/exposure? Q6 = Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed? Q7 = Were the outcomes of participants included in any comparisons measured in the same way? Q8 = Were outcomes measured in a reliable way? Q9 = Was appropriate statistical analysis used?

Table 2: Critical appraisal results for randomized controlled trial

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Ma XY 2017[22]	Y	N	Y	U	N	N	Y	Y	Y	Y	Y	Y	Y

Y = Yes, N = No, U = Unclear
JBI critical appraisal checklist for randomized controlled trials: Q1 = Was true randomization used for assignment of participants to treatment groups? Q2 = Was allocation to treatment groups concealed? Q3 = Were treatment groups similar at baseline? Q4 = Were participants blind to treatment assignment? Q5 = Were those delivering treatment blind to treatment assignment? Q6 = Were outcome assessors blind to treatment assignment? Q7 = Were treatment groups treated identically other than the intervention of interest? Q8 = Was follow-up complete, and if not, were strategies to address incomplete follow-up utilized? Q9 = Were participants analyzed in the groups to which they were randomized? Q10 = Were outcomes measured in the same way for treatment groups? Q11 = Were outcomes measured in a reliable way? Q12 = Was appropriate statistical analysis used? Q13 = Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Characteristics of included studies

There were three included studies in this review, one randomized controlled trial,[22] and two quasi-experimental.[7,19] Table 3 provides details of the characteristics of the included studies (see Appendix III for further details). All studies were published between 2014 and 2017.[7,19,22] One study took place in Malaysia, the second in Beijing China and the third in Punjab India.[7,19,22] All study participants were healthy adults, and one study looked at males exclusively. In one study, the participants were college students, in the second study they were industrial workers and in the third they were the employees of a technology company.[7,19,22] Group sizes in the study ranged from 39 to 761 participants.[7,19,22]

Review findings

Randomized controlled trial

Ma *et al.*[22] concluded that diaphragmatic breathing had a significant positive effect of decreased breathing rates in the breathing intervention group (BIG) when compared to the control group (CG). The

Table 3: Characteristics of included studies

Study	Intervention group name and size	Control group name and size	Number of sessions for intervention group	Outcome measure	Measurement tool	Person teaching the Intervention
Joshi *et al.*[7] Population: engineering students from India	Experimental group n=123 participants divided between each group (researchers did not specify how they were divided)	Control group n = 123 participants divided between each group (researchers did not specify how they were divided)	1 breathing exercise consisting of ordinary breathing followed by a ten minute session of deep breathing technique	Systolic and diastolic blood pressure	Sphygmomanometer	Deep breathing training was done by yoga experts

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Table 3. (*Continued*)

Study	Intervention group name and size	Control group name and size	Number of sessions for intervention group	Outcome measure	Measurement tool	Person teaching the Intervention
Ma *et al.*[22] Population: IT company employees, both male and female from China	Breathing intervention group n = 19	Control group n = 20	20 sessions, over 8 weeks	Respiratory rate was measured during the entire 30-minute training. Each session was conducted every other day on weekdays. Salivary cortisol levels were measured 4 times at 2 time points before and after diaphragmatic breathing at baseline and final test.	Breathing recorded Salivette cortisol (Art. No 51.1534)	Breathing coach
Sundram *et al.*[19] Population: male automotive workers from Malaysia	Plant A (also called Group A) received deep breathing exercise training n = 468, all males	Plant B (also called Group B) n = 293, all males	DBE training at initiation of the experiment, 4 follow-up reinforcement sessions after baseline, 2, 4, 6, and 8 months	Anxiety sub-scale: Depression Anxiety Stress Scales (DASS-21) measured at 2, 4, 6 and 8 months, and at the end of the 9 months.	DASS-21	Primary investigator who himself had undergone training with a certified trainer in relaxation techniques

control group received only an introduction of breathing and rest. Ma *et al.*[22] concluded that the BIG had a statistically significant effect in terms of frequency of respiratory breathing rates when compared to the CG, with $p \leq 0.05$ in the BIG. Repeat Measures Analysis was used to measure change over the eight-week period for respiratory rate; this allowed for statistical analysis with a small number of participants. There was a significant effect of time when measuring within group factors such as breathing conditions for the BIG versus the CG and the intervention times of 20 sessions over eight weeks. There was a significant effect of breathing condition with a $p \leq 0.000$ for measurement of respiratory rate. The researchers equated the ''breathing condition'' to the respiratory rate. Ma *et al.*[22] also concluded a statistically significant decrease in salivary cortisol over time as seen using a simple effect measurement with a p-value ≤ 0.05. The BIG showed a significant decrease in salivary cortisol concentration after intervention and over time. There was no similar effect in the CG with a $p \geq 0.05$. The between-group factor was the overall effect on the groups (BIG versus CG) while the within-group factor was the test times, four time points at baseline and before and after deep breathing, and before and after final intervention. The concentration result revealed a significant interaction of time and group. A simple effect measurement was conducted; the BIG showed a significant decrease in salivary cortisol concentration after the intervention, whereby the levels were lower at test three and four, more than one and two (see Figures 2 and 3).[22]

Quasi-experimental studies

The Joshi *et al.*[7] study measured the effect of deep breathing technique (DBT) in the experimental group and ordinary breathing technique (OBT) in the control group on systolic and diastolic blood pressure before and after one intervention. The study concluded that DBT in the experimental group, when compared to OBT in the control group, had a statistically significant effect on lowering systolic and diastolic blood pressure, with $p \leq 0.01$.[7] There was no change in systolic or diastolic blood pressure demonstrated after ordinary breathing ($p \geq 0.01$) (see Figure 4).[7,22]

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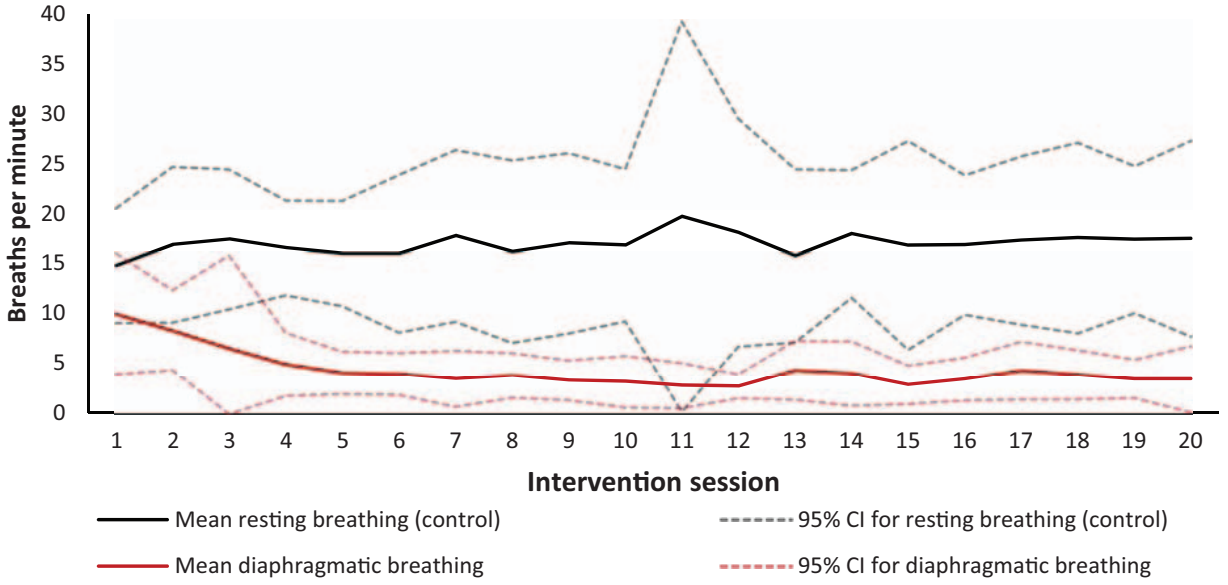

Figure 2: Mean respiratory rates with 95% confidence intervals (CI) for breathing intervention group by intervention session

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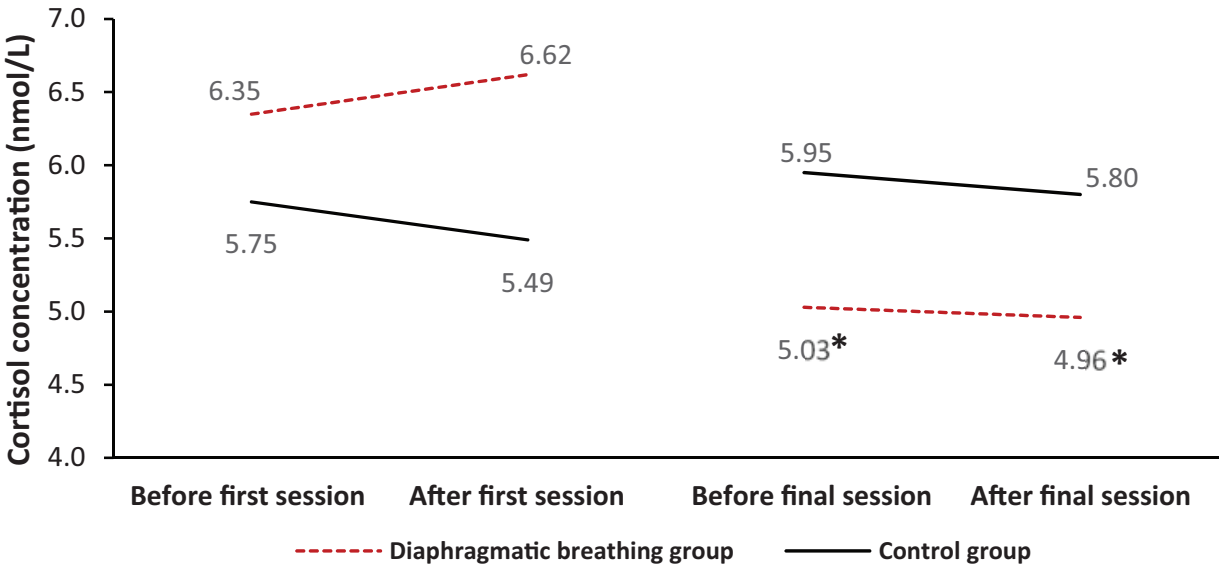

Figure 3: Mean salivary cortisol concentration pre-post diaphragmatic breathing by group and session

$*$ = Significance at $P < 0.005$ when compared to before first session measurement of the diaphragmatic breathing group

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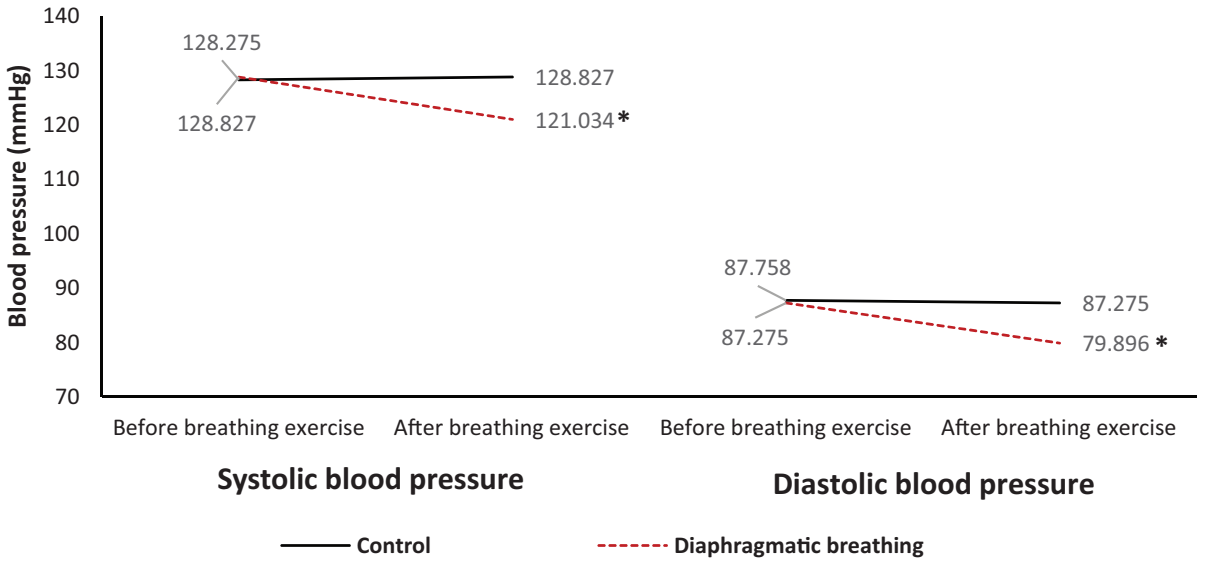

Figure 4: Mean blood pressure readings pre-post diaphragmatic breathing by group
$*$ = Significance at $P < 0.000$
Information from reference 7.

Sundram *et al.*[19] found a statistically significant difference in perceived stress between the treatment group (Group A) and control group (Group B). Group A was taught diaphragmatic breathing exercise (DBE) and Group B was not.[19] The stress subscale of the DASS-21 was measured at baseline, and at the end of the 2nd, 4th, 6th and 8th month. Results showed a change in the mean DASS-21 sub-scale scores across Group A from baseline to 9 months. The study results showed that group A had a statistically significant effect over time with a $p \leq 0.001$ as compared to group B.[19] There was also a large effect size in Group A compared to Group B across groups as well. The study concluded that diaphragmatic breathing had a statistically significant effect on the perceived stress level as reported within and between group comparison, as seen with a p-value of ≤ 0.01.[19]

Discussion

Due to the pervasive issue of stress across all settings, it is essential to identify self-administered, low-cost, non-pharmacologic, evidence-based interventions to help individuals cope with the stressors of everyday life to support their health and wellbeing. Diaphragmatic breathing is an easily taught intervention that can be self-administered in different environments such as schools or the workplace. This systematic review included three studies that demonstrated a positive relationship between the effects of diaphragmatic breathing and both physiological and psychological stress reduction. Although showing positive effects on stress reduction, there was a low grade of certainty of the evidence (grade B) in two of the studies which used physiological measurement tools. These tools included blood pressure, respiratory rate and salivary cortisol measures. Although a positive correlation is seen, these tools can be considered an indirect measurement of stress. Only one study using a psychological measurement tool, DASS-21, had a moderate certainty of the evidence. Only one study demonstrated a positive correlation between reducing blood pressure and diaphragmatic breathing; however, the intervention did not show long-term effects as it measured the impact of one intervention of diaphragmatic breathing. Similarly, this study did not allow for any comparison over time to show long-term positive outcomes and sustainability of the intervention. Another study concluded that diaphragmic breathing practice over a period of nine months showed a continued positive effect in decreasing stress as measured by the DASS-21

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subscale, self-report tool. The study demonstrated a positive effect of diaphragmatic breathing on stress reduction as measured by respiratory rate and cortisol levels. Respiratory rate and cortisol levels were measured before and after 20 sessions over an eight-week period. Additionally, this study provided demographic information regarding education, work experience and age, but failed to report the gender of participants. The three studies all shared a common limitation; as each independent study lacked homogeniety within their sample populations, it would be hard to apply generalizability of these findings to a larger population. None of these studies stated the training and background of the persons who introduced diaphragmatic breathing to the experimental groups. All three of these studies measured and found that diaphragmatic breathing had positive effects on reducing physiological and psychological stress, as demonstrated by the study outcome measures. Although all researchers were able to establish the importance of diaphragmatic breathing on reducing stress, it will be necessary for future studies to precisely describe the intervention of interest.

There are several limitations to this review. There were very few studies available for review that looked at diaphragmatic breathing alone, without any other intervention. The studies available were not always consistent in how they defined diaphragmatic breathing and often used terms such as yogic breathing or used breathing in conjunction with other alternative methods such as meditation or deep muscle relaxation. Many studies had to be eliminated based on this criterion alone. The studies selected for review lacked homogeneity due to the differences in the populations, interventions and outcome measures between studies. Additionally, the search strategy limited the results to English and therefore limited the number of studies available for review. The dissimilarity between the type of diaphragmatic breathing and populations used in the studies limited the ability to synthesize results for a meta-analysis.

Conclusion

Diaphragmatic breathing can be a widely utilized intervention for physiological and psychological stress reduction. The evidence presented in this systematic review shows that diaphragmatic breathing may decrease physiological stress as measured by blood pressure, respiration and cortisol levels, and psychological stress as measured by the DASS-21 stress subscale. Although there appears to be a correlation, the evidence is limited; there is insufficient evidence that clearly measures the effects of diaphragmatic breathing with hard biomarkers on stress reduction. Even fewer studies measure diaphragmatic breathing as the single intervention. Given the potential benefits of diaphragmatic breathing for physiological and psychological stress reduction, ongoing research is needed to continue to establish the evidence base for this self-administered, low-cost and non-pharmacologic intervention.

Recommendations for practice

Diaphragmatic breathing has the potential to offer a readily available and inexpensive treatment to help manage stress on a daily basis. Once the person has been taught diaphragmatic breathing, it can be practiced at any time and in any circumstance. However, due to the small number of studies available for review that looked at only diaphragmatic breathing, it is difficult to apply generalizability for this intervention. Therefore, although results are promising for practice, it is difficult to provide definitive recommendations.

Recommendations for research

Overall, there is limited research on diaphragmatic breathing as an independent intervention to reduce physiological and psychological stress. Further research is needed to continue to develop the evidence base on the effectiveness of diaphragmatic breathing on physiological and psychological stress. Well-designed studies such as randomized control trials with appropriate sample size and power are recommended. Study designs should include data that reflect effects over time of the positive impact of diaphragmatic breathing on stress reduction. This future research will help to define guidelines and develop measurement tools that more clearly identify how to assess the effectiveness of diaphragmatic breathing on stress. It will also be essential to consider additional reliable and valid outcome measures, such as the stress Visual Analog Scale (stress VAS) and the Perceived Stress Scale (PSS) to assess the effects of diaphragmatic breathing on psychological stress, and salivary alpha-amylase to assess the effects of diaphragmatic breathing on physiological stress. The stress VAS has been used effectively to assess stress with acceptable levels of reliability

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and validity.[28,29] The PSS is a self-report tool that is a reliable and valid tool which measures the degree to which a person assesses stress based on individual circumstances.[30] Salivary alpha-amylase is noted to increase with physical stressors and believed to increase with psychological stress and decrease with rest conditions.[31] Further testing with these tools will be needed to continue to demonstrate the efficacy of diaphragmatic breathing for stress reduction. Finally, additional research will help to develop cost savings related to diaphragmatic breathing in the reduction of stress.

Acknowledgements

This review will partially fulfill degree requirements for the successful completion of the Doctor of Nursing Practice Program at Pace University, College of Health Professions, New York, USA, for SIH and SLM.

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Appendix I: Search strategy

PubMed (pubmed.gov)

Searched January 2018

Repeated supplemental search May 2018 (without new articles found)

Search	Query	Records retrieved
1	Search "diaphragmatic breathing" [All Fields]	218
2	Search "deep breathing"[All Fields]	1715
3	Search "stress"[All Fields]	7,089,208
4	Search "psychological stress"[All Fields]	110,197
5	Search "stress, psychological"[MeSH Terms] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "psychological stress"[All Fields] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "stress, psychological"[All Fields]	142,872
6	Search "stress, physiological"[MeSH Terms] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "physiological stress"[All Fields] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "stress, physiological"[All Fields]	226,972
7	Search "physiological stress"[All Fields]	69,783
8	Search "diaphragmatic breathing"[All Fields] OR "deep breathing" [All Fields]	1926
9	Search (((("physiological stress"[All Fields] OR ("stress, physiological"[MeSH Terms] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "physiological stress"[All Fields] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "stress, physiological"[All Fields])) OR ("stress, psychological"[MeSH Terms] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "psychological stress"[All Fields] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "stress, psychological"[All Fields])) OR "psychological stress"[All Fields]) OR "stress"[All Fields]	797,008
10	Search ((((("physiological stress"[All Fields] OR ("stress, physiological"[MeSH Terms] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "physiological stress"[All Fields] OR ("stress"[All Fields] AND "physiological"[All Fields]) OR "stress, physiological"[All Fields])) OR ("stress, psychological"[MeSH Terms] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "psychological stress"[All Fields] OR ("stress"[All Fields] AND "psychological"[All Fields]) OR "stress, psychological"[All Fields])) OR "psychological stress"[All Fields]) OR "stress"[All Fields]) AND ("diaphragmatic breathing"[All Fields] OR "deep breathing"[All Fields])	149

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CINAHL via EBSCOhost
Searched January 2018

Repeated supplemental search May 2018 (without new articles found)

#	Query	Limiters/Expanders	Records retrieved
S5	(S1 AND S4)	Search modes - Boolean/Phrase	15
S4	(S2 OR S3)	Search modes - Boolean/Phrase	Display
S3	(MH "Stress, Physiological") OR "physiological stress"	Search modes - Boolean/Phrase	Display
S2	(MH "Stress, Psychological") OR "psychological stress"	Search modes - Boolean/Phrase	Display
S1	"deep breathing" OR "diaphragmatic breathing"	Search modes - Boolean/Phrase	Display

Embase via Elsevier
Searched January 2018

Number	Query	Records retrieved
# 9	#3 AND #7 AND [embase]/lim	215
# 8	#3 AND #7	253
# 7	#4 OR #5 OR #6	1,018,925
# 6	'physiological stress'/de OR 'physiological stress'	17,937
# 5	'psychological stress'/de OR 'psychological stress'	73,151
# 4	'stress'/de OR stress	1,018,025
# 3	#1 OR #2	2839
# 2	'diaphragmatic breathing'	342
# 1	'deep breathing'	2512

Cochrane Central Register of Controlled Trials (CENTRAL)
Searched January 2018

ID	Search	Records retrieved
# 1	("diaphragmatic breathing" or "deep breathing")	520
# 2	MeSH descriptor: [Stress, Physiological] explode all trees	3791
# 3	MeSH descriptor: [Stress, Psychological] explode all trees	4989
# 4	stress	3711
# 5	#2 OR #3 OR #4	3716
# 6	#5 AND #1	135

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ProQuest Dissertations and Theses A&I
Searched January 2018

Set number	Searched for	Databases	Records retrieved
S1	ab((“deep breathing” OR “diaphragmatic breathing”)) AND (“physiological stress” OR “psychological stress”)	ProQuest Dissertations and Theses A&I	49

PsycINFO via EBSCOhost
Searched January 2018 (without new articles found)

#	Query	Limiters/Expanders	Records retrieved
S5	S1 AND S4	Search modes - Boolean/Phrase	107
S4	S2 OR S3	Search modes - Boolean/Phrase	242,288
S3	stress	Search modes - Boolean/Phrase	242,288
S2	DE “Stress” OR DE “Physiological Stress” OR DE “Psychological Stress”	Search modes - Boolean/Phrase	63,007
S1	(“diaphragmatic breathing” or “deep breathing”)	Search modes - Boolean/Phrase	44

ProQuest Nursing & Allied Health Database
Searched January 2018

Supplemental search May 2018 (without new articles found)

#	Query	Records retrieved
S1	stress	64,339
S2	physiologic stress	108
S3	physiological stress	2,457
S4	psychological stress	16,137
S5	deep breathing	189
S6	diaphragmatic breathing	38
S7	S1	64,339
S8	S1 OR S2 OR S3 OR S4	64,339
S9	S5 OR S6	225
S10	S8 AND S9	27

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Health Source: Nursing/Academic Edition via EBSCOhost
Searched January 2018
Supplemental search May 2018 (without new articles found)

#	Query	Records retrieved
S1	stress	64,339
S2	physiologic stress	108
S3	physiological stress	2,457
S4	psychological stress	16,137
S5	Deep breathing	189
S6	diaphragmatic breathing	38
S7	S1	64,339
S8	S1 OR S2 OR S3 OR S4	64,339
S9	S5 OR S6	225
S10	S8 AND S9	27

Gray literature

The New York Academy of Medicine

Initial search November 2017

Supplemental search October 2018 (without new articles found)

#	Query	Records retrieved
S5	(Deep Breathing) and ((Physiological stress) or (Psychological Stress))	0
S4	Diaphragmatic Breathing	0
S3	Deep Breathing	5
S2	Psychological Stress	278
S1	Physiological Stress	40

Virginia Henderson Global Nursing-e repository

Initial search November 2017

Supplemental search October 2018 (without new articles found)

Initial search	Supplemental search	Query
November 2017	October 2018	All Content: (''deep breathing'') and (''physiological stress'' or ''psychological stress'')
	Yield 26	Screened and eliminated by title or duplicate

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Google Scholar

Initial search November 2017

Supplemental search October 2018 (without new articles found)

Initial search	Supplemental search	Query
November 2017	October 2018	''deep breathing'' or ''diaphragmatic breathing'' and ''physiological stress'' or ''psychological stress''
	Yield 43	Screened and eliminated by title or duplicate

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Appendix II: Studies ineligible following full text review

Alexopoulos EC, Zisi, M, Manola G, Darviri C. Short-term effects of a randomized controlled worksite relaxation intervention in Greece. Annals of agricultural and environmental medicine. 2014; 21(2): 382-387.
Reason for exclusion: This study did not look at the intervention of interest independently. Deep breathing was evaluated in combination with muscle relaxation.

Christakis I, Pagkratis MT, Varvogli L, Darviri C, Chroussos G. Measuring the stress of the surgeons in training and use of a novel interventional program to combat it. J Korean Surg Soc. 2012;82 (5):312-6.
Reason for exclusion: This study did not look at the intervention of interest independently. Deep breathing was evaluated in combination with muscle relaxation.

Conrad A, Müller A, Doberenz S, Kim S, Meuret AE, Wollburg E, Roth WT. Psychophysiological effects of breathing instructions for stress management. Applied Psychophysiology and Biofeedback. 2007 Jun 1; 32(2):89-98.
Reason for exclusion: This study did not look at the intervention of interest. They did not use diaphragmatic breathing; they used shallow breathing.

Consolo K, Fusner S, Staib S. Effects of diaphragmatic breathing on stress levels of nursing students. Teaching and Learning in Nursing. 2008; Apr 1; 3(2): 67–71.
Reason for exclusion: This study did not measure the effect of diaphragmatic breathing on stress reduction. Diaphragmatic breathing was used to reduce heart rate and improve cognitive test scores in nursing students.

Iglesias SL, Azzara S, Argibay JC, Arnaiz ML, de Valle Carpineta M, Granchetti H, Lagomarsino E. Psychological and physiological response of students to different types of stress management programs. American Journal of Health Promotion. 2012 Jul; 26(6): e 149-58.
Reason for exclusion: This study did not look at the intervention of interest independently. Deep breathing was evaluated in combination with meditation and relaxation programs.

Mancini J, Lavecchia C, Clegg R. Graduate nursing students and stress. J Nurs Educ. 1983; 22(8): 329-34.
Reason for exclusion: This study did not look at the intervention of interest independently. Diaphragmatic breathing was evaluated in combination with relaxation response and imagery.

Paul G, Elam B, Verhulst SJ. A longitudinal study of students' perceptions of using deep breathing meditation to reduce testing stresses. Teaching and Learning in Medicine. 2007; 19(3):287-92.
Reason for exclusion: This study did not look at the intervention of interest independently. Deep breathing was evaluated in combination with mediation.

Piazza-Waggoner CA, Cohen LL, Kohli K, Taylor B. Stress management for dental students performing their first pediatric restorative procedure. J Dent Educ. 2008; 67(5):542-8.
Reason for exclusion: This study did not look at the intervention of interest independently. The deep breathing intervention was combined with muscle relaxation and did not look at stress reduction.

Perciavalle V, Blandini M, Fecarotta P, Buscemi A, Di Corrado D, Bertolo L, *et al.* The role of deep breathing on stress. Neurol Sci. 2017; 38(3):451-8.
Reason for exclusion: This study did not look at the intervention of interest independently. Deep breathing was evaluated in combination with an anti-stress protocol.

Prato CA. Biofeedback-assisted relaxation training program to decrease test anxiety in nursing students. 2009.
Reason for exclusion: This study did not look at the intervention of interest but used biofeedback for testing anxiety reduction.

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Sona Janet MSK, Mangala Gowri P. Effectiveness of deep breathing exercise on blood pressure among patients with hypertension. International Journal of Pharma and Bio Sciences. 2017; 8(1):B256-B60.
Reason for exclusion: The aim of this study was a reduction of hypertension with deep breathing exercise. The conclusion of the study did not say that it reduced stress. They stated in their study that it improved quality of life but failed to demonstrate this finding by measurement using any quality of life scales. The authors also did not clarify if the experimental group was on medication, compliant with medication or when medication was administered. The authors utilized hospitalized patients but did not explain the reason for hospitalization. Based on our attempt to find studies that clearly demonstrated the correlation between blood pressure and stress reduction, this study lacked the information needed to make this correlation.

Walsh BD. Do specific stress management techniques interrupt or lower psychoneuroimmunological responses to stress? Capella University; 2007.
Reason for exclusion: This study did not look at the intervention of interest independently. This study looked at healthy college students and their response to either guided imagery or deep breathing and the effects of stress. The study did not separate out deep breathing from guided imagery in the study.

Wells R, Outhred T, Heathers JA, Quintana DS, Kemp AH. Matter over mind: a randomized controlled trial of single-session biofeedback training on performance anxiety and heart rate variability in musicians. PLoS One. 2012; 7 (10): e46597.
Reason for exclusion: None of the outcomes of interest were evaluated in this study. This study looked at and assessed musicians for the anticipation of psychosocial stress associated with music performance. The intervention of interest was not evaluated separately but with.

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Appendix III: Characteristics of included studies

Author (year)	Ma, *et al.* (2017)[22]
Study method	Randomized controlled trial
Participants	40 healthy adults
Setting	Outpatient information technology company in Beijing, China
Intervention	Deep breathing with eyes closed sitting in chair, 20 sessions, 15 minutes of resting breathing and 15 minutes deep breathing
Control	Control group received only an introduction of breathing and rest
Outcomes	Salivary cortisol level were obtained at baseline and after completion of the final intervention for both groups. Saliva samples were collected from both groups between the hours of 11 and 12 o'clock, and participants were asked not to eat or drink for 20 minutes prior to collection. Researchers collected data at two time points, before and after diaphragmatic breathing at baseline and final intervention. The researchers did not specify at what point after the breathing exercise the salivary cortisol levels were taken.
Results	The result showed a significant positive effect on the respiratory rate and cortisol levels. Ma *et al.* concluded diaphragmatic breathing had a statistically significant effect on the frequency of respiratory rate for diaphragmatic breathing over time when compared to resting breathing with $p < 0.05$ in the diaphragmatic breathing group. Ma *et al.* also concluded a statistically significant decrease in salivary cortisol over time as seen using a simple effect measurement with a p-value < 0.05.
Authors' onclusions	Ma *et al.* conclude that deep breathing has a positive effect on stress reduction in healthy adults, but requires further investigation to ensure benefits.
Reviewers' comments	There is a risk for selection bias due to the weakness of randomization, along with small sample size.

Author (year)	Joshi, *et al.* (2016)[7]
Study method	Quasi-experimental study
Participants	123 students of which 80 were divided into two groups: control and experimental
Setting	Punjab, India, Indian college students
Intervention	Deep breathing
Control	Control was given information on deep breathing

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Outcomes	The intervention for the control group was 10 minutes of ordinary breathing technique (OBT). For the experimental group, three measures of systolic and diastolic blood pressure were obtained using an electronic sphygmomanometer. The first measurement was obtained before the 10-minute intervention of OBT, the second immediately after OBT and the third and final was obtained after 10 minutes of deep breathing technique (DBT).
Results	Joshi *et al.* concluded that deep breathing, when compared to ordinary breathing, had a statistically significant effect on lowering systolic and diastolic blood pressure ($p < 0.01$). There was no change in systolic or diastolic blood pressure demonstrated after ordinary breathing ($p > 0.01$).
Authors' conclusions	Joshi *et al.* concluded that deep breathing had a significant effect on systolic as well as diastolic blood pressure.
Reviewers' comments	The Joshi *et al.* study had a concern for risk of selection bias as there were 123 students who responded but only 80 were selected for the study. There is no discussion as to how the 80 participants were selected.

Author (year)	Sundram, *et al.* (2014)[19]
Study method	Quasi-experimental study
Participants	Plant A (N=468) Plant B (N=293)
Setting	Two automotive assembly plants in Malaysia
Intervention	Diaphragmatic deep breathing
Control	Control group was given pamphlets on stress and its ill effects
Outcomes	Sundram *et al.* conducted five interventions over nine months using subscale for stress from the Depression, Anxiety Stress Scale (DASS-21) at baseline, and at the end of 2nd, 4th, 6th and 8th month from baseline to assess stress.
Results	Sundram *et al.* showed a statistically significant effect on perceived stress level at baseline as reported within and between group comparison as seen with a p-value of <0.01.
Authors' conclusions	Sundram *et al.* concluded that the study showed improvement in stress levels and the potential of deep breathing exercise training as part of Employee Assistance Program in an automotive plant. The authors concluded that more studies were needed.
Reviewers' comments	The Sundram *et al.* study showed a potential for attrition bias. The study started with a large number of participants for the intervention and control group. At the end of the study, the attrition rate was high and although the authors state that the power was high enough for a positive effect size, it may have affected the outcome of the results. Additionally, a limitation identified in this study included a convenience sampling of all male participants.

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