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Relationship of breathing pattern with vascular tone and arterial stiffness in young healthy individuals

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ABSTRACT

Objectives: A dynamic interaction exists between respiration, cardiovascular system, and autonomic nervous regulatory mechanisms as demonstrated by respiratory sinus arrhythmia. The vascular tone might also demonstrate a similar variability during inspiration and expiration. The breathing patterns by influencing the sympathetic outflow may have an impact on the vascular tone and hence cardiovascular system at large. The present study was undertaken to assess the quiet breathing pattern and its relation with vascular tone, hemodynamics, and arterial stiffness in normal young healthy individuals.

Materials and Methods: The study involved 46 young healthy adults (both males and females) aged 19–25 years. Breathing parameters included were respiratory rate (RR), inspiration time (IT), expiration time (ET), and inspiration-expiration ratio (I/E ratio). Vascular parameters included were reflection index (reflects vascular tone) and stiffness index (reflects arterial stiffness). Blood pressure (BP in mmHg) and heart rate (bpm) were measured.

Results: IT and ET were almost equal with no significant difference. ET was weekly correlated with diastolic BP ($r = -0.410$; $P = 0.058$) in females but not in males. Breathing pattern was not significantly associated with vascular tone and arterial stiffness.

Conclusion: IT, ET, I/E ratio, and RR were not significantly correlated with vascular tone and arterial stiffness suggesting that breathing does not influence the arterial health and function in young healthy individuals. There was a weak negative correlation between ET and diastolic BP in females but not in males, implicating the existence of fundamental differences in basic BP regulation between the sexes.

Keywords: Breathing pattern, Inspiration time, Expiration time, Respiratory rate, Vascular tone, Arterial stiffness

INTRODUCTION

A dynamic interaction exists between respiration, cardiovascular system, and autonomic nervous regulatory mechanisms. The autonomic nervous mechanisms that regulate cardiovascular function in particular heart rate (HR) and blood pressure (BP) are influenced or are mediated by respiration.[1]

There is sufficient evidence describing a link between respiratory rate (RR) and heart rate variability measures, muscle sympathetic nerve activity, cardiac output, and total peripheral resistance.[2] Some of these studies have demonstrated the effects of paced breathing (frequency 0.1 Hz and 6 breaths/min) on the above-mentioned parameters.[3,4] However, effects of normal breathing pattern on vascular function are lacking. The breathing pattern includes the breathing frequency, tidal volume, inspiration time (IT), expiration time (ET), inter-breath interval, and the time ratio of inspiration/expiration. All these aspects of breathing pattern display marked inter-individual differences, although in a given individual, the characteristics are similar from day to day.[2]

Vascular tone refers to the degree of constriction experienced by the blood vessel relative to its maximally dilated state. Under basal conditions all arterial and venous vessels possess tone. Dynamics of vascular tone is determined by the degree of smooth muscle contraction whose major determinant is sympathetic outflow.[5] The breathing patterns by influencing the sympathetic outflow may have an impact on the vascular tone and arterial health and hence cardiovascular system at large.

A majority of the patients with respiratory diseases end up with cardiovascular complications including hypertension and arterial stiffness, the exact pathologic mechanisms of which are not clear. Altered RR and breathing patterns are observed to accompany respiratory diseases.[6] Possibility of altered breathing patterns contributing to deregulated vascular tone in the development of the cardiovascular complications cannot be ruled out. Hence, a thorough understanding of the normal physiological interplay between breathing patterns and vascular function is required to fill the gaps in the existing knowledge. Therefore, the present study was undertaken to study the relation of quiet breathing pattern with vascular tone, hemodynamics, and arterial stiffness in normal young healthy individuals.

MATERIALS AND METHODS

Study design and population

A cross-sectional study was conducted on 46 young healthy adults aged between 19 years and 25 years of both sexes with normal body mass index (BMI) (18.0–24.9). The estimation of sample size was based on the standard deviation of dependent and independent variable from our pilot data and other study.[7] Subjects with history of respiratory, cardiovascular, metabolic, and endocrine diseases; history of smoking, tobacco chewing, and alcohol consumption; and history of psychiatric disorders, overweight, and obese individuals subjects on any treatment or taking any drug including herbals or vitamins and refusal for participation in the study were excluded from the study.

Ethical considerations

Written informed consent was obtained from all the participants before their enrolment in the study. Prior approval for the study was obtained from the institutional ethical committee as per guidelines of Indian Council of Medical research (2006).

Method of collection of data

All the data were collected from November 2018 to March 2019 in the morning between 8.00 am and 11.00 am at room temperature (air-conditioned and temperature were maintained between 22°C and 25°C) to minimize biological circadian rhythm variations. The participants were advised to have a good sleep on the previous day and to have light meal about 1 h before the recordings and to abstain from drinks containing caffeine (Tea/Coffea/Energy drinks) known to influence the study variables. Subjects were asked to take supine rest for 10 min before the data recordings.

BMI

It was calculated using body mass (kg) divided by square of the body height (m) and was expressed as kg/m^2.

Measurement of BP and HR

BP and HR were measured using digital BP monitor (Omron HEM 7111) in a sitting posture. The difference between systolic and diastolic BP was estimated as pulse pressure (PP). Mean arterial pressure was calculated by adding diastolic BP and one-third of PP.

Assessment of breathing pattern

Normal breathing was recorded using a digital spirometry (Spiro-excel, Medicaid Systems Ltd, India). Breathing indices included in the study were RR (RR - in Cycle/min), IT (IT - in s), ET (ET – in s), and inspiration-expiration ratio (I/E ratio).

Assessment of arterial stiffness and vascular tone

Arterial stiffness and vascular tone were assessed from the analysis of digital volume pulse wave forms obtained by photoplethysmography (PPG) technique (Dicrowin, Genesis Medical Systems Ltd, India). A digital volume pulse (DVP) was recorded by placing PPG transducer transmitting infra-red light on the left finger of the subject in supine position for 15 s using a PPG analysis system. This system incorporates normalized average calculation for complete test, first, and second derivative waveforms for photo-plethysmogram and pulse quality control for validation of test. It displays the results automatically after 15 s of recording. The DVP wave has two components: (1) First systolic component of the pulse wave (forward wave) is caused by the systolic pressure wave that is transmitted from the aorta to the finger; (2) and the second diastolic component is caused by wave reflection (pressure wave that is reflected back from the lower body to the aorta). Stiffness index and reflection tone were calculated from the data obtained by PPG analysis system.

Stiffness index (SI)

Arterial stiffness was assessed using SI. The SI is a non-invasive technique of measuring arterial stiffness peripherally. The peak-to-peak time (PPT) was calculated from the time difference between the peaks of two waves (systolic and diastolic peaks). The PPT is inversely proportional to the arterial stiffness. The SI (m/s) is calculated by dividing the height (meters) and PPT (seconds) of the subject.

SI = Height (m)/PPT (s).

SI is an estimate of pulse wave velocity and is a measure of large artery stiffness. More the SI higher is the arterial stiffness.[8]

Reflection index (RI)

RI is a measure of vascular tone. RI was calculated by the percentage of ratio of height of the diastolic component of the DVP to systolic peak from the data recorded for 15 s.[9,10]

Statistical analysis

Data were analyzed for normality using Shapiro–Wilk test. Data obtained were expressed as mean and standard deviation. Based on the data distribution, parametric or non-parametric tests were applied for further analysis of data. The gender difference in baseline characteristics was determined by unpaired-t-test or Mann–Whitney U-test. The correlation between breathing pattern and vascular parameters was determined using Pearson or Spearman correlation coefficient. Data were analyzed using SPSS-21.

RESULTS

Characteristics of participants

A total of 46 participants (Male = 24 and Female = 22) were included in the study. Mean age of the total participants, males and females were 20.74 + 4.52, 21.41 + 6.19, and 20.00 + 5.94 years. BMI and BP were within normal range. There was no significant difference in breathing pattern, RI, and SI between males and females [Table 1]. IT and ET were 1.73 + 0.64 and 1.85 + 0.79, respectively. I/E ratio (0.96 + 0.24) was more than normal in all the participants. RI and SI were 53.59 + 11.54 and 6.99 + 1.37, respectively, with no significant gender difference.

Relationship between breathing pattern, vascular indices, and BP

Breathing indices (IT, expiration time, I/E ratio, and RR) were not significantly related with RI, SI, and BP in young healthy individuals [Table 2]. Further, in individual analysis of relation in males and females, there was a weak negative relationship (borderline: $r = -0.410$; $P = 0.058$) between ET and diastolic BP in females but not in males. While systolic BP and mean arterial pressure were not related with breathing in both genders. We did not find any correlation between breathing pattern, vascular tone, and arterial stiffness [Table 3].

DISCUSSION

The present study was aimed to understand the influence of breathing pattern such as IT and ET, I/E ratio and RR on vascular tone, BP, and arterial stiffness. IT and ET were almost equal with no significant difference. Breathing pattern was not significantly associated with vascular tone and arterial stiffness. ET was weekly correlated with diastolic BP in females but not in males.

The physiological knowledge of the relationship between normal breathing patterns and cardio-vascular system function will provide a base for better understanding of the influence of various breathing techniques (core of yoga) on the neuro-autonomic and cardiovascular systems. Such understanding will allow delivering patient specific and appropriate breathing therapies for cardiovascular diseases including hypertension.

At rest during quiet breathing, ET is longer than the IT and the I:E ratio is 1:2 or 0.5.[11] In the present study, I/E ratio was about 0.95–1, suggesting a change in the normal breathing pattern with equal inspiration and expiration duration in young healthy individuals. Increased IT increases mean airway pressure and favors better oxygenation but at the cost of carbon dioxide (CO_2) clearance while more expiratory duration increases CO_2 clearance and favors ventilation.[12] As cardiac function is influenced by respiration, variation in the normal breathing pattern may modulate the HR and hence BP. HR increases during inspiration and falls during expiration. Decrease in ET may increase basal heart. In this study, quiet breathing was recorded in supine posture with the subject being conscious that the breathing is recorded. This may influence normal breathing pattern, which might be a limitation of the study.

Normally, systolic BP falls during inspiration and increases during expiration. The mechanism by which systolic BP increases during inspiration is due to change in intrathoracic pressure. Decrease in intra-thoracic pressure increases systemic venous return to the right atrium but pulmonary venous return to the left atrium decreases resulting in reduced filling of the left-side of the heart and decrease in stroke volume and hence, decrease in systolic BP.[12] A variation in the BP response to different breathing patterns was observed. A deep thoracic inspiration (but not prolonged) leads to fall in systolic BP while a deep diaphragmatic breathing increases systolic BP. During thoracic and diaphragmatic expiration the effects on BP are reverse or vice-versa.[13] In the present study, we observed a negative relationship (borderline:

Table 1: Characteristics of study participants.

Variables	Total (*n*=46)	Males (*n*=24)	Females (*n*=22)	*P*-value
	Mean±SD	Mean±SD	Mean±SD	
Age (years)	20.74+4.52	21.41+6.19	20.00+5.94	0.464[b]
BMI (Kg/m²)	23.56+4.26	23.78+4.34	23.31+4.25	0.716[a]
SBP (mmHg)	117.96+11.21	124.58+9.50	110.72+8.10	<0.001[a***]
DBP (mmHg)	74.0+9.21	74.75+10.48	73.18+7.74	0.565[a]
PP (mmHg)	43.95+9.19	49.83+7.8	37.54+5.65	<0.001[a***]
MAP (mmHg)	88.69+8.96	91.42+9.45	85.72+7.51	0.03[a*]
HR (bpm)	82.87+10.79	79.91+9.60	86.09+11.30	0.054[a]
RR (cycles/min)	19.39+6.85	19.99+6.64	17.24+1.25	0.145[a]
Inspiration time (sec)	1.73+0.64	1.64+0.60	1.85+0.68	0.267[b]
Expiration time (sec)	1.85+0.79	1.74+0.78	1.99+0.77	0.524[b]
I/E ratio	0.96+0.24	0.95+0.161	1.01+0.3	0.395[a]
Reflection index	53.59+11.54	56.40+13.30	54.93+13.10	0.708[a]
Stiffness index	6.99+1.37	7.38+1.49	6.66+1.31	0.111[b]

BMI: Body mass index, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, PP: Pulse pressure, MAP: Mean arterial pressure, HR: Heart rate, RR: Respiratory rate, I/E ratio: Inspiration-expiration ratio.****P*** < 0.05, *****P*** < 0.01, ******P*** < 0.001: Indicates the difference between males and females, a: Unpaired-t-test, b: Mann–Whitney U-test

Table 2: Bivariate correlations between respiration and vascular parameters in all the participants (*n*=46).

Variables	Reflection index	Stiffness index	SBP (mmHg)	DBP (mmHg)	MAP (mmHg)
	r-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)
RR (cycles/min)	0.090 (0.551)	0.026 (0.862)	0.018 (0.907)	0.007 (0.961)	0.012 (0.935)
Inspiration time (s)	−0.038 (0.800)	0.014 (0.927)	−0.037 (0.805)	−0.049 (0.746)	−0.014 (0.928)
Expiration time (s)	0.008 (0.957)	−0.029 (0.847)	−0.084 (0.580)	−0.131 (0.384)	−0.112 (0.458)
I/E ratio	0.063 (0.678)	−0.013 (0.932)	0.087 (0.567)	0.062 (0.684)	0.106 (0.484)

SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, RR: Respiratory rate, I/E ratio: Inspiration-expiration ratio, a: Pearson correlation, b: Spearman correlation

Table 3: Bivariate correlations between respiration and vascular parameters in males and females.

Variables	Reflection index		Stiffness index		SBP (mmHg)		DBP (mmHg)		MAP (mmHg)	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
	r-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)	*r*-value (*P*-value)
RR (cycles/min)	−0.072 (0.738)	0.271 (0.223)	0.290 (0.169)[b]	−0.315 (0.154)[b]	−0.378 (0.069)	0.200 (0.372)	−0.145 (0.500)	0.225 (0.315)[b]	−0.232 (0.274)	0.164 (0.465)[b]
Inspiration time (s)	0.15 (0.485)[b]	−0.196 (0.383)	−0.276 (0.192)[b]	0.350 (0.111)[b]	0.343 (0.101)[b]	−0.175 (0.435)	0.066 (0.761)[b]	−0.223 (0.319)[b]	0.159 (0.457)[b]	−0.151 (0.503)[b]
Expiration time (s)	0.063 (0.770)[b]	−0.289 (0.192)	−0.270 (0.202)[b]	0.208 (0.352)[b]	0.312 (0.138)[b]	−0.317 (0.151)	0.119 (0.581)[b]	−0.410 (0.058)[b]	0.200 (0.349)[b]	−0.383 (0.078)[b]
I/E ratio	0.264 (0.212)	−0.146 (0.516)[b]	0.123 (0.568)[b]	−0.178 (0.428)[b]	0.009 (0.966)	0.353 (0.108)[b]	−0.145 (0.500)	0.250 (0.262)[b]	−0.105 (0.624)	0.320 (0.147)[b]

SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, RR: Respiratory rate, I/E ratio: Inspiration-expiration ratio, a: Pearson correlation, b: Spearman correlation

r = −0.410; P = 0.058) between ET and diastolic BP in females, suggesting that increase in ET decreases diastolic BP. This relation did not exist in the males. However, we did not find any association between breathing and systolic BP.

Further, whether the breathing pattern by influencing the sympathetic outflow may modulate the BP by altering vascular tone is not known. In the present study, we investigated presence of any link between breathing pattern and vascular tone. There was no significant correlation between breathing pattern (RR, IT, ET, and I/T ratio) with RI (a measure of vascular tone).

Arterial stiffness is a major cardiovascular risk and is an independent strong predictor of cardiovascular morbidity and mortality in hypertensive,[14-17] diabetes,[18] and also in well-functioning elderly individuals.[19] Few studies have shown an increased arterial stiffness in patients with chronic obstructive pulmonary disease when compared with healthy controls.[20,21] Inomoto *et al*. have shown a significant correlation of brachial-ankle pulse wave velocity (measure of regional arterial stiffness) with dynamic lung function (forced vital capacity and FEV1: Forced expiratory volume in first second) in healthy middle-aged workers.[22] While in our study, we have evaluated the relationship between breathing pattern (IT, expiration time, I/E ratio, and RR) and arterial stiffness, where we did not find any association between them in young healthy individuals. Although, we found a change in the breathing pattern in young healthy individuals, it does not show any impact on arterial health in young healthy individuals. Korcarz *et al*. studied the effect of sleep-disordered breathing on arterial stiffness in normotensive individuals aged between 45 years and 77 years. They have shown that the markers of sleep-disordered breathing were correlated with arterial stiffness but were not significant after adjustment. They also noticed that effects of sleep-disordered breathing were amplified with aging.[23] These findings imply that change in breathing pattern at younger age may have an impact on arterial health with advancing age. Hence, future studies should assess the breathing pattern and arterial health relationship in middle-aged and elderly healthy individuals.

CONCLUSION

IT, expiration time, I/E ratio, and RR were not significantly correlated with vascular tone and arterial stiffness suggests that breathing does not influence the vascular tone in young healthy individuals. There was a moderate negative correlation between ET and diastolic BP in females but not in males, implicating the existence of fundamental differences in basic BP regulation between the sexes. Change in the breathing pattern was observed with a decrease in ET indicating a need of respiratory training by which breathing is stabilized and impact on cardiovascular and respiratory function can be prevented.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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