Psychophysiology of Slow Breathing Exercises Using Heart Rate Variability Measurements for Stress Reduction: A Preliminary Qualitative Study and Review of the Technique

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Abstract: Slow breathing exercises, associated with meditation and other eastern style modalities like tai chi and hatha yoga, are now increasingly employed in mainstream medicine to reduce stress, attenuate moderate hypertension, and alleviate symptoms of lifestyle-related illnesses. The clinical literature on slow breathing exercises includes studies employing various physiological measurements, including heat rate variability (HRV), galvanic skin response, and changes in skin temperature. HRV has been increasingly used to measure the activity of the autonomic nervous system in various human studies employing healthy and chronically ill subjects. 1. Objective: To understand the physiological effects of slow breathing exercises as complementary interventions for future clinical studies using the technique of HRV measurements. 2. Method: Four subjects, through repetitive trials, were instructed to slow down their breathing following a metronome at 10 breaths per minute or 6 breaths per minute or spontaneously relax to slow down their respiratory rate. The ECG, heart rate, respiratory rate were recorded using a Powerlab set-up (ADInstruments). 3. Key Results: Results showed an increase in heart rate variability during these slow breathing exercises, either through the metronome-guided or spontaneous slow-breathing exercises, especially around a breathing frequency of 6 breaths per minute. The increased amplitude of heart rate variability can be seen as a positive sign, a marker for sympatho-vagal balance.
4. Conclusion: Heart rate variability (HRV) measurements can be a useful tool for looking at efficacy of slow breathing exercises for stress reduction, and to alleviate other symptoms of lifestyle-related illnesses. Future protocols for clinical trials are being projected using the HRV technique and other physiological measurements for studying effects of yoga-based complementary interventions for stress reduction.

Key Words: slow breathing exercises; heart rate variability (HRV)

1. INTRODUCTION

Slow breathing exercises associated with yoga and meditation training have been advocated by mainstream healthcare associations such as the American Heart Association (2014) , and the American Psychological Association (Davis, DM, and Hayes JA, 2011), with many Western medical centers adopting these techniques. Mechanisms for stress reduction and other health benefits of these breathing exercises are being studied from various angles, including effects on autonomic parameters which can also be seen in heart rate variability (HRV) studies.

HRV is a "a simple non-invasive method to evaluate the sympatho-vagal balance at the sinoatrial level" read from a normal ECG. Digital electronics and software has made it possible to show rapid changes in heart rate, including variations in the R-R interval (also known as NN). Heart rate variability first gained attention in the area of fetal monitoring, when the diminished beat-to-beat variation in the fetal heart rate was seen as a sign of fetal distress, necessitating doctors to deliver the baby fast (Akselrod, Gordon, Ubel, Shannon, Barger & Cohen, 1981). It has also been noted in one extensive, longitudinal study that hypertensive individuals tend to have a diminished HRV at baseline; of 7099 individuals without hypertension at baseline, there was a greater risk of developing hypertension over 9 years of follow-up for those with low HRV (Schroeder, Liao, Chambless, Prineas, Evans & Heiss, 2003). An increase in heart rate variability is therefore seen to be a good sign.

Diaphragmatic breathing, also a form of slow breathing, has also been shown to reduce exercise-induced oxidative stress (Martarelli, Cocchioni, Scuri & Pompei, 2011). Self-guided forms of slow breathing during meditation, as well as device-guided breathing to train patients have been used also to lower high blood pressure in some clinical trials (Howorka, Pumprla, Tamm, Schabmann, Klomfar, Kostineak, Howorka, & Sovova, 2013).

To study the effects of slow breathing exercises as a tool for stress reduction in our yoga training program at De Lasalle Health Sciences Institute (DLSHSI) , the heart rate variability (HRV) methodology was explored and initially used by the author in a Japanese research institute (RIEM) at Nagoya University, in preparation for possible future clinical trials at DLSHSI. At the Nagoya University, the following study was conducted on the effects of yoga-based slow breathing exercises on autonomic parameters using the method of Heart Rate Variability (HRV) measurements as an economical way to measure noninvasively the interaction of sympathetic and parasympathetic inputs to the heart.

2. METHODOLOGY

Four subjects were given training on performing the method of diaphragmatic slow breathing with the aid of a metronome by slowing down breathing rate at either 10 breaths per minute or 6 breaths per minute (Protocol 1), or with self-guidance (Protocol 2) by relaxing and slowing down breathing without the use of a metronome. These breathing interventions were done after baseline spontaneous breathing records were recorded. Respiratory rate (measured with a Piezo respiratory belt) and ECG were recorded, with wireless sensors on the chest, hooked up to PowerLab (ADnstrumentIs) analogue-digital recording system, using LabChart with a heart rate variability add-on software. Respiratory rate, ECG (along with heart rate and HRV parameters), body temperature and blood pressure readings were collected prior to, during and after the breathing exercises for segments of 5 minutes each. Two minute- or 5-minute segments of data were used for analysis in appropriate parts of the study, using the Powerlab LabChart software. All recordings were done in a special chamber, to maintain room temperature at around 25 C.

Overview of 2 PROTOCOLS:

Table 1. Protocol 1: Spontaneous breathing (awake) versus Metronome-guided deep, slow breathing (awake) 4 subjects, 38 trials.

	Protocol 1 (38 Trials)
Part I	5 minutes of spontaneous breathing, awake, sitting on chair
Part II	5 minutes of metronome-guided controlled breathing at 10 breaths per minute
Part III	5 minutes of metronome-guided controlled breathing at 6 breaths per minute
Part IV	5 minutes of spontaneous breathing, awake, sitting on chair
	HRV data analysis = 2 minute segments from 5 minute records of each Part.

Table 2. Protocol 2: Spontaneous breathing (awake) versus Self-Guided Deep, Slow Breathing, (awake); 3 subjects, 9 trials.

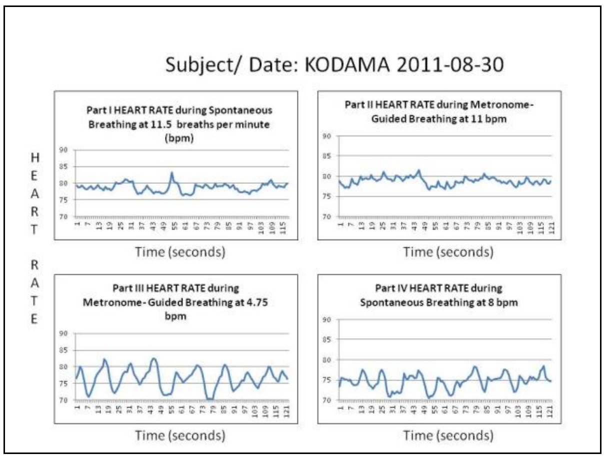
	Protocol 2 (9 Trials, 4 subjects)
Part I	10 minutes of spontaneous breathing, sitting on chair, reading.
Part II	5 minutes of self-guided, deep, slow breathing (no metronome used)
Part III	10 minutes of spontaneous breathing, sitting on chair, reading.

Only 6 representative recordings from 4 subjects (out of 47 recordings) are presented in this paper for a qualitative appraisal of the effects of the breathing intervention from the two Protocols for lack of space. Statistical evaluation of heart rate variability changes were not done at this stage due to the insufficient number of subjects who participated in this preliminary 3-month study.

3. RESULTS AND DISCUSSION

3.1 An increase in amplitude of heart rate variability in metronome-guided slow breathing compared to baseline spontaneous breathing.

Metronome device-guided breathing (part II, and Part III of protocol 1) produced increases in the amplitude of the oscillations of heart rate, also known as heart rate variability, in comparison with baseline recordings shown in part I of the protocol (Fig. 1, 2, 3 and 4).



.Fig. 1. Changes in heart rate variability; during spontaneous breathing versus metronome-guided breathing. This subject initially had difficulty to synchronize breathing rate with metronome frequency at 10 cycles per second or 6 cycles per second. Subject: Male, 52 yrs old Kodama 2011-08-30.

There was a general tendency towards a decline in average heart rate during metronome guided breathing at 10 breaths per minute and 6 breaths per minute.

One subject initially had difficulty synchronizing his breathing rhythm with the metronome (Fig. 1). Final respiratory rate achieved was 11 bpm (part II, Fig. 1) and 4.75 bpm (part III, Fig. 1), during device-guided slow breathing with changes in heart rate variability. With additional training, he was able to synchronize his breathing rate down to the desired slow rhythm.

Similar results with three other subjects are shown below.

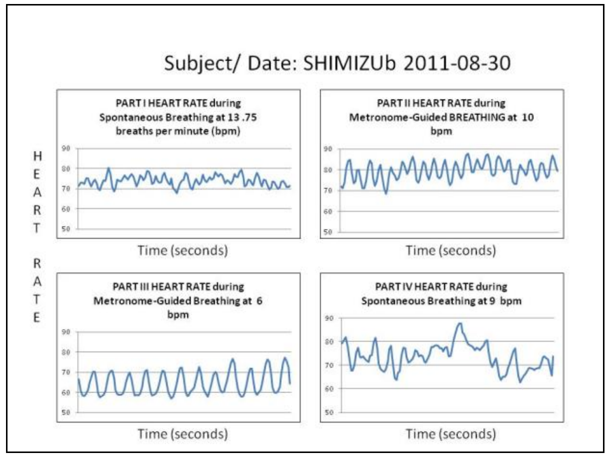


Fig. 2. Changes in heart rate variability; during spontaneous breathing vs. metronome-Guided Breathing (10 or 6 bpm). Subject: Male, Shimizub, 25 yrs old, 2011-08-30

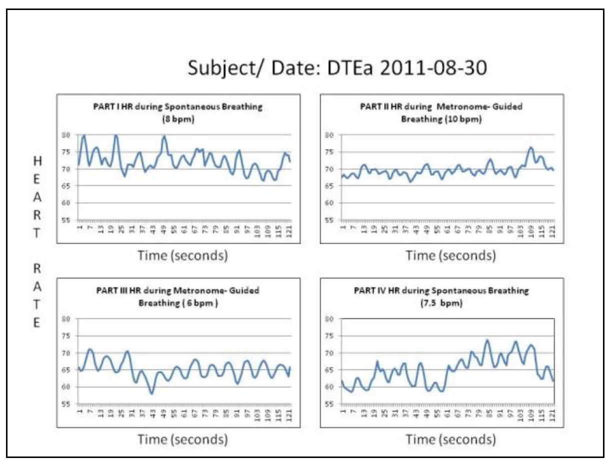


Fig. 3. Changes in heart rate variability; spontaneous breathing vs. metronome-guided breathing (10 or 6 bpm). Subject: Male, DTEa, 54 yrs old, 2011-08-30

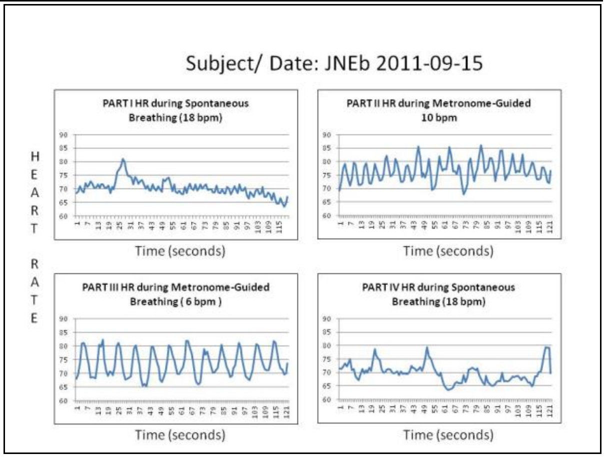


Fig. 4. Changes in heart rate variability; spontaneous breathing vs. metronome-guided breathing (10 or 6 bpm). Subject: Female, JNEb, 37 yrs old, 2011-09-15

Compared to baseline spontaneous breathing, metronome-guided slow breathing exercises at a rate of 6 breaths per minute caused an increase in the low frequency (LF) component of the power spectrum of heart rate variability (HRV) in agreement with results of other laboratories. Metronome-guided slow breathing at a rate of 10 breaths per minute produced an increase in the high frequency (HF) component of HRV.

3.2 An increase in amplitude of heart rate variability in self-guided slow breathing exercises (without metronome "external pressure") versus baseline spontaneous breathing.

Compared to baseline spontaneous breathing, self-guided slow breathing exercises caused an increase in heart rate variability (note the increased amplitude of the fluctuations) as shown in Fig. 5 and Fig. 6.

Note that the subject below (Fig. 5) is a regular yoga and meditation practitioner, conditioned since 2003 in slow breathing exercises, and engaged in regular sports activities which explains his baseline bradycardia (low resting heart rate).

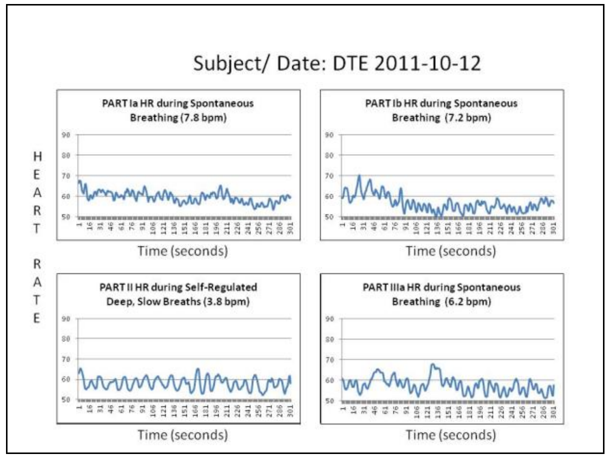


Fig. 5. Changes in heart rate variability; spontaneous breathing vs. self-guided slow breathing. Subject: Male, DTEa, 54 yrs old, 2011-10-12

In self-guided slow breathing , subjects allow themselves to relax and slow down their breathing voluntarily, without pressure from following the rhythm of a metronome, as shown by Fig. 5, increasing the amplitude of heart rate oscillations. This method seems to be less stressful for practioners, according to the oral reports of subjects tested. For example, the previous subject who had difficulty synchronizing his breathing rate using a metronome in the earlier section was able to slow down breathing 'effortlessly' using the self-guided approach, increasing the amplitude of heart rate oscillations (HRV), as shown below in Fig. 6.

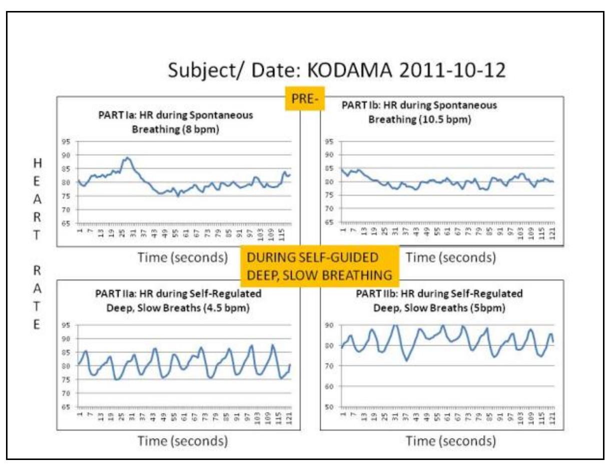


Fig. 6. Changes in heart rate variability; spontaneous breathing vs. self-guided slow breathing. Subject: Male, KODAMA 52 yrs old, 2011-10-12

The preliminary data presented here is in general agreement with studies on device-guided slow breathing, as well as slow breathing during meditation. Many studies have shown that slow breathing increases the low frequency component of heart rate variability, which is an indicator of sympatho-vagal balance (Cysarz & Büssing, 2005). In another study on metronome-guided breathing which was paced at 12 breaths/min, an increase in high-frequency oscillations in heart rate variability was observed (Driscoll & Dicicco G., 2000), in agreement with our high-frequency oscillations in heart rate variability when metronome-guided breathing was paced around 10 breaths per minute. In addition, in our study, it is clear that pacing breathing with a metronome at around 6 breaths per minute would dampen the high-frequency component of HRV changes, and increase the low-frequency component of HRV. In one study with participants employing Zen meditation which does not require one to control breathing, recorded respiration rate was around 15 – 16 breaths which explains their findings that they registered high frequency fluctuations in heart rate variability (Wu & Lo, 2008).

4. CONCLUSIONS and FUTURE DIRECTIONS

Voluntary or device-guided slow breathing exercises can slow down heart rate by prolonging the RR interval, by increasing vagal inputs to the sinoatrial node. In addition, by the mechanism of respiratory sinus arrhythmia (RSA), paced slow breathing can be employed to achieve balance between the sympathetic and parasympathetic system, increasing heart rate variability as a possible contributor to cardiovascular health, among other benefits. It is noteworthy that commercial devices are in the market to aid people with moderate hypertension to learn slow-breathing exercises. Exercises such as yoga, tai chi, mindfulness meditation and other forms of "mind training" which can slow down breathing can be beneficial in stress reduction. The technique of heart rate variability measurements can be employed, alongside biochemical markers, to measure levels of stress and stress reduction using various interventions. In addition to these regular breathing exercises which have potential for stress reduction accompanied by favourable HRV markers, regular athletic exercise would seem to also have favourable influences on HRV (Aubert, Seps, & Beckers, 2003).

It is thus important to look into integration of stress reduction techniques, such as slow breathing exercises associated with Tai Chi, Yoga and other forms of meditation, as complementary interventions for general stress reduction for healthy subjects, as well as for people at risk for heart disease, alongside other lifestyle adjustments covering diet, exercise, and improving psycho-emotional life. Starting with our breath is surely a mindful, and economical way, alongside mainstream therapeutic interventions.

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