Published in final edited form as:

Psychosom Med. 1999 ; 61(4): 525–531.

Acute Effects of Transcendental Meditation¹ on Hemodynamic Functioning in Middle-Aged Adults

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Abstract

Objective—Increased peripheral vasoconstriction (ie, total peripheral resistance, or TPR) has been implicated as playing an important role in the early development of essential hypertension. Some studies have demonstrated that Transcendental Meditation (TM) reduces high blood pressure, but the hemodynamic adjustments behind these blood pressure reductions have not been elucidated. The aim of this study was to provide a preliminary investigation of the acute effects of TM on TPR.

Methods—Subjects were 32 healthy adults (16 women and 16 men; 30 white and two African American; mean age, 46.4 ± 3.9 years). Subjects were divided into a TM group of long-term TM practitioners (eight white women, nine white men, and one African American man; mean years of twice-daily TM practice, 22.4 ± 6.7) and a control group (eight white women, five white men, and one African American man). Hemodynamic functioning was assessed immediately before and during three conditions: 20 minutes of rest with eyes open (all subjects), 20 minutes of TM (TM group), and 20 minutes of eyes-closed relaxation (control group).

Results—During eyes-open rest, the TM group had decreases in systolic blood pressure (SBP) and TPR, compared with increases in the control group (SBP: -2.5 vs. $+2.4$ mm Hg, $p < .01$; TPR: -0.7 vs. $+0.5$ mm Hg/liter per minute, $p < .004$). During TM, there was a greater decrease in SBP due to a concomitantly greater decrease in TPR compared with the control group during eyes-closed relaxation (SBP: -3.0 vs. $+2.1$ mm Hg, $p < .04$; TPR: -1.0 vs. $+0.3$ mm Hg/liter per minute, $p < .03$).

Conclusions—TPR decreased significantly during TM. Decreases in vasoconstrictive tone during TM may be the hemodynamic mechanism responsible for reduction of high blood pressure over time. The results of this study provide a preliminary contribution to the understanding of the underlying hemodynamic mechanisms responsible for the beneficial influence of TM on cardiovascular risk factors.

Keywords

hemodynamics; total peripheral resistance; blood pressure; cardiac output; stroke volume; Transcendental Meditation

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INTRODUCTION

Essential hypertension continues to be a significant health problem in the United States, with approximately 50 million persons affected (1). Behavioral stress reduction programs have been acknowledged to be potentially cost-effective in the treatment of essential hypertension and its sequelae (2, 3). One behavioral stress reduction approach that has received increasing attention is the TM program. The TM technique has been described as a simple, natural procedure practiced for 15 minutes twice a day while sitting comfortably with one's eyes closed (4). The TM program was introduced in the West by Maharishi Mahesh Yogi in 1959 and has its origin in the ancient Vedic approach to health (5). The TM technique does not require changes in personal beliefs, lifestyle, or philosophy (6).

Individuals practicing TM have been found to have lower resting SBP and DBP than matched controls (7, 8). Recently, studies have reported BP reductions (9, 10) as well as reduced cardiovascular disease mortality and total mortality (10–13) with TM. However, there is little information on the underlying hemodynamic mechanisms responsible for TM-induced changes in BP.

BP is the product of CO and TPR. Thus, decreases in BP are due to decreases in CO and/or TPR. Few studies have evaluated changes in CO during TM, and the findings have been mixed. An early study using five research subjects and no control subjects observed a 25% decrease in CO (14). Two larger studies found significant increases in CO during TM (16% and 6%) (15, 16). Finally, a meta-analysis of 31 studies on the physiological differences between TM and rest indicated that TM was associated with a larger decrease in HR and that long-term TM practitioners exhibited significantly lower baseline HR compared with control subjects (17).

Increased peripheral vasoconstriction (ie, TPR) has been implicated as playing an important role in the early development of essential hypertension (18). To our knowledge, there are no published data available on the effect of TM on TPR. In view of the dearth of studies on changes in underlying hemodynamic mechanisms during TM, we examined the acute effects of TM on BP, CO, and TPR in long-term practitioners of TM compared with a control group of healthy adults. On the basis of findings to date, we predicted that among a group of healthy adults, long-term TM practitioners would exhibit greater decreases in resting BP due to concomitant declines in TPR during the practice of TM compared with a control group practicing eyes-closed relaxation.

METHODS

Subjects

Thirty-two healthy, normotensive men and women, African American and white, aged 39 to 55 years (mean age, 46.4 ± 3.9 years), were recruited for this study. Eighteen were long-term practitioners of TM (eight white women, nine white men, and one African American man; mean years of twice-daily TM practice, 22.4 ± 6.7), and 14 were healthy control subjects (eight white women, five white men, and one African American man). TM subjects were recruited through a notice posted at the Maharishi Ayur-Veda School in Atlanta, Georgia, and an announcement in a newsletter sent to TM practitioners in Georgia. Control subjects were recruited among parents of youth participating in a longitudinal study of cardiovascular health or from the Medical College of Georgia.

Criteria for inclusion in the study included (1) age of 39 to 55 years; (2) no history of heart attack, hypertension, diabetes, or any chronic illness that required regular pharmacological

treatment; and (3) no history of major psychiatric disorder, current alcohol abuse/dependency disorder, or other drug use/dependency disorder. Subjects were paid \$150 for their participation.

Anthropometric Measurements

After a consent form was signed, the following measurements were recorded using established protocols (19, 20): (1) height and weight, by means of the Detecto CN20 (Detecto, Inc., Webb City, MO); (2) waist and hip circumferences, by means of steel measuring tape; and (3) triceps, subscapular, and suprailiac skinfold measurements, by means of a Lange caliper (Cambridge Scientific Industries, Inc., Cambridge, MD).

Hemodynamic Measurements

SBP and DBP were monitored with a Dinamap Vital Signs Monitor (model 1846SX, Critikon, Inc., Tampa, FL). An appropriately sized cuff was attached to the right arm. SV, CO, HR, and TPR measurements were obtained using impedance cardiography. For each subject, two sets of tetrapolar electrodes (one current emitting and one sensing) were interfaced with a noninvasive thoracic electrical bioimpedance system (NCCOM-3, model 6, Bo-Med Medical Manufacturing, Ltd., Irvine, CA). This system has been used extensively on previous occasions in our laboratory (20) and validated by comparison with simultaneous CO values derived from oximetric measurements using the Fick equation (21, 22).

Procedure

After instrumentation with the hemodynamic monitoring equipment, the subject was seated in a comfortable chair in a quiet room separated from the monitoring equipment by a wall with a large one-way mirror. All subjects completed the eyes-open rest condition. The instructions for this condition were as follows: "Now please sit in the chair with your eyes open for 20 minutes. Please keep your feet on the floor, and do not cross your legs. From time to time, we will be measuring your blood pressure. If you need to speak to us at any time, just talk in a normal manner, and we will hear you." The TM group then completed the 20-minute meditation condition. Instructions for this condition were as follows: "In a few minutes, we will ask you over the intercom to begin meditating. At that time, please close your eyes and meditate for 20 minutes. Please keep your feet on the floor, and do not cross your legs. From time to time, we will be measuring your blood pressure, so when you feel the cuff inflating, continue your meditation in a normal fashion. If you need to speak to us at any time, just talk in a normal manner, and we will hear you. At the end of your meditation, there will be an instruction given over the intercom, and you may take a few minutes before opening your eyes slowly." Control subjects completed a 20-minute eyes-closed relaxation condition. They were given the same instructions as the TM group, except instead of being told to "begin meditating," they were told "to relax as completely as possible by closing your eyes, freeing your mind of distracting thoughts, and concentrating on breathing in a slow regular manner." The words "relax" and "relaxation" replaced "meditate" and "meditation." With these instructions, there were no incidents of subjects speaking during any of the testing sessions.

Hemodynamics were measured immediately before and every 5 minutes during each 20-minute condition (eyes-open rest, TM, and eyes-closed relaxation). HR and CO were calculated at completion of every successive 12 QRS complexes with the NCCOM bioimpedance monitor while the Dinamap was inflating and calculating BPs. These values were averaged to provide one measurement for each BP evaluation. Simultaneously measured BP and CO values were used to calculate TPR using the equation $TPR = (SBP + 2 \times DBP)/3/CO$ and expressed as mm Hg/liter per minute.

The eyes-open rest condition (all subjects) and the TM or eyes-closed relaxation condition were counterbalanced in a sequentially alternating fashion. Immediately after the TM and relaxation sessions, each subject completed a form rating his or her experience during the session. The TM group form contained Likert scale questions concerning how their meditation compared with a usual meditation at home, how nervous and how much physical discomfort they felt, how much they worried and were bothered by noise, whether they had periods of “pure awareness,” and any comments about their experience. A questionnaire with similar questions concerning noise, nervousness, physical discomfort, and worry was given to control subjects after their eyes-closed relaxation session.

Lifestyle Questionnaire

Questionnaires on health history, demographics, diet assessment, and daily physical activity were completed by the subjects. The health history questionnaire evaluated smoking and medication status. Demographics included marital status, education, and occupation. Fat consumption (g/day) was assessed with a 13-item dietary screen (23). Sum of energy expended in stair climbing, walking, sports, and recreational physical activity (kJ/week) was computed using the Harvard Alumni Survey (24). All questionnaires were selected on the basis of adequacy of psychometric properties, including test–retest reliability, concurrent validity, and/or usefulness in prediction of cardiovascular disease risk (25, 26).

Calibration of SV

The NCCOM bioimpedance monitor has been found to provide accurate measurements of relative changes in SV and CO in nonhumans and humans ranging from infants to adults by comparisons with standard invasive CO readings (27, 28). Impedance cardiography alone, however, provides less accurate information about absolute magnitude of SV and thus CO. Therefore, a Doppler examination was conducted using a continuous-wave transducer directed toward the aortic valve. The beam was directly parallel to aortic flow to achieve maximum flow velocity. Utilizing computer analysis and the area under the velocity curve (flow velocity integral), SV and CO were calculated. These average Doppler-derived SV values for each subject, in conjunction with their HR values, were compared with the subject's impedance-derived SV at the same HR. The percentage differences in SV were used as a calibration for impedance-derived SV measures during the formal evaluation.

Data Analyses

Examination of the data did not indicate a consistent pattern of increasing depth of meditation. That is, we found that the deepest point of meditation (assumed to be so by the largest drop in BP or TPR) did not occur at the end of the 20-minute meditation for all subjects but rather at various points during the meditation. Thus, hemodynamic data were reduced for each 20-minute condition (ie, eyes-open rest, TM, and eyes-closed relaxation) by computing mean scores from the four sets of measures (one every 5 minutes) obtained during each condition. Change scores were then calculated by subtracting mean values obtained immediately before starting a condition from the mean value obtained during the condition (eg, TM or relaxation and eyes-open rest). Changes scores for each group were then compared for each hemodynamic evaluation using a series of 2×2 (sex $\times$ group) analyses of covariance with the respective resting baseline hemodynamic value serving as a covariate. A series of 2×2 (sex $\times$ group) analyses of variance were performed for all descriptive characteristics.

RESULTS

Descriptive Characteristics

Descriptive characteristics and hemodynamic values for eyes-open rest for both groups are presented in Table 1. There were no significant differences between groups in the proportion of men to women. The TM group reported significantly higher educational status ($p < .03$). Men were heavier, taller, and had higher body surface area, waist-to-hip ratio, physical activity levels, and resting DBP than women (for all, $p < .04$). No other significant main or interaction effects were observed for the descriptive characteristics or resting hemodynamics (for all, $p > .05$).

Eyes-Open-Rest Hemodynamic Evaluations

Mean changes in hemodynamic values during the 20 minutes of eyes-open rest and the 20 minutes of TM or eyes-closed relaxation from hemodynamic measures immediately before the particular condition adjusted for baseline resting levels are presented in Table 2. During the 20 minutes of resting with eyes open, the TM group had a decrease in SBP, compared with an increase in the control group (-2.5 vs. $+2.4$ mm Hg, $p < .01$). HR and CO increased more in the TM group than in the control group during eyes-open rest (for both, $p < .03$). Finally, TPR decreased in the TM group and increased in the control group (-0.7 vs. $+0.5$ mm Hg/liter per minute, $p < .004$). No differences in hemodynamic change values between men and women were observed (for all, $p > .09$). Adjusted mean changes in hemodynamic functioning during eyes-open rest for the TM and control groups for SBP, TPR, and CO are depicted in Figure 1.

TM vs. Relaxation Hemodynamic Evaluations

As shown in Table 2, the TM group exhibited a decrease in SBP during TM, compared with an increase in the control group during eyes-closed relaxation (-3.0 vs. $+2.1$ mm Hg, $p < .04$). TPR decreased significantly in the TM group and increased in the control group (-1.0 vs. 0.3 mm Hg/liter per minute, $p < .03$). Changes in DBP, SV, and HR were not significant (for all, $p > .05$). A trend was observed for CO, with an increase in the TM group and a decrease in the control group ($+0.13$ vs. -0.11 liter/min, $p < .07$). No differences in hemodynamic change values between men and women were observed (all $p > .09$). Figure 1b, presents adjusted mean changes in SBP, TPR, and CO during TM and eyes-closed relaxation.

DISCUSSION

Eyes-Open Rest Condition

This study reports on acute changes in hemodynamic functioning during an eyes-open rest condition and during practice of the TM technique by a group of long-term TM practitioners as compared with a control group. During a 20-minute session of resting with the eyes open, the TM group exhibited significant decreases in SBP and TPR, compared with increases in the control group. HR and CO increased significantly more in the TM group than in the control group during eyes-open rest.

TM vs. Relaxation Condition

Comparison of TM vs. eyes-closed relaxation in the control group indicated that the TM practitioners exhibited significant decreases in SBP and TPR, compared with increases in the control group. The TM group exhibited a significant 6.5% decrease in TPR during TM, compared with a 1.6% increase in the control group during eyes-closed relaxation. A 14% decrease in TPR during TM can be estimated from BP and CO data published by Jevning et

al. (15). Our findings also indicated a 2.7% increase in CO during TM, compared with a 2.2% decrease in the control group during eyes-closed relaxation. These findings are lower than those observed in two previous studies that evaluated CO (+16% and +6%) (15, 16). The latter study used impedance cardiography and attributed the 6% increase in CO during TM to a 6% increase in SV (16). There were no significant changes in HR among the TM or control groups in either of these studies (15, 16). Our findings indicated a 2% increase in SV during TM, compared with a decrease of 2.5% in the control group, and no significant changes in HR during TM or eyes-closed relaxation.

The decrease in SBP during TM is in accord with previous findings (29). That BP did not drop very much during TM is not surprising, because the subjects (long-term meditation practitioners) already had very low BP for their age (ie, 111.5/74.1 mm Hg), indicating a possible “physiological floor effect.” This SBP is 14% lower than the population mean for this age group (129 mm Hg) (30) and is in agreement with previous findings of long-term TM practitioners having lower BP than population norms (8). In this context, it is worth noting that the largest drop in SBP during TM was observed in the subject with the highest BP during eyes-open rest.

Reasons for the unexpected lack of significant differences in resting BP between the TM and control group are unknown. The criteria for participation resulted in a very healthy group of middle-aged adults that is not representative of the general population. For example, as noted above, the average resting SBP for this age group (46.4 years) in the United States is 129 mm Hg SBP. Both the TM and control groups’ resting SBP fell well below that (111.5 and 115.4 mm Hg, respectively). Although there were no statistically significant differences in anthropometric, demographic, or lifestyle variables between the two groups, the TM group reported greater physical activity and lower fat consumption than the control group. However, even after statistically controlling for energy expenditure and fat consumption, the pattern of significant group differences in hemodynamic responses to resting and relaxation/TM conditions did not change.

Possible Neurohormonal Mechanisms Responsible for Hemodynamic Changes During TM

The practice of TM has been described as altering the thinking process to a more settled state, resulting in a distinctive psychophysiological state characterized as “restful alertness” (31). Individuals in this state have demonstrated enhanced neurophysiological function (32, 33) and decreases in respiration rate (34), sympathetic nervous system tone (35, 36), hypothalamo–pituitary–adrenocortical system activation (36), and cortisol level (37). Such physiological changes have been associated with a concomitant reduction in BP (37). Alteration of vasoactive neuropeptide release in the vascular endothelium responsible for vascular tone may have been partially responsible for the decrease in TPR during TM. Two prime candidates may have been decreased production of endothelin-1, the most potent vasoconstrictor produced in humans, and/or increased production of nitric oxide relaxation factor, which is responsible for vasodilation (38). Evaluation of such neurohormonal mechanisms is needed in future research, because this may be one pathway by which, over time, TM-induced behavioral stress reduction through repeated reductions in vasoconstrictive tone results in reduced resting BP.

Other Considerations

Although the findings are intriguing and informative, four points concerning the TM group and their experience during the study are noteworthy. First, four TM subjects reported that inflation of the BP cuff every 5 minutes was painful and created a significant disturbance to their meditation practice. None of the control subjects reported any problem with cuff

inflation. The intrusiveness of the repeated BP measurements may have prevented the TM subjects from having a normal, restful TM session.

Second, most of the TM group had to travel more than 140 miles to reach the laboratory. The control group comprised local residents. It is possible that the additional travel effort may have had an adverse impact on the quality of the TM sessions. Third, all subjects were instructed to keep their feet on the floor and not to cross their legs to avoid confounding due to differences in postural positions. A number of TM subjects reported that not being able to sit in a Lotus position (ie, cross-legged), as they were accustomed to doing at home, created discomfort and that their meditation experiences at home were different from that during the laboratory visit. Fourth, all participants in the TM group had been practicing TM for many years. They also had very low resting BPs, which may be related to this. Accordingly, change score differences during the experimental conditions may have been minimized by the very low nature of their baseline BPs. If the study were repeated using subjects who had recently learned TM, eyes-open rest condition values might not be as low, and the change from eyes-open rest to the TM condition might be even greater.

Although the potential impact of all these considerations is speculative, in each case any influence that did occur would likely have *lessened* the difference between eyes-open rest and TM condition values. That is, these influences would tend to lessen change scores (ie, decreases). Given that we found a significantly larger decrease in the TM group, the difference between the TM and control groups may have been even greater in the absence of these influences.

In conclusion, this study demonstrated that TM resulted in greater decreases in SBP and TPR than manifested during eyes-closed relaxation by subjects who do not regularly meditate. Reduced TPR may be an underlying mechanism related to reduced BP in essential hypertension. The results of this study provide a preliminary contribution to understanding the underlying hemodynamic mechanisms responsible for beneficial influence of TM on cardiovascular risk factors.

Acknowledgments

This work was supported in part by Grant HL62976 from the National Institutes of Health. We thank the Maharishi Ayur-Veda School in Atlanta, GA, for its assistance in recruiting long-term practitioners of the TM program.

Glossary

BP	blood pressure
CO	cardiac output
DBP	diastolic blood pressure
HR	heart rate
SBP	systolic blood pressure
SV	stroke volume
TM	Transcendental Meditation
TPR	total peripheral resistance

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Fig. 1. Changes in hemodynamic function during 20-minute periods of (a) eyes-open rest and (b) during TM and eyes-closed relaxation for the TM and control groups. Mean change scores adjusted for baseline values. Positive values indicate an increase and negative values indicate a decrease from the minute 0 reading.

TABLE 1

Descriptive Characteristics^a

	TM Group		Control Group	
	Men (<i>n</i> = 10)	Women (<i>n</i> = 8)	Men (<i>n</i> = 6)	Women (<i>n</i> = 8)
Anthropometric characteristics				
Age, years	46.6 ± 3.5	48.6 ± 3.7	45.7 ± 3.4	44.4 ± 4.5
Weight, kg ^b	79.3 ± 11.6	63.6 ± 8.6	80.9 ± 10.1	74.6 ± 20.3
Height, cm ^b	177.0 ± 8.0	167.2 ± 7.4	170.6 ± 7.0	170.0 ± 3.1
Body surface area, m ^{2b}	2.0 ± 0.2	1.7 ± 0.1	1.9 ± 0.1	1.8 ± 0.2
Quetelet index, kg/m ²	25.4 ± 3.9	22.8 ± 3.5	27.9 ± 4.4	25.9 ± 6.9
Waist-to-hip ratio ^b	0.91 ± 0.06	0.80 ± 0.04	0.92 ± 0.06	0.82 ± 0.10
Conicity index	3.0 ± 0.6	3.0 ± 0.2	3.1 ± 0.2	3.1 ± 0.4
Ponderal index	14.4 ± 2.5	13.7 ± 2.4	16.4 ± 3.1	15.3 ± 4.0
Sum skinfold measurements (3), mm	58.5 ± 23.0	62.0 ± 18.6	65.5 ± 17.8	67.5 ± 28.1
Demographic and lifestyle characteristics				
Activity level (1–4) ^b	2.0 ± 0.9	2.8 ± 1.3	1.5 ± 0.8	2.9 ± 1.1
Blocks walked per day	14.9 ± 14.2	9.9 ± 10.7	8.8 ± 3.8	4.0 ± 4.4
Flights climbed per day	7.5 ± 4.9	4.5 ± 5.5	2.3 ± 2.6	4.4 ± 4.5
Total energy expenditure, kJ/week	7860 ± 6012	4348 ± 4554	5500 ± 5868	4206 ± 4996
Educational status, (years) ^c	17.4 ± 1.0	16.3 ± 2.0	14.8 ± 4.0	14.6 ± 2.8
Fat consumption, g/day	23.2 ± 10.4	21.8 ± 13.6	31.7 ± 20.1	27.7 ± 14.4
Hemodynamic values during eyes open rest				
SBP, mm Hg	114.6 ± 4.5	107.6 ± 5.0	121.0 ± 5.8	111.1 ± 5.0
DBP, mm Hg ^b	78.9 ± 2.7	68.1 ± 2.9	79.4 ± 3.4	70.9 ± 2.9
HR, bpm	66.6 ± 3.4	71.4 ± 3.8	68.0 ± 4.9	66.9 ± 4.3
CO, liter/minute	5.3 ± 0.3	4.4 ± 0.3	4.9 ± 0.4	4.9 ± 0.4
SV, ml	80.1 ± 3.8	62.7 ± 4.2	73.9 ± 5.5	73.0 ± 4.8
TPR, mm Hg/liter per minute	17.6 ± 1.0	18.7 ± 1.1	19.0 ± 1.4	18.1 ± 1.2

^aValues are mean ± standard deviation.^b*p* < .04 for sex differences.^c*p* < .03 for group differences.

Within-Session Mean Hemodynamic Change Scores^a

	Eyes-Open Rest			TM Condition or Eyes-Closed Relaxation		
	TM Group	Control Group	p^b	TM Group	Control Group	p^b
SBP	-2.5	2.4	.01	-3.0	2.1	.04
DBP	-1.4	-0.5	NS	-2.9	-1.3	NS
HR	2.9	1.0	.03	0.3	-0.2	NS
CO	0.11	-0.14	.01	0.13	-0.11	NS
SV	-1.8	-3.3	NS	1.4	-1.8	NS
TPR	-0.7	0.5	.004	-1.0	0.3	.03

^aMean change scores adjusted for baseline values. Positive values indicate an increase, and negative values indicate a decrease from the minute 0 reading. All ns P values > .05.

^b NS = not significant.