

# Stress Reduction Programs in Patients with Elevated Blood Pressure: A Systematic Review and Meta-analysis

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Substantial evidence indicates that psychosocial stress contributes to hypertension and cardiovascular disease (CVD). Previous meta-analyses of stress reduction and high blood pressure (BP) were outdated and/or methodologically limited. Therefore, we conducted an updated systematic review of the published literature and identified 107 studies on stress reduction and BP. Seventeen trials with 23 treatment comparisons and 960 participants with elevated BP met criteria for well-designed randomized controlled trials and were replicated within intervention categories. Meta-analysis was used to calculate BP changes for biofeedback,  $-0.8/-2.0$  mm Hg ( $P = \text{NS}$ ); relaxation-assisted biofeedback,  $+4.3/+2.4$  mm Hg ( $P = \text{NS}$ ); progressive muscle relaxation,  $-1.9/-1.4$  mm Hg ( $P = \text{NS}$ ); stress management training,  $-2.3/-1.3$  mm Hg ( $P = \text{NS}$ ); and the Transcendental Meditation program,  $-5.0/-2.8$  mm Hg ( $P = 0.002/0.02$ ). Available evidence indicates that among stress reduction approaches, the Transcendental Meditation program is associated with significant reductions in BP. Related data suggest improvements in other CVD risk factors and clinical outcomes.

## Introduction

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) recommends lifestyle modifications for prevention and treatment of hypertension [1]. Lifestyle modifications are recommended as sole therapy when blood pressure (BP) is greater than 120/80 mm Hg and less

than 140/90 mm Hg (prehypertension), and as adjunctive therapy when blood pressure is equal to or greater than 140/90 mm Hg (stage I or II hypertension). Thus the first line of treatment for high BP is modifying lifestyle risk factors, including recommendations about weight, physical activity, and dietary intake of sodium, fruits, vegetables, saturated and total fats, and alcohol [1].

Another lifestyle risk factor that has been shown to contribute to high blood pressure is psychosocial stress [2]. Yet, the JNC 7 guidelines do not include recommendations for patients to reduce stress. However, the 2007 Canadian Hypertension Education Program recommends considering stress reduction intervention for normotensive and hypertensive patients [3].

## Stress, Hypertension, and Cardiovascular Disease

Recent reviews [2,4•] have concluded that psychosocial stress is a major independent risk factor for hypertension, coronary artery disease, and cardiovascular mortality. Whereas earlier reviews found only weak or inconsistent evidence, several new lines of evidence have emerged.

Longitudinal studies of more than 3000 European adults found that chronic stress for a period of several years predicts high blood pressure during 3 to 7 years of follow-up [5]. This finding was replicated in young American adults in the Coronary Artery Risk Development in Young Adults (CARDIA) study, where impatience and time pressure at baseline predicted hypertension 15 years later [6]. The INTERHEART study of 24,767 adults in 52 countries showed that myocardial infarction (MI) was associated with chronic psychosocial stress [7]. In terms of MI risk, psychosocial stress was as important in magnitude as traditional cardiovascular disease (CVD) risk factors, including smoking, obesity, diabetes, and hypertension.

In addition, studies have shown that individuals who exhibit exaggerated cardiovascular responses to

mental stress tasks are at increased risk for developing hypertension in subsequent years [8]. These experiments are particularly noteworthy because, whereas “stress” is often considered difficult to define and measure, the stress variables were under laboratory control. Cardiovascular responses represent plausible mediators between daily experience of stress and long-term impact on the cardiovascular system. Responses to acute stress are triggered through the sympathetic nervous system and the hypothalamic-pituitary-adrenocortical axis and increase cardiac output, heart rate, and peripheral resistance [8]. Chronic stress is believed to lead to chronically elevated BP levels through persistent hyperactivation of the sympathetic nervous system and hypothalamic-pituitary-adrenocortical axis [4•,9].

### Stress Reduction Programs

It has been suggested that therapies such as relaxation, meditation, or biofeedback may help patients to reduce the effects of stress by reducing physiologic arousal and restoring autonomic balance, thereby reducing blood pressure [10].

Relaxation therapies aim to enable patients to achieve physical and mental relaxation. Examples include progressive muscle relaxation, using exercises to tense and release muscle groups [11], and autogenic training, which involves concentrating on somatic sensations and using autosuggestion [12]. Frequently, these therapies are combined with use of mental imagery or breathing exercises.

Meditation practices aim to cultivate a state of inner awareness and calm [13]. The most widely researched form is the Transcendental Meditation (TM) technique [13,14]. It is described as a unique and effortless process of taking the attention to successively finer states of a thought, until thought is transcended and the mind experiences pure awareness [15]. Instruction requires a qualified teacher who is certified through Maharishi Vedic Education Foundation [16]. Other meditative practices usually involve a form of contemplation or concentration and include mindfulness meditative practice [17]. Some mind-body practices, such as tai chi and qi gong, include meditative elements [13] but also involve significant exercise training effects and are usually categorized as forms of exercise [18]. Hence these practices are not included in the present review.

Biofeedback [19] involves use of electronic devices to monitor information on physiologic indicators of states of relaxation, such as muscle tension, skin temperature, skin conductance levels, or blood pressure. There are two major biofeedback categories: simple biofeedback (ie, as a standalone therapy), and relaxation-assisted biofeedback (ie, biofeedback plus relaxation training) [19].

Stress management training involves modification of psychologic and behavioral responses to stress. Psychologic approaches include cognitive restructuring and

adaptive learning [20]. Often these approaches are combined with relaxation training [20].

Below we summarize the existing meta-analyses on stress reduction and elevated blood pressure, followed by a critique and an update and re-analysis of the data.

### Previous Meta-analyses on the Efficacy of Stress Reduction Programs

To identify meta-analyses on stress reduction programs and high blood pressure, we conducted computer searches of MEDLINE for articles on stress reduction programs published from its inception through July 2007. Search terms used included “relaxation,” “meditation,” “biofeedback,” “stress management,” “lifestyle modification,” “blood pressure,” and “hypertension.” We also conducted hand searches of the bibliographies of these reviews. These searches located nine published meta-analyses [12,13,18–24].

Another recent review by Linden and Moseley [10] examined seven of the published meta-analyses [12,19–24] on stress reduction programs and hypertension. The authors of this review concluded that stress reduction programs yield reliable decreases in systolic BP of 6 to 10 mm Hg, with slightly larger BP reductions for multicomponent interventions [10]. This review focused on BP reductions *within* active treatment groups. It should be noted that within-group changes in BP do not take into account the control group and do not discriminate real treatment effects from BP changes due to BP monitoring, habituation to BP measurement, or effects of attention from trainers. Although Linden and Moseley [10] noted inconsistency between meta-analyses of technique-specific effects, they did not attempt to control for these differences by pooling the primary studies. Differences between categories of treatments were attributed, at least in part, to differences in study selection and categorization.

Two of the meta-analyses [20,21] reviewed by Linden and Moseley [10] underscored the importance of adequacy of the baseline period and of control for attention and subject expectancy factors. Eisenberg et al. [20] found that poor control of either factor resulted in positively biased estimates of treatment effects. Reductions in BP were larger by 10.6 mm Hg systolic and 7.7 mm Hg diastolic in poorly designed studies compared with well-designed studies. Key experimental design features included adequacy of baseline measurement and control for attentional factors. However, the review by Linden and Moseley [10] did not attempt to quantitatively account for these factors.

In contrast to the large treatment effects suggested by Linden and Moseley’s review, a more recent meta-analysis by Dickinson et al. [18] reported a reduction of -4.0/-3.1 mm Hg across all stress reduction trials. Moreover, it was found that treatment effects were only significant when comparisons were made with no treatment and not relative to attention controls.

Eisenberg et al. [20] found that for randomized controlled trials with multiple baseline sessions and

comparison with an attention-control group, the average BP changes were -2.8/-1.3 mm Hg and were not statistically significant. Jacob et al. [21] found that the magnitude of BP reductions depended on the strength of the research design, including protocol for baseline BP measurements and type of control groups used (no treatment or waitlist vs attention-control or self-monitoring). They concluded that the data did not support recommendations concerning the efficacy of stress reduction interventions for high BP, and did not provide an estimate for the overall average BP reductions. These reviewers cautioned that evidence regarding efficacy of stress reduction interventions was sparse in view of the small number of well-designed studies [20,21].

Several meta-analyses have examined effects of different types or categories of stress reduction interventions. Relaxation techniques formed the largest treatment category in Jacob et al.'s [21] meta-analysis and also among the well-designed studies in Eisenberg et al.'s [20] meta-analysis, but were among the least effective of all types of intervention. Stetter and Kupper [12] examined health outcomes of autogenic training, a specific type of relaxation therapy. In the hypertension studies they examined, positive effect sizes were observed within groups and relative to no treatment, but not relative to attention-control groups.

Nakao et al. [19] performed a meta-analysis of randomized controlled trials that administered biofeedback to hypertensive patients. Significant effects were reported for biofeedback combined with relaxation therapy but not for biofeedback alone. The overall net reduction in BP across all biofeedback studies was significant, yet the comparison of active intervention with attention controls was not significant. Similarly, a meta-analysis by Yucha et al. [24] found significant effects of biofeedback only in comparison to untreated controls. Eisenberg's [20] results suggested that, in general, biofeedback is ineffective. Thus, there is at best weak evidence from these meta-analyses that biofeedback is effective in reducing chronically elevated high BP.

In summary, previous meta-analyses have provided only limited evidence that stress reduction programs are associated with significant BP reductions.

### AHRQ Review of Meditation Practices for Health

Recently, a health technology assessment of meditation practices was commissioned by the Agency for Healthcare and Research Quality (AHRQ) and funded by the National Institutes of Health (NIH)-National Center for Complementary and Alternative Medicine (NCCAM) [13]. It was notable because the authors endeavored to exhaustively locate all available studies and analyzed each meditation technique separately. Among the 813 studies of meditation and health outcomes located, there were 27 controlled trials on hypertension, including 24 randomized trials. The

main conclusions of the report on high BP were that, with exceptions, the majority of meditation research was of low methodologic quality and that selected meditation practices may be effective in reducing hypertension.

The AHRQ report [13] suffered from severe limitations associated with data collection, analytic, and reporting procedures [25]. The review methodology failed to use study design factors that have shown to bias results in behavioral trials of hypertension. The adequacy of baseline BP measurement protocols and the quality and adequacy of controls were ignored. Most of the trials in the AHRQ report compared meditation practices to untreated or waitlist controls. Relevant trials on adolescents and youth were not incorporated [34,35]. An important methodologic factor that was not considered was blinding of BP assessment. The authors focused on whether trials were double-blinded, which is generally not feasible in behavioral trials, in contrast to pharmacologic trials [10]; indeed, no double-blinding was found among the trials on hypertension. However, no attempt was made to identify single-blinded trials, even though this reduces experimenter bias and several such trials on stress reduction and hypertension exist among the studies included in the AHRQ report [26–28,29••]. Whereas the report repeatedly emphasized the overall poor quality of meditation studies, appropriate analyses were not conducted on a selected set of well-designed trials.

### Revisiting the Evidence for Stress Reduction Programs and High BP

Based on previous meta-analyses, it is not entirely clear whether any stress reduction treatments are consistently effective in treating high BP. Two meta-analyses [18,22] did not report results for specific treatments, and two [20,21] did not include trials published after 1991. Criteria for study inclusion varied, complicating comparisons of findings. Three meta-analyses [13,21,23] included non-randomized trials. Outcomes reported were not always comparable: some reported net BP change [13,18,20,24], others reported BP changes within the intervention groups only [22], or effect sizes only [12,23], and another reported residual BP change after adjusting for study characteristics [21]. Six of the previous meta-analyses [12,13,18,19,23,24] did not account for adequacy of baseline protocols as a potential confound. Only four of the meta-analyses controlled for attentional factors by performing analyses that included only comparisons with attention-control groups [12,19,20,24].

In view of variations in review methodology applied in previously published meta-analyses on stress reduction programs and high BP, the only way to draw sound, up-to-date inferences was to pool all the primary studies available to date and rigorously apply uniform criteria for study selection and meta-analysis. Hence, following criteria used in meta-analyses by Dickinson et al. [18]

and Eisenberg et al. [20], we collected all studies in the published literature that met the following inclusion criteria: 1) randomly allocated subjects to experimental or control interventions; 2) compared BP changes for a stress reduction program versus a minimally treated or attention-control group; 3) assessed baseline BP levels over multiple clinic visits or used 24-hour ambulatory BP recording in lieu of multiple clinic visits; 4) were of at least 8 weeks in duration from baseline to post-test or follow-up assessment; and 5) published in peer-reviewed English-language journals. Criteria 1, 2, 3, and 5 were based upon Eisenberg et al. [20]; criterion 4 was based upon Dickinson et al. [18]. However, none of the previous meta-analyses used all of these criteria. Articles were located by performing a series of MEDLINE searches from its inception through July 2007. Search terms were “hypertension” or “blood pressure,” in conjunction with “relaxation therapy,” “relaxation training,” “progressive muscle relaxation,” “autogenic training,” “guided imagery,” “meditation,” “mindfulness,” “relaxation response,” “biofeedback,” and “stress management.” In addition, we performed hand searches of bibliographies of published meta-analyses and reviews [12,13,18–24]. All studies that met the above criteria were extracted.

The sixth criterion was that studies included prehypertensive and/or hypertensive subjects. This was done because the JNC 7 recommendations advise lifestyle modifications for patients with high BP in both the prehypertensive and hypertensive ranges [1]. Data from randomized controlled trials with a crossover design was incorporated only from the first phase of the study, before treatment crossover.

The previous meta-analyses and MEDLINE searches provided a pool of 107 primary studies. Of these, 75 were randomized controlled trials, of which 37 employed an attention-control group. Among these, 15 trials lacked an adequate BP baseline measurement protocol and two others were shorter than 8 weeks' duration. Hence, 20 trials met the above criteria, and these provided 27 comparisons of an active treatment group with an attention-control group [11,26–44]. (A list of excluded studies and reasons for exclusion is available from the authors.)

Following the approach taken in the AHRQ report [13], the present systematic review focused on specific categories of stress reduction programs. We synthesized evidence by meta-analysis from categories with two or more studies on the same intervention. Review Manager 4.2 software (The Cochrane Collaboration, <http://www.cc-ims.net/RevMan>) for meta-analysis was used to estimate the mean BP change for each type of program and to calculate *P*-values and 95% CIs, based on a random effects model.

Table 1 lists the data for the 27 treatment group comparisons and their BP outcomes according to category of stress reduction intervention from the 20 trials [11,26–28,29••,30–44]. As shown in Table 1, six treatment groups from four trials [30–33] involved simple biofeed-

back. Three involved relaxation training [31,26,27]. Two relaxation studies employed progressive muscle relaxation [26,27]. Six trials studied the Transcendental Meditation technique [26–28,29••,34,35]. In 11 interventions, two or more types of stress reduction modalities were combined [11,37–39,40–44]. Four of these interventions combined biofeedback with relaxation training (relaxation-assisted biofeedback) [11,37–39] and five combined stress-management training with relaxation training [11,40–42]. Four interventions were not replicated: one on autogenic training [31], one trial on other meditation (SRELAX—“self-relaxation”) [36], and two studies on miscellaneous treatment combinations that did not fit into any category [43,44].

Table 2 shows the results of meta-analyses for treatment categories with at least two studies employing the same intervention. These meta-analyses included 23 treatment comparisons from 17 trials and involved 960 subjects. Three trials did not have an intervention group that was replicated in another trial [26,43,44]. The mean BP changes shown in Table 2 represent the average net change in BP for the active treatments relative to attention controls. These are weighted mean differences (obtained from the random effects model), in which averages are weighted according to the numbers of subjects in the treatment-control comparisons and the variability in BP outcomes. Mean BP changes for progressive muscle relaxation, simple biofeedback, relaxation-assisted biofeedback, and stress management training ranged on systolic BP from -2.3 mm Hg to +4.3 mm Hg, and on diastolic BP from -2.0 mm Hg to +2.4 mm Hg. These results were not statistically significant. Studies on the Transcendental Meditation program formed the largest category, with six clinical trials and 449 research subjects. The mean BP reductions across these trials were -5.0 mm Hg systolic and -2.8 mm Hg diastolic and were statistically significant ( $P = 0.0002$  and  $P = 0.02$ ).

Among the studies from Table 1 that were synthesized in Table 2, there were eight single-blinded trials [26–28,29••,30,38,39,41]. Four single-blinded trials investigated effects of the Transcendental Meditation program [26–28,29••] and yielded an average net BP change of -5.1/-2.1 mm Hg (95% CI = -9.4 to -0.8 mm Hg,  $P = 0.02$  for systolic BP; and 95% CI = -5.4 +1.4 mm Hg,  $P = 0.22$  for diastolic BP), which was similar to the results for all six studies on the Transcendental Meditation program. Both of the studies on progressive muscle relaxation (PMR) listed in Table 1 [26,27] and summarized in Table 2 were single-blinded. The results for these two studies showed BP reductions of -1.9/-1.3 mm Hg, which were not statistically significant (95% CI = -6.8 to +3.1 mm Hg,  $P = 0.46$  for systolic; 95% CI = -4.3 to +1.4 mm Hg,  $P = 0.32$  for diastolic). The only other category with at least two single-blinded studies was relaxation-assisted biofeedback [38,39], which showed BP increases of +4.3/+2.4 mm Hg, which were not statistically significant (95% CI = -2.9 to +11.7 mm Hg,

**Table 1. Well-designed trials\* of stress reduction interventions on BP change in patients with elevated BP levels**

Study	Active treatment	Control treatment	Experimental/control	Net change SDP/DBP, <sup>†</sup> mm Hg
Blanchard et al. [30]	BF	S-R	10/9	+6.1/+4.1
Blanchard et al. [30]	BF	S-R	9/9	+4.2/+4.5
Blanchard et al. [31]	BF	S-R	20/18	-4.3/-5.7
Blanchard et al. [32]	BF	BPM	11/12	+1.2/-2.9
Blanchard et al. [32]	BF	BPM	10/12	-0.8/-4.7
Blanchard et al. [33]	BF	BPM	21/21	-3.1/-2.9
Chesney et al. [11]	BFR	PMR	24/24	+4.3/+2.7
Frankel et al. [37]	BFR	Sham BF	7/7	+3.0/+2.0
Jacob et al. [38]	BFR	Stress education	10/9	+3.9/+5.2
McGrady et al. [39]	BFR	Restricted sensory stimulation + AT	11/6	+4.9/-0.6
Blanchard et al. [31]	AT	S-R	21/18	-6.2/-3.8
Schneider et al. [26]	PMR	Health education	37/38	-4.7/-3.3
Schneider et al. [27]	PMR	Health education	52/44	+0.4/-0.3
Barnes et al. [34]	TM	Health education	15/18	-7.4/-4.7
Barnes et al. [35]	TM	Health education	50/50	-3.5/-3.8
Castillo-Richmond et al. [28]	TM	Health education	29/31	-1.1/+2.4
Paul-Labrador et al. [29••]	TM	Health education	39/45	-6.0/-0.7
Schneider et al. [26]	TM	Health education	36/38	-10.7/-6.4
Schneider et al. [27]	TM	Health education	54/44	-2.2/-3.1
Seer and Raeburn [36]	Other meditation	Sham meditation	14/14	+0.3/+1.2
Amigo et al. [40]	SMT + PMR	Mild exercise	15/15	-4.5/-5.0
Chesney et al. [11]	SMT + PMR	PMR	24/24	-2.4/+0.0
Chesney et al. [11]	SMT + BFR	PMR	25/24	+1.3/+5.2
Irvine et al. [41]	SMT + BFR	Mild exercise	16/16	-7.0/-7.6
Johnston et al. [42]	SMT + relaxation	Mild exercise	40/32	-0.2/-0.5
Bali [43]	PMR + mantra meditation + breathing exercises	Counseling + rest	9/9	-12.0/-8.0
van Montrans et al. [44]	Yoga + PMR + AT + RR	S-R + counseling	18/17	+0.3/+0.7

\*Criteria for well-designed trials: 1) randomized controlled trial in prehypertensive and/or hypertensive patients; 2) adequate baseline BP assessment; 3) used attention control group; 4) duration of at least 8 weeks; and 5) published in peer-reviewed journal.

<sup>†</sup>Net BP change is change in experimental group minus change in control group. Change is from baseline to posttest; negative numbers indicate decreased BP.

AT—autogenic training; BF—simple biofeedback; BFR—relaxation-assisted biofeedback; BP—blood pressure; BPM—blood pressure self-monitoring; DBP—diastolic blood pressure; PMR—progressive muscle relaxation; RR—relaxation response meditation; SBP—systolic blood pressure; SMT—stress management training; S-R—simple relaxation without instructions; TM—Transcendental Meditation.

$P = .24$  for systolic; 95% CI =  $-3.5 + 8.3$  mm Hg,  $P = .43$  for diastolic).

Consistent with earlier reviews [13,20] reporting that well-designed studies were in the minority of randomized controlled trials on stress reduction and high BP, 75 eligible trials were located, of which 20 met the inclusion criteria for well-designed studies. The criteria were met by four of 15 studies on simple biofeedback [30–33], four of 12 on relaxation-assisted biofeedback [11,37–39], two of 20 on relaxation training [26,27], four of 14 on stress

management training [11,40–42], and six of seven on the Transcendental Meditation program [26–28,29••,34–35].

### Comparison with Previous Meta-analyses

The findings of this updated systematic review and meta-analysis agree with results of previous meta-analyses in some respects, particularly in the finding that when only well-designed randomized controlled trials were analyzed, the results for most interventions were not significant in

**Table 2. Mean blood pressure change by treatment category from randomized controlled trials with adequate blood pressure baseline measurement and using attention-control groups\***

Treatment category (study)	No. of treatment comparisons (total no. of subjects)	Systolic blood pressure, net change			Diastolic blood pressure, net change		
		Mean, mm Hg	95% CI	P	Mean, mm Hg	95% CI	P
Simple biofeedback (Blanchard et al. [30], Blanchard et al. [31], Blanchard et al. [32], Blanchard et al. [33])	6 (141)	-0.8	[-4.1, +2.6]	NS	-2.0	[-5.1, +1.2]	NS
Relaxation-assisted biofeedback (Chesney et al. [11], Frankel et al. [37], Jacob et al. [38], McGrady et al. [39])	4 (98)	+4.3	[-0.8, +9.3]	NS	+2.4	[-0.7, +5.6]	NS
Progressive muscle relaxation (Schneider et al. [26], Schneider et al. [27])	2 (171)	-1.9	[-6.8, +3.1]	NS	-1.4	[-4.3, +1.4]	NS
Transcendental Meditation (Schneider et al. [26], Schneider et al. [27], Castillo-Richmond et al. [28], Paul-Labrador et al. [29••], Barnes et al. [34], Barnes et al. [35])	6 (449)	-5.0	[-7.6, -2.3]	0.0002	-2.8	[-5.0, -0.5]	0.02
Stress management, including relaxation (Chesney et al. [11], Amigo et al. [40], Irvine et al. [41], Johnston et al. [42])	5 (207)	-2.3	[-5.0, +0.5]	NS	-1.3	[-5.4, +2.7]	NS

\*Means for each treatment category are weighted mean differences, indicating net change relative to control groups in systolic BP and change in diastolic BP. Because some intervention categories shared the same control subjects, numbers of subjects are not additive.  
NS—not statistically significant.

lowering high BP. However, the present meta-analysis of well-designed clinical trials indicates that the Transcendental Meditation program is associated with significantly reduced systolic and diastolic BPs.

Results on the Transcendental Meditation program from the current meta-analysis differ significantly from the AHRQ report [13] for several reasons. Overlapping studies were removed, data collection errors were corrected, and additional studies were identified [25]. Two trials of adolescent subjects with high normal or prehypertensive BP levels were included here, consistent with NIH guidelines that require including children in medical research [34,35]. A 2006 trial [29••] not included in the AHRQ report due to its relatively recent publication was included in the present analysis.

The BP reductions of -5.0/-2.8 mm Hg found with the Transcendental Meditation program were similar to or greater than the reported effects of other lifestyle modifications recommended by JNC 7. Systolic BP reductions with these other lifestyle interventions were weight-reducing diet, -5.0 mm Hg; aerobic exercise, -4.6 mm Hg; alcohol restriction, -3.8 mm Hg; and sodium restriction, -3.6 mm Hg. Corresponding diastolic BP changes ranged from -3.7 to -2.5 mm Hg [18].

The results of this systematic review and meta-analysis indicate lack of homogeneity among stress reduction approaches, that is, all stress reduction categories do not result in similar decreases in BP. In fact, the data indicate that most do not significantly lower elevated BP. This heterogeneity of effects is consistent with other meta-analyses on stress reduction and anxiety, psychologic health, substance abuse, and physiologic indicators of autonomic arousal [45].

### Additional Effects of the Transcendental Meditation Program on CVD Risk

Meta-analyses and controlled studies have found related effects of the Transcendental Meditation program on modulating CVD risk factors, surrogate markers, and clinical outcomes: anxiety and psychologic health [17,45], smoking and alcohol abuse [46], need for anti-hypertensive medications [27], myocardial ischemia [47], and carotid atherosclerosis [28]. For example, a systematic review and meta-analysis found that the Transcendental Meditation program is substantially more effective than other categories of stress reduction for reducing trait anxiety [17]. A meta-analysis of randomized controlled trials of subjects with elevated BP and average follow-up of 8 years showed a 23% lower rate of all-cause mortality and a 30% lower rate of CVD mortality in the Transcendental Meditation group compared with controls [48••]. This result is particularly salient because no other stress reduction or lifestyle modification recommended for hypertension has been shown in randomized controlled trials to reduce mortality rates [1,3].

Finally, in terms of mechanism, the Transcendental Meditation program may promote cardiovascular balance and homeostasis through integrated neurophysiologic, neuroendocrine, and cardiovascular mechanisms [49••]. It has been documented that the brain triggers physiologic stress responses through cortical modulation of the autonomic nervous system and hypothalamic-pituitary-adrenocortical axis [9]. Of primary importance are the prefrontal cortex and the limbic system, which process cognitive and emotional responses to potentially stressful situations [9]. Studies indicate that the Transcendental Meditation practice modulates neurophysiologic, neuroendocrine, and physiologic mechanisms associated with stress. For example, controlled studies have reported reduced sympathetic nervous system and hypothalamic-pituitary-adrenocortical axis activation along with more coherent neurophysiologic functioning with the Transcendental Meditation program [49••,50]. This more coherent and integrated functioning of the nervous system may facilitate adaptive physiologic responses to stress, thereby helping to prevent negative physiologic consequences such as hypertension and CVD [49••].

### Conclusions

Results of meta-analyses showed that simple biofeedback, relaxation-assisted biofeedback, progressive muscle relaxation, and stress management training did not show statistically significant reductions in elevated BP. Analysis of trials of the Transcendental Meditation program showed clinically and statistically significant changes in BP (-5.0/-2.8 mm Hg). Other published research on the Transcendental Meditation program suggest complementary effects on other CVD risk factors, disease markers, and clinical events for reducing psychosocial stress, smoking, alcohol abuse, myocardial ischemia, carotid atherosclerosis, and mortality rates. Thus, there is sufficient evidence that, among stress reduction programs, the Transcendental Meditation program is effective and warrants recommendation to patients with elevated blood pressure in preventing or treating hypertension and CVD.

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Note: Transcendental Meditation and TM are service marks registered in the US Patent and Trademark Office, licensed to Maharishi Vedic Education Development Corporation and used under sublicense.

## References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

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