Evaluation of Cardiovascular Functions during the Practice of Different Types of Yogic Breathing Techniques

Abstract

Introduction: Yoga is the science of right living practice to promote health. Many studies have documented the cardiovascular effects of various yogic breathing techniques (YBTs), comparing the cardiovascular changes before and after the practice. However, there is a lack of study reporting the cardiovascular changes during the practice of YBT. **Materials and Methods:** Twenty healthy individuals performed four different YBTs (*Bhastrika*, *Bhramari*, *Kapalbhati*, and *Kumbhaka*) in four different orders. Cardiovascular variables such as systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), stroke volume (SV), cardiac output (CO), pulse interval (PI), and total peripheral resistant (TPR) were assessed using a continuous noninvasive blood pressure monitoring system, before, during, and immediately after each YBT. Data were analyzed using repeated measures analysis of variance followed by *post hoc* analysis with Bonferroni adjustment for multiple comparisons using Statistical Package for the Social Sciences, Version 16.0. **Results:** Results of this study showed a significant increase in DBP, MAP, HR, and CO along with a reduction in PI during *Bhastrika*; a significant increase in DBP, MAP, HR, and TPR with a reduction in SV, CO, and PI during *Bhramari pranayama*; a significant increase in SBP, DBP, MAP, HR, and CO with a reduction in PI during *Kapalbhati*; and a significant increase in SBP, DBP, MAP, and TPR with a reduction in SV and CO during *Kumbhaka* practice. **Conclusion:** In healthy individuals, cardiovascular changes during the practice of *Bhastrika* and *Kapalbhati* are more or less similar to each other and are different from those of *Bhramari* and *Kumbhaka* in most of the variables.

Keywords: *Blood pressure, cardiovascular functions, pranayama, yoga*

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Introduction

Yoga is the science of right living and can be included in daily life.[1] It consists of the practice of definite posture (*asana*), controlled breathing (*pranayama*), etc.[2] Breathing forms the bridge between the voluntary and autonomic nervous systems. The yogic breathing techniques (YBTs) involve nostrils manipulation, breathe holding/retention, modification in the pace of breath, production of humming sounds, etc.[3,4] Different types of YBT have been shown to produce different cardiovascular[5] and autonomic effects.[6] Many studies have evaluated the autonomic functions during various yoga practices such as breath awareness, alternate nostril breathing (ANB),[7] yoga-based–guided relaxation,[8] and meditative states.[9] Likewise, many studies have documented the cardiovascular effect of various YBTs such as breath awareness, right nostril breathing, left nostril breathing,[6] ANB,[6,10] *Kapalbhati*, *Bhastrika*, *Kukuriya*, *Savitri*, *Pranav*,[10] and *Bhramari pranayama*,[11] comparing before and after the practice. However, only very few studies have documented the cardiovascular changes during the practice of YBTs such as breath awareness and ANB.[7] It suggests that there is a lack of scientific evidence reporting the cardiovascular changes during the practice of various YBTs that are commonly practiced in India and in many parts of the world such as *Bhastrika* (bellows breath), *Bhramari* (humming bee breath), *Kapalbhati* (frontal brain cleansing breathing), and *Kumbhaka* (voluntary breath retention). Hence, this study was conducted to evaluate the cardiovascular effect of *Bhastrika*, *Bhramari*, *Kapalbhati*, and *Kumbhaka* in healthy individuals.

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Materials and Methods

Participants

Twenty healthy individuals with the mean (standard deviation) age of 23.40 (3.05) years were recruited from a residential university located in South India. Both male and female participants aged 18 years and above and willing to participate in the study were included, while participants with a history of any illness (systemic or mental), chronic smoking, or alcoholism and the participant who is not able to perform the selected YBT were excluded. The study protocol was approved by the Institutional Ethics Committee, S-VYASA (Deemed to be University), Bengaluru (RES/IEC-SVYASA/76/2015), and signed written informed consents were obtained from participants.

The study design

A single-group repeated measures design was adopted, in which all participants performed four different types of YBT in four different orders. The order was randomly selected using a lottery method as follows: twenty papers (five containing the word "*Bhastrika*" [i.e., 1st order], five containing the word "*Bhramari*" [i.e., 2nd order], five containing the word "*Kapalbhati*" [i.e., 3rd order], and five containing the word "*Kumbhaka*" [i.e., 4th order]) were put in an envelope, and each participant was asked to draw a paper from the envelope. The paper each participant drew out determined the order in which the respective YBTs were done.[2] In the first order (n = 5), participants performed *Bhastrika* followed by *Bhramari*, *Kapalbhati*, and *Kumbhaka*; in the second order (n = 5), participants performed *Bhramari* followed by *Kapalbhati*, *Kumbhaka*, and *Bhastrika*; in the third order (n = 5), participants performed *Kapalbhati* followed by *Kumbhaka*, *Bhastrika*, and *Bhramari*; and in the fourth order (n = 5), participants performed *Kumbhaka* followed by *Bhastrika*, *Bhramari*, and *Kapalbhati* with the interval of 5 min between each YBT. Baseline assessment was taken at rest before starting of the YBT, whereas during and post assessments were taken during and immediately after each YBT.

Assessments

Cardiovascular variables such as systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), stroke volume (SV), cardiac output (CO), pulse interval (PI), and total peripheral resistant (TPR) were assessed in a sitting position using a noninvasive blood pressure (BP) monitoring system (Finapres Continuous Non-Invasive Blood Pressure Systems, Netherlands). A finger cuff was positioned in between the interphalangeal joints of the left middle finger. A noninvasive BP cuff was positioned on the left upper arm at heart level and ensured that the cuff marker was directly above the brachial artery. The elbows were flexed and the hands were kept on the knees. The brachial correction was made before assessment and assessments were taken at rest (during normal breathing) before starting of the YBT (baseline), during, and immediately after each YBT.

Intervention

Bhastrika (5 min)

Participants were asked to perform forceful inhalation and forceful exhalation through both nostrils for the duration of 1 min. This is one round and it was repeated for three rounds with a rest (normal breath) period of 1 min between each round.[1]

Bhramari (5 min)

Participants were asked to perform inhalation through both nostrils and then while exhaling should produce sound of a humming bee for the duration of 5 min.[2]

Kapalbhati (5 min)

Participants were asked to perform forceful exhalation followed by normal inhalation through both nostrils[1] for the duration of 1 min. This is one round and it was repeated for three rounds with a rest (normal breath) period of 1 min between each round.

Kumbhaka (breath retention) (5 min)

Participants were asked to take a deep inhalation through both nostrils, followed by a voluntary breath-holding/retention[1] by closing the right and left nostrils using participants' thumb and ring finger of the right hand, respectively, for the duration of 1 min. Then, the participants were asked to slowly exhale through both nostrils and maintain the normal breath for 1 min. The same procedure was repeated for another two times (total 3 times of breath-holding [1 min each] with a rest [normal breath] period of 1 min between each breath-holding). The time of breath-holding and rest period was maintained using a stopwatch. To ensure the breath-holding, respiration was monitored using a volumetric pressure transducer fixed around the trunk about 8 cm below the lower costal margin while the participants sat erect.

Data extraction

Brachial artery SBP and DBP were derived from finger arterial pressure using a height correction unit and waveform filtering and level correction methods supplied by the BeatScope software package (Finapres Medical Systems B.V., 184 Netherlands).[3,12] SV, CO, and TPR were also derived from the standard formula using BeatScope Easy version 2.0 (Smart Medical, Cotswold Business Village, Moreton-in-Marsh, United Kingdom) computer-based program. The data obtained were transformed into a Microsoft Excel sheet for data analysis.[12]

Data analysis

Statistical analysis was performed using repeated measures analysis of variance (RMANOVA). If there was a significant difference exists in RMANOVA, then a *post hoc* analysis with Bonferroni adjustment was performed for multiple comparisons using Statistical Package for the Social Sciences (SPSS) for Windows, Version 16.0. Chicago, SPSS Inc. A $P < 0.05$ was considered statistically significant.

Results

Of 36 participants, 16 participants did not fulfill the inclusion criteria and hence did not include in the study. Recruited twenty participants' data were collected and performed the analysis. The details of the results are provided in Table 1.

Bhastrika

During *Bhastrika* practice, a significant increase in DBP, MAP, HR, and CO along with a significant reduction in PI was observed. In the recovery period, the increase in DBP, MAP, and HR along with a reduction in PI was sustained.

Bhramari

During *Bhramari* practice, a significant increase in DBP, MAP, HR, and TPR with a significant reduction in SV, CO, and PI was observed. In the recovery period, the reduction in SV and CO was sustained, whereas the rest of the variables revert back to normal.

Kapalbhati

During *Kapalbhati* practice, a significant increase in SBP, DBP, MAP, HR, and CO with a significant reduction in PI was observed. In the recovery period, the increase in DBP and HR along with a reduction in PI was sustained.

Kumbhaka

During *Kumbhaka* practice, a significant increase in SBP, DBP, MAP, and TPR with a significant reduction in SV and CO was observed. In the recovery period, the increase in MAP was sustained, whereas the rest of the variables revert back to normal.

Table 1: Cardiovascular changes while practicing various *pranayama* techniques (repeated measures analysis of variance and *post-hoc* analysis with Bonferroni adjustment for multiple comparisons)

Pranayama techniques	Assessments	SBP (mmHg)	DBP (mmHg)	MAP (mmHg)	HR (beats/min)	SV (l)	CO (l/min)	Pulse interval (ms)	TPR (mmHg.min/l)
Baseline		115.03±14.54	70.82±9.23	87.91±10.64	83.97±10.91	70.29±13.00	5.84±1.23	735.84±98.40	1.03±0.28
Bhastrika	During	119.50±14.14	74.91±9.23*	91.99±10.69*	114.20±13.92*	66.46±12.05	7.50±1.58*	570.27±80.90*	0.97±0.29
	Post	122.06±14.11	77.31±10.88*	94.61±12.12*	93.74±14.80*	63.99±9.90	5.95±1.26	679.75±114.09*	1.13±0.38
Bhramari	During	119.82±15.17	78.40±10.67*	94.34±11.72*	92.40±11.28*	58.25±8.94*	5.30±1.06*	673.11±81.04*	1.23±0.36*
	Post	111.98±13.82	72.11±8.79	88.08±9.90	86.45±12.47	62.48±9.93*	5.34±1.08*	719.30±106.70	1.12±0.40
Kapalbhati	During	123.81±12.97*	76.73±8.89*	96.03±10.31*	106.90±13.01*	71.27±12.39	7.58±1.79*	592.33±76.40*	1.00±0.30
	Post	116.97±12.96	75.23±8.30*	91.68±9.26	92.01±11.32*	63.61±11.15	5.78±1.12	676.74±91.34*	1.07±0.31
Kumbhaka	During	126.47±18.60*	82.44±8.98*	99.54±12.51*	88.75±11.47	59.43±16.24*	5.15±1.39*	698.56±93.99	1.31±0.37*
	Post	120.05±11.40	73.26±8.03	91.95±8.71*	85.77±11.43	73.02±10.89	6.19±1.16	728.46±114.98	1.13±0.83

All values are in mean±SD. *$P<0.05$. SBP=Systolic blood pressure, DBP=Diastolic blood pressure, MAP=Mean arterial pressure, HR=Heart rate, SV=Stroke volume, CO=Cardiac output, TPR=Total peripheral resistant, SD=Standard deviation

Discussion

Autonomic nervous system plays a vital role in regulating and maintaining the cardiovascular functions, such as SBP, DBP, and HR.[13] Literature suggests that SBP is the byproduct of peripheral resistance (PR) and CO, in which CO is the byproduct of SV and HR.[14] The results of this study showed a significant increase in SBP during the practice of *Kapalbhati* and *Kumbhaka* (*Kumbhaka* > *Kapalbhati*). In *Kapalbhati*, a significant increase in SBP might attribute to the significant increase in CO due to a significant increase in HR during the practice. However, in *Kumbhaka*, the significant increase in SBP might attribute to the significant increase in TPR during the practice. Hence, *Kapalbhati* increases SBP by increasing CO through increased HR, whereas *Kumbhaka* increases SBP by increasing TPR.

Although there was a significant increase in DBP during all YBTs (*Kumbhaka* > *Bhramari* > *Kapalbhati* > *Bhastrika*), it was sustained in the recovery period only after *Bhastrika* >*Kapalbhati* and revert back to normal after *Bhramari* and *Kumbhaka*. Here, even though DBP increases during all YBTs, the contributing factors are different in different YBTs. For example, the increased DBP during *Bhastrika* and *Kapalbhati* might attribute to the significant increase in HR and CO; during the *Bhramari*, it might attribute to the significant increase in HR and TPR; and during the *Kumbhaka*, it might attribute to the significant increase in TPR. The sustained increase in DBP even after the practice of *Kapalbhati* and *Bhastrika* could be due to the sustained increased level of HR after these practices.

A significant increase in MAP during all YBTs (*Kumbhaka* > *Kapalbhati* > *Bhramari* > *Bhastrika*) might attribute to the significant increase in DBP during all the practices because MAP is the byproduct of DBP and pulse pressure. MAP reverts back to normal only after *Bhramari* and *Kapalbhati*, and this could possibly be due to the reduction in the TPR after *Bhramari* and CO after *Kapalbhati*.

A significant increase in HR and reduction in PI were observed in *Bhastrika* > *Kapalbhati* > *Bhramari*, no such significant change was observed during *Kumbhaka*, and it was sustained after *Bhastrika* > *Kapalbhati* and revert back to normal after *Bhramari*. It might have attributed to the increased breath rate during the practice of *Bhastrika* and *Kapalbhati*, whereas the significant increase in HR and reduction in PI during *Bhramari* might attribute to parasympathetic withdrawal.[15]

During *Bhramari* and *Kumbhaka*, a significant reduction in SV (*Bhramari* > *Kumbhaka*) and CO (*Kumbhaka* > *Bhramari*) was observed but the reduction was sustained only after *Bhramari* and revert back to normal after *Kumbhaka*. The reduction in the CO might be due to the significant reduction in the SV. In contrast to *Bhramari* and *Kumbhaka*, there was a significant increase in CO during *Kapalbhati* and *Bhastrika*. This effect could be due to the significant increase in HR during these practices.

During *Bhramari* and *Kumbhaka*, a significant increase in TPR (*Kumbhaka* > *Bhramari*) was observed and revert back to normal after the practice. The reason for this change is not clear, and thus, it needs to be explored in the future studies.

The exact mechanism of the YBT on cardiovascular functions is not well defined. However, the possible mechanisms for the effect of various YBTs are as follows: Literature suggests that slow-pace *Bhastrika* (6 breaths/minute) produces a reduction in BP and HR (indicative of parasympathetic activation), while fast-pace *Bhastrika* (>60 breaths/minute) produces an increase in HR, rate pressure product, and double product[13] (indicative of an increase in load on the heart and subsequent reduction in HR variability [HRV]).[14] Thus, the cardiovascular effect of fast-pace *Bhastrika* provided in our study might be attributed to increased workload on the heart and reduced HRV due to increased sympathetic activation or reduced parasympathetic activity.

Evidence suggests that Kapalbhati increases low-frequency (LF) spectrum of HRV, and LF: HF ratio and reduces high-frequency (HF) spectrum of HRV, indicating increase in sympathetic activity[4] or reduction in parasympathetic activity and arterial baroreflex sensitivity.[4,13,16] The cardiovascular findings of the study during *Kapalbhati* are consistent with the previous study findings (i.e., increase in SBP, DBP, and HR).[16] Thus, the cardiovascular changes during the *Kapalbhati* practice might be attributed to sympathetic arousal or reduced vagal tone and/or reduced baroreflex sensitivity.

A previous study showed an increase in the LF spectrum of HRV and a reduction in the HF spectrum of HRV and time-domain variables (indicative of parasympathetic withdrawal) during *Bhramari* practice.[15] Likewise, literature suggests that breath retention leads to increased sympathetic tone in response to hypoxia and hypercapnia.[3] Results of the present study showed a significant increase in TPR (indicative of a possible sympathetic shift in the autonomic activity)[4] during *Bhramari* and *Kumbhaka* practice. Breathing at the resonant frequency and breath retention has been shown to reduce the circulatory load by improving oxygen saturation and gaseous exchange. Thus, the reduction in SV and CO during *Bhramari* and *Kumbhaka* might be a result of the body’s compensatory mechanism to either increased TPR or low circulatory load.[4] Hence, cardiovascular changes during *Bhramari* and *Kumbhaka* might be due to either parasympathetic withdrawal or sympathetic activity.

In summary, cardiovascular changes during *Bhastrika*, *Kapalbhati*, *Bhramari*, and *Kapalbhati* might be due to either parasympathetic withdrawal or sympathetic activity. It might be due to the nature of intervention that needed constant attention during the practice. However, the results of the study suggest that during the fast YBT, parasympathetic withdrawal or sympathetic activity might have influenced the cardiovascular functions by directly acting on the central, i.e., the heart (i.e., by increasing the workload of the heart as indicated by increased HR and CO), while during *Bhramari* and *Kumbhaka*, it might have influenced the cardiovascular functions by acting on the peripheral (i.e., by increasing peripheral vasoconstriction as indicated by increased TPR). Moreover, the results of the study also suggest that the parasympathetic withdrawal or sympathetic activity was sustained even after fast YBT (i.e., *Bhastrika* and *Kapalbhati*), while it was reverted back to normal immediately after *Bhramari* and

Kumbhaka. However, the reason for the above statement is not clear, and thus, the exact underlying mechanisms needs to be studied in the future studies.

Strengths of the study are (i) this is the first study evaluating the cardiovascular effect of selected YBT during the practice itself, and (ii) beat-to-beat changes in the BP were measured using a standard, advanced, noninvasive BP monitoring system. Limitations of the study are (i) small sample size, (ii) the sample size calculation was not made based on any previous study, and (iii) assessments such as HRV and baroreflex sensitivity would have provided more information. Hence, further studies are required with larger sample size using all the above-mentioned objective variables for the better understanding.

Conclusion

In healthy individuals, cardiovascular changes during the practice of *Bhastrika* and *Kapalbhati* are more or less similar to each other and are different from those of *Bhramari* and *Kumbhaka* in most of the variables.

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Conflicts of interest

There are no conflicts of interest.

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