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Effect of yoga on arterial stiffness in elderly subjects with increased pulse pressure: A randomized controlled study

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ABSTRACT

Objective: We aimed to determine the effect of yoga on arterial function in elderly with increased pulse pressure (PP).
Design: Randomized controlled study with two parallel groups.
Participants: Elderly subjects with PP ≥ 60 mmHg ($n = 60$).
Interventions: Yoga group ($n = 30$) was assigned for yoga training and brisk-walking (BW) group ($n = 30$) for brisk-walk with stretching exercise for 1 h in the morning for 6 days in a week for 12 weeks.
Main outcome measures: Arterial stiffness measures: Brachial-ankle pulse wave velocity (baPWV), Carotid-femoral pulse wave velocity (c–f PWV), aortic augmentation index (AIx@75), arterial stiffness index at brachial (bASI) and tibial arteries (aASI). Total serum nitric oxide concentration (NO*x*) as an index of endothelial function. Heart rate variability (HRV) measures: Low frequency and high frequency in normalized units (LFnu, HFnu) and LF/HF ratio.
Results: The mean between-group change (with 95% CI) in arterial stiffness: c–f PWV(m/s) [1.25(0.59–1.89); $p < 0.001$], baPWV(m/s) [1.96(0.76–3.16), $p < 0.01$], AIx@75 [3.07(0.24–5.89), $p = 0.066$], aASI [8.3(4.06–12.53), $p < 0.001$]; endothelial function index: NO(μmol/L) [−9.03(−14.57 to −3.47), $p < 0.001$]; SBP(mmHg) [14.23(12.03–16.44), $p < 0.001$], DBP(mmHg) [0.1(−1.95–2.15), $p = 0.38$], PP(mmHg) [14.07(11.2–16.92), $p < 0.001$], MAP(mmHg) [4.7(3.08–6.32), $p < 0.001$]; and cardiac autonomic function: LF(nu) [4.81(1.54–8.08), $p < 0.01$], HF(nu) [−4.13(−7.57 to −0.69), $p < 0.01$], LF/HF ratio [0.84(0.3–1.37), $p < 0.001$], indicate significant difference in effects of two intervention on arterial stiffness, endothelial function, BP and cardiac autonomic activity. There was significant change within-yoga group in vascular function, BP and autonomic function, while no significant change within-BW group was observed.
Conclusion: Our findings suggest that yoga program offered was more effective than brisk-walk in reducing arterial stiffness along with BP in elderly individuals with increased PP. Yoga can also significantly reduce sympathetic activity and improve endothelial function with enhancement in bioavailability of NO.

1. Introduction

Hypertension along with aging is a major risk factor for cardiovascular (CV) morbidity and mortality.[1] Vascular stiffness and endothelial dysfunction are the major contributing factors and predominant mechanism that develop hypertension in elderly. Two major age-related structural changes that take place in elastic arteries are stiffness and dilatation. These changes results in decline or failure in expansion of aorta in response to ventricular systole which leads to elevation in systolic blood pressure (SBP) (ISH: isolated systolic hypertension) and failure to recoil leads to decrease in diastolic blood pressure (DBP) thus causing widening of pulse pressure (PP). Hence, PP is a best tool for measuring vascular aging and a good marker for CV risk in elderly. Another factor related to arterial stiffness that elevates SBP in elderly is early arrival of wave reflection during systole.[1] Pulse pressure; a pulsatile component of blood pressure (BP) is more closely associated to CV events than SBP or DBP alone.[2]

Arterial stiffness is an independent and strong predictor of CV morbidity and mortality in hypertensive without any overt CV disease[3,4] and also in well-functioning elderly individuals.[5] Studies have shown a positive correlation between PP and arterial stiffness.[6–8] Pulse wave velocity (PWV), augmentation index (AIx)

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and arterial stiffness index (ASI) are recommended measures of arterial stiffness.[9,10] PWV is a measure of regional arterial stiffness. More the stiffness, higher is the PWV. AIx is a measure of wave reflection which elevates with an increase in arterial stiffness.[9]

The age-related endothelial dysfunction associated with decreased bioavailability of nitric oxide (NO), a potent vasodilator, contributes to vascular stiffness and hypertension.[11] Other age-related physiological changes that contribute to hypertension in elderly are increased sympathetic activity, decreased baroreceptor sensitivity, decreased alpha- and beta- adrenergic receptor responsiveness and low plasma renin activity.[1]

The elderly individuals suffering from ISH are often resistant to pharmacological treatment, so any attempts to reduce the SBP aggressively lowers DBP (decreased with age) to such an extent to compromise coronary blood flow.[12] Moreover, it has also been reported that arterial stiffness increases at a faster rate even in treated hypertensives with well controlled BP than in a normotensives.[13] These findings necessitate an alternative approach that controls hypertension along with the progression of arterial stiffness with age in order to prevent the CV mortality and morbidity. Among the life-style modalities, we have found a significant reduction in SBP and PP following yoga practice for 6 weeks in elderly subjects with grade-I hypertension in a preliminary study.[14] But, the exact underlying mechanism of benefit remains unknown. Therefore, we aimed (1) to determine the effect of yoga on arterial stiffness in elderly with increased PP and (2) to explore the benefits of mechanism of yoga on hypertension.

2. Methods

2.1. Ethics statement

The study was approved by the institutional ethical committee of Shri B.M.Patil Medical College, Hospital and Research Centre, BLDE University, India, as per the guidelines (2006) of Indian Council of Medical Research.[15] We followed the declaration of Helsinki and the study was reported as per the recommendations of the CONSORT group.[16] Informed written consent was obtained from participants for participation in the study. The study was registered retrospectively in the Clinical Trial Registry-India (CTRI/2011/10/002077).

2.2. Participants and study design

A total of 60 elderly subjects ≥60 years with increased PP ≥ 60 mmHg were recruited through advertisements and geriatric health camp for the study. The probability was 80% that study will detect a treatment difference at a two-sided 0.05 significant level, if the true difference between treatments was 4 units and standard deviation of the outcome variable was 5.[14] An open parallel-group randomized controlled study design was adopted. Subjects with SBP □ 159 mmHg and DBP □ 99 mmHg; CV risk factors such as diabetes mellitus, hypercholesterolemia and high triglyceride level; history of secondary hypertension, neuromuscular disorders, alcoholism, regular yoga practice and on any medications were excluded from the study. Participants were asked to stop if taking any vitamin supplements or herbal drugs before enrollment. This criterion for selection of subjects for life-style changes intervention for 3 months was as per the 2007 guidelines of the task force for the management of arterial hypertension of the European Society of hypertension and of the European Society of Cardiology.[17]

Volunteers were screened at visit 1–3. At visit 4, the baseline examination, randomization and allocation of selected subjects to either study group or control group was done. Subjects were randomly allocated to Yoga group ($n = 30$) and brisk-walking (BW) group ($n = 30$) by using random number table. Post-intervention investigations were made at visit 5. All the recordings were made in the morning between 8.00 h and 10.00 h after supine rest for 10 min. No intervention was given on the day of investigation. Persons handling data analysis were kept blinded.

2.3. Intervention

The yoga training includes loosening practices, asanas (maintaining postures), pranayama (breathing exercises) and cyclic meditation[18]: yoga based guided relaxation technique (Table S1, Supplementary material). Yoga practice (asanas, pranayama & meditation) was taught for the first 2 weeks and the complete module was practiced for the last 10 weeks. Loosening practices and asanas were practiced for 15–20 min while pranayama and relaxation technique/meditation for 40–45 min. Emphasis was placed on practicing all the components of yoga in a relaxed way with slow and paced breathing. The protocol for the BW group consists of flexibility or stretching practices for 20 min followed by brisk-walk for 35 min and rest for 5 min (Table S2, Supplementary material). Both the groups received their respective training for 6 days in a week for 1 h daily in the morning from 06:00 h to 07:00 h for 12 weeks under the supervision of experienced authorized instructors.

2.4. Measurement of blood pressure

As BP is more variable in older people, so we have taken average of nine BP readings. Brachial BP was measured thrice with an interval of 1 min on every visit for three consecutive days in a sitting posture using mercury sphygmomanometer.[1,19] Pulse pressure was estimated as the difference between systolic and diastolic BP. Mean arterial pressure (MAP), an average arterial pressure in an individual during single cardiac cycle was estimated by adding 1/3rd of PP to the DBP.

2.5. Evaluation of arterial stiffness

Vascular stiffness was evaluated by oscillometric method using a validated 8-channel non-invasive automatic device (Periscope, Genesis Medical Systems, India).[20] Periscope is a real time PC-based simultaneous acquisition (200 samples per second) and analysis system. This device uses four BP cuffs and two-channel ECG leads to record arterial pressure waveforms and ECG simultaneously. The recordings were made in supine position. BP cuffs were wrapped over both upper arms (brachial artery) and legs (tibial artery) above ankle. ECG electrodes were placed on the ventral surface of both wrists and medial side of the ankles. The BP cuffs were connected to oscillometric pressor sensor and plethysmographic sensor to determine pressure waveforms and volume pulse waveform. The data obtained in 10 s was stored in the computer for further analysis. Periscope supports a sophisticated digital-signal algorithm to calculate all the results. As the device is fully automated and does not require any operator for handling any probe to record the waveforms, so it is devoid of any operator bias.

2.5.1. Calculation of pulse wave velocity

Brachial-ankle PWV (baPWV), a measure of central and peripheral arterial stiffness was measured using arterial pressure waveforms and ECG recordings. The pulse transit time (PTT) in seconds elapsed between brachium and respective ankle was calculated as the time difference between the R-wave of ECG and foot of respective pulse wave. The distance between the brachium and ankle was calculated automatically according to the height of the subject. The PWV was calculated by dividing the distance by PTT. The carotid-femoral PWV (c–f PWV), a measure of aortic stiffness