The Experimental Study on the Effects of Pause Breathing Patterns on Heart Rate Variability

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Abstract: In order to observe the effect of Pause Breathing (PB) patterns on Autonomic Nervous and determine the Yin and Yang modulating mechanism of PB, two different PB patterns: Inhaling-Exhaling-Pause (I-E-P), Inhaling-Pause-Exhaling (I-P-E) with two different respiratory frequencies: 16 breaths/min and 5 breaths/min were observed on 10 healthy adults. We used R-R interval spectral analysis of Heart Rate Variability (HRV) to determine the Parasympathetic Nervous System (PNS) and Sympathetic Nervous System (SNS) activities. We found (1) I-E-P and I-P-E at 16 breaths/min didn't exert significant influence on autonomic nervous systems, (2) Both I-E-P and I-P-E at 5 breaths/min increased sympathetic activity, on basis of which, I-E-P which could enhance exhaling, also increased parasympathetic activity, and I-P-E which could enhanced inhaling, induced more increased sympathetic activity. From the view of Chinese Medical theory, the former breathing had the action of strengthening Yang, while the latter reducing Heat and enhancing Yin. (3) There were physiological after-effects after the respiratory regulation.

Keywords: Qigong, respiration, heart rate variability, spectral analysis, autonomic nervous systems, sympathetic nervous system, parasympathetic nervous system

Introduction

Qigong is a unique method of healing developed as a component of Traditional Chinese Medicine. It has a rich and vivid history dating back at least 5000 years during which it has been proven effective for the treatment and prevention of diseases.1)

Qigong has three key techniques done by the Qigong practitioner’s self-initiative: adjustment of posture, regulation of breath, and regulation of the mind. The regulation of breath is important because it enables the Qigong practitioner to reach the Qigong state, which has been shown to trigger a wide array of physiological mechanisms having profound healing benefits. There are various breath patterns, such as pause breath, abdominal breath, breath combined with vocalization, breathe combined with imagination, etc. The breath itself adjusts the respiratory center and autonomic...
nervous activity (ANA), so the physiological functions of viscera can be regulated and improved.

Many researchers have studied the physiological mechanisms of Qigong state, such as electroencephalograph, electrocardiogram, blood pressure, temperature, blood flow etc. However there are only limited qualitative and quantitative studies on autonomic nervous activity in breathing adjustment.

In this study, we observed how the Pause Breathing (PB) patterns with different breath frequencies affect autonomic nervous activities. We looked at two PB patterns: Inhaling-Exhaling-Pause (I-E-P) and Inhaling-Pause-Exhaling (I-P-E) and two breathing frequencies: 16 breaths/min and 5 breaths/min. We used R-R interval spectral analysis of Heart Rate Variability (HRV) to determine the Parasympathetic Nervous System (PNS) and Sympathetic Nervous System (SNS) activities. From the HRV component, we calculated the integrated powers in the high--frequency (0.1525-0.4 Hz, HF) and low--frequency (0.0488-0.1525 Hz, LF) regions. The HF region reflected PNS activity, and the LF region represented SNS activity. The sympathovagal indices were determined from the ratio of LF/HF.

Methods

Subjects
Ten healthy persons (4 males and 6 females, aged 21.3±0.8 years) were recruited from college students for this study. Based on their medical history and physical examination, no subjects had hypertension, any concurrent illness or used medication. Subjects were nonsmokers and without evidence of cardiovascular disease as seen from their history and electrocardiograms. Subjects avoided consuming caffeine on the day of study and alcohol 24 hours before the study. None had engaged in regular Qigong exercise before beginning the program.

Apparatuses for measurements

Electrocardiogram

BioView G, NEC Medical Systems, Inc. (Japan)

Respiration

Nasal Respiration (Thermistor Method), Abdominal Respiration (Expander Method)

Data Acquisition System MP100, BioPAC Inc. (USA) Software AcqKnowledge

Multimedia file (sound file to help control the pause breath times)

Conditions of laboratory room:
The respiratory experiments were performed in a quiet laboratory room with temperature between 20-24°C and humidity between 25%-35%.

Breathing tests:
There were four breathing tests. The 10 subjects took all four breathing tests giving 40 breathing tests/person. There was at least a 30-min break between any two tests taken in one day, and no more than two tests were completed on one day.

A1 Test: pre-PB (natural breathing for 3 min) – PB (Inhaling-Exhaling-Pause at 16 breaths/min for 9 min) – post-PB (natural breathing for 9 min)

A2 Test: pre-PB (natural breathing for 3 min) – PB (Inhaling-Pause-Exhaling at 16 breaths/min for 9 min) – post-PB (natural breathing for 9 min)

B1 Test: pre-PB (natural breathing for 3 min) – PB (Inhaling-Exhaling-Pause at 5 breaths/min) for 9 min –
post-PB (natural breathing for 9 min)
B2 Test: pre-PB (natural breathing for 3 min) – PB
(Inhaling - Pause - Exhaling at 5 breaths/min) for 9 min –
post-PB (natural breathing for 9 min)

Requirements of Pause Breathing
The subject took a sitting posture with orthodromic
abdominal breathing (dilating the abdomen while
inhaling and contracting it while exhalting), the mouth
was closed lightly and then breathing was through the
nose.
Inhaling-Pause-Exhaling (I-P-E): The subject inhaled,
and at the same time directed Qi down to lower abdomen
by self-will. The breath was held for a moment and then
exhaled.
Inhaling-Exhaling-Pause (I-E-P): The subject inhaled,
and at the same time directed Qi down to lower abdomen
by self-will. This was followed by exhaling and then
holding the breath for a moment.

Data collection
The subject sat in a chair in a quiet, motionless,
relaxed, but awake, state with the eyes closed.
Various sensors were placed on the subject and data
(including ECG, wave of nasal and abdominal respiration,
etc.) were acquired continuously through the data
acquisition system MP 100. Data were analyzed using
the software AcqKnowlegment.

Spectral analysis of HRV:
Spectral analysis of HRV was performed. FFT (Fast
Fourier Transformation) analyzed the electrocardiogram
data using a hamming filter. In accordance with the
previous protocol, the HRV data of the first 3 min of
natural breathing, middle 9 min of PB, and the final 9 min
of natural breathing were subjected to spectral analysis.
For HRV, the integrated powers in the low-frequency
region (0.0488–0.1525 Hz, LF) and in the high-frequency
region (0.1525–0.4 Hz, HF) were calculated. The ratio of
LF/HF was obtained.

Statistical analysis
Means ± SE are reported throughout. Paired t test
was used to compare baseline values (Pre-PB) of HRV
between the two different PB patterns (I-E-P and I-P-E)
with two different frequencies (16 breaths/min and 5
breaths/min), and to compare differences among PB
patterns and differences between Pre-PB and post-PB.

Results

1. Effects of PB patterns on LF, HF and LF/HF ratio

Fig. 1 Effects of PB patterns on LF, HF, and LF/HF

We saw the following points from Fig. 1.
(1) A1-PB in comparison with A2-PB:
There were no significant differences between the two
patterns (I-E-P and I-P-E) in the values of LF, HF and
LF/HF ratio below 16 breaths/min.
2. Results of A2 breathing test for LF, HF and LF/HF

We saw the following points from Fig. 3.

(1) I-P-E breathing in comparison with Pre-PB:
There were no significant differences in the values of LF, HF and LF/HF ratio.

(2) Post-PB in comparison with Pre-PB:
Post-PB increased LF/HF significantly (LF: 1.000±0.000 to 1.609±0.866, p<0.05; LF/HF: 1.000±0.000 to 2.342 to 1.571, p<0.05)

1. Results of A1 breathing test for LF, HF and LF/HF

We saw the following points from Fig. 2.

(1) I-E-P breathing in comparison with pre-PB:

There were no significant differences in the values of LF, HF and LF/HF.

(2) B1-PB in comparison with B2-PB:
B1 and B2 tended to increase LF, but there were no significant differences between the LF values.
HF during B1-PB breathing seemed higher than that in B2-PB, but no statistical difference was observed.
LF/HF during B2 breathing was significantly higher than during B1 (3.092±2.461 to 15.405±12.458, p<0.05).

(3) B1-PB in comparison with A1-PB
For the same PB pattern (I-E-P), B1-PB increased LF significantly in comparison with A1-PB (0.926±0.447 to 7.738±5.986, p<0.01), and also increased HF (1.038±0.545 to 2.798±2.324, p<0.05), and LF/HF (1.176±0.773 to 3.092±2.461, p<0.05).

(4) B2-PB in comparison with A2-PB
B2-PB increased LF significantly from (0.699±0.497 to 11.748±9.429, p<0.01).
No statistical significant difference was found for the value of HF.
B2-PB increased LF/HF significantly from (0.879±0.599 to 15.405±12.458, p<0.01).

3. Results of B1 breathing test for LF, HF and LF/HF

We saw the following points from Fig. 4.

(1) I-P-E breathing in comparison with Pre-PB:
There were no significant differences in the values of LF, HF and LF/HF ratio.

(2) Post-PB in comparison with Pre-PB:
Post-PB increased LF and LF/HF significantly (LF: 1.000±0.000 to 1.609±0.866, p<0.05; LF/HF: 1.000±0.000 to 2.342 to 1.571, p<0.05)
Fig. 4 Results of B1 breathing test for LF, HF and LF/HF

We saw the following points from Fig. 4.

1. I-E-P breathing in comparison with Pre-PB:
   I-E-P breathing tended to increase HF, but there were no statistically significant differences in the HF values. I-E-P breathing increased LF/HF ratio significantly (1.000±0.000 to 3.092±2.461, p<0.05).

2. Post-PB in comparison with Pre-PB:
   Post-PB increased LF significantly (1.000±0.000 to 1.739±0.764, p<0.05), but no statistically significant changes were found in values of HF and LF/HF.

5. Results of B2 breathing test for LF, HF and LF/HF

Fig. 5 Results of B2 breathing test for LF, HF and LF/HF

We saw the following points from Fig. 5.

1. I-P-E breathing in comparison with Pre-PB:
   I-P-E breathing increased LF and LF/HF significantly (LF: 1.000±0.000 to 11.748±9.429, p<0.01; LF/HF: 1.000±0.000 to 15.404±12.458, p<0.01), but there were no statistically significant differences in the HF values. I-P-E breathing increased LF/HF ratio significantly (1.000±0.000 to 3.092±2.461, p<0.05).

2. Post-PB in comparison with Pre-PB:
   Post-PB increased LF and LF/HF significantly (LF: 1.000±0.000 to 2.755±2.209, p<0.05; LF/HF: 1.000±0.000 to 4.689±4.687, p<0.05), but no statistically significant changes were found in the HF values.

Discussion

1. The PB at 16 breaths/min

The normal breath frequency is about 12-18 breaths/min for adult. In this study, the effects of the pause breathing at 16 breaths/min were observed. We found that I-P-E and I-E-P did not produce significant changes in the values of LF, HF and LF/HF ratio in comparison with Pre-PB, and there were no significant differences between the two PB patterns in the values of LF, HF and LF/HF ratio. So we could see that when subjects imitated Qigong's pause breathings at 16 breaths/min, the two patterns did not change the indexes of HRV remarkably. This suggested that the two did not significantly influence autonomic nervous activities. The sympathovagal balance remained. This result is consistent with a previous Qigong experimental report2).

After much Qigong practice, the most significant and obvious physiological change has been reported to be the reduction of respiratory frequencies; the breath frequency can even be reduced to 6-3 breaths/min3). This suggested to us that the reduction of breath frequency has more impact on the autonomic nervous system than the changes of the breathing patterns.

2. The PB at 5 breaths/min

a. I-E-P and I-P-E at 5 breaths/min in comparison with that at 16 breaths/min
The most obvious physiological change in Qigong state is the slow respiratory frequency. In this study, when subjects imitated PB at 5 breaths/min by consciously slowing down and deepening their breath, we found that both I-P-E and I-E-P produced increased LF and LF/HF ratio which reflected the enhanced sympathetic activity. However, in addition to the decreased breathing frequency and deepening of breath, some Qigong studies have shown increased HF in Qigong state that represent enhanced parasympathetic activities\(^{3,4}\). So therefore, the breath exercises imitating Qigong breathing patterns are not equivalent to Qigong state.

Qigong practice emphasizes the unification of posture, breathing and the mind. A person will fail to enter Qigong state by only doing breathing exercises without the supplement of mind and posture. Over concentrating on breath regulation without taking proper posture and relaxing the mind may induce Qigong deviation and suffocating feeling. In this study, many subjects felt a bit suffocated during the PB tests.

There were two possible reasons for the increased SNS activity during the pause breathing at 5 breaths/min: i. The cerebral cortex regulated central respiratory activity and influenced respiration effectively, so subjects could regulate their respiration consciously. In this study, the subjects overemphasized PB itself making some region of the cortex stimulated, thus exciting the lower respiration center which spread along the nervous system, and enhanced the sympathetic activity.

ii. Since subjects overemphasized breath regulation by lower the breath frequency and deepening the breath, so it may produce mental and muscular tension which lead to excitement of sympathetic nerve activity.

b. Under 5 breaths/min, I-E-P in comparison with I-P-E the increased LF and LF/HF ratio in I-E-P and I-P-E at 5 breaths/min imply enhanced sympathetic activity, but we observed that LF/HF ratio in I-P-E was significantly higher than I-E-P. PAusing after inspiration made the SNS (Sympathetic Nervous System) hyperactive, which damaged the balance of sympathovagal activity. The LF/HF ratio in I-E-P was relatively low; this meant that the pause after expiration enhanced the parasympathetic activity.

From the above results, we concluded different PB could produce different physiological effects at the same slow breath frequency. PB after inspiration may lead to excitement of SNS and after expiration it may lead to excitement of PNS. Traditional medical practitioners in ancient times had already realized different effects of inspiration and expiration. Xue Yanggui in the Qing Dynasty (Mei Hua Wen Da) said: “The inspiration and expiration are critical to human beings, when inspired, the Qi of the earth and heaven enter the human body, when expired, the Qi of the human body will return back to the heaven and earth.” Sheng Ji Zong Lu stated: “The Qi entering the body belongs to Yin, and Qi out of the body belongs to Yang.” From the viewpoint of Yin and Yang property for inspiration and expiration, one belongs to yang, one to Yin. From their effects, expiration tends to go outward and upward and inspiration, to go inward.

From this study and other studies, inspiration and expiration have been found to exert different physiological impacts on the SNS and PSN. The effects of I-P-E and I-E-P on the autonomic nerve system are owing to the characters of Yin and Yang, therefore they carry the different modulating effects on internal organs.

From Qigong practice and application, we found that Qigong concentrated at inspiration is suitable for people
with hypertension, pulmonary emphysema, glaucoma and discomfort of the head, while Qigong emphasized on expiration is suitable for people with poor digestion and aversion to cold due to Yang deficiency. The I-P-E breathing pattern in Neiyang Gong (Inner-nourishing Qigong Form) is regarded to suit people with Yang deficiency, and to have effect of invigorating Yang and expelling coldness. The I- E-P breathing pattern suits people with Yin deficiency, and has the effect of nourishing Yin and clearing heat.

There is a statement in Jing Yue Quan Shu (Jing Yue’s Complete works): “Qigong concentrated on inspiration is not suitable for persons with Yang depletion, and Qigong concentrated on expiration is not suitable for persons with Yin depletion”

In view of effect of PB on the autonomic nerve system, the I-P-E pattern strengthening inspiration leads to enhanced SNS activities, possessing the effect of invigorating Yang. The I-E-P pattern strengthening expiration may enhance PNS activities, having the effect of clearing heat.

So our study has released the Yin and Yang regulatory mechanisms of the two different PB patterns with their different effects on autonomic activities. This provides a guideline for Qigong practice. Accurate understanding on the physiological effects and Yin-Yang regulation of each Qigong form and correct identification of syndrome patterns should be beneficial to the selection of the proper Qigong form and should lead to better results and balance of Yin and Yang.

3. Physiological after-effects from PB

We observed that the indexes of HRV in the post-PB period, some values in Post-PB was changed or enhanced. So it will take a period of time to return to the normal state. This result awaits further study. The above results suggested we should consider after-effects when we design Qigong experiments in order to avoid the error. We had tried to avoid the error by setting a 30-min break between two breathing tests.

In conclusion, different combinations of PB patterns and frequencies produced different physiological effects, and directly influenced the autonomic nervous system activity; furthermore they regulated functions of the viscera.

References

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