Randomized controlled trial of stress reduction with meditation and health education in black men and women with high normal and normal blood pressure

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ABSTRACT

Background: Black men and women suffer from disparities in morbidity and mortality from hypertension, cardiovascular disease, and currently, COVID-19. These conditions are associated with social determinants of health and psychosocial stress. While previous trials demonstrated that stress reduction with meditation lowered BP in the grade I range in Black adults, there is a paucity of evidence for high normal and normal BP.

Objective: This randomized controlled trial was conducted to evaluate the effect of stress reduction with the Transcendental Meditation (TM) technique in Black adults with high normal BP and normal BP using international classifications.

Methods: A total of 304 Black men and women with high normal (130–139/85–89 mm Hg) and normal BP (120–129/80–84 mm Hg) were randomized to either TM or health education (HE) groups. BP was recorded at 3, 6, 9, 12, 24, 30 and 36 months after baseline. Linear mixed model analysis was conducted to compare the BP change between TM and HE participants in the high-normal BP and normal-BP groups. Survival analysis for hypertensive events was conducted.

Results: After an average of 19.9 ± 11.1 months follow-up, TM participants in the high-normal BP group showed significantly lower posttest SBP (-3.33 mm Hg, *p* = 0.045). There was no difference in DBP (-0.785 mm Hg, *p* = 0.367) compared to HE participants. In the normal BP group, the SBP and DBP were not different between the TM and HE participants. The hazard ratio for hypertensive events was 0.52 (*p* = 0.15) in the high normal BP group (7 TM vs 13 HE) with no difference in the normal BP group

Conclusion: This RCT found that meditation lowered systolic BP in Black men and women with high normal BP but not in normal BP participants. These results may be relevant to reducing health disparities in CVD and related co-morbidities.

1. Introduction

Black adults in the United States suffer from disproportionately high mortality compared to whites [1,2]. The largest contributor to this disparity is cardiovascular disease (CVD) [3]. Despite overall decline in CVD mortality in the general population in recent decades, Black adults continue to have the highest total burden of CVD from coronary heart disease (CHD), cerebrovascular disease, and heart failure compared to other racial/ethnic groups [1,3]. While Black men and women have higher rates of several CVD risk factors, hypertension arguably confers the greatest risk [3,4]. The prevalence of high blood pressure (≥130/80 mm Hg) in Black adults is 56% and the incidence is 75% by age 55. These rates are 30% and 60% higher respectively than in white adults and is amongst the highest in the world [4,5]. Estimates are that

hypertension accounts for 50% of the disparities in mortality between Black and white adults [6,7]. These racial disparities begin in youth and track into adulthood [8].

In 2020, coronavirus disease 2019 (COVID-19) was the leading cause of death in the United States [9,10]. Death rates from COVID-19 were 200–300% higher in Black Americans than white Americans [11]. Comorbid hypertension and CVD increase the risk for COVID-19 mortality [12,13]. Therefore, the Black-white racial disparity in COVID-19 morbidity and mortality may be due, at least in part, to the disproportionate rates of high blood pressure in Black Americans [11,14-16].

Two recent American Heart Association (AHA) scientific statements conclude that social determinants of health (SDOH) and associated psychosocial stress contribute to these racial disparities in hypertension and CVD [3,17]. This conclusion is echoed by the American Psychological Association (APA) report on health disparities [18]. The 2020 International Society of Hypertension (ISH) Global Hypertension Practice Guidelines acknowledge the association of stress with hypertension and potential role of stress reduction for hypertension [19]. The AHA, APA, and ISH statements all recommend stress management interventions, such as meditation to reduce health disparities in high risk groups, such as Black adults [3,17,18]. While there have been trials on meditation for treatment of grade I hypertension in Black Americans conducted by our collaborative team and others [20–23], to our knowledge, there have been no published clinical trials on stress reduction for high normal or normal BP in Black adults. This is particularly relevant to clinical practice because lower levels of high blood pressure are recommended for intervention, especially nonpharmacologic intervention in the latest American, European and international clinical practice guidelines [19,24-26]

In response to the renewed recognitions of: 1. racial disparities in health, 2. associations of racial disparities in CVD health to social determinants of health and 3. the clinical importance of high normal and normal BP, we analyzed results from an earlier clinical trial on effects of stress reduction in Black men and women with high normal and normal BP [11,14,19,27,28]. This research was conceived, conducted and reported in consideration of best practices for research in racial and ethnic health disparities [29].

2. Methods

2.1. Overall design

This was a randomized, controlled, single-blind clinical trial that compared the efficacy of stress reduction with the Transcendental Meditation (TM) technique to a health education (HE) control in two groups of Black adults without known CVD. The first group had high normal BP (130–139 SBP and/or 85–89 DBP mm Hg). The second group had normal BP (120–129 mm Hg SBP and/or 80–84 mm Hg DBP). The BP classifications for this study were originally based on the classification system of the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 6) [30,31]. This classification is consistent with the BP strata used in the global hypertension practice guidelines of the International Society of Hypertension [19], and the guidelines of the European Society of Cardiology/European Society of Hypertension [24] and are similar to the 2017 American College of Cardiology/American Heart Association definitions of stage I hypertension and elevated BP [32,33].

The protocol was modified in the first year of the study. That is, the original protocol called for the inclusion of participants with high normal BP. However, in the first year of the trial, the executive committee approved addition of participants with normal BP. This modification allowed the subsequent analysis of high normal BP and normal BP groups in parallel (see Fig. 1, Participant Flow Chart).

This randomized controlled trial was conducted between January 1999 and April 2005. The clinical center for the trial was the Department of Medicine, Medical College of Wisconsin (MCW), Milwaukee, Wiscon-

sin. The administrative and data coordinating center was the Institute for Natural Medicine and Prevention, Fairfield, Iowa. Written informed consent was provided by all participants. The trial was approved by the institutional review boards of both institutions.

2.2. Subjects

The sample included self-identified Black women and men, aged 21–75 years with either high normal BP (130–139 mm Hg and/or DBP 85–89 mm Hg) or normal BP (SBP 120–129 mm Hg and/DBP 80–84 mm Hg) without antihypertensive medications. Participants were excluded if they had a history of cardiovascular disease: myocardial infarction, angina, peripheral artery disease, heart failure, stroke, renal failure, diabetes mellitus, major psychiatric disorder or substance abuse disorder or other life-threatening disease. In addition, potential participants who were planning to move out of the study area, unwilling to accept randomization or unwilling to give informed consent were excluded.

2.3. Study protocol

Participants were assessed during the baseline period that comprised three BP and behavioral assessment visits on three separate days. Stratified block randomization (with stratification for gender, age, and baseline levels of SBP and DBP) was used to assign participants in a 1:1 ratio to either meditation or health education groups. The random allocation sequence was based on computer-generated random numbers. Allocation concealment was maintained by the study biostatistician, who allocated each participant to treatment intervention and informed the study coordinator of treatment assignments, who then notified the participants.

Investigators, staff assessing outcomes, and data management staff were blinded to treatment group assignment. Participants were posttested for at 3, 6, 12, 18, 24, 30, and 36 months after baseline for blood pressure and at 12, 24 and 36 months for behavioral and psychological factors.

2.4. Outcomes

The primary outcome was office blood pressure, measured with a mercury sphygmomanometer using standard clinical trial technique [34,35]. A trained research technician measured BP in the supported right arm after the participant remained seated and resting for 5 min. Participants were told not to practice any stress reduction technique immediately before or during BP recording. Three successive readings were taken at one-minute intervals. To control for possible whitecoat BP variability, the first reading was discarded and the average of the last two readings was used in the data analysis. All BP observers were trained and certified using the Shared Care Research and Education BP Quality assurance program [36] and were re-certified every 6 months by direct observation of performance using AHA measurement guidelines [37] and by double stethoscope and video testing of the ability to record and interpret Korotkoff sounds.

Secondary outcomes were hypertensive events, heart rate, BMI, physical activity, anger expression and adherence. Hypertensive events were defined as SBP ≥140 and/or DBP ≥90 mm Hg on two successive occasions or first prescribed use of antihypertensive medications. Heart rate was measured manually by the research technician in the right radial artery. Anger expression was assessed by anger-in, anger-out and anger-total scores with the \ State-Trait Anger Scale [38]. In previous studies, anger expression was consistently associated with high BP [39,40]. Physical activity was assessed by standardized questionnaire derived from the Minnesota Physical Activity Questionnaire [41].

Intervention adherence was measured using a blinded self-report form at each clinic visit. Meeting attendance was recorded at each visit session by the instructors for both the TM and HE groups.
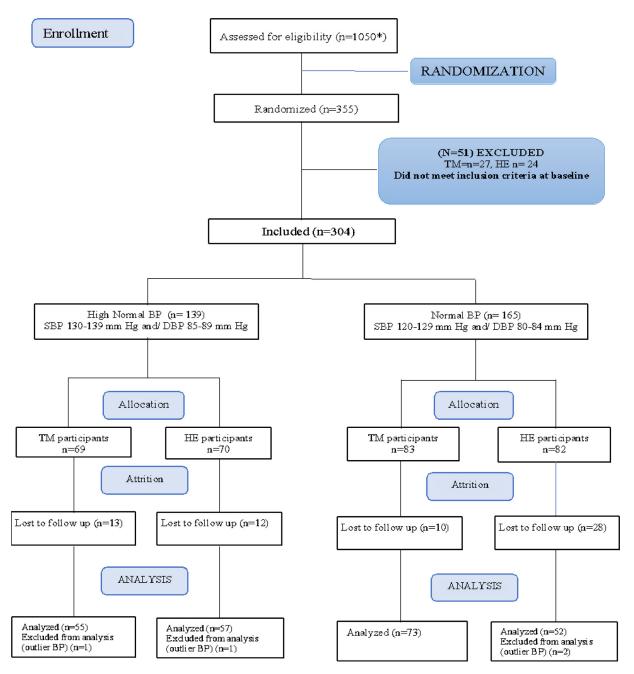
Enrollment

Assessed for eligibility (n=1050*)

RANDOMIZATION

Randomized (n=355)

(N=51) EXCLUDED
TM=n=27, HE n= 24
Did not meet inclusion criteria at baseline

Included (n=304)

High Normal BP (n= 139)
SBP 130-139 mm Hg and/ DBP 85-89 mm Hg

Normal BP (n= 165)
SBP 120-129 mm Hg and/ DBP 80-84 mm Hg

Allocation

TM participants
n=69

HE participants
n=70

Allocation

TM participants
n=83

HE participants
n=82

Attrition

Lost to follow up (n=13)

Lost to follow up (n=12)

Attrition

Lost to follow up (n=10)

Lost to follow up (n=28)

ANALYSIS

Analyzed (n=55)
Excluded from analysis
(outlier BP) (n=1)

Analyzed (n=57)
Excluded from analysis
(outlier BP) (n=1)

ANALYSIS

Analyzed (n=73)

Analyzed (n=52)
Excluded from analysis
(outlier BP) (n=2)

Fig. 1. Participant Flow Chart.

2.5. Interventions

The two study interventions were matched for attention, duration, expectancy, and other nonspecific factors. Both the meditation and health education interventions had previously demonstrated acceptability and feasibility in Black adults with hypertension [20–22]. All participants continued their usual medical care during the trial.

The Transcendental Meditation (TM) technique was a standardized and validated meditation technique that is used for stress reduction that is practiced twice a day for 20 min while sitting comfortably with eyes closed. [42]. Instruction in the TM technique involved a seven-step course over five sessions of 1.5 h each as previously described [22]. This included an introduction and brief personal interview (session 1), personal instruction (session 2), and three follow-up meetings in small groups (sessions 3,4, and 5). The last four sessions were conducted over four consecutive days. Participants were advised to practice the tech-

nique for 20 min twice daily at home for the duration of the study. Follow-up refresher meetings were conducted 1 week later, every 2 weeks for 2 months, and once a month for the duration of the study. There were no instructions to modify lifestyle in the meditation course. A trained and certified instructor of Transcendental Meditation taught the course.

The health education (HE) intervention comprised a series of classes and group discussions on lifestyle modification for high blood pressure and CVD prevention that matched the meditation course in time and attention. The curriculum was based on methods of the Trials of Hypertension Prevention [43,44]. This group received written materials, structured presentations, didactic instructions and group support for modifying the major cardiovascular risk factors including salt restriction, weight reduction, aerobic exercise, alcohol, and smoking cessation. The topic of stress and BP was described, but participants did not learn a specific stress reduction technique. The HE group participants

attended a 90-minute meeting once a week for the first 5 weeks, followed by bi-weekly sessions for two months, and then once a month for the duration of the study. The HE intervention was taught by a qualified health educator.

2.6. Data analysis

Analyses were conducted for the high-normal BP and normal BP groups in parallel (Fig. 1). All participants, regardless of their adherence to the intervention protocols, who completed at least one posttest were analyzed according to the modified intention-to-treat (ITT) principle [45]. Baseline characteristics of the TM and HE participants were compared with t-tests and chi-square tests. The changes in primary and secondary outcomes between TM and HE participants were calculated by linear mixed model analysis. The effects of attrition on the composition of the groups was evaluated by t-test of the baseline variables with treatment and attrition versus non-attrition as grouping variables. Data was checked for extreme outliers using the method of Hoaglin and Iglewicz in SPSS [46].

Changes in systolic and diastolic BP between TM and HE interventions in the high normal and normal BP groups were analyzed as the adjusted difference in posttest BP between TM and HE using linear mixed model analysis. Adjustment factors were significant predictors for SBP (baseline SBP, age, heart rate, education, and income). For DBP, baseline DBP, age, heart rate, income, and education were covariates. For heart rate, the anger-in, anger-out, and anger-total, the baseline value of the respective variables were used as covariates.

For analysis of hypertensive events, we constructed Kaplan–Meier curves according to intervention (TM and HE) group using time-to-first event. Hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated using the Cox proportional hazard model. All data analyses were conducted using SPSS software (IBM SPSS Statistics, v25).

3. Results

The participant flow diagram is presented in Fig. 1. Of the 304 eligible and randomized participants, 139 participants were in the high normal BP group (69 TM, 70 HE). Of these, 114 or 82% completed follow-up testing. Two participants' baseline BP were extreme outliers and were removed from the analysis set, resulting in 112 participants in the final analysis of high normals. There were 165 participants in the normal BP group (83 TM, 82 HE). Of these, 127 or 77% completed follow-up testing. Two participants' baseline BP were in the extreme outlier range and were excluded, resulting in 125 participants in the final analysis of normals.

3.1. Baseline characteristics

Baseline characteristics of the high normal BP group and the normal BP group participants are presented in Tables 1 and 2.

For the comparison of completers and attritors in high-normal BP group, there was no significant difference between participants who completed posttesting ($n = 114$) and those who did not ($n = 25$) on the primary or secondary outcome variables at baseline. For the comparison of completers and attritors in normal BP group, there was no significant difference between subjects who completed post-testing and those who did not on the primary or secondary outcome variables at baseline.

3.2. Outcomes in high normal BP group

Changes in the primary and secondary outcomes for the high normal group are presented in Table 3.

In the high normal BP group, the average follow-up period was 19.9 ± 11.1 months (range = 3–36 months). There was a significantly greater SBP reduction in the TM compared to HE group of -3.2 ± 1.6 mm

Table 1
Baseline Characteristics of High-Normal BP Group.

Variable	Intervention	N	Mean	SD	p-value
Age (years)	TM	55	43.4	9.3	0.545
	HE	57	44.5	10.9	
Females	TM	29 (52.7%)			0.717
	HE	32 (56.1%)			
BMI kg/m^2	TM	55	30	7	0.076
	HE	52	32.6	8.2	
Exercise (hours/day)	TM	54	7.3	4.3	0.801
	HE	54	7.5	4.1	
Education (years)	TM	53	12.1	3.3	0.501
	HE	53	12.8	3.2	0.402
Income (annual)	TM	55	$18,650		
	HE	55	$22,400		
SBP mm Hg	TM	55	128.7	6.5	0.298
	HE	57	130	3.9	
DBP mm Hg	TM	55	84.2	4.8	0.059
	HE	57	82.7	7.3	
HR bpm	TM	55	73.7	7	0.813
	HE	53	73.4	0.9	
Anger In score	TM	55	2.7	0.9	0.669
	HE	55	2.8	0.7	
Anger Out score	TM	55	2.5	0.7	0.308
	HE	55	2.6	14.2	
Anger Total score	TM	55	29.4	12.5	0.985
	HE	55	29.5		

As seen in Table 1, the mean SBP for the high-normal group was 129.3 ± 6.8 mm Hg and DBP were 83.4 ± 4.3 mm Hg; the participants were aged (43.9 ± 10.0 years), and there were 54.5% ($n = 61$) females.

Table 2
Baseline Characteristics of Normal BP Group.

Variable	Intervention	N	Mean	SD	P-value
Age (years)	TM	73	41.38	9	0.878
	HE	52	41.63	9	
Females	TM	44 (60.3%)			0.772
	HE	30 (57.7%)			
BMI Kg/m2	TM	70	30.99	8.3	0.435
	HE	48	32.14	7.5	
Exercise (hours/day)	TM	68	7.65	4.8	0.872
	HE	50	7.52	3.7	
SBP mm Hg	TM	73	122.59	4.7	0.673
	HE	52	122	5.4	
DBP mm Hg	TM	73	77.92	5.3	0.811
	HE	52	78.15	5.2	
HR bpm	TM	71	72.58	8.2	0.257
	HE	48	74.35	8.4	
Anger In score	TM	71	2.59	0.9	0.234
	HE	49	2.78	0.8	
Anger Out score	TM	71	2.59	0.8	0.619
	HE	49	2.66	0.6	
Anger Total score	TM	71	27.73	12.5	0.383
	HE	49	29.75	12.4	
Income (annual)	TM	72	$23,490		
	HE	51	$20,833		
Education (years)	TM	56	12.1		
	HE	55	12.8		

As seen in Table 2 for the normal BP group, the mean SBP was 122.3 ± 5.0 mm Hg and DBP were 78.0 ± 5.2 mm Hg; the participants were aged (41.5 ± 8.8 years), and there were 59.2% ($n = 74$) females.

Hg, $p = 0.045$) (Fig. 2). The adjusted DBP difference of (-0.9 mm Hg, $p = 0.53$) was not significant between TM or HE participants (Table 3).
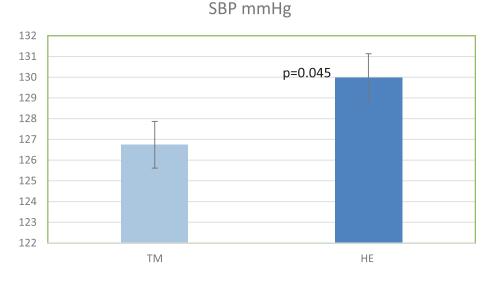
There were 7 hypertensive events in the group assigned to a TM intervention (12.7%) and 13 in the group assigned to HE (22.8%). The hazard ratio was 0.523 (95% confidence interval [CI], 0.208 to 1.1313, $p = 0.15$) for the high normal BP group. Anger in, anger out and anger total change scores were not different between the TM and HE participants (Table 3)

Table 3
Outcomes in High Normal BP Group.

Variable	TM Posttest Adjusted Mean (SEM)	HE Posttest Adjusted Mean (SEM)	Adjusted Mean Difference (SEM)	95% Confidence Interval Lower bound	Upper bound	p value
N (Sample size)	55	57				
Follow-up (months)	20.1 ± 9.9	19.7 ± 12.2	0.4 ± 2.1	−3.8	4.6	.850
SBP (mmHg)	126.7 ± 1.1	130 ± 1.2	−3.2 ± 1.6	−6.4	−0.7	.045*
DBP (mm Hg)	81.2 ± 1.0	82.9 ± 1.1	−0.92 ± 1.5	−3.8	2.0	.533
HR (bpm)	71.8 ± 0.7	72.3 ±.6	−0.50 ±.9	−2.2	1.2	.151
Anger In	2.5 ±.10	2.7 ±.1	−0.19 ±.1	−0.5	0.1	.559
Anger Out	2.7 ± 0.1	2.7 ±.1	−0.06 ±.1	−0 0.3	.19	.173
Anger Total	28.9 ± 1.6	30.3 ± 1.7	−1.3 ± 2.2	−5.8	3.1	.649
Body Mass Index (BMI, kg/m^2)	29.9 ± 7	32.5 ± 8.1	−2.6 ± 1.5	−5.5	0.3	.545
Physical activity (active hours/day)	7.3 ± 4.4	7.5 ± 4.0	−0.2 ±.8	−1.8	1.4	.076
Hypertensive events (N and hazard ratio)	7	13	0.52	0.21	1.13	.15
Adherence- Home practice (at least once/day)	84%	90%				.371
Adherence - Meeting attendance (% total)	48%	42%				.203

* $p < 0.05$ level of significance.

SBP mmHg

Fig. 2. Comparison of Posttest SBP between TM and HE Participants in the High-Normal BP group.

Regarding treatment adherence in the high normal BP group, 84% of the TM participants reported practicing meditation at home at least once a day for the duration of the study while 90% of the HE participants reported adherence with at least one recommended healthful activity at home at least once a day. For meeting attendance in the high normal BP groups, the TM participants attended 48% of all possible meetings compared to 42% for the HE group.

3.3. Outcomes in the normal BP group

The follow-up period averaged 13.84±10.13, SD months (range = 3–36 months). The linear mixed model analysis showed no difference in changes in SBP (0.84±1.55 mm Hg, $P = 0.589$), DBP (−0.23±1.14 mm Hg, $P = 0.841$), heart rate (1.16±.94 beats/ minute, $p = 0.220$), anger-in (−0.27±.14, $p = 0.071$), anger-out (−0.08±.12, $p = 0.517$), or anger total (−1.58±1.66, $p = 0.342$), or between the TM and the HE participants. There were 7 hypertensive events in the participants assigned to a TM intervention (9.5%) and 3 in the participants assigned to HE (5.7%) intervention in the Normal BP group. The hazard ratio was 1.768 (95% confidence interval [CI], 0.456 to 6.852, $p = 0.40$) for the normal BP group. (See table 4.)

For treatment adherence in those in the normal BP group, 67% of the TM participants reported regular home practice while the 100% of the HE group reported home practice of their healthy activity at least once a day. Regarding meeting attendance, 47% of the TM participants attended meetings compared to 40% of the HE group.

4. Discussion

In consideration of the substantial and persistent disparities in hypertension, CVD and related co-morbidities, such as COVID-19 in Black adults which are associated with social determinants of health and psychosocial stress, this randomized controlled trial compared the long-term effects of stress reduction with meditation to health education control in Black men and women with high normal and normal blood pressure. The results showed a significant reduction in systolic BP (−3.2 mm Hg) in the high normal group assigned to the meditation condition over an average of 20 months. The relative risk reduction of 48% for hypertensive events in the high normal BP meditation group did not reach statistical significance (HR = 0.52 (95% CI 0.20 to 1.13, $p = 0.15$). In the normal BP group, there were no significant changes in systolic or diastolic BP or hypertensive events. These findings suggest that the practice of Transcendental Meditation may lower BP over an average of 20 months in Black men and women with high normal BP and perhaps contribute to the prevention of hypertension, CVD and related health disparities.

The major international and national clinical practice guidelines recognize that systolic BP in the 130–139 mm Hg range confers excess risk for CVD mortality and morbidity[19, 24, 33]. Current International Society on Hypertension (ISH) and European Society of Cardiology/European Society of Hypertension (ESC/ESH) guidelines classifies this range as high normal BP while the American College of Cardiology/American Heart Association (ACC/AHA) guidelines classify it as stage I hypertension [19,24]. In the Prospective Studies Collaboration

Table 4
Outcomes in the Normal BP Group.

Variable	TM Posttest Adjusted mean (SEM)	HE Posttest Adjusted mean (SEM)	Adjusted Mean difference (SEM)	95% Confidence Interval Lower Bound	Upper Bound	P value
N (Sample size)	73	52				
Follow-up (months)	19.8 ± 11.1	21.1 ± 10.6	−1.3 ± 2	−5.3	2.6	.496
SBP (mmHg)	123.9 ± 1.1	123.1 ± 1.2	−0.8 ± 1.5	−2.2	3.9	.589
DBP (mm Hg)	78.9 ±.8	79.1 ±.9	−0.2 ± 1.1	−2.5	2.0	.841
Hypertensive events (N and hazard ratio)	7	3	1.77	.46	6.85	.402
HR (bpm)	72.6 ±.6	71.4 ±.7	1.2 ±.9	−0.7	3.0	.220
Anger In	2.5 ±.1	2.7 ±.1	−0.3 ±.1	−0.5	.02	.071
Anger out	2.7 ±.1	2.8 ±.1	−0.1 ±.1	−0.3	.16	.517
Anger Total	28.8 ± 1.1	30.4 ± 1.4	−1.6 ± 1.7	−4.9	1.7	.342
Body Mass Index (BMI, kg/m^2)	31±8.3	32.1 ± 7.5	−1.1 ± 1.5	−4.1	1.8	.444
Physical activity (hours/day)	7.6 ± 4.8	7.5 ± 3.7	.1±.8	−1.5	1.7	.872
Adherence-home practice (at least once/day)	67%	100%				.423
Adherence -meeting attendance (% total)	47%	40%				.008

meta-analysis from one million adults, BP is "strongly and directly related to vascular and overall mortality to at least 115/75 mm Hg." [47]. Recently, Whelton et al. confirmed that every 10 mm Hg increase in systolic BP above 90 mm Hg is associated with a 50% increase in risk for atherosclerotic CVD events [48]. Notably, the majority of CVD events occur in individuals with BP < 140/90 mm Hg. Amongst Black adults, the proportion of CVD events in individual with BP < 140/90 is nearly 60% [49].

There is a dearth of clinical trials of nonpharmacologic interventions in individuals with high normal BP. The Blood Pressure Lowering Treatment Trialists' Collaboration (BPLTT) reported a meta-analysis of 48 trials of pharmacologic interventions with 350,000 participants with a wide range of baseline blood pressures [50,51][52]. In patients with systolic BP in the high normal range and with no prior CVD, as was the case for participants in this trial, a standardized reduction of 5 mm Hg SBP was associated a 10% reduction in major adverse cardiovascular events with [50,52,53]. For these reasons, the International, European and American guidelines all recommend lifestyle modification for individuals with high normal BP (or stage I equivalent), especially for those without concomitant CVD as was the case for participants in this trial. [19,24,54].

It has been reported that 40% of individuals with high normal BP develop hypertension in two years and 63% become hypertensive over four years [55]. The risk is especially high in Black men and women compared to other racial groups [56,57]. In our study, there was a 48% lower rate of hypertensive events over 20 months in the high normal TM group compared to controls, although this did not reach statistical significance (p = 0.15). However, the present study was not adequately powered to assess hypertensive event incidence due to limitations of both sample size and duration of follow-up. It is possible that this estimate of risk reduction may be used to gauge the effect size for future definitive trials. Previous studies with adequate statistical power reported significantly lower risk for major adverse cardiovascular events (MACE) in the TM groups compared to controls with high BP [22,58].

There have been few RCTs of lifestyle interventions for individuals with high normal BP and even fewer trials in Black populations. The Trials of Hypertension Prevention (TOHP II) evaluated effects of lifestyle modification with weight loss and sodium restriction in overweight people with high normal BP. The average net BP reductions in the lifestyle group were −2.0/−1.3 mm Hg after 18 months. The follow up period and BP severity in TOHP were similar to the current trial. The PREMIER trial employed lifestyle modification with the DASH diet in participants with high normal BP [59]. After six months of intervention, the net changes were −3.1/−1.8 mm Hg in the active intervention groups compared to controls. Therefore, in the present trial, the net reduction of −3.2 mm Hg systolic BP in the high normal group practicing meditation was similar to or greater than changes in somewhat similar trials of lifestyle modification in general population samples [59,60]. It may

be possible that meditation is additive or synergistic with other lifestyle modifications for lowering BP. This may tested in future pragmatic clinical trials.

There have been several previous trials of lifestyle modification with Transcendental Meditation in Black adults with high BP [23,61-64]. However, these were conducted in patient populations with BP > 140/90 mm Hg [20,21] or in patients with documented coronary heart disease [22] and thus substantially differ from the current trial of participants with either normal BP or high normal BP without known CVD.

In the meta-analyses of randomized controlled trials of Transcendental Meditation and blood pressure, the average reduction in SBP was – 4 to 5 mm Hg and in DBP – 2 to 3 mm Hg for all BP groups. At the same time, these meta-analyses found that changes were inversely associated with baseline BP [63]. That is, the higher the baseline BP, the greater BP reduction over time. Larger effects with higher baseline BPs may be related to the mechanisms of high BP and meditation. Excess sympathetic nervous system tone is a pathophysiologic mechanism for high BP [65–69]. Excess cardiovascular reactivity to stress is one possible mechanism for high BP [70]. Furthermore, one of the proposed etiologies for sympathetic overactivation in high BP is psychosocial stress [71–73]. The role of social determinants of health and psychosocial stress in contributing to high BP in Black men and women is well described [3,17].

Previous studies reported that Transcendental Meditation practice reduces sympathetic activation [74–76]. Therefore, it is plausible that meditation practice lowered SNS tone in the high normal BP group in the current trial. It is also possible that the normal BP group had insufficient SNS tone to be modified by a stress reducing practice.

There are several limitations to the present study. This trial included Black participants exclusively and the results may not generalize to other racial groups. However, other trials have reported lower BP with Transcendental Meditation practice in general population samples [77,78]. The blood pressure outcomes employed office BP readings with standardized clinical trial technique. Technological limitations did not allow the use of ambulatory BP monitoring. For the high normal BP group, subjects were recruited with systolic BP of 130–139 and/or diastolic BP of 85–89. However, the average baseline BP in this group was 129.3 ± 6.8 mm Hg and DBP were 83.4 ± 4.3 mm Hg. Although the group average is 1–2 mm less than the SBP or DBP entry criteria, we estimate that this is due to the distribution of subjects meeting either SBP and/or DBP criteria at entry. Adherence to the interventions were relatively high with approximately 80% of participants reporting daily practice of at least once per day. However, instructional meeting attendance was lower at approximately 50%. While there may be bias in self-reported adherence, we are unable to determine if meeting attendance or self-report is a more accurate indicator of adherence in this trial. Nevertheless, a strength of this study is that all subjects were included in the data analysis regardless of their level of adherence to the treatments and all BP recordings were masked to treatment assignment.

The planned follow-up period was 36 months, yet the average follow-up was 20 months. Thus, there was attrition from long-term BP measurement visits. In the data analysis, subjects with a minimum of one follow-up visit regardless of treatment assignment or adherence were included in the modified intent-to-treat analysis which reduces bias [45]. The approximately 1 mm Hg reduction in DBP in the high normal group did not reach statistical significance. This differs from meta-analyses of TM and BP that did find significant differences in DBP [62,63]. This null finding may relate to insufficient power to detect a small difference in DBP. The possibility of confirmation bias cannot be ruled out in participants who volunteered for a randomized controlled trial of lifestyle interventions; however, the randomization process mitigated this effect [79]. At baseline, participants reported an average of seven hours of physical activity per day. It is possible that this level of physical activity was be related to occupations of the participants that required this level of physical activity since the average education was 12 years and average income was approximately $20,000 per year.

This study did not find a significant difference in anger between TM and HE participants. This null finding may be because of variability in the perception of anger. Studies have reported that TM decreases the physiological correlates of psychosocial stress factors including anger, such as sympathetic activity [80,81], plasma catecholamines [82], cortisol [83], and cardiovascular reactivity [76]. It is possible that while the perception of anger was not significantly changed, TM practice may have reduced the physiological correlates of psychosocial stress and BP. Future studies might examine neurophysiological and neuroendocrine mechanisms simultaneously with BP and psychosocial stress. Future studies might also address the combination of stress reduction with conventional health education compared to no treatment or behavioral controls.

5. Conclusion

This was the first randomized controlled trial of meditation as a lifestyle intervention in Black men and women with high normal BP and normal BP without known CVD. The results of this trial suggest that the efficacy of the TM technique in reducing systolic BP in patients with high normal BP,for whom pharmacotherapy may not be indicated, but who nevertheless are at elevated risk for CVD. Meditation may be a clinically useful lifestyle modification for reducing high blood pressure, CVD and associated co-morbidities in high-risk Black populations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

Trial Registration

clinicaltrials.gov NCT# 0482150

Data Sharing Plan

Research data that documents, supports, and validates research findings will be made available upon request.

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