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Cardiac Autonomic Control during Alternate Nostril Breathing in Subjects Novice to Yoga Practice

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ABSTRACT

Objectives: To examine heart rate variability during alternate nostril breathing (ANB) in a group of individuals novice to yoga practice and to compare the effects of ANB to that of paced breathing (PB) at the same respiratory rate. Design: The study involved randomized repeated measures of two different breathing patterns. Participants: Twenty healthy individuals (22.3 ± 2.9 years) participated. Intervention: Subjects were asked to rest for 5 minutes (PRE-ANB and PRE-PB) before they participated in two different breathing exercises (ANB and PB) in a random order for 30 min. Outcome Measures: Heart rate (HR), mean arterial pressure (MAP) and heart rate variability (HRV) were measured during PRE-ANB, PRE-PB, ANB, and PB and compared using analysis of variance.
HRV was reported as frequency and time domain parameters. Total power (TP; 0.0-0.4 Hz), low- (LF; 0.04-0.15 Hz), and high-frequency (HF; 0.15-0.40 Hz) ranges were selected and were natural log (ln) transformed. Time domain variables such as RMSSD, pNN50, and SDNN were also reported. Results: There was a main effect of breathing condition on HR and MAP ($p < 0.05$ for both) such that HR was higher during PRE-ANB and ANB compared to PRE-PB and PB and that MAP was greater during ANB compared to the other conditions. There were main effects of time on lnTP, lnLF, and lnHF ($p < 0.001$ for all) such that lnTP and lnLF were greater and lnHF was lower during ANB and PB compared to the PRE conditions. There was a breathing x time interaction on lnLF/lnHF ($p < 0.05$) such that it was greater during PB compared to ANB and that it was greater during ANB and PB compared to PRE-ANB and PRE-PB. There was a main effect of breathing on pNN50 such as that it was lower during Pre ANB and ANB. There was also a main effect of time on SDNN such that it was higher during PB and ANB. No significant changes were noted in RMSSD measurements during any conditions. Conclusions: During both ANB and PB, there was a decrease in parasympathetic and/or

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increase sympathetic control of the heart. Additionally, ANB may result in less of a reduction in parasympathetic control than PB.

***Keywords*:** Yoga, Alternate nostril breathing, Slow breathing, Anulom-Vilom breathing, Pranayama

1. INTRODUCTION

Alternate nostril breathing or Anulom-Vilom (ANB/AV) is one of the many Yogic breathing exercises which aims to provide many health benefits [1]. One cycle of ANB involves right nostril inhalation followed by left nostril exhalation and then left nostril inhalation followed by right nostril exhalation. This is a follow-up study in reference to a study published by Ghiya et al. regarding alternate nostril breathing [2]. Previously [2], changes in autonomic control of the heart after 30 min of ANB was reported while the current paper highlights the changes in the autonomic system during the practice of ANB.

Many studies have evaluated the effects of ANB [3-8] and have reported improved parasympathetic activity after regular practice of ANB. By contrast, there is very limited information available on physiological changes happening during the practice of ANB. Raghuraj et al. [9] and Bhagat et al. [10] noted that there was a reduction in parasympathetic control of the heart during ANB. However, Telles et al. [11] noticed an increase in time domain parameters of HRV during the 15-minute practice of ANB. Therefore, it appears that autonomic control during ANB differs than that assessed after, or in response to chronic ANB practice. However, in all of the above studies both ANB and control groups had different breathing rate. Influence of breathing rate on HRV is established fact [12] and since ANB is a breathing exercise practiced at reduced breathing frequency, changes in the autonomic nervous system associated with ANB possibly can be explained by low breathing rate.

Therefore, this study was aimed to evaluate HRV during ANB in a group of individuals who were not regular practitioners of ANB and compare that to paced breathing at the same respiratory frequency.

2. MATERIALS AND METHODS

2. 1. Participants

There were twenty healthy subjects (8 males, 12 females in this study. An a-priori power analysis found that this number of participants would yield 80% power at an alpha level of 0.05. All of the participants were the novice to Yoga and ANB. All procedures were approved by the university's Committee for the Protection of Human Subjects.

2. 2. Experimental Design

All subjects were asked to report to exercise physiology laboratory twice. During their first visit, participants were explained the study design briefly and practiced two breathing exercises [ANB and Paced breathing (PB) at a rate of 5 breaths·min^{-1}] under the guidance of an author as a practice round for five minutes. They also filled out a pre-participation questionnaire, gave written informed consent to study. Their height and weight were taken.

The subjects were given 5-minute of rest periods (without any breathing manipulation) (PRE-ANB and PRE-PB) before each 30- minute session of ANB and PB. Order of the sessions for ANB and PB were selected randomly. An EKG was continuously recorded at a sampling rate of 500 Hz during PRE- ANB, PRE-PB, ANB, and PB via a Biopac MP100 Data Acquisition System (Goleta, CA) for analysis of HRV. Blood pressure was collected via a sphygmomanometer and stethoscope during the PRE periods and during the last 5-minutes of ANB and PB.

Breathing Techniques

Both breathing exercises were performed at the rate of 5 breaths per minute. An author used a timer to provide verbal cues to maintain the constant breathing frequency. *Alternate nostril breathing*: While sitting in a crossed leg position, participants inhaled through the left nostril, held the breath for a moment while keeping both nostrils closed, then exhaled from the right nostril keeping the left nostril closed. This was followed by inhalation through the right nostril and exhalation through left nostril in the same manner. The participant repeated this cycle at a breathing rate of 5 breaths·min^{-1} for 30 minutes. *Paced Breathing*: In a sitting position, the participants normal breathing (without nostril manipulation) while maintaining a breathing rate of 5 breaths·min^{-1} for 30 minutes.

Data Analysis

The mean R wave-t- R wave (mean RR) interval was obtained from EKG signals derived from PRE-ANB and PRE-PB periods as well the last 5 minutes of ANB and PB sessions. Heart rate was obtained by dividing the mean RR interval into 60.

The RR interval sequences were transformed into the temporal RR sequences using the Kubios software program (Kuopio, Finland) to obtain the following time domain parameters of heart rate variability. RMSSD (Root Mean Square of the Successive Differences), pNN50 (The proportion of NN50 (The number of pairs of successive NN (R-R) intervals that differ by more than 50 ms) divided by the total number of NN (R-R) intervals) and SDNN (Standard deviation of normal to normal R-R intervals) were derived.

Pre-processed temporal 5-min RR series were used to perform autoregressive spectral analysis using the same software to obtain the estimates of power spectral densities. The limits for the spectral HRV bands were defined as below: total power (TP; 0.0-0.4 Hz), low-frequency power (LF; 0.04-0.15 Hz), and high-frequency power (HF; 0.15-0.40 Hz). LF reflects a combination of sympathetic and parasympathetic activity in relation to cardiac function, HF reflects parasympathetic (vagal) modulation, and TP reflects the total variance in heart rate fluctuations [1,3]. LF and HF were further normalized [LFNU: LF/(TP - power below 0.04 Hz) * 100, and HFNU: HF/(TP - power below 0.04 Hz) * 100]. The ratio of LF-to-HF was also reported. Because the raw values of TP, LF, and HF were skewed toward higher values and violated assumptions of normality, natural log (ln) transformation was applied (lnTP, lnLF, and lnHF). Both systolic (SBP) and diastolic (DBP) blood pressure were collected and were reported as mean arterial pressure (MAP) using the following equation: MAP = DBP + 0.333 * (SBP – DBP). Resting mean RR interval, heart rate, and MAP were derived from the PRE condition that was performed first (PRE-PB or PRE-ANB).

Statistical Analysis

Differences in descriptive and resting variables between males and females were evaluated using independent t-tests. A 2 (breathing type) X 2 (time) repeated measures analysis of variance (ANOVA) was used to examine any significant main effects and/or interactions of breathing type and time. When significance was found, post-hoc analysis was performed using Duncan's multiple range test to examine where the differences occurred. All tests were considered significant at the 0.05 level.

3. RESULTS

Table 1. Descriptive statistics for the participants (Mean ± SD).

	Age (yr)	Body Mass (kg)	Height (cm)	BMI (kg·m^{-2})	Mean RR (ms)	Heart Rate (bpm)	MAP (mmHg)
Males (n = 8)	22.1 ± 2.6	88.7 ± 20.0	178.2 ± 6.6	27.8 ± 5.1	859.7 ± 105.1	70.8 ± 9.4	93.4 ± 7.2
Females (n = 12)	22.4 + 3.2	55.6 ± 7.6*	160.9 ± 9.4*	21.5 ± 2.1*	792.3 ± 54.8	76.1 ± 5.1	80.7 ± 7.6*
All (n = 20)	22.3 ± 2.9	68.9 ± 21.4	167.8 ± 11.9	24.0 ± 4.7	819.3 ± 83.4	73.9 ± 7.4	85.8 ± 9.7

* $p < 0.01$ vs. males; BMI: body mass index; Mean RR: mean RR interval; MAP: mean arterial pressure

Table 1 describes the descriptive variables, resting mean RR interval, heart rate, and MAP. Females had a significantly lower height, BMI, and resting MAP compared to males. However, age, resting mean RR interval, and all of the HRV parameters were similar between the sexes. Table 2 depicts the changes in the mean RR interval, heart rate, and MAP during all four breathing conditions. The ANOVA revealed that there was a main effect of breathing condition on the mean RR interval ($F = 5.9$; $p = 0.025$) and heart rate ($F = 6.5$; $p = 0.020$) such that mean RR interval was lower and that heart rate was higher during PRE-ANB and

ANB. There was also a main effect of breathing condition on MAP ($F = 7.3$; $p = 0.014$), such that it was greater during ANB.

Table 2. Mean RR interval, heart rate, and MAP during the conditions (Mean ± SE).

	Conditions				p-values		
	PRE-PB	**PB**	**PRE-ANB**	**ANB**	**Main effect of time**	**Main effect of breathing**	**Interaction**
Mean RR (ms)	858.6 ± 25.6	858.1 ± 20.7	831.4 ± 22.1*	815.4 ± 18.6*	0.482	0.025	0.336
Heart Rate (bpm)	71.1 ± 2.1	70.7 ± 1.7	73.1 ± 1.9*	74.3 ± 1.8*	0.644	0.020	0.228
MAP (mmHg)	86.1 ± 2.2	85.6 ± 2.4	86.6 ± 2.2	88.5 ± 2.6*	0.507	0.014	0.075

* p < 0.05 vs. PRE-PB and PB

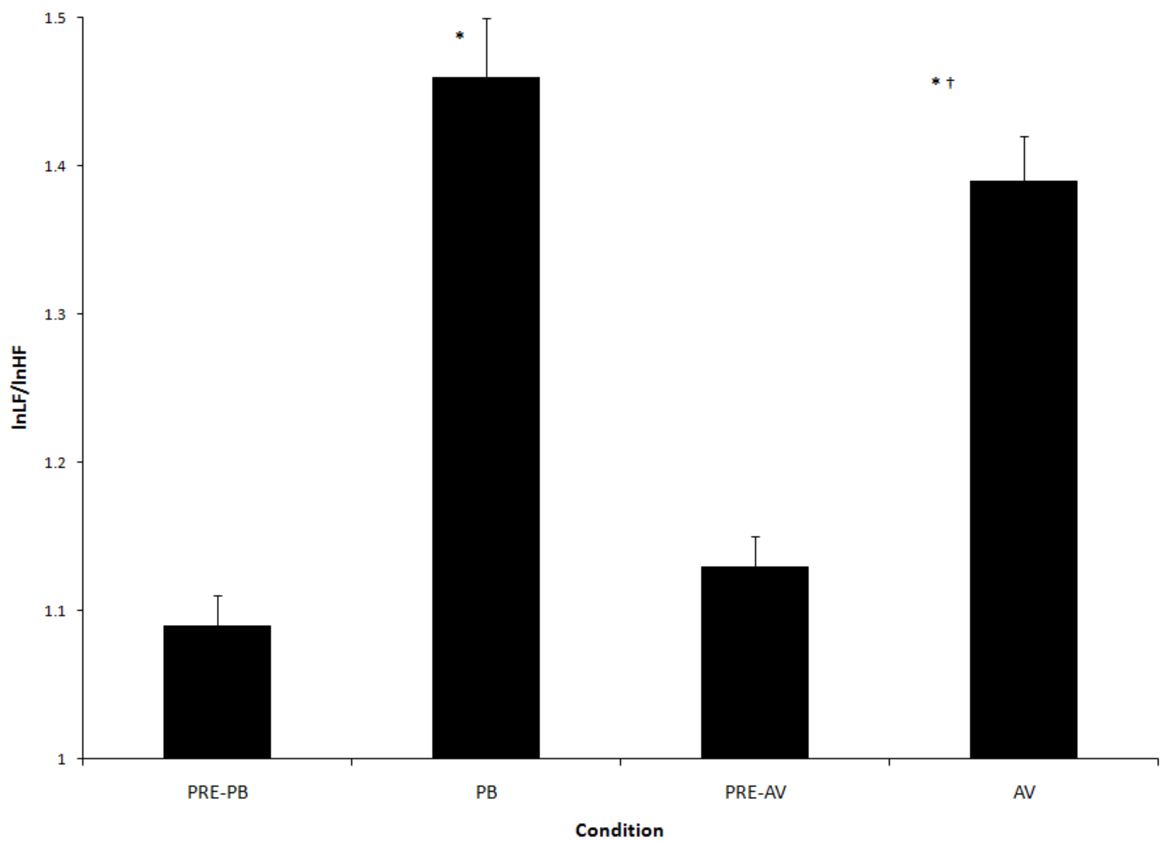
Changes in HRV indices during all four breathing conditions are presented in Table 3. There were main effects of time on lnTP ($F = 33.5$; $p < 0.001$) and lnLF ($F = 120.1$; $p < 0.001$) such that these variables were greater during ANB and PB compared to the PRE-ANB and PRE-PB periods. There was also a main effect of time on lnHF such that it was lower during ANB and PB compared to the PRE-ANB and PRE-PB periods ($F = 22.6$; $p < 0.001$). There was a breathing x time interaction on lnLF/lnHF ($F = 6.7$; $p = 0.018$). Post-hoc analysis revealed that lnLF/lnHF was greater during PB compared to ANB and that it was greater during ANB and PB compared to PRE-ANB and PRE-PB (Figure 1). There were also breathing x time interactions on LFNU ($F = 6.1$; $p = 0.023$) and HFNU ($F = 6.1$; $p = 0.023$). Post-hoc analysis revealed that LFNU was greater and HFNU was lower during ANB and PB compared to PRE-ANB and PRE-PB, but no differences were found between PB and ANB.

Table 3. Heart rate variability indices during the different conditions (Mean ± SE).

		lnTP (ms^2)	lnLF (ms^2)	lnHF (ms^2)	lnLF/lnHF	LFNU (%)	HFNU (%)	RMSSD (ms)
Conditions	PRE-PB	8.81 ± 0.16	7.73 ± 0.16	7.09 ± 0.17	1.09 ± 0.02	64.9 ± 2.8	35.1 ± 2.8	56.91 ±4.7
	PB	9.32 ± 0.16*	9.10 ± 0.16*	6.32 ± 0.22*	1.46 ± 0.04*	93.0 ± 0.9*	7.0 ± 0.9*	60.5 ±5.9
	PRE-ANB	8.67 ± 0.13	7.68 ± 0.13	6.83 ± 0.17	1.13 ± 0.02	69.0 ± 2.2	31.0 ± 2.2	51.72 ±5.2
	ANB	9.10 ± 0.13*	8.78 ± 0.15*	6.39 ± 0.18*	1.39 ± 0.03*†	89.3 ± 2.4*	10.7 ± 2.4*	52.9 ± 3.8
p-values	Main effect of time	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.58
	Main effect of breathing	0.132	0.087	0.577	0.445	0.892	0.892	0.167
	Interaction	0.597	0.115	0.072	0.018	0.023	0.023	0.347

pNN50 (%)	30.6 ±3.2	29.6 ±3.2	24.63 ±3.1#	26.34 ±3.06#	0.941	0.04	0.402
SDNN (ms)	89.52 ±6.65	111.27 ±8*	83.04 ±6.21	98.77 ±6.03*	0.001	0.1	0.474

* p < 0.05 vs. PRE-PB and PRE-ANB; † p < 0.05 vs. PB; # p < 0.05 vs. PRE-PB and PB
ln: natural log; PB: Paced breathing; ANB: Anulom-vilom breathing; TP: total power; LF: low-frequency power; HF: high-frequency power; NU: normalized units, RMSSD: Root Mean Square of the Successive Differences; pNN50: The proportion of NN50 (The number of pairs of successive NN (R-R) intervals that differ by more than 50 ms) divided by the total number of NN (R-R) intervals; SDNN: Standard deviation of normal to normal R-R intervals



* p < 0.05 vs. PRE-PB and PRE-ANB(PRE-AV); † p < 0.05 vs. PB; # p < 0.05 vs. PRE-PB and PB
ln: natural log; PB: Paced breathing; AV/ANB: Anulom-vilom breathing; TP: total power; LF: low-frequency power; HF: high-frequency power; NU: normalized units,

There was a main effect of breathing on pNN50 ($F = 4.9$; $p = 0.04$) such as that it was lower during Pre ANB and ANB. There was also a main effect of time on SDNN ($F = 17.74$;

$p = 0.001$) such that it was higher during PB and ANB. No significant changes were noted in RMSSD measurements during any conditions.

4. DISCUSSION

This study was aimed to evaluate changes in HRV during the practice of ANB and to compare that to during PB. This study is part of the study earlier published by Ghiya et al [2] which reported changes in HRV after practicing ANB for 30 min. To our knowledge, this is the first investigation to compare cardiac autonomic control during ANB and PB at the same respiratory rate in individuals previously unfamiliar with yogic breathing techniques. Based on the results from this study it can be interpreted that both ANB and PB resulted in a reduction of parasympathetic control of the heart while practicing these breathing exercises.

There is very limited information available on changes in cardiac autonomic modulation during ANB though many studies have reported changes after practicing ANB. Raghuraj et al. [9] and Bhagat et al. [10] both suggested reduced parasympathetic activity during ANB. Our findings during ANB are consistent with the findings of above two mentioned studies, although the breathing rate during ANB in the current study and the study by Telles et al. [11] was slightly lower then study by Raghuraj et al. [9] (5 br·min^{-1} vs. ~9 br·min^{-1}).

In contrast, Telles et al. [10] reported increased parasympathetic control due to increase in time domain variables of HRV without any changes in mean RR interval and in frequency domain variables of HRV. It should be noted that the breathing rate was reported 12 breaths/ minute in ANB group and 15 breaths/ minute in the control group. It seems that changes in autonomic control during ANB is mediated through the reduction in breathing frequency rate. On the other hand, we found significant breathing-by-time interactions on lnLF/lnHF, suggesting that ANB resulted in less of a shift in sympathovagal balance towards sympathetic dominance compared to PB. This finding supports the idea that ANB may affect autonomic balance via other mechanisms and not just simply via the reduction in respiratory rate.

Our findings of an increase in lnLF and a decrease in lnHF during ANB and PB suggest that both conditions reduced parasympathetic and/or increased sympathetic outflow to the heart. However, our findings during PB are not consistent with previous research suggesting slow breathing rates increase cardiac vagal modulation [12, 14-16]. A possible explanation for this contrast is that both breathing techniques resulted in significant mental stress to the participants. Given that the participants were not regular practitioners of yogic breathing techniques, we speculate that the constant attention they were paying to their respiration may have caused significant anxiety/discomfort and resulted in a reduction in parasympathetic and/or increase in sympathetic activity. This hypothesis is supported by the study [17] that have found reductions in parasympathetic control of the heart during mental challenges and by reports of Saoji et al. [18] of increased baroreflex sensitivity and increased sympathetic control immediately after doing breathing exercises for 20 min with breath retention at the breathing rate of 3 breaths /min.

Another possible explanation for increased sympathetic activity during ANB and PB is that these exercises provide a healthy challenge to the cardiovascular system. During an acute bout of this breathing exercises even though sympathetic control is increased with regular practice system becomes stronger and the autonomic balance draws towards the parasympathetic dominance. This possibility would also explain the results of improved blood pressure and cardiac functioning even at rest in the regular practitioners of ANB.

Results of HRV from time domain methods are inconsistent. There was a significant increase in SDNN during PB and ANB but there were no changes in RMSSD while pNN50 decreased during ANB. Even though 5 min time of EKG is accepted recording time, it is possible that this duration might not be enough as time domain variables are dependent on the length of recordings.

It is should be noted that although other HRV parameters were not significantly different between Pre-PB versus Pre-ANB, there was a significant difference for HR and RR between above-mentioned conditions which is hard to explain.

There are a few limitations of this investigation. First, our HRV measures were taken during the last 5 minutes of 30-minute sessions of ANB and PB. It is possible that autonomic modulation at this time period may not be reflective of the earlier portions of the 30-minute period. However, the last 5 minutes were chosen in an effort to allow the participants to become comfortable with the breathing techniques. Second, female participants were not asked to report the phase of the menstrual cycle.

Given that all participants practiced both breathing exercises on the same day in a random order, the influence from hormones should affect both breathing exercises equally. There were no differences in HR and RR interval between male and female participants.

5. CONCLUSION

In conclusion, we found that both ANB and PB resulted in decreased parasympathetic and/or increased sympathetic control of the heart. Furthermore, ANB may result in less of an increase in sympathetic and/or less of a reduction in parasympathetic control than PB.

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