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Breathing at a rate of 5.5 breaths per minute with equal inhalation-to-exhalation ratio increases heart rate variability

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ABSTRACT

Objectives: Prior studies have found that a breathing pattern of 6 or 5.5 breaths per minute (bpm) was associated with greater heart rate variability (HRV) than that of spontaneous breathing rate. However, the effects of combining the breathing rate with the inhalation-to-exhalation ratio (I:E ratio) on HRV indices are inconsistent. This study aimed to examine the differences in HRV indices and subjective feelings of anxiety and relaxation among four different breathing patterns.

Methods: Forty-seven healthy college students were recruited for the study, and a Latin square experimental design with a counterbalance in random sequences was applied. Participants were instructed to breathe at two different breathing rates (6 and 5.5 breaths) and two different I:E ratios (5:5 and 4:6). The HRV indices as well as anxiety and relaxation levels were measured at baseline (spontaneous breathing) and for the four different breathing patterns.

Results: The results revealed that a pattern of 5.5 bpm with an I:E ratio of 5:5 produced a higher NN interval standard deviation and higher low frequency power than the other breathing patterns. Moreover, the four different breathing patterns were associated with significantly increased feeling of relaxation compared with baseline.

Conclusion: The study confirmed that a breathing pattern of 5.5 bpm with an I:E ratio of 5:5 achieved greater HRV than the other breathing patterns. This finding can be applied to HRV biofeedback or breathing training in the future.

1. Introduction

Heart rate variability (HRV) is an index of cardiac autonomic activation as well as an outcome variable in breathing training or HRV biofeedback research (Del Pozo et al., 2004; Sakakibara et al., 2013; Patron et al., 2012). HRV indices were shown to be related to breathing rate (Song and Lehrer, 2003; Vaschillo et al., 2006). Spontaneous breathing rate at rest is usually about 9–24 breaths per minute (bpm) in healthy adults (Lehrer et al., 2000), and respiratory sinus arrhythmia (RSA), which is modulated by the cardiac parasympathetic nervous system (PNS), then occurs in the high frequency range (HF; 0.15–0.4 Hz) (Lehrer, 2007; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Slow breathing has been applied as a non-pharmacological method in stress management programs and biofeedback training (Lehrer et al., 2000; Lehrer, 2007), because slowing down the breathing rate to about 3–9 bpm results in an increase of the power spectrum of the low frequency (LF; 0.04–0.15 Hz).

Interpretation of LF heart rate variability is more controversial. Earlier studies reported LF to be a marker of cardiac sympathetic nervous system (SNS) activity (Pagani et al., 1986; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). However, other studies failed to confirm this association (Hopf et al., 1995; Moak et al., 2007). A number of reviews indicated that LF is most likely affected both by cardiac SNS and PNS as well as by the baroreflex modulation of autonomic outflows (Billman, 2011, 2013; Moak et al., 2007; Reyes del Paso et al., 2013).

The ratio of LF to HF (LF/HF ratio) was previously considered to be an index of cardiac autonomic balance with an increase in the ratio reflecting the dominance of the SNS and a decrease in the ratio the dominance of the PNS (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). However, recent studies have revealed that the LF/HF ratio does not necessarily reflect SNS or cardiac sympatho-vagal balance (Billman, 2013; Haensch et al., 2009). The LF/HF ratio is affected by numerous factors such as vagal activity, SNS, PNS, and respiratory parameters (Billman, 2013; Reyes del Paso et al., 2013), and its interpretation should consider the separate variations in LF and HF heart rate variability (Billman, 2013).

Slow breathing within the LF range of approximately 0.1 Hz (about 6 bpm) is accompanied by a high amplitude in RSA, in which inhalation

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temporarily suppresses vagal/parasympathetic activity and causes an immediate increase in the heart rate (Berntson et al., 1993). On the other hand, exhalation decreases the heart rate and restores vagal/parasympathetic activity (Lehrer et al., 2000; Vaschillo et al., 2006). Resonant frequency is observed when synchrony in heart rate oscillations occur in an individual with the respiration that can yield the highest LF peak and maximum LF power (Lehrer et al., 2000, 2003, 2010; Vaschillo et al., 2006). When individuals breathe at their resonant frequency, an increase in the amplitude of the heart rate, narrow shape of the waveform at the LF band of the HRV power spectrum, increase of HRV and baroreflex sensitivity (Lehrer et al., 2006; Vaschillo et al., 2006), and decrease of psychosomatic symptoms (Lehrer et al., 2010) are observed.

Regarding slow breathing and HRV indices, a number of studies used paced breathing to control breathing rate in order to standardize the experimental protocol and precisely interpret HRV data (Billman, 2013; Lehrer et al., 2000; Song and Lehrer, 2003). Vaschillo et al. (2002) found that trying to produce heart rate oscillations at approximately 3 bpm stimulated negative resonance effects in HRV, with decreased RSA amplitude at the respiratory frequency, while trying to produce heart rate oscillations of 6 bpm, increased the positive resonance in HRV, as evidenced by increased in RSA. Similarly, Song and Lehrer (2003) found that breathing 3 and 4 bpm were associated with higher LF compared with 10, 12, or 14 bpm. Other studies found that slow breathing at 6 bpm had beneficial effects on cardiovascular and respiratory functions. Moreover, it was shown to increase RSA, baroreflex sensitivity, and oxygen saturation in healthy controls and patients with chronic heart failure and to decrease blood pressure in individuals with essential hypertension (Bernardi et al., 2002; Joseph et al., 2005). Vaschillo et al. (2006) compared the breathing rates of 6.5, 6, 5.5, 5, and 4.5 bpm and showed that the breathing rate of 5.5 was associated with significantly higher heart rate oscillations, LF peak amplitude, and resonant frequency in the cardiovascular function.

Regarding the inhalation-to-exhalation ratio (I:E ratio), a study by Cappo and Holmes (1984) showed that, while breathing at a rate of 6 bpm inhaling quickly and exhaling slowly (I:E ratio of 2:8) was more effective in reducing physiological and psychological arousal in threatening situations than inhaling slowly and exhaling quickly (I:E ratio of 8:2) at the same rate, or with equal time for inhalation and exhalation (I:E ratio of 5:5). Strauss-Blasche et al. (2000) examined short inspiration followed by long expiration (SILE) and long inspiration followed by short expiration (LISE) in RSA and HRV in 12 healthy subjects and reported that SILE was associated with higher RSA and HF power than that of LISE. Klintworth et al. (2012) examined the effects of various breathing patterns (inspiration controlled, inspiration/expiration controlled 1:2, 1:1, 2:1 ratios), and inspiration controlled again on HRV indices. The result found that there were no significant differences at various breathing patterns in time and frequency domains of HRV indices, but the ratios of 1:1 and 2:1 were higher heart rate asymmetry than that of the ratio of 1:2. However, these studies had a number of limitations. Cappo and Holmes (1984) used the pattern of 6 bpm and a controlled I:E ratio but did not measure the HRV indices, and the spontaneous breathing rates in the study by Strauss-Blasche et al. (2000) were 9.6 and 10.0 for LISE and SILE, respectively (Lehrer et al., 2000). Although Strauss-Blasche et al. (2000) confirmed that prolonged exhalations produced higher HF HRV than prolonged inhalations, but this situation did not happen in Klintworth et al. (2012) study. Therefore, the effects of different breathing rates with different I:E ratios on HRV indices are still unknown.

The aim of this study was to examine the differences in the effect of breathing rates with prolonged exhalations and those with an equal I:E ratio on subjective feelings as well as an increase in HRV indices. In particular, we explored whether two breathing rates (6 and 5.5 bpm) with two I:E ratios (5:5 ratio and 4:6 ratio) had different effects on HRV indices and the subjective feelings of anxiety and relaxation. We hypothesized that slow breathing rate with an I:E ratio of 4:6 was associated with higher HRV indices and more intensive feeling of relaxation than that with an I:E ratio of 5:5.

2. Methods

2.1. Participants

This study recruited 48 healthy college students aged from 19 to 24 years without any physical illnesses (for example, cancer, cardiovascular disease, liver disease, etc.) or any mental disorders (for example, major depressive disorder, anxiety disorder, substance use, etc.) in the past 6 months based on the participants' self-report. None of the participants took any medications; all participants were instructed not to exercise excessively, consume caffeinated or alcoholic beverages, or smoke 3 h prior to the study. All investigations were conducted between 9 a.m. and 5 p.m. Institutional review board approval was obtained from the human ethics committee of Kaohsiung Medical University Hospital (KMUH-IRB-20120044), and informed consent was obtained from each participant before enrollment in the study. All participants received a gift for their participation.

2.2. Research design and experimental protocol

A within-subject design was used to examine cardiac autonomic activation under various breathing patterns. A Latin square experimental design of 2 × 2 with a four sequence counterbalance was used to manipulate the two breathing rates (6 and 5.5 bpm) and two I:E ratios (5:5 and 4:6). Participants were randomly assigned to one of the four sequences, and the sequence was determined according to the time they signed up for the study. Physiological sensors were attached, and after a 10 min rest in a sitting position, the experiment was started. The experimental protocol (22 min) included the following stages (Fig. 1):

(1) Baseline (5 min): participants were seated comfortably at rest in a sound-attenuated temperature-controlled room (24–26 °C).
(2) Paced breathing (12 min): the pacer stimuli were presented on a 17-inch computer monitor using the ProComp Infiniti™ software (Thought Technology Ltd, Quebec, Canada). Participants were instructed to inhale as the yellow ball went up and to exhale as it went down. The four types of breathing patterns were applied in four sequences: group 1 = ABCD; group 2 = BCDA; group 3 = CDAB; and group 4 = DABC. Participants were randomly assigned to one of the four groups. The four different breathing patterns were described as follows:
A: 6 bpm with an I:E ratio of 5:5 (6 bpm 5:5).
B: 6 bpm with an I:E ratio of 4:6 (6 bpm 4:6).
C: 5.5 bpm with an I:E ratio of 5:5 (5.5 bpm 5:5).
D: 5.5 bpm with an I:E ratio of 4:6 (5.5 bpm 4:6).
Each breathing pattern was practiced for 2 min with 1 min of rest between each trial. During the rest, the researcher asked participants to breathe naturally and inquired if they felt any discomfort. Participants were asked to follow a breathing guideline on a 20-inch computer screen that had the following instruction: *We are going to measure the cardiac autonomic activation of four different breathing patterns. Please adjust to a comfortable position and concentrate on the yellow ball on the screen. When the yellow*

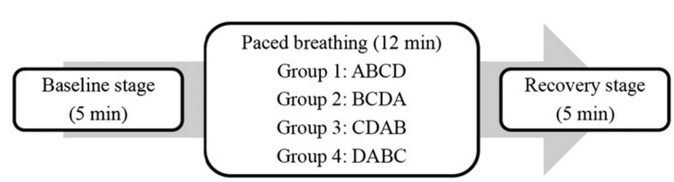

Fig. 1. Experimental protocol.

ball goes up, please inhale slowly, and when the yellow ball goes down, please exhale slowly (Fig. 2). We will adjust the breathing patterns, so you will breathe using each breathing pattern for 2 min with 1 min of rest between the 2 trials. Please relax, and just follow the yellow ball while breathing naturally and slowly. Before we start, do you have any questions?

(3) Recovery stage (5 min): participants were seated comfortably at rest.

2.3. Material

2.3.1. Measurement and analysis of HRV

The ProComp Infiniti™ (Thought Technology Ltd, Quebec, Canada) with an electrocardiogram (ECG) and respiratory sensors was used to collect the raw signals. Lead II of the ECG, with a sampling rate of 2048 per second, was placed onto the participant's skin. Using strain gages, the respiratory sensors were placed on the participant's chest and abdomen to monitor their breathing patterns. The CardioPro Infiniti™ HRV Analysis Module (Thought Technology Ltd, Canada) with a fast Fourier transform was set to acquire the real-time interbeat intervals of the ECG and transfer them to the time and frequency domains of HRV. The time domain index of HRV included the standard deviation of the NN intervals (SDNN) and reflected the total variance of HRV. The frequency domain indices of HRV included: (1) LF (0.04–0.15 Hz); (2) HF (0.15–0.4 Hz); and (3) the LF/HF ratio (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Billman, 2013; Reyes del Paso et al., 2013).

ECG artifact identification included four steps: First, we set up a five-second window for detecting each ECG raw signals and interbeat interval (IBI) by visually inspected. Second, procedure for normalizing IBI data involved combining three operations while detecting the ECG artifacts: (a) adding short IBI values together when extra beats occurred; (b) splitting IBI values into two equal parts when beats were missed; (c) averaging pairs of consecutive IBI values when they include one long and one short IBI value. This step was used because it did not disturb the continuity of the IBI series which were important for the frequency analysis. Third, we consulted the cardiologists for abnormal ECG raw signals. Fourth, time and frequency domains of HRV indices were analysis by CardioPro Infiniti HRV analysis module.

2.3.2. Subjective feelings of anxiety and relaxation

A visual analog scale (VAS) with a 10-cm horizontal line with the word descriptors at the ends "was presented", such as "extremely anxious" or "extremely relaxed" on the right-hand end and "not at all anxious" or "not at all relaxed" on the left-hand end. Participants were asked to mark a point on the line that best represented their levels of anxiety and relaxation at baseline and when practicing each of the four breathing patterns. The instruction was as follows: "Please use the pen to mark your anxiety and relaxation levels on this line. If you mark the point on the left side, it means that you were not at all anxious/not at all relaxed; if you mark the point on the right side, it means that you were extremely anxious/extremely relaxed. Please evaluate your anxiety/relaxation levels at baseline and for four different breathing patterns." The level of anxiety and relaxation was determined by measuring the distance, in centimeters, between the left-hand end of the line and the point marked by a participant.

2.4. Statistical analysis and data reduction

This study calculated the absolute HRV power, including the absolute LF and HF, and the LF/HF ratio at baseline and for four different breathing patterns. The one-way analysis of variance (ANOVA) with Scheffe's method for post-hoc comparison was used to examine the differences in demographic data and baseline HRV indices between the groups. One-way repeated measures ANOVA with Fisher's least significant difference (LSD) for post-hoc comparison was used to examine the changes in HRV indices and anxiety and relaxation levels at baseline and those induced by four different breathing patterns. The effect size of the partial eta-squared (η_p^2) was calculated for each HRV index: an η_p^2 of 0.01–0.05 reflected a small effect size; an η_p^2 of 0.06–0.14 reflected a medium effect size; and that exceeding 0.14 reflected a large effect size (Stevens, 2002). The statistical analyses were performed using the SPSS predictive analytics software, version 18.0 (SPSS Inc., Chicago, IL, United States).

3. Results

One of the female participants in group 4 was excluded from data analysis, because ECG raw signals revealed premature ventricular contractions; she was referred to a cardiologist for further diagnosis and treatment. A total of 47 participants, including 37 women (78.70%), completed the study (mean age, 20.98 ± 1.03 years). There were no significant differences between the groups in age, sex, body mass index, exercise frequency, and baseline breaths rate ($F = 1.01$, $p > 0.05$; $\chi^2 = 1.27$, $p > 0.05$; $F = 0.42$, $p > 0.05$; $F = 1.17$, $p > 0.05$; and $F = 1.23$, $p > 0.05$, respectively) (Table 1).

There were no significant differences between the groups with respect to baseline HRV indices including SDNN, LF, and HF (Table 1). However, there was a significant difference between the groups in the LF/HF ratio ($F = 3.05$, $p < 0.05$), but it was not confirmed by the Scheffe's post-hoc comparison.

3.1. Breathing rate of 5.5 bpm with an I:E ratio of 5:5 significantly increases HRV

Regarding HRV indices, a repeated measures ANOVA with the Greenhouse–Geisser correction showed statistically significant differences between the four different breathing patterns for SDNN ($F_{1,\ 46} = 94.41$, $p < 0.001$; effect size = 0.67), LF ($F_{1,46} = 64.26$, $p < 0.001$; effect size = 0.58), and LF/HF ratio ($F_{1,46} = 25.17$, $p < 0.001$; effect size = 0.35) (Table 2). The Fisher's LSD post-hoc comparison revealed the following: (1) there was a higher SDNN for pattern 5.5 bpm 5:5 than for pattern 6 bpm 4:6; (2) there was a higher LF for pattern 5.5 bpm 5:5 than for pattern 6 bpm 4:6 and pattern 5.5 bpm 4:6; and (3) there was a higher LF/HF ratio for pattern 6 bpm 5:5 and 5.5 bpm 5:5 than for pattern 6 bpm 4:6 (Fig. 3). There were no significant differences in HF between the four different breathing patterns ($F_{1,46} = 2.93$, $p > 0.05$; effect size = 0.06).

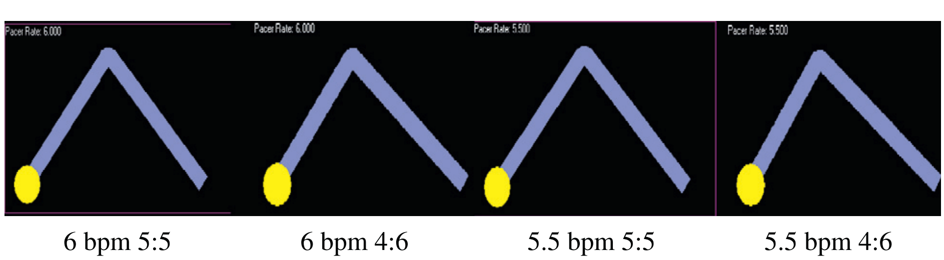

Fig. 2. Paced breathing with four types of breathing patterns.

Table 1
The demographic data and baseline HRV indices ($N = 47$).

Variables	Group 1 ($n = 12$)	Group 2 ($n = 12$)	Group 3 ($n = 12$)	Group 4 ($n = 11$)	χ^2/F
Age	21.17 (1.53)	20.58 (0.67)	21.25 (1.06)	20.91 (0.54)	$F = 1.01$
Sex	9F/3M	9F/3M	9F/3M	10F/1M	$\chi^2 = 1.27$
Body mass index (BMI)	21.76 (5.13)	20.45 (2.59)	21.45 (4.66)	20.22 (1.99)	$F = 0.42$
Exercise frequency	1.00 (0.85)	1.08 (0.67)	0.64 (0.67)	0.60 (0.84)	$F = 1.17$
Baseline breaths rate	13.93 (3.66)	11.07 (4.71)	12.48 (2.68)	13.22 (3.94)	$F = 1.23$
Baseline HRV indices					
SDNN	51.91 (22.64)	52.49 (15.30)	55.44 (14.41)	52.02 (26.48)	$F = 0.08$
LF	555.04 (1093.89)	530.17 (507.06)	469.76 (399.66)	494.89 (391.34)	$F = 0.04$
HF	346.64 (191.25)	276.07 (306.73)	418.45 (299.70)	312.15 (503.58)	$F = 0.38$
LF/HF ratio	1.66 (2.63)	6.60 (7.85)	1.99 (1.67)	3.18 (2.78)	$F = 3.05$[*,a]

[*] $p < 0.05$.
[a] No significant difference between 4 groups as shown by the Scheffe's post-hoc comparison.

3.2. Breathing slowly increases the subjective feeling of relaxation

A repeated measures ANOVA with the Greenhouse–Geisser correction showed differences in the relaxation level ($F_{1,\ 46} = 7.91$, $p < 0.001$; effect size $= 0.15$) between the four types of breathing patterns; the Fisher's LSD post-hoc comparison revealed that participants reported higher relaxation levels for the four different breathing patterns compared with baseline ($t = -0.84$, $p < 0.01$; $t = -0.99$, $p < 0.01$; $t = -0.72$, $p < 0.05$; and $t = -0.99$, $p < 0.001$, respectively). However, there was no significant difference in the anxiety level between spontaneous breathing at baseline and four different breathing patterns ($F_{1,\ 46} = 1.40$, $p > 0.05$; effect size $= 0.03$) (Fig. 4).

4. Discussion

This study used a Latin square experimental design to control the variation in HRV indices and to examine breathing patterns with respect to HRV indices and subjective feelings of anxiety and relaxation. The results revealed that slow breathing significantly increased SDNN, LF, LF/HF ratio, and the subjective feeling of relaxation compared with spontaneous breathing. In addition, a breathing pattern of 5.5 bpm with an I:E ratio of 5:5 was associated with higher LF power and resonant frequency than that of 6 or 5.5 bpm with an I:E ratio of 4:6; moreover, this study also confirmed that 5.5 bpm with a 5:5 ratio was associated with a higher SDNN than that of 6 bpm with a 4:6 ratio.

Regarding the breathing rate and HRV indices, slow breathing with both 6 and 5.5 bpm resulted in higher HRV indices compared with spontaneous breathing at baseline. This finding was consistent with previous studies showing that slow breathing produced beneficial effects on physiological function (Bernardi et al., 2002; Joseph et al., 2005; Vaschillo et al., 2002), including increased LF power in healthy adults, patients with asthma, and those with major depressive disorder (Karavidas et al., 2007; Lehrer, 2007; Lehrer et al., 2006; Song and Lehrer, 2003; Vaschillo et al., 2002) as well as increased SDNN in patients with coronary artery disease and major depressive disorder (Del Pozo et al., 2004; Karavidas et al., 2007). In addition, our study confirmed that a breathing rate of 5.5 bpm was associated with higher PNS and baroreflex function (SDNN, LF, and LF/HF ratio) than that of 6 bpm. An increase in LF power and SDNN may be explained by the fact that slow breathing at this resonance frequency may stimulate vagal tone or baroreflex to modulate the sinoatrial node, increase heart rate oscillation, and increase HRV (Bernardi et al., 2001; Lehrer et al., 2003, 2006). In addition, increased LF power contributes to an increase in the LF/HF ratio (Billman, 2013).

Regarding the I:E ratio and HRV indices, our results indicate that an I:E ratio of 5:5 was associated with higher LF heart rate variability compared with an I:E ratio of 4:6; and suggest that an equal I:E ratio may have been associated with a greater increase in cardiac vagal activity compared with a ratio with longer exhalation than inhalation. Similar to the findings of a previous study, a breathing pattern of 6 bpm and an equal I:E ratio in a yoga beginner were associated with higher baroreflex sensitivity and oxygen saturation compared with spontaneous breathing (Mason et al., 2013); as well as equal I:E ratio in healthy adults produced higher heart rate asymmetry (Porta's and Guzik's indices) than prolonged expiration (1:2 of I:E ratio) (Klintworth et al., 2012). In contrast, Strauss-Blasche et al. (2000) found that prolonged exhalation was associated with greater RSA and HF compared with prolonged inhalation or an equal I:E ratio in spontaneous breathing. However, participants in the study by Strauss-Blasche et al. breathed at a spontaneous breathing (9.6 and 10.0 bpm). Participants breathed more slowly (6 or 5.5 bpm) both in our study and in that by Mason et al. (6 bpm). Thus, the differences between these studies in HRV indices may be influenced by an interaction between breathing rate and I:E ratio.

Using a HRV biofeedback protocol instructing an individual to slow down the breathing rate to about 6 bpm (Lehrer et al., 2000), previous studies have demonstrated increases in RSA amplitude and in LF HRV in patients with asthma, coronary artery disease, cardiac surgery, prehypertension, and major depressive disorder (Del Pozo et al., 2004; Karavidas et al., 2007; Lehrer et al., 2004; Lin et al., 2012; Patron et al., 2012; Wang et al., 2010). A recent study has also found that HRV biofeedback training significantly increases HF and the LF/HF ratio (Wells et al., 2012) and decreases blood pressure (Mikosch et al., 2010).

Slow breathing was shown to increase the subjective feeling of relaxation that could reinforce participants to practice continually. However, slow breathing may be uncomfortable during the first few sessions and difficult for a novice to maintain. Our results suggest that participants could decrease the breathing rate progressively and achieve 5.5 bpm with an I:E ratio of 5:5 as the final goal for clinical implications. Moreover, breathing at this pattern may increase PNS and baroreflex function, as well as increase subjective feeling of relaxation simultaneously.

Table 2
The mean and standard deviation of heart rate variable at baseline and 4 types of breathing pattern ($N = 47$).

Variables/stages	Baseline (BL)	6 bpm 5:5 (A)	6 bpm 4:6 (B)	5.5 bpm 5:5 (C)	5.5 bpm 4:6 (D)	F	Effect size (η_p^2)	Fisher's LSD post-hoc comparison
SDNN	52.99 (19.57)	90.91 (27.99)	88.55 (29.27)	92.92 (27.43)	89.97 (25.93)	94.41[***]	0.67	C > B; ABCD > BL
LF	512.84 (648.24)	2843.59 (1858.47)	2611.33 (1765.57)	2908.88 (1757.75)	2658.34 (1643.42)	64.26[***]	0.58	C > B,D; ABCD > BL
HF	338.88 (332.75)	227.03 (288.35)	260.29 (371.05)	217.18 (239.06)	255.70 (241.47)	2.93	0.06	
LF/HF ratio	3.36 (4.77)	23.46 (16.66)	17.74 (12.31)	22.45 (14.82)	20.12 (21.79)	25.17[***]	0.35	A,C > B; ABCD > BL

[***] $p < 0.001$.

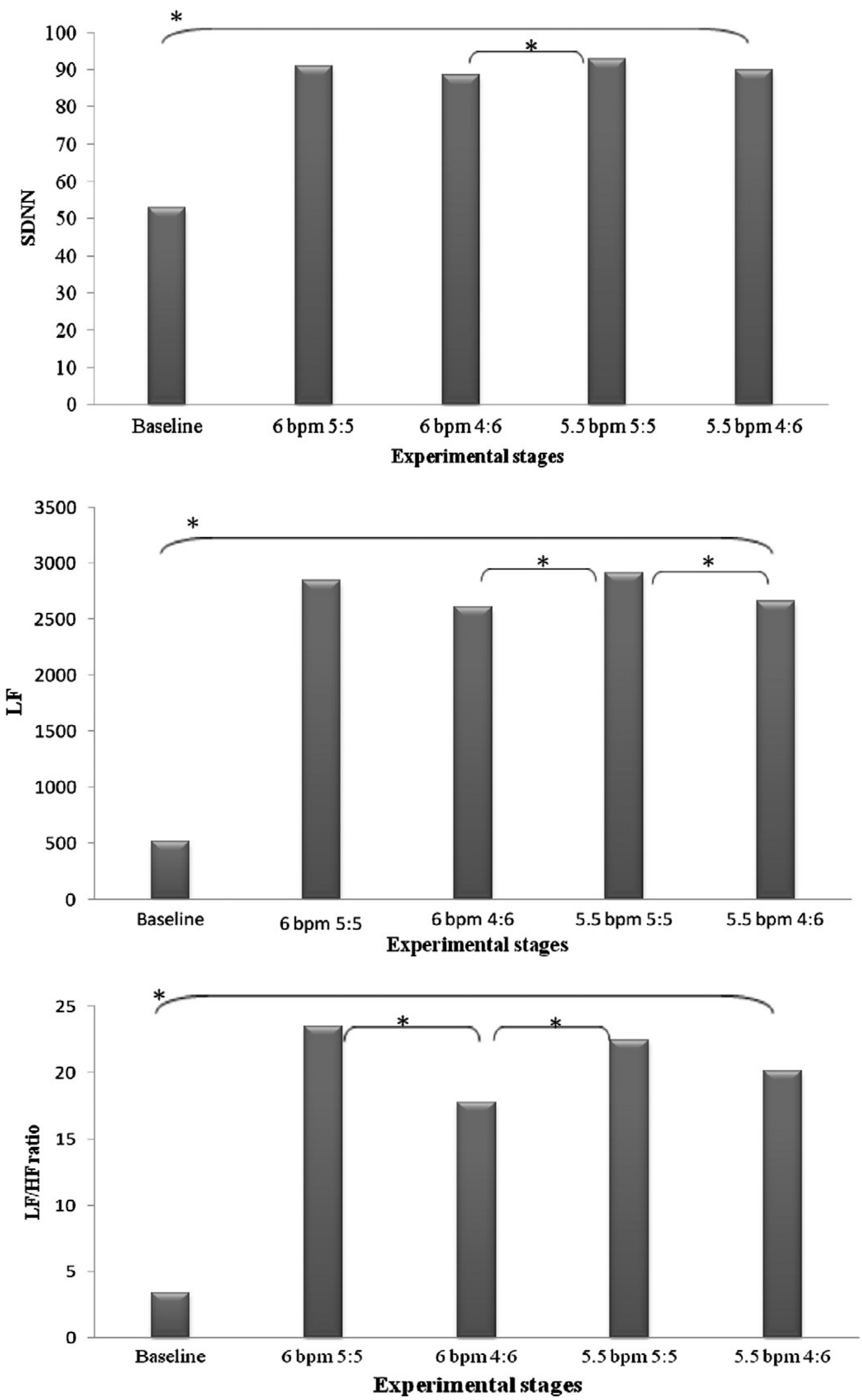

Fig. 3. SDNN (top), LF (medium), and LF/HF ratio (bottom) in four different types of breathing patterns.

Some limitations of the study have to be acknowledged. First, because of nonequal sample size in each group, the Bonferroni correction for post-hoc tests was not used to control for the type-I error in multiple comparisons. Second, although we applied a counterbalanced design, a 1 min rest between each trial might have produced spillover or residue effects. Third, this study did not measure the end-tidal volume, oxygen saturation, carbon dioxide, and baroreflex sensitivity at baseline and for four different breathing patterns. These variables might be recorded for comprehensive measures. In the future, the effects of slow breathing with an equal I:E ratio should be explored in clinical patients.

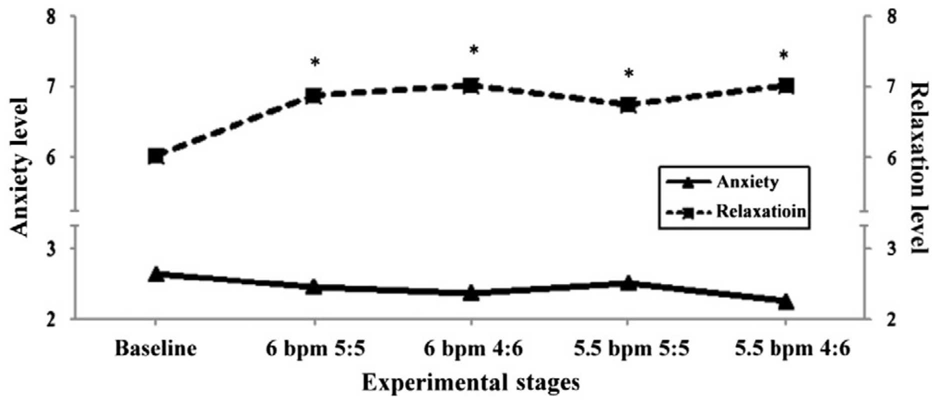

Fig. 4. Relaxation and anxiety levels in four different types of breathing patterns.

In summary, this study revealed that 5.5 bpm with an I:E ratio of 5:5 increased vagal/PNS activations or baroreflex function than the other breathing patterns. This result can be applied to clinical populations with a low HRV, such as coronary artery disease, major depressive disorder, and anxiety disorder in the future studies (Kemp et al., 2010; Kleiger et al., 1987; Licht et al., 2009).

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