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# Conscious Slower Breathing Predominates Parasympathetic Activity and Provides a Relaxing Effect, in Healthy Japanese Adult Women

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## Abstract

**Background:** The optimal breathing pattern (BP) to effectively regulate autonomic nervous activity is yet to be determined. **Objective:** We aimed to clarify the effects of four BPs (BP-1, BP-2, BP-3, and BP-4) on autonomic nervous activity and mood changes. **Methods:** Eleven healthy adult female volunteers performed each BP in a sitting position for 5 min in a resting state. The time required for one breathing for BP-1 (30 breaths/min), BP-2 (20 breaths/min), BP-3 (15 breaths/min), and BP-4 (10 breaths/min) were 2 s, 3 s, 4 s, and 6 s, respectively. The inspiratory/expiratory time of one breathing was 1 s/1 s, 1 s/2 s, 2 s/2 s, and 2 s/4 s. The high-frequency component (HF) and low-frequency component (LF)/HF ratio during and before (control) performing a BP were calculated from heart rate variability data recorded using the wearable biometric information tracer M-BIT. Three mood changes, which are, "pleasure—unpleasure", "relaxation—tension", and "sleepiness—arousal", in the subjects were assessed using the visual analog scale (VAS) before and after performing a BP. **Results:** Slower breathing induced an increase in HF power and a reduction in LF/HF ratio, indicating increased parasympathetic activity and decreased sympathetic dominance. Furthermore, VAS revealed that slower breathing increased the tendency to feel "pleasure", "relaxation", and "sleepiness". **Conclusion:** Our results suggest that slower breathing predominates parasympathetic activity in the autonomic nervous system, resulting in a relaxing effect. This result may help lay the foundation for deriving breathing methods that efficiently regulate an individual's autonomic activity.

**Keywords**

Breathing, Autonomic Activity, Heart Rate Variability Analysis, Visual Analog Scale

## 1. Introduction

Homeostasis is the property of maintaining a constant physiological function regardless of changes in internal and external environmental factors and is extremely important for human health. It is maintained by balancing the three functions of the autonomic nervous, endocrine, and immune systems [1]. One of the factors that disturb this balance is "stress". Cortisol, a representative stress hormone, is secreted into the blood from the adrenal cortex via the hypothalamic- pituitary-adrenal (HPA) axis upon receiving a stress stimulus and induces a stress response. It is an essential hormone for the body that has various metabolic actions such as hepatic gluconeogenesis, lipolysis, protein metabolism, and hypoglycemic action, and it is also involved in anti-inflammatory and immunosuppressive actions. However, excessive stress chronically increases the secretion of cortisol, resulting in stress-related physical and psychological symptoms, including insomnia, depression, anxiety, headaches, and diminished attention [2]. Therefore, understanding how to deal with stress is crucial in the modern society called "stress society". Recently, attention has been focused on approaches for controlling the imbalance of autonomic nervous activity caused by stress: excessive sympathetic nerve activity and decreased parasympathetic nerve activity. One of these approaches is abdominal breathing [3] [4]. This utilizes the regulatory mechanisms of the respiratory and circulatory systems, which increases the heart rate (sympathetic nerve activity) in the inspiratory phase and decreases the heart rate (parasympathetic nerve activity) in the expiratory phase to regulate the autonomic nervous system.

We breathe unknowingly, but in breathing controlled by the autonomic nervous system, inspiration and expiration are controlled by the sympathetic and parasympathetic nerves, respectively [5]. In other words, sympathetic and parasympathetic activities are affected by inspiration and exhalation, respectively [6] [7]. Thus, breathing is the only way to consciously control the activity of the autonomic nervous system.

We can consciously control the speed and frequency of breathing. Therefore, consciously controlling unconscious breathing makes it possible to balance the sympathetic nerve and parasympathetic nerve activities. The advantage of using conscious breathing methods is that they can alleviate and prevent various physical and psychological symptoms caused by imbalances in the activity of the autonomic nervous system.

Autonomic imbalance (or dysautonomia) is more common in women than in men. This is because women are more susceptible to hormonal imbalances than men. Specifically, menstruation, pregnancy, childbirth, and menopause have a significant impact on hormone balance and the autonomic nervous system. Conscious breathing techniques may alleviate dysautonomia in women [8]. For example, it has been reported that attempting a slow breathing pattern (BP) increases parasympathetic activity and has an effective relaxing effect [9] among women with premenstrual syndrome (PMS) or dysmenorrhea who have mental and physical stress symptoms, such as active sympathetic activity and difficulty in relaxing [9] [10]. However, more scientific evidence is needed to verify the optimal BP to effectively regulate its activity.

Recent advances in science and technology have made it easier to understand the balance between sympathetic and parasympathetic activation by analyzing heart rate variability (HRV). Power spectral analysis of HRV has been widely used to quantify the regulatory state of autonomic nervous system activity [11] [12]. This technique partitions the total variance of HRV into its frequency components, typically identifying two main peaks, which is, low (LF, 0.04 - 0.15 Hz) and high frequencies (HF, 0.15 - 0.4 Hz). It has been widely believed that the HF peak reflects parasympathetic nerve activity, while the LF reflects both parasympathetic and sympathetic components. Therefore, the LF-to-HF (LF/HF) ratio could be used to quantify the changing relationship between sympathetic and parasympathetic activities in health and disease [12]. That is, a higher LF/HF ratio indicates sympathetic dominance, whereas a lower ratio indicates parasympathetic dominance [7] [13].

In this study, four breathing patterns (BPs) were performed in 11 healthy adult female volunteers to determine the effects of conscious breathing on autonomic activity and mood in women. Slow breathing and prolonged exhalation are widely thought to activate the parasympathetic nerves, resulting in a relaxed state [6] [7] [14] [15]. The four BPs used in this study have two elements: respiratory rate (10 - 30 breaths/min) and exhalation (inspiration/exhalation ratio = 1:1 and 1:2). The autonomic activity was assessed using the HF component and LF/HF ratios from HRV power spectral analysis. Mood status was assessed using the visual analog scales (VAS) for "pleasure—unpleasure", "relaxation—tension", and "sleepiness—arousal".

## 2. Methods

### 2.1. Participants

In total, 11 healthy female subjects, who provided informed consent, were examined in this study. The mean ± standard error of participants' age, height, weight, and obesity index was 32.2 ± 5.1 years, 161.0 ± 6.4 cm, 48.4 ± 4.4 kg, and 18.7 ± 1.9, respectively. Participants were instructed not to eat one hour before the measurement and not to consume caffeine on the day of the study. They were also instructed to sleep well, avoid strenuous exercise, and refrain from drinking alcohol the day before. We confirmed that participants adhered to these instructions on themselves reports.

### 2.2. Ethics

This investigation was carried out in accordance with the Helsinki Declaration, and all subjects provided informed consent. The study protocol was approved by the Ethics Committee of Juntendo University Graduate School of Health and Sports Science, Japan (Grad. 29-59).

### 2.3. Experimental Design

In this experiment, four types of BPs, that is, BP-1, BP-2, BP-3, and BP-4, as shown in Table 1, were set to investigate the relationship between breathing method and autonomic nervous activity or mood status. Experiments were performed in a quiet room set at room temperature 25˚C - 28˚C and humidity 40% - 60%. Each subject performed a different BP once a day for 4 days.

For BP-1, the inspiratory/exhalation time ratio (TI/TE ratio) was set to 1:1 and consisted of 1-s inspiratory time (TI) and 1-s expiratory time (TE). The time required for one breath (breathing cycle) was 2 s, and the respiratory rate was 30 breaths/min. For BP-2, the TI/TE ratio was set to 1:2 and consisted of a 1-s TI and a 2-s TE. The time required for one breath was 3 s, implying that the respiratory rate was 20 breaths/min. For BP-3, the TI/TE was 1:1, similar to BP-1, but the TI and TE were twice as long as BP-1. The time required for one breath was 4 s, and the respiratory rate was 15 breaths/min. In the case of BP-4, the TI/TE was 1:2, which was similar to BP-2, but the TI and TE were twice as long as BP-2. The time required for one breath was 6 s, and the respiratory rate was 10 breaths/min.

The experimental procedure, as shown in Figure 1, was explained to the subjects before the experiment. The experimental time for each BP was 35 min. Briefly, all female subjects attached an M-BIT to their left chest to obtain HRV data. After a 30-min rest in the sitting position, a BP was performed for 5 min. HRV data during the 5-min BP and for 10 min before performing BP were recorded using M-BIT. The data acquired before performing each BP served as a preliminary value (control). Additionally, the mood status of each subject was assessed using a VAS 5 min before and immediately after performing the BP. All parameters were assessed by the rate of change of the pre-values before performing BP.

**Table 1.** Four types of breathing patterns used in this study.

| Breathing pattern (BP) | Inspiratory and expiratory time (sec) per one breathing | | One breathing time (sec) | Respiratory rate (breaths/min) |
|---|---|---|---|---|
| | Inspiration | Expiration | | |
| BP-1 | 1 | 1 | 2 | 30 |
| BP-2 | 1 | 2 | 3 | 20 |
| BP-3 | 2 | 2 | 4 | 15 |
| BP-4 | 2 | 4 | 6 | 10 |

One breathing time for BP-1 (30 breaths/min), BP-2 (20 breaths/min), BP-3 (15 breaths/min), and BP-4 (10 breaths/min) was 2 s, 3 s, 4 s, and 6 s, respectively. The inspiratory/expiratory time (TI/TE) of one breathing for BP-1, BP-2, BP-3, and BP-4 was 1 s/1 s, 1 s/2 s, 2 s/2 s, and 2 s/4 s, respectively.

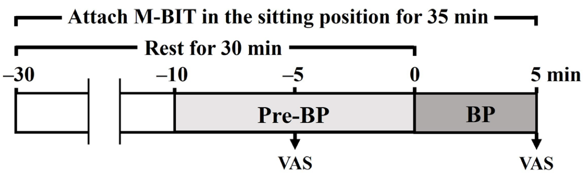



**Figure 1.** Experimental schedule HRV data during the 5-min BP and for 10 min before performing BP were recorded using M-BIT. The subject's mood was assessed using VAS before and after performing a BP.

### 2.4. Measurement of Autonomic Nervous Function Using M-BIT

HRV data for assessing autonomic nervous function were recorded using the wearable biometric information tracer, M-BIT (Institute of Man and Science, INC, Japan). HF component and LF/HF ratio were analyzed using the BIT analysis software (Institute for Research in Humanities). The HF component and LF/HF ratio were used as indicators of parasympathetic activity and sympathetic dominance of autonomic activity. The effect of the 5-min BP on each parameter was assessed by the rate of change of the pre-values for 10 min before performing BP.

### 2.5. Evaluation of Mood Status Using VAS

Mood states, including "pleasure—unpleasure", "relaxation—tension", and "sleepiness—arousal", were assessed for all subjects before and after performing each BP using three 100-mm VAS [16]. Briefly, the left point (0 mm) on each VAS line indicated "pleasure, relaxation, or sleepiness", and the right point (100 mm) indicated "unpleasure, tension, or arousal". All subjects marked the degree of their mood on the line. The intensities of unpleasure, tension, and arousal were quantified by measuring the distance from 0 mm. The effect of each BP on the mood status was assessed by the rate of change before (control) and after performing the BP.

### 2.6. Statistical Analyses

All values are represented as the mean ± S.E.M. Statistical analysis among BP groups was performed using Dunn's multiple comparison test after Friedman's nonparametric factorial analysis in the GraphPad Prism software version 8.4.2 (GraphPad Software Inc., San Diego, CA, USA). The accepted significance level was $P < 0.05$.

## 3. Results

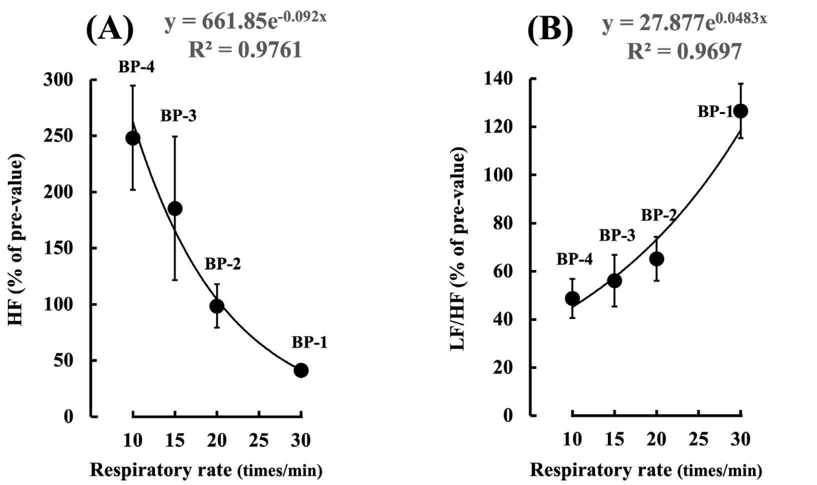
### 3.1. Effects of Breathing Patterns on Autonomic Nervous Activity

Figure 2 shows the effects of four BPs (BP-1, 30 breaths/min; BP-2, 20 breaths/min; BP-3, 15 breaths/min; and BP-4, 10 breaths/min) on (A) HF component and (B) LF/HF ratio. A very high exponential approximation correlation (R2) was found between the BP (*i.e.*, respiratory rate) and (A) HF components (R2 = 0.9761) or (B) LF/HF ratio (R2 = 0.9697). It was discovered that slower breathing had a higher HF than faster breathing and, conversely, a lower LF/HF ratio.

Comparing BP-1 and BP-3, the TI/TE ratio was the same as 1:1, but the TI and TE of BP-3 were found to be twice as long as those of BP-1. Moreover, the TI/TE ratio of BP-2 and BP-4 was the same as 1:2, but the TI and TE of BP-4 were twice as long as those of BP-2. Thus, BP-3 and BP-4, which reduced the respiratory rate by doubling TI and TE, were noted to have a higher HF component and a lower LF/HF ratio than BP-1 and BP-2.

Furthermore, a comparison of BP-1 and BP-2 or BP-3 and BP-4 revealed the effect of TE on the HF component and LF/HF ratio. Respiratory rates of BP-2 and BP-4 were reduced by increasing the TE by twice the TI of BP-1 and BP-3, respectively. As a result, BP-2 and BP-4, which reduced the respiratory rate by doubling TE, had a higher HF component and a lower LF/HF ratio than BP-1 and BP-3.

Factorial analysis detected significant differences in both HF (F = 18.93, P < 0.001) and LF/HF (F = 13.58, P < 0.001). Post-hoc analysis found a statistically significant difference between BP-1 and BP-3 (P < 0.05) or BP-4 (P < 0.001) in the HF component. Additionally, the LF/HF ratio showed a statistically significant difference between BP-1 and BP-2 (P < 0.05), BP-3 (P < 0.01), or BP-4 (P < 0.05).




**Tukey's multiple comparison test** (A)

| Comparison | P value | Significance |
|---|---|---|
| BP-1 vs. BP-2 | 0.2851 | ns |
| BP-1 vs. BP-3 | 0.0494 | * |
| BP-1 vs. BP-4 | 0.0001 | *** |
| BP-2 vs. BP-3 | >0.9999 | ns |
| BP-2 vs. BP-4 | 0.1247 | ns |
| BP-3 vs. BP-4 | 0.5919 | ns |

**Tukey's multiple comparison test** (B)

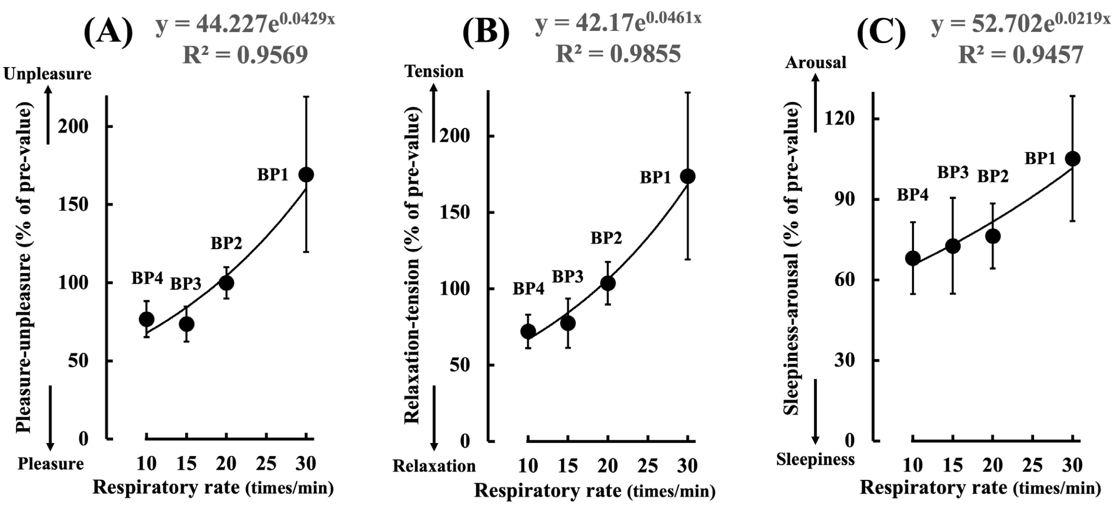
| Comparison | P value | Significance |
|---|---|---|
| BP-1 vs. BP-2 | 0.03 | * |
| BP-1 vs. BP-3 | 0.0057 | ** |
| BP-1 vs. BP-4 | 0.03 | * |
| BP-2 vs. BP-3 | >0.9999 | ns |
| BP-2 vs. BP-4 | >0.9999 | ns |
| BP-3 vs. BP-4 | >0.9999 | ns |

Figure 2. Correlation between the respiratory rate and HF component (A) or LF/HF ratio (B) in the four BPs. HRV data for 5 min during BP and 10 min before performing BP were recorded using M-BIT. The HF component and LF/HF ratio from the HRV data were analyzed using the BIT analysis software. The effect of the 5-min BP on each parameter was assessed by the rate of change of the 10-min pre-values. The data represent the mean ± SEM (n = 11). Statistical analysis was performed using Türkiye's multiple comparison test. **P < 0.01, ***P < 0.001, and ****P < 0.0001. ns: No significance.

Considering that the HF component indicates parasympathetic activity and the LF/HF ratio indicates sympathetic dominance, it was demonstrated that slower breathing increased parasympathetic activity; conversely, faster breathing decreased parasympathetic activity and increased sympathetic dominance of autonomic activity.

### 3.2. Effects of Breathing Patterns on Moods

Figure 3 shows the effects of four BPs on three moods as assessed using the VAS: (A) pleasure—unpleasure, (B) relaxation—tension, and (C) sleepiness—arousal. Factorial analysis detected significant differences between pleasure—unpleasure and respiratory rate among the four BPs (F = 13.25, P < 0.001). Post-hoc analysis found statistically significant differences between BP-1 and BP-3 (P < 0.05) or BP-4 (P < 0.01). With respect to relaxation-tension and sleepiness-arousal, no statistically significant differences were detected among the four BPs. However, a very high exponential approximation correlation ($R^2 > 0.9$) was found between the respiratory rate and each VAS mood, with or without statistical significance. These results imply that slower breathing caused "pleasure", "relaxation", and "sleepiness", and as breathing became faster, it turned into "unpleasure", "tension", and "arousal".




**Tukey's multiple comparison test** (A)

| Comparison | P value | Significance |
|---|---|---|
| BP-1 vs. BP-2 | 0.2851 | ns |
| BP-1 vs. BP-3 | 0.0177 | * |
| BP-1 vs. BP-4 | 0.0057 | ** |
| BP-2 vs. BP-3 | >0.9999 | ns |
| BP-2 vs. BP-4 | >0.9999 | ns |
| BP-3 vs. BP-4 | >0.9999 | ns |

**Tukey's multiple comparison test** (B)

| Comparison | P value | Significance |
|---|---|---|
| BP-1 vs. BP-2 | >0.9999 | ns |
| BP-1 vs. BP-3 | 0.1908 | ns |
| BP-1 vs. BP-4 | 0.1547 | ns |
| BP-2 vs. BP-3 | >0.9999 | ns |
| BP-2 vs. BP-4 | >0.9999 | ns |
| BP-3 vs. BP-4 | >0.9999 | ns |

**Tukey's multiple comparison test** (C)

| Comparison | P value | Significance |
|---|---|---|
| BP-1 vs. BP-2 | >0.9999 | ns |
| BP-1 vs. BP-3 | >0.9999 | ns |
| BP-1 vs. BP-4 | 0.5919 | ns |
| BP-2 vs. BP-3 | >0.9999 | ns |
| BP-2 vs. BP-4 | >0.9999 | ns |
| BP-3 vs. BP-4 | >0.9999 | ns |

Figure 3. Correlation between respiratory rate and mood changes in the four BPs. Pleasure—unpleasure (A), relaxation—tension (B), and sleepiness—arousal (C) were assessed using VAS before and after performing each BP. The data calculated as the rate of change before and after performing each BP represent the mean ± SEM (n = 11). Statistical analysis was performed using Tukey's multiple comparison test.

Comparing BP-1 and BP-3, the TI/TE ratio was the same as 1:1, but the TI and TE of BP-3 were twice as long as those of BP-1. The TI/TE ratio of BP-2 and BP-4 was also the same as 1:2, but the TI and TE of BP-4 were twice as long as those of BP-2. BP-3 and BP-4 with slower breathing tended to be more “pleasure”, “relaxation”, and “sleepiness” than BP-1 and BP-2 with faster breathing. These results indicate that doubling TI and TE to reduce the respiratory rate increases the tendency to feel “pleasure”, “relaxation”, and “sleepiness”.

Additionally, a comparison of BP-1 and BP-2, as well as BP-3 and BP-4, indicated the effect of TE on mood. Respiratory rates of BP-2 and BP-4 were reduced by doubling the TE of BP-1 and BP-3, respectively. Therefore, BP-2 and BP-4 tended to be more “pleasure”, “relaxation”, and “sleepiness” than BP-1 and BP-3, respectively. These results indicate that slower breathing with longer TE increases the tendency to feel “pleasure”, “relaxation”, and “sleepiness”.

## 4. Discussion

In the spectral analysis of HRV, LF (0.04 - 0.15 Hz), and HF (0.15 - 0.40 Hz), two critical frequency domain parameters have been widely used to evaluate autonomic activity: LF power reflects both sympathetic and parasympathetic activities, while HF power reflects the parasympathetic activity. Furthermore, the LF/HF ratio reflects the balance between sympathetic and parasympathetic activities, *i.e.*, sympathetic dominance of autonomic activity [17]. The HF component is also referred to as the respiratory component or respiratory sinus arrhythmia, as it coincides with the respiratory cycle, and its peak frequency depends on the respiratory rhythm, such as respiratory rate, inspiration, and expiratory ratio [18] [19]. Therefore, if the breathing is too fast or too slow, the respiratory component will not fit into the HF band. Particularly, when the respiratory rate is <9 breaths/min, the HF component peak shifts toward the LF band so that the apparent HF component decreases while the LF component and LF/HF ratio increase. This could result in a misinterpretation of sympathetic and parasympathetic activities [7] [17]. Therefore, in this study, we set four BPs (10 - 30 breaths/min), namely, BP-1, BP-2, BP-3, and BP-4, which can completely separate the LF and HF components, and investigate the relationship between respiratory rate and autonomic nervous activity.

A very high exponential approximation correlation was found between respiratory rate and HF component or LF/HF ratio (**Figure 2**), implying that slower breathing had higher HF power and a lower LF/HF ratio than faster breathing. In contrast, faster breathing reduced HF power and increased the LF/HF ratio. Considering that the HF component reflects parasympathetic activity and the LF/HF ratio reflects the sympathetic dominance of autonomic activity [7] [12] [13], these results suggest that slower breathing increases parasympathetic activity and decreases the sympathetic dominance of the autonomic activity. Conversely, faster breathing is suggested to decrease parasympathetic activity and increase the sympathetic dominance of autonomic activity. This result is consistent with reports that reducing the respiratory rate suppresses sympathetic nerve activity and activates parasympathetic nerve activity [14].

Additionally, comparing BPs with TI/TE ratios of 1:1 and 1:2, it was discovered that the 1:2 slower breathing had higher HF power and lower LF/HF ratio than the 1:1 faster breathing. This result is supported by previous reports that prolonged exhalation breathing activates parasympathetic function [6]. One of the causes is thought to be the movement of the diaphragm during abdominal breathing, which then prolongs exhalation and functions as a stimulus to the parasympathetic nerves [20].

Parasympathetic activity is known to be promoted during rest and relaxation. For example, listening to slow-tempo music has been demonstrated to increase parasympathetic activity and relaxing effects due to increased salivary oxytocin levels and HF components and decreased heart rate [21]. Furthermore, in women in the early postpartum period, who often show instability in autonomic activity, back massage has been reported to increase parasympathetic dominance, such as decreased blood pressure and heart rate and increased HF, resulting in increased relaxation [22]. In this study, the relationship between the four BPs and mood changes, such as "pleasure—unpleasure", "relaxation—tension", and "sleepiness—arousal", was evaluated using VAS. A very high correlation was observed between breathing frequency and these three mood swings (**Figure 3**). Faster breathing (BP-1), with low HF component power, had higher VAS indicators of unpleasure, tension, and arousal compared to slower breathing (BP-4). Conversely, slower breathing, including expiratory prolongation with a higher HF component, shifted the VAS index to pleasure, relaxation, and sleepiness. This result suggests that slower breathing, including prolonged exhalation and increased parasympathetic activity, provided a relaxing effect.

The LF/HF ratio increased with increasing respiratory rate, and the VAS index revealed higher unpleasure, tension, and arousal. Conversely, the LF/HF ratio decreased with slower breathing, including prolonged exhalation, and the VAS index shifted to pleasure, relaxation, and sleepiness. This result indicates that the relaxing effect was caused by the relative decrease in the sympathetic nerve activity of the autonomic nervous balance.

Limited to the experimental conditions in this study, our findings indicate that slower breathing (BP-3 and BP-4) induced by prolongation of both TI and TE, or prolongation of TE, predominates parasympathetic activity in the autonomic nervous system, which, in turn, could result in a relaxing effect.

This study was conducted in healthy women because autonomic imbalance is more common in women than in men [8]. However, conscious abdominal breathing has been attempted for relaxation, health maintenance, and stress management in various fields, such as healthy people [23], elderly people [2], athletes [20], women with PMS and dysmenorrhea [9], patients with impaired pulmonary function [14], and patients with essential hypertension [11]. Thus, our results may help lay the foundation for deriving respiratory methods that efficiently regulate individual autonomic activity in various fields.

## 5. Conclusion

Slower breathing induced by prolongation of TI and TE, or of TE, predominates parasympathetic activity in the autonomic nervous system, resulting in a relaxing effect. Among the BPs examined in this study, BP-4 (respiratory rate: 10 breaths/min, breathing cycle: 6 s, TI/TE: 2 s/4 s) was the most suitable breathing pattern for relaxation.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] Kubo, C. (2003) Stress and Immune Function. *Japan Medical Association Journal*, **46**, 50-54. https://www.med.or.jp/english/pdf/2003_02/050_054.pdf

[2] Bauld, R. and Brown, R.F. (2009) Stress, Psychological Distress, Psychosocial Factors, Menopause Symptoms and Physical Health in Women. *Maturitas*, **62**, 160-165. https://doi.org/10.1016/j.maturitas.2008.12.004

[3] Tanaka, M., Nagasaka, M., Yano, T., *et al.* (2011) Autonomic Nervous Responses during the Controlled Abdominal Breathing Using the Diaphragm in the Elderly. *Struct Functions*, **10**, 8-16.

[4] Telles, S., Singh, N. and Balkrishna, A. (2011) Heart Rate Variability Changes during High Frequency Yoga Breathing and Breath Awareness. *BioPsychoSocial Medicine*, **5**, Article No. 4. https://doi.org/10.1186/1751-0759-5-4

[5] Milic-Emili, J. (1982) Recent Advances in Clinical Assessment of Control of Breathing. *Lung*, **160**, 1-17. https://doi.org/10.1007/BF02719267

[6] Komori, T. (2018) The Relaxation Effect of Prolonged Expiratory Breathing. *Mental Illness*, **10**, Article 7669. https://doi.org/10.4081/mi.2018.7669

[7] Russo, M.A., Santarelli, D.M. and O'Rourke, D. (2017) The Physiological Effects of Slow Breathing in the Healthy Human. *Breathe*, **13**, 298-309. https://doi.org/10.1183/20734735.009817

[8] Cheng, C.A., Liang, Y.C., Chang, Y.H., *et al.* (2021) Increased Incidence of Premenstrual Syndrome in Females with Palmar Hyperhidrosis. *International Journal of Environmental Research and Public Health*, **18**, Article 4697. https://doi.org/10.3390/ijerph18094697

[9] Ohira, M., Machiura, M., Saito, S. and Muramoto, J. (2013) Effect of Breathing Method on Relaxation for Women with Premenstrual Syndrome. *Maternal Health*, **53**, 497-504. https://cir.nii.ac.jp/crid/1520853832658624256

[10] Baker, F.C., Colrain, I.M. and Trinder, J. (2008) Reduced Parasympathetic Activity

during Sleep in the Symptomatic Phase of Severe Premenstrual Syndrome. *Journal of Psychosomatic Research*, **65**, 13-22. https://doi.org/10.1016/j.jpsychores.2008.04.008

[11] Li, C., Chang, Q., Zhang, J. and Chai, W.S. (2018) Effects of Slow Breathing Rate on Heart Rate Variability and Arterial Baroreflex Sensitivity in Essential Hypertension. *Medicine*, **97**, e0639. https://doi.org/10.1097/MD.0000000000010639

[12] Malliani, A., Pagani, M., Lombardi, F. and Cerutti, S. (1991) Cardiovascular Neural Regulation Explored in the Frequency Domain. *Circulation*, **84**, 482-492. https://doi.org/10.1161/01.CIR.84.2.482

[13] Billman, G.E. (2013) The LF/HF Ratio Does Not Accurately Measure Cardiac Sympatho-Vagal Balance. *Frontiers in Physiology*, **4**, Article 26. https://doi.org/10.3389/fphys.2013.00026

[14] Bernardi, L., Spadacini, G., Bellwon, J., *et al.* (1998) Effect of Breathing Rate on Oxygen Saturation and Exercise Performance in Chronic Heart Failure. *The Lancet*, **351**, 1308-1311. https://doi.org/10.1016/S0140-6736(97)10341-5

[15] Lin, I.M., Tai, L.Y. and Fan, S.Y. (2014) Breathing at a Rate of 5.5 Breaths per Minute with Equal Inhalation-to-Exhalation Ratio Increases Heart Rate Variability. *International Journal of Psychophysiology*, **91**, 206-211. https://doi.org/10.1016/j.ijpsycho.2013.12.006

[16] Kato, K. (2011) Changes in Autonomic Nerve Activity and Pleasure-Displeasure during Hot Compresses to the Posterior Region of the Neck: A Comparison between 40 and 60 Degrees Centigrade. *Journal of Japan Society of Nursing Research*, **34**, 39-48.

[17] Ziemssen, T. and Siepmann, T. (2019) The Investigation of the Cardiovascular and Sudomotor Autonomic Nervous System—A Review. *Frontiers in Neurology*, **10**, Article 53. https://doi.org/10.3389/fneur.2019.00053

[18] Berntson, G.G., Cacioppo, J.T. and Quigley, K.S. (1993) Respiratory Sinus Arrhythmia: Autonomic Origins, Physiological Mechanisms, and Psychophysiological Implications. *Psychophysiology*, **30**, 183-196. https://doi.org/10.1111/j.1469-8986.1993.tb01731.x

[19] Yasuma, F. and Hayano, J. (2004) Respiratory Sinus Arrhythmia: Why Does the Heartbeat Synchronize with Respiratory Rhythm? *Chest*, **125**, 683-690. https://doi.org/10.1378/chest.125.2.683

[20] Martarelli, D., Cocchioni, M., Scuri, S. and Pompei, P. (2011) Diaphragmatic Breathing Reduces Postprandial Oxidative Stress. *The Journal of Alternative and Complementary Medicine*, **17**, 623-628. https://doi.org/10.1089/acm.2010.0666

[21] Ooishi, Y., Mukai, H., Watanabe, K., Kawato, S. and Kashino, M. (2017) Increase in Salivary Oxytocin and Decrease in Salivary Cortisol after Listening to Relaxing Slow-Tempo and Exciting Fast-Tempo Music. *PLOS ONE*, **12**, e0189075. https://doi.org/10.1371/journal.pone.0189075

[22] Nakakita Kenyon, M. (2015) Randomized Controlled Trial on the Relaxation Effects of Back Massages for Puerperants on the First Post-Partum Day. *Japan Journal of Nursing Science*, **12**, 87-98. https://doi.org/10.1111/jjns.12053

[23] Sakaki, K. (2001) The Effects of Abdominal Breathing on Autonomic Nervous Function in Women: The Relationship among Individual Differences in Autonomic Nervous System Activity in Supine Position at Rest. *Japanese Journal of Physical Fitness and Sports Medicine*, **50**, 105-118. https://doi.org/10.7600/jspfsm1949.50.105