ORIGINAL RESEARCH

Arterial Blood Pressure and Cardiovascular Responses to Yoga Practice

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ABSTRACT

Context • Yoga is qualitatively different from any other mode of physical activity in that it consists of a unique combination of isometric muscular contractions, stretching exercises, relaxation techniques, and breathing exercises. In particular, yoga postures consist of systemic isometric contractions that are known to elicit marked increases in mean blood pressure that are not observed during dynamic exercise. Stretching can also induce increases in blood pressure and sympathetic nerve activity in the muscles. Currently, not much is known about changes in blood pressure and other cardiovascular responses to yoga practice.

Objective • The study intended to determine the acute effects of one session of hatha yoga practice on blood pressure and other cardiovascular responses. To gain insight into the long-term effects of yoga practice, both novice (n =19) and advanced (n=18) yoga practitioners were studied.

Design • The two groups were matched for age, gender, BMI, and blood pressure.

Setting • The setting was a research laboratory at a university.

Participants • Thirty-six apparently healthy, nonobese, sedentary, or recreationally active individuals from the community participated in the study.

Intervention • The intervention comprised one session of yoga practice, in which participants followed a custom-made instructional video providing a yoga routine that consisted of a series of 23 hatha-based yoga postures.

Outcome Measures • Prior to arriving at the laboratory, each participant completed a research health questionnaire, a training-status questionnaire, and a yoga-experience questionnaire. Prior to the yoga practice, each participant's height, body fat percentage, trunk or lumbar flexibility, and arterial stiffness as assessed by carotid-femoral pulse wave velocity (cfPWV) were measured. For each posture during the yoga practice, the study continuously measured systolic, mean, and diastolic blood pressures, heart rate, stroke volume, and cardiac output.

Results • Systolic, mean, and diastolic blood pressures increased significantly during the yoga practice. The magnitude of these increases in blood pressure was greatest with standing postures. Heart rate and cardiac output increased significantly during yoga practice, especially with standing postures. Overall, no differences existed in cardiovascular responses between the novice and advanced practitioners throughout the yoga testing session; cfPWV velocity was significantly and inversely associated with lumbar flexion but not with sit-and-reach test scores.

Conclusions • The research team concluded that a variety of hatha yoga postures, especially standing postures, evoked significant increases in blood pressure. The elevation in blood pressure due to yoga practice was associated with increases in cardiac output and heart rate, which are responses similar to those observed in isometric exercise. The lack of obvious differences in blood pressure and other cardiovascular responses between novice and advanced yoga practitioners suggests that long-term yoga practice does not attenuate acute yoga responses. (*Altern Ther Health Med.* 2013;19(1):38-45.)

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Yoga is an alternative form of exercise that is designed to improve flexibility, muscular strength, and overall health. It is rapidly gaining popularity in the United States with an estimated 6.9% of Americans or 15.8 million people engaging in yoga in 2008.[1] Approximately half of yoga practitioners started practicing yoga to improve their overall health.[1] Evidence is accumulating to suggest the beneficial effects of yoga on mental and physical health, stress and anxiety, blood pressure, and glucose tolerance.[2-4]

Yoga is qualitatively different from any other mode of physical activity in that it consists of a unique combination of whole-body isometric muscular contractions, stretching exercises, relaxation techniques, and breathing exercises. Similar to other modes of physical activity, practice of yoga elicits acute increases in heart rate and oxygen consumption,[5, 6] albeit to a smaller extent. Much less is known about changes in blood pressure and other cardiovascular responses to yoga practice.

Yoga postures (asanas) consist of systemic isometric contractions and stretching of the skeletal muscles. Isometric muscle contractions are known to elicit marked increases in mean blood pressure that are not observed during dynamic exercise.[7] Stretching can also induce increases in blood pressure and sympathetic nerve activity in the muscles through the modulation of muscle mechanoreceptors.[8] On the other hand, relaxation techniques and meditation are integral components of yoga practice that could counteract the effects of muscle contraction and stretching related to increases in blood pressure Additionally, some yoga postures require whole-body inversion that results in a translocation of blood from the lower body to the upper body and the subsequent loading of cardiopulmonary baroreceptors, which could suppress sympathetic vasoconstrictor activity on the arterial wall.[9]

Accordingly, the primary aim of the present study was to determine the acute effects of one session of hatha yoga practice on blood pressure and other cardiovascular responses. To gain insight into the long-term effects of regular yoga practice, the research team studied both novice and advanced yoga practitioners.

The working hypothesis was that the mean blood pressure would increase markedly during yoga exercise, more substantially so in novice versus advanced practitioners

METHODS

Participants

The participants were recruited from the city of Austin, Texas, and its surrounding communities. A total of 36 healthy, nonobese, and sedentary or recreationally active individuals participated in the study. The participants were either novice yoga practitioners (n = 19) or advanced yoga practitioners (n = 18). Novice yoga practitioners must have never or rarely practiced yoga. Advanced yoga practitioners must have practiced yoga an average of 3 or more hours per week for a minimum of 12 consecutive months. Exclusion criteria included (1) smoking within the past 6 months; (2) uncontrolled hypertension; (3) a history of heart disease, peripheral artery disease, kidney disease, or other known cardiovascular problems; (4) a history of diabetes, gout, or other metabolic disease; (5) obesity, defined as a Body Mass Index (BMI) >30 kg/m^2; and (6) regular exercise training (endurance or resistance). The research team matched novice and advanced yoga groups for age, gender, BMI, and blood pressure. The Institutional Review Board reviewed and approved the study, and informed consent was obtained from all participants.

Intervention

Prior to the intervention, participants fasted a minimum of 4 hours and abstained from alcohol and caffeine for the previous 12 hours and from strenuous physical activity for the previous 24 hours.

The intervention comprised one session of yoga practice, in which participants followed a custom-made instructional video providing a yoga routine that consisted of a series of 23 hatha-based yoga postures. The categories of postures included (1) standing—nine postures, including Awkward 1, Awkward 2, Awkward 3, Standing Bow, Balancing Stick, Warrior, Triangle, Separate Leg Stretch, and Tree Pose; (2) floor—11 postures, including Savasana, Cobra, Full Locust, Half Tortoise, Camel Pose, Head to Knee, Stretch, Pigeon, Spine Twist, Bridge, and Easy Pose; (3) inversion—three postures, including Shoulder Stand, Plow, and Head Stand, all designed to mimic a typical hatha yoga session. Participants attempted each yoga posture as many times as necessary for successful completion of the entire yoga routine. Participants held the postures on average for 22 ± 2 seconds.

Procedures

Prior to arriving at the laboratory, each participant completed a research health questionnaire, a training-status questionnaire, and a yoga-experience questionnaire. All testing for female participants took place during the follicular phase of the menstrual cycle or during the placebo portion of the birth-control cycle.

Before the intervention, height and body mass and then performed skinfold-thickness measurements using the Lange skinfold caliper (Beta Technology, Santa Cruz, CA) to calculate body-fat percentage. Prior to the intervention, each participant's trunk or lumbar flexibility was measured using a traditional sit-and-reach test[10] and an inclinometer[11] (Isomed Uni-Level Inclinometer, Isomed, Inc, Portland, OR), following a 5-minute warm-up on a treadmill. Arterial stiffness (hardening of the arterial wall) was measured using the VP-2000 machine (Omron, Bannockburn, IL) while participants were in the supine position for at least 15 minutes in a quiet, dimly lit, temperature-controlled room (23-25°C). A neck brace held the carotid tonometry sensor in place, while a Velcro strap secured the femoral sensor. These measures of pulse transit time were used in conjunction with the measured distance between sensors to calculate the carotid-femoral pulse wave velocity (cfPWV),[12] the most established index of arterial stiffness

Arterial blood pressure (systolic, mean, and diastolic blood pressure) was measured continuously throughout the session using beat-by-beat, finger plethysmography (the Portapres Finger Plethysmograph, Finapres Medical Systems BV, Amsterdam, Netherlands). In this technique, the plethysmographic cuff was placed around the middle phalanx of the finger, and the modulated cuff pressure maintained transmural pressure at an effective zero. Prior to the yoga practice, the finger blood pressure was calibrated to the brachial blood pressure. The beat-by-beat results were subsequently analyzed with the Beatscope software (Finapres Medical Systems BV, Amsterdam, Netherlands), which calculated stroke volume and cardiac output using the validated Model Flow method. Sugawara et al have evaluated the use of this technology and found it to be valid during exercise.[13] For the values to be valid for analysis, the cardiovascular responses to each yoga posture must have reached steady state. The *steady state* was defined as at least 10 consecutive measurements in which the heart rate did not vary by more than 10 beats per minute and systolic blood pressure did not vary by more than 20 mm Hg. Total peripheral resistance was calculated as mean blood pressure/cardiac output. To assess how hard the participant worked or exerted himself or herself during the yoga postures, ratings on Borg's perceived exertion (RPE) scale was determined between the series of standing, floor, and inversion postures.

Statistical Analyses

An independent *t* test was used to compare baseline values between the novice and advanced groups and a two-way repeated measure ANOVA (postures x groups) to assess cardiovascular responses to yoga postures in both groups. Fisher's LSD post hoc analyses were used to identify significant differences among mean values and Pearson product-moment correlation analyses to assess associations. Significance was set a priori at $P<.05$ and reported descriptive statistical data as a mean ± SD for participants' characteristics and as a mean ± SEM (standard error of the mean) for cardiovascular responses, as the figures show.

RESULTS

Table 1 presents participants' selected characteristics. Prior to the intervention, the sit-and-reach score was significantly higher in the advanced than in the novice yoga group, whereas the lumber-flexion score was not different between the groups. Arterial stiffness, as measured by cfPWV, was not different between the groups.

Figure 1 displays blood-pressure responses to the yoga practice. Systolic, mean, and diastolic blood pressures increased significantly during yoga practice for both groups. The magnitude of increases in blood pressure was greatest with the standing postures (Table 2). Overall, no difference existed in blood-pressure responses between novice and advanced practitioners throughout the yoga testing session. As depicted in Figure 2, heart rate and cardiac output increased significantly during yoga practice, especially with standing postures. No differences existed between groups in cardiac output, total peripheral resistance, or rate-pressure product (or double product) an index of myocardial oxygen demand at any time during the yoga testing session. The rating of perceived exertion (RPE) was not different between novice and advanced groups for any yoga posture (13 ± 2 vs 12 ± 1 with standing; 11 ± 2 vs 10 ± 1 with floor postures; 13 ± 2 vs 11 ± 2 with inversion).

Table 1. Selected Participant Characteristics

Variable	Novice Group (n = 19) F/M	Advanced Group (n = 18) F/M
Gender, n	13/6	13/5
	Mean ± SD	**Mean ± SD**
Age, y	44 ± 16	44 ± 13
Body Mass Index, kg/m^2	23 ± 4	23 ± 4
Body Fat, %	22 ± 7	22 ± 7
Heart rate, beat/minute	54 ± 11	60 ± 8[a]
Systolic blood pressure, mm Hg	115 ± 11	115 ± 17
Diastolic blood pressure, mm Hg	69 ± 7	68 ± 11
Carotid-femoral PWV, cm/sec	940 ± 180	961 ± 238
Sit-and-reach, cm	32 ± 8	44 ± 7[a]
Lumbar flexion, degree	35 ± 9	42 ± 14
Physical Activity Score, unit	39 ± 19	37 ± 27
Yoga experience, y	0 ± 0	10 ± 6

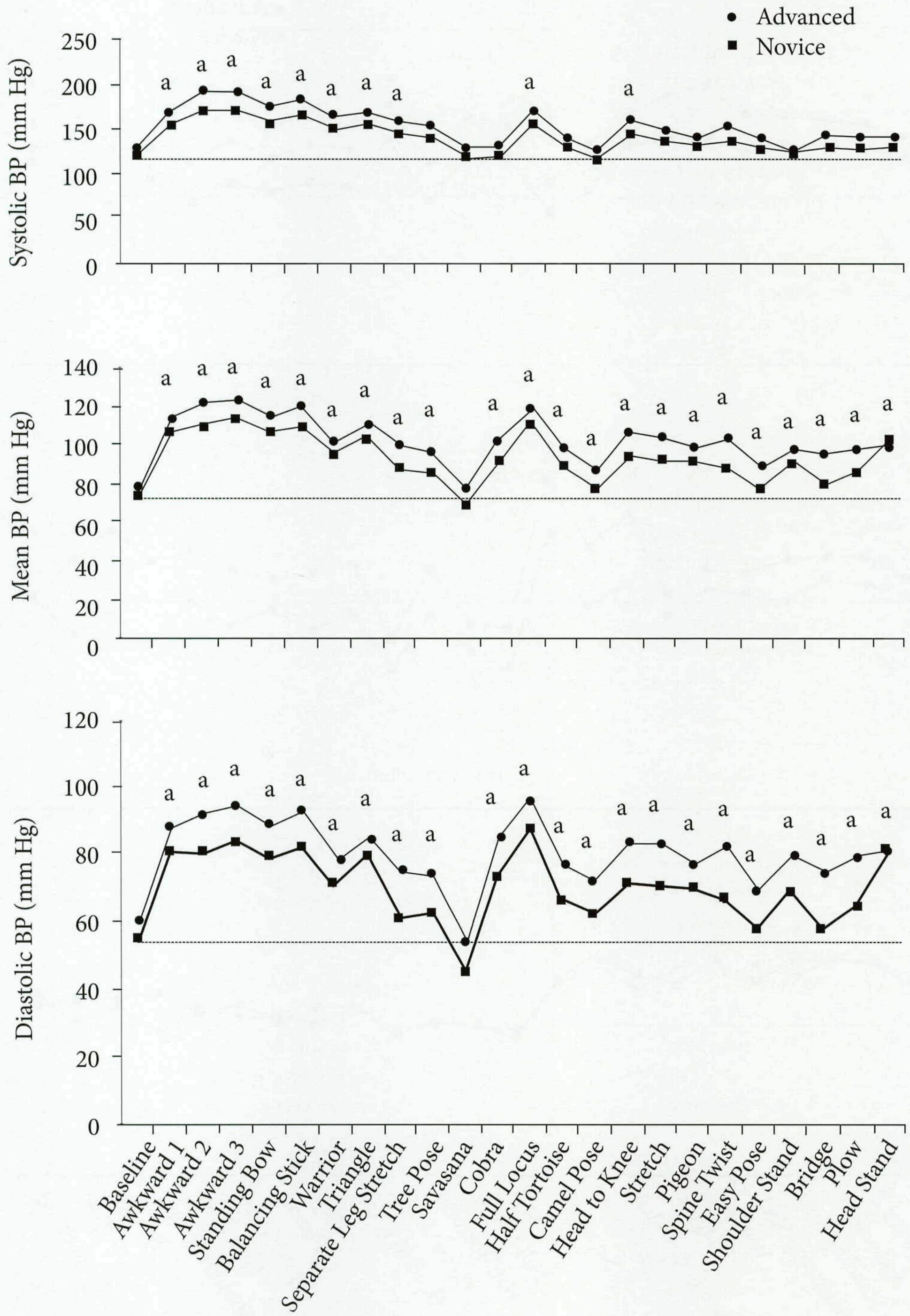
[a]$P<.05$ vs the novice group.
Abbreviations: kg/m^2 = kilogram per meter squared; mm Hg = millimeters of mercury; PWV = pulse-wave velocity; cm = centimeters.

Table 3 displays intercorrelations between age, blood pressure, carotid-femoral pulse wave velocity, trunk flexibility (lumbar flexion and sit-and-reach test), and years of yoga experience. Carotid-femoral pulse wave velocity was significantly and inversely associated with lumbar flexion (Figure 3) but not with the sit-and-reach test. Years of yoga experience was significantly associated with sit-and-reach test scores.

DISCUSSION

The salient findings of the current study are as follows. First, a variety of hatha yoga postures, especially standing postures, evoked significant increases in mean blood pressure. Second, the increases in blood pressure related to yoga practice were associated with elevations in cardiac output and heart rate, responses similar to those observed in isometric exercise. Third, no obvious differences existed in blood pressure and cardiovascular responses between novice and advanced yoga practitioners, suggesting that long-term yoga practice does not attenuate acute yoga responses.

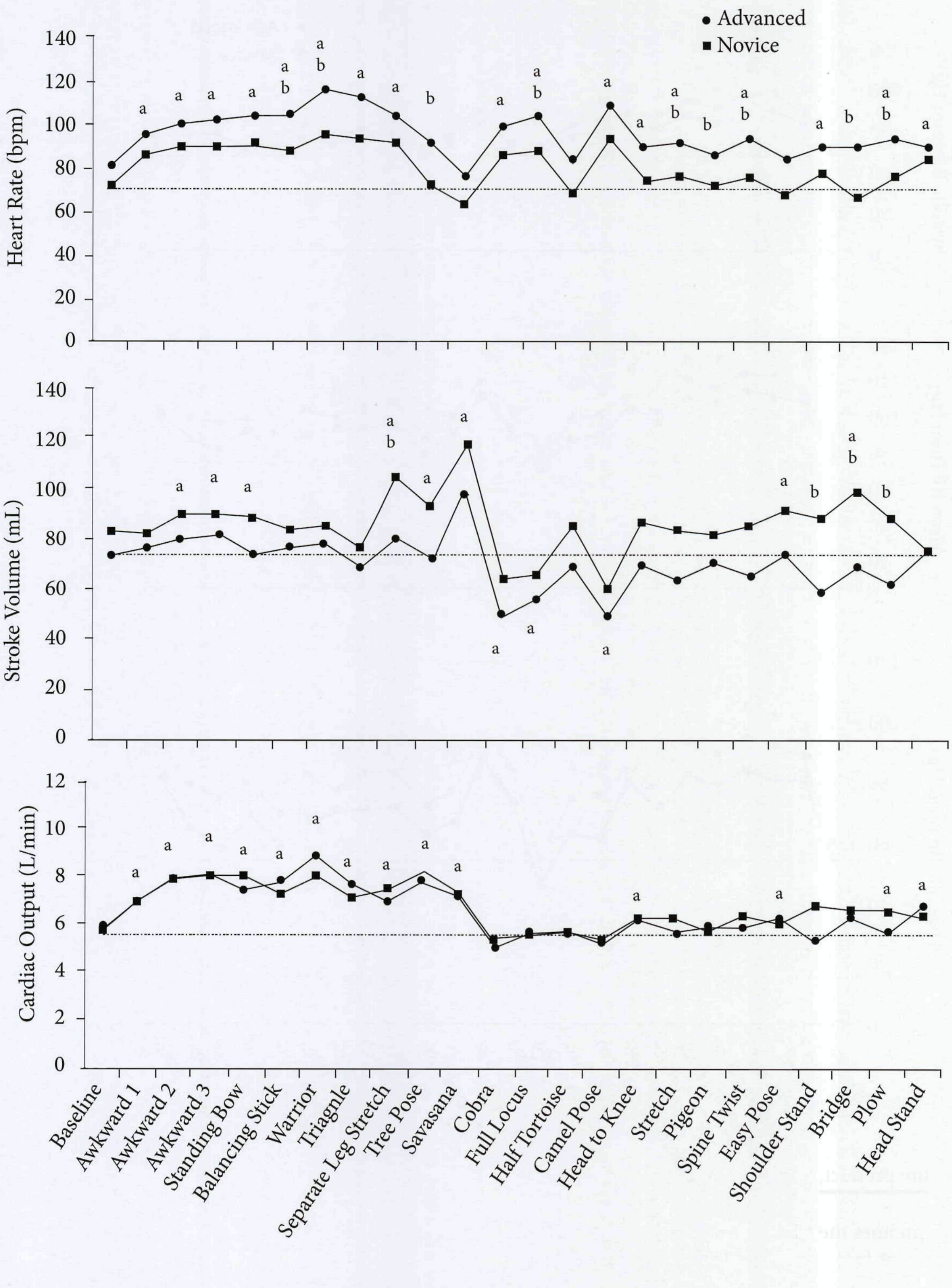
Figure 1. Changes in Blood Pressure (BP) in Response to Different Yoga Postures



[a] $P < .05$ vs baseline for both groups.

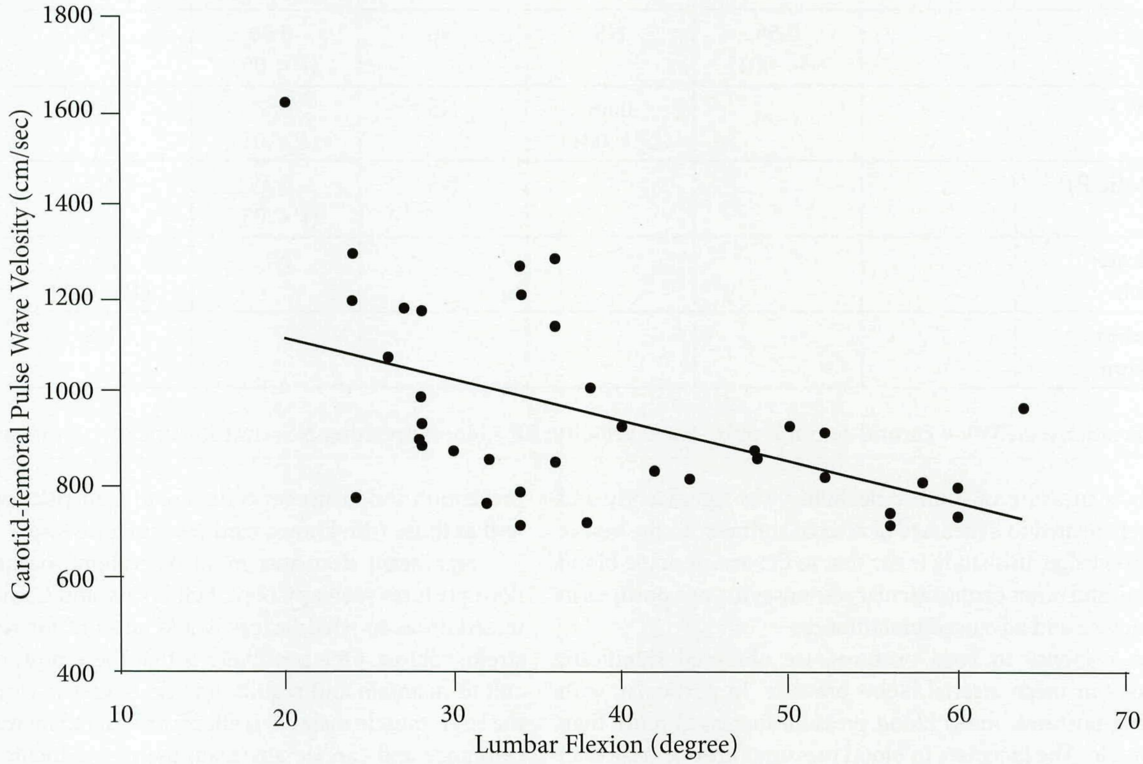
Note: No significant differences occurred in systolic, mean, and diastolic blood pressure between the groups.

Figure 2. Changes in Heart Rate, Stroke Volume, and Cardiac Output in Response to Different Yoga Postures



[a]$P < 0.05$ vs baseline for both groups; [b]$P < 0.05$ Advanced vs Novice

Figure 3. Association Between Lumbar Flexion and Carotid-Femoral Pulse Wave Velocity



Note: $r = -0.52$; $P < .01$

Table 2. Cardiovascular Responses to Different Categories of Yoga Postures[a]

	BASELINE (standing)	Δ with INVERSION postures	Δ with FLOOR postures	Δ with STANDING postures
Systolic BP, mm Hg	124	11	16	41[b,c,d]
Diastolic BP, mm Hg	57	18[b]	17[b]	23[b]
Mean BP, mm Hg	76	19[b]	19[b]	31[b]
Heart rate, beat/minute	75	0	8[b,c]	20[b,c,d]
Cardiac output, L/min	5.70	0.47[b]	0.09[c]	1.96[b,c,d]
Rate pressure product, unit	95	21[b]	25[b]	66[b,c,d]

[a]The table combines the novice and advanced groups because group differences were not apparent in most cardiovascular measures (except for heart rate; see Figures 1 and 2).
[b]$P < .05$ from baseline.
[c]$P < .05$ from inversion postures.
[d]$P < .05$ from floor postures.
Abbreviations: BP = blood pressure; mm Hg = millimeters of mercury; L/min = liters per minute.

Table 3. Pearson Product-Moment Correlation Coefficients

	Age	cfPWV	Systolic BP	Sit-and-Reach	Lumbar Flexion	Yoga Experience
Age		0.58 ($P < .001$)	NS	NS	-0.39 ($P < .05$)	NS
cfPWV			0.66 ($P < .001$)	NS	-0.52 ($P < .01$)	NS
Systolic BP				NS	-0.38 ($P < .05$)	NS
Sit-and-Reach					NS	0.56 ($P < .001$)
Lumbar Flexion						NS

Abbreviations: cfPWV = carotid-femoral pulse-wave velocity; BP = blood pressure; NS = not statistically significant.

Finally, a measure of lumbar flexibility was significantly and inversely related to a measure of arterial stiffness. To the best of our knowledge, this study is the first to determine acute blood pressure and other cardiovascular responses to yoga postures in both novice and advanced practitioners.

In response to yoga postures, we observed significant increases in mean arterial blood pressure. In particular, with standing postures, mean blood pressure increased more than 30 mm Hg. The increases in blood pressure (pressor response) were significantly and positively associated with the corresponding increases in heart rate and cardiac output. This pressor response, accompanied by a systemic cardiovascular response, mimics those typically observed during isometric exercise. Isometric contractions cause markedly greater increases in mean blood pressure than does dynamic aerobic exercise.[14] Although cardiac output increases simultaneously, it serves no useful purpose in increasing blood flow to the contracting and ischemic muscles, whose requirements for blood flow, metabolism, and vascular conductance do not increase.[14] Many yoga postures necessitate isometric contractions of small and large muscle mass, often for a prolonged period of time. Despite the more systemic nature of isometric contractions, however, the magnitude of the blood pressure and cardiovascular responses was rather small. It is plausible that other essential components of yoga, including relaxation techniques and meditation, may have acted to suppress excessive increases in blood pressure.

In the present study, standing yoga postures did evoke a significantly higher blood pressure response than floor or inversion postures. As such, medical practitioners may cautiously prescribe these postures to individuals who have recently experienced a cardiovascular event (stroke, myocardial infarction, coronary revascularization, etc) or those individuals with a high risk score due to uncontrolled hypertension, genetic disorders, a history of transient ischemic attacks, etc. This finding could be of clinical importance given the ever-increasing popularity of yoga exercise as an alternative method for prevention and treatment of disease in high-risk populations as well as those with known cardiovascular disease.[4,15]

Significant decreases in stroke volume occurred during floor postures such as Cobra, Full Locus, and Camel Pose. It is uncertain as to what factors would account for reductions in stroke volume. One possibility is that these postures are difficult to maintain and require intense isometric contractions of the large-muscle mass. This effect could act to increase vascular resistance and cardiac afterload, thereby reducing stroke volume.

Some investigators have suggested that poor postures or postural malalignments may be responsible for elevated blood pressure responses previously observed during yoga exercises.[6,16] If this notion is correct, advanced yoga practitioners should demonstrate attenuated blood pressure response to yoga postures. The results of the current study do not support this notion as no differences in blood-pressure responses occurred between novice and advanced practitioners. These results suggest that habitual yoga practices do not appear to attenuate the pressor responses that yoga practitioners experience.

In the present study, sit-and-reach test scores of trunk flexibility were significantly greater in the advanced practitioners and were significantly associated with years of yoga experience. This positive association is in accordance with previous studies demonstrating improvements in flexibility following a yoga intervention.[17,18] This improvement is highly conceivable given the fact that practitioners consider good hip flexibility to be the most important requirement for at least half the postures in hatha yoga.[19] A recent study reported that poor trunk flexibility, as measured by a sit-and-reach test, was associated with arterial stiffening in older populations.[20] Unlike this previous study, in the present study the sit-and-reach test scores were not related to measures of arterial stiffness, whether groups were combined, analyzed independently, or stratified by age. Interestingly, a significant correlation exists between lumbar flexion, as assessed by an inclinometer, and arterial stiffness. The validity of sit-and-reach tests for the assessment of trunk flexibility remains controversial.[10] It is likely that the sit-and-reach test and lumbar flexion may be capturing different entities (eg, hamstring flexibility).

CONCLUSION

In conclusion, we observed a significant increase in mean blood pressure as well as elevations in heart rate and cardiac output in response to yoga postures in general and standing yoga postures in particular. These pressor responses were not different between novice and advanced yoga practitioners. As such, medical practitioners may cautiously prescribe these postures to individuals who have recently experienced a cardiovascular event or those individuals with elevated risks of experiencing cardiac events.

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