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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

Background: Slow breathing exercises are associated with meditation and other eastern practices such as tai chi and hatha yoga. They are employed in mainstream medicine to reduce stress, attenuate moderate hypertension, and alleviate symptoms of lifestyle-related illnesses. Physiological measurements, including heart rate variability (HRV), galvanic skin response, and changes in skin temperature have been employed to assess stress reduction. HRV has become a common means of measuring the activity of the autonomic nervous system in human studies employing healthy and chronically ill subjects.

Objective: To understand the effects of slow breathing exercises on HRV by comparing metronome-guided slow breathing and mindful slow breathing used for stress reduction.

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. ECG, heart rate, and respiratory rate were recorded using a Powerlab set-up.

Results: An increase in amplitude of HRV 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 was observed. The increased amplitude of HRV can be interpreted as a positive sign and marker for sympatho-vagal balance.

Conclusion: Both metronome-guided and mindful slow breathing exercises can increase HRV.

KEYWORDS: Slow breathing exercises, Stress reduction, Heart rate variability [HRV], Sympathovagal balance

INTRODUCTION

Slow breathing exercises associated with yoga and meditation training have been advocated by mainstream healthcare associations including the American Heart Association[1] and the American Psychological Association[2], with many Western medical centres 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 measurement is a simple non-invasive method to assess the interaction of the sympathetic and parasympathetic outflow at the sinoatrial node, reading from a normal ECG. Digital electronics and software has made it possible to measure and visualize oscillations in heart rate rapidly, expressed as variations in the R-R interval. 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 quickly[3]. It has also been noted in one extensive, longitudinal study that hypertensive individuals tend to have a diminished HRV at baseline; of 7,099 individuals without hypertension at baseline, there was a greater risk of developing hypertension over nine years of follow-up for those with low HRV[4]. An increase in heart rate variability is therefore seen as a positive sign.

Diaphragmatic breathing, a form of slow breathing, has also been shown to reduce exercise-induced oxidative stress[5]. 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 clinical trials[6].

Our yoga training program for general fitness and stress management was started in 2006 at the De La Salle Health Sciences Institute; it includes slow breathing exercises. To study the effects of slow breathing exercises as a tool for stress reduction, specifically on HRV, a HRV methodology was explored and initially used by the author in a Japanese research institute (RIEM) at Nagoya University in 2010, in preparation for possible future clinical trials for yoga as adjunct therapy at DLSHSI.

It was hypothesized that both methods of slow breathing would impact HRV in a similar way.

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 (Table 1 Protocol 1), or with self-guidance (Table 2 Protocol 2) by relaxing and slowing down breathing without the use of a metronome (mindful slow breathing). Mindful slow breathing consisted of feeling the physical sensations associated with incoming and outgoing air through the nostrils, or that associated with movements of the belly or chest. These breathing interventions were done after baseline data collection period of spontaneous breathing. Respiratory rate (measured with a Piezo respiratory belt) and ECG were recorded, with wireless sensors on the chest, hooked up to PowerLab (ADInstruments) analogue-digital recording system, using LabChart with a heart rate variability (HRV) add-on software which computed for HRV based on Fast Fourier Transformation of changes in RR interval, based on a sampling frequency of 1000/sec. 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 carried out in a special chamber to maintain room temperature at 25 degrees celsius. The non-invasive collection of data from volunteer human subjects was approved by the ethics committee of the Research Institute of Environmental Medicine.

Overview of 2 Protocols:

Protocol I (38 Trials): Metronome-Guided Slow Breathing	
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
Note:	HRV data analysis = 2 minute segments from 5 minute records of each part

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

Protocol 2 (9 Trials, 4 subjects): Mindful, Slow Breathing	
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

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

Six representative recordings from 4 subjects (out of 47 trials) are presented herein for a qualitative appraisal of the effects of the paced breathing interventions from the two protocols. Statistical evaluation of HRV changes was not done at this stage due to the insufficient number of subjects who participated in this preliminary 3-month study.

RESULTS AND DISCUSSION

Protocol 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, Table 1 above) produced increases in the amplitude of the oscillations of heart rate, also known as heart rate variability, in comparison with baseline recordings as shown in part I of the protocol in all 4 subjects, with a sample recording from one subject seen in Figure 1.

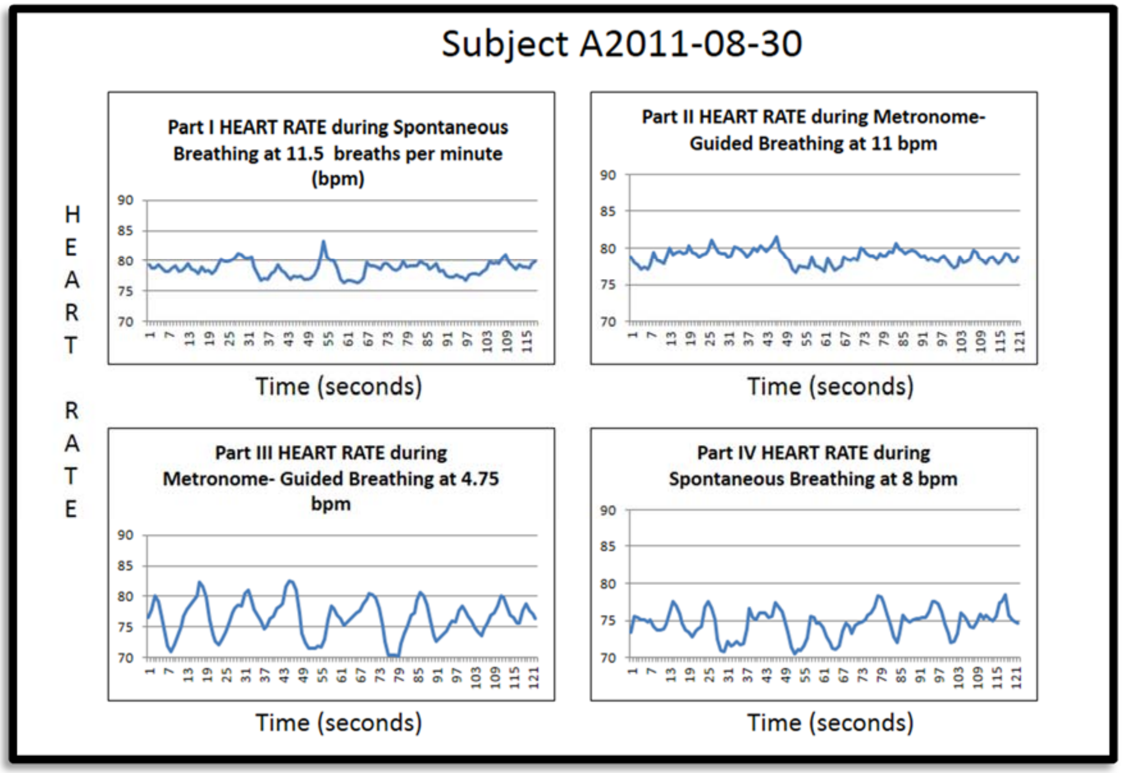

Figure 1 Changes in heart rate variability; during spontaneous breathing versus metronome-guided breathing. This subject initially had difficulty to synchronize breathing rate with metronome frequency at 10 cycles per second or 6 cycles per second. Subject A, Male 52 years old, date recorded on 2011-08-30.

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

This subject initially had difficulty synchronizing his breathing rhythm with the metronome (Fig. 1). Final respiratory rate achieved was 11 bpm (for part II of Fig. 1) and 4.75 bpm (for part III of 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 found in Figures 2, 3 and 4, showing increases in the amplitude of the oscillations of heart rate.

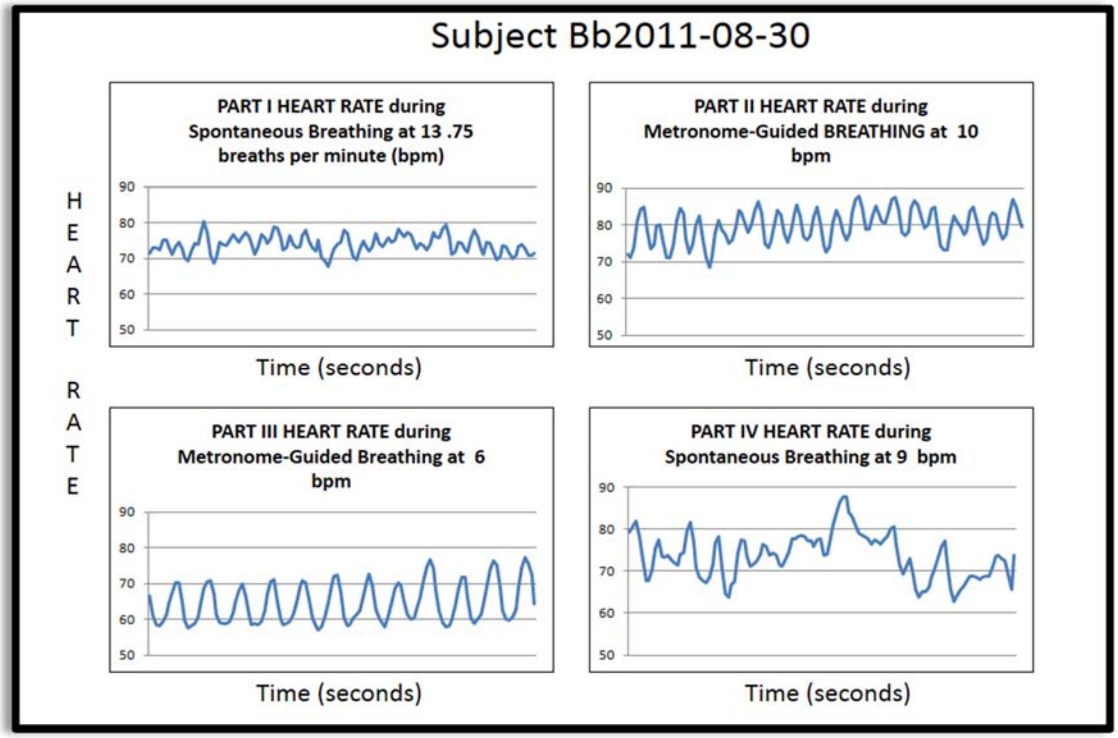

Figure 2 Changes in heart rate variability; during spontaneous breathing versus metronome-Guided Breathing [10 or 6 bpm]. Subject B, Male, 25 years old, date recorded on 2011-08-30.

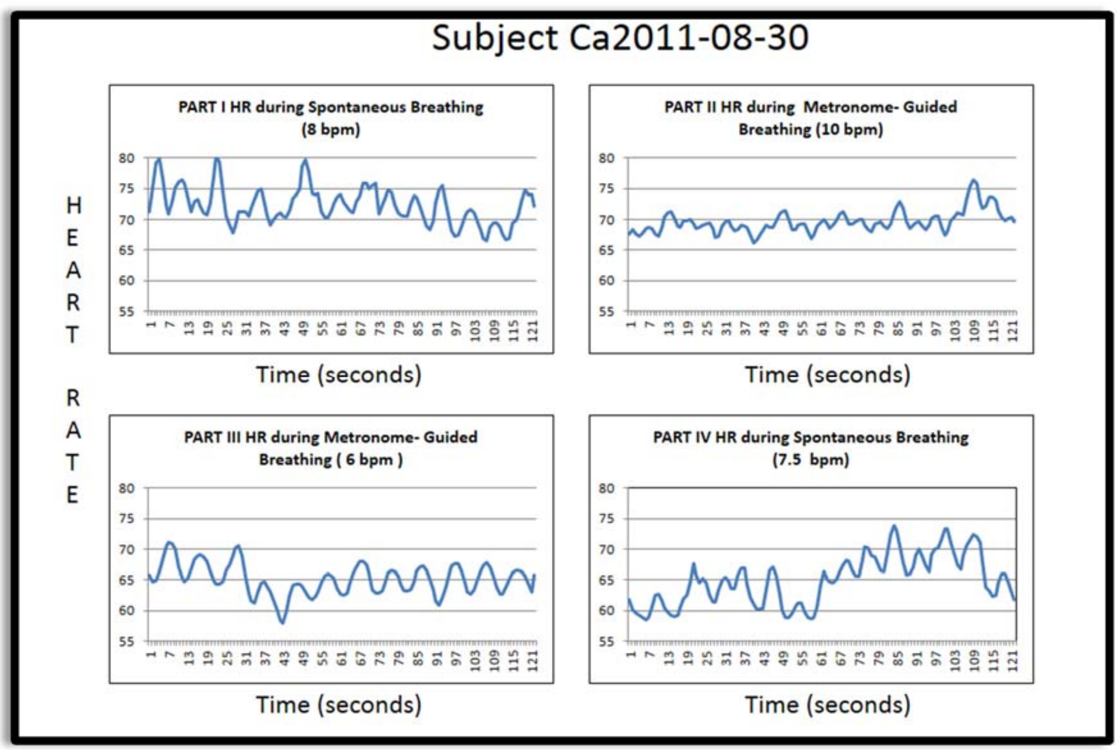

Figure 3 Changes in heart rate variability; spontaneous breathing vs. metronome-guided breathing [10 or 6 bpm]. Subject C, Male, 54 years old, date recorded on 2011-08-30.

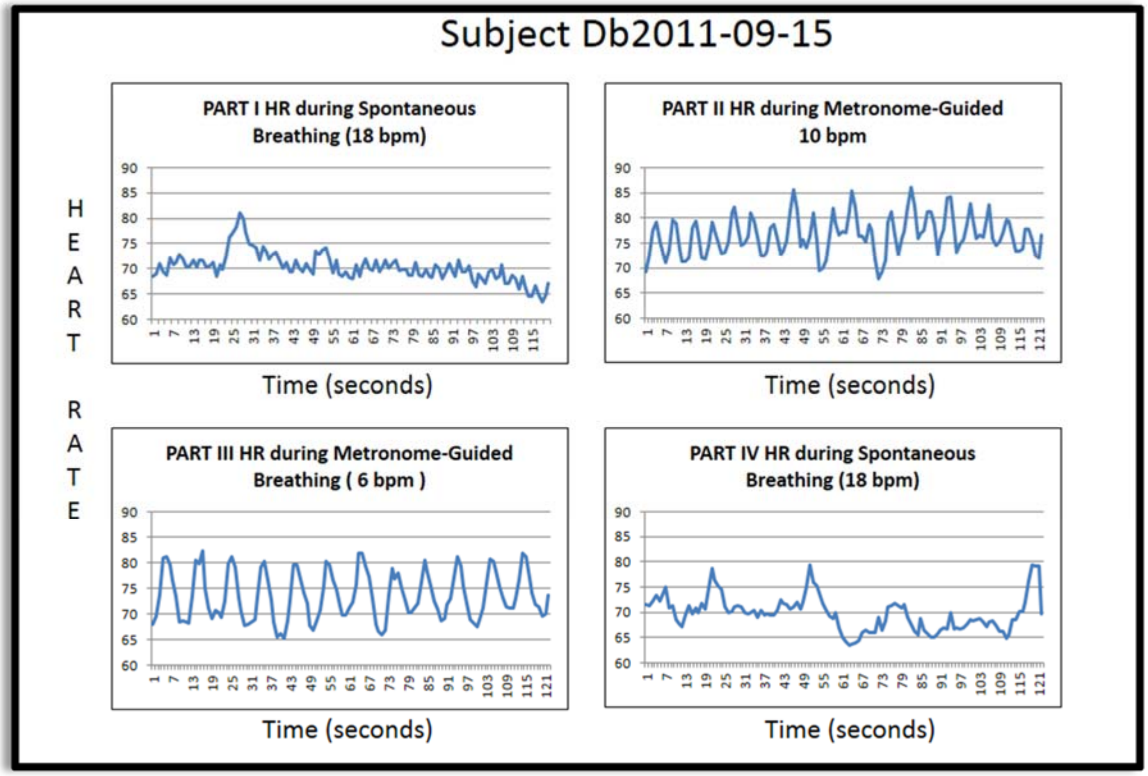

Figure 4 Changes in heart rate variability; spontaneous breathing vs. metronome-guided breathing [10 or 6 bpm]. Subject D, Female, 37 years old, date recorded on 2011-09-15.

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 HRV consistent 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.

Protocol 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 (expressed in the increased amplitude of the fluctuations) as shown in Figures 5 and 6.

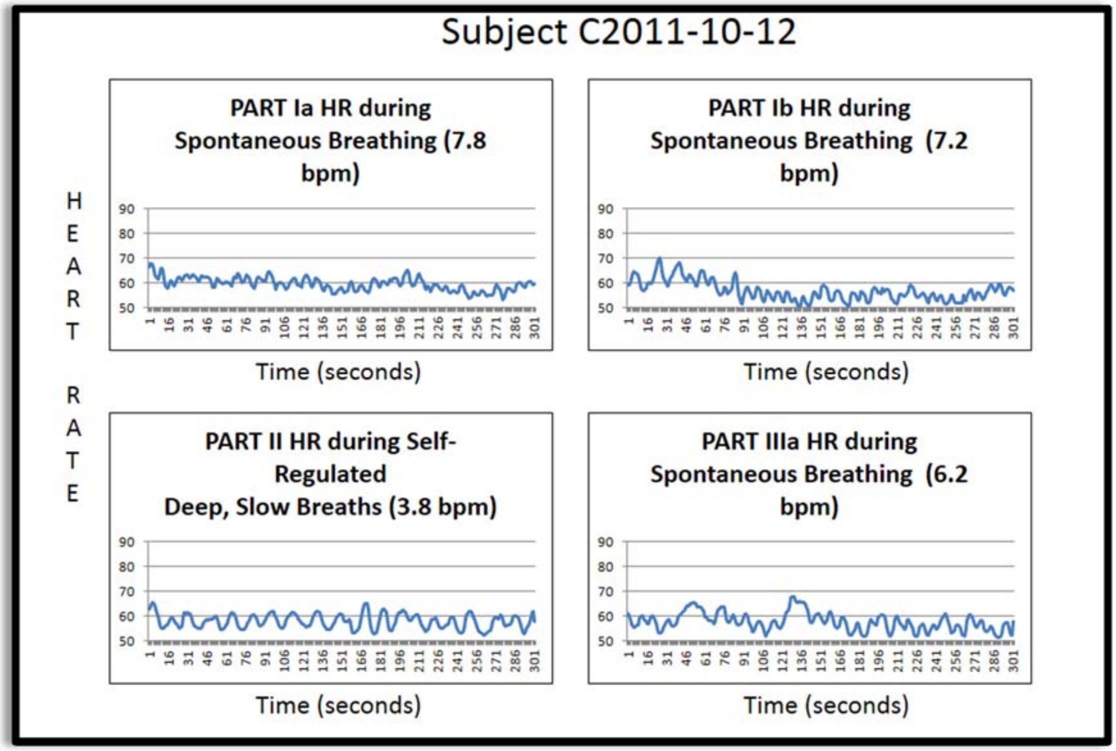

Figure 5 Changes in heart rate variability; spontaneous breathing versus self-guided slow breathing. Subject C: Male, 54 years old, date recorded on 2011-10-12.

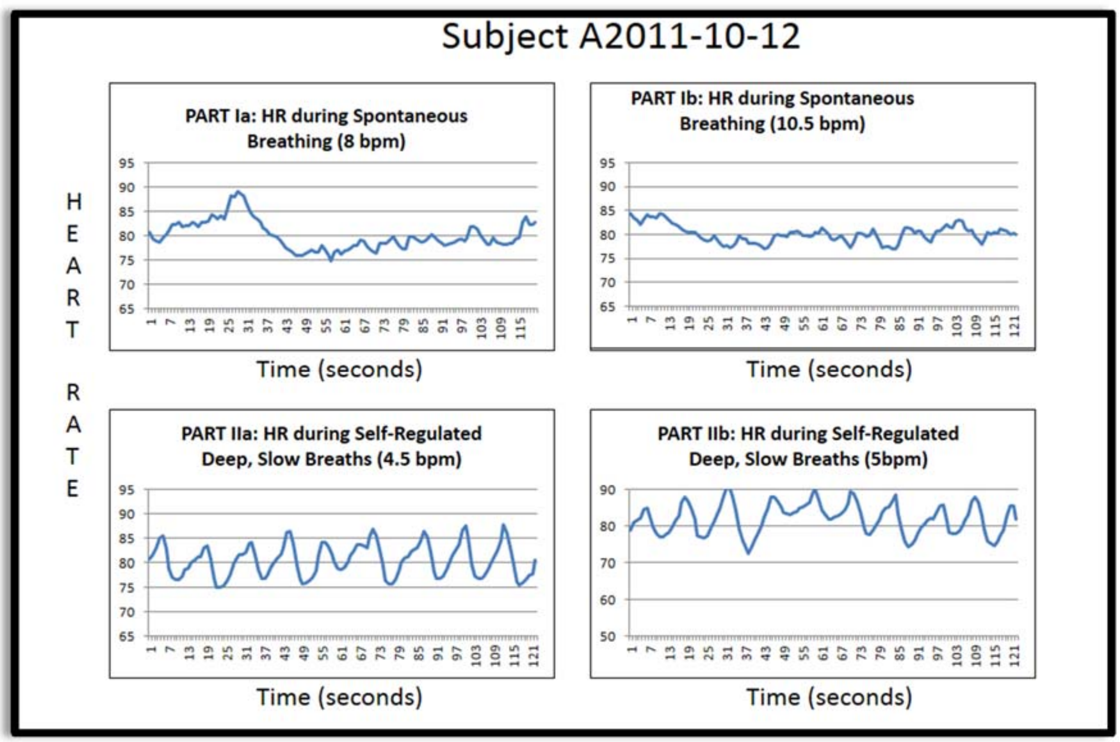

Figure 6 Changes in heart rate variability; spontaneous breathing versus self-guided slow breathing. Subject A, Male, 52 years old, date recorded on 2011-10-12.

Note that the subject in Figure 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.

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 Figures 5 and 6, increasing the amplitude of heart rate oscillations. This method seems to be less stressful for practitioners, according to the oral reports of the volunteer subjects. For example, the previous subject who had difficulty synchronizing his breathing rate using a metronome in the earlier section (Figure 1) was able to slow down breathing 'effortlessly' using the self-guided approach, increasing the amplitude of heart rate oscillations (HRV), as shown in Figure 6.

The preliminary data presented here is in general agreement with studies on device-guided slow breathing, as well as spontaneous 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 sympathovagal balance[7]. 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[8]. This is consistent with the high-frequency oscillations in heart rate variability when metronome-guided breathing was paced around 10 breaths per minute in the present study. Moreover, it is clear that pacing breathing with a metronome at around 6 breaths per minute dampened the high-frequency component of HRV changes, and increased the low-frequency component of HRV. In comparison with one study with participants employing Zen meditation (which does not require one to control breathing), recorded respiration rate was around 15 – 16 breaths per minute which explains that they registered higher frequency fluctuations in heart rate variability[9].

The present study sheds light on using the technique of HRV measurements from ECG recordings using HRV software which can visualize the low and high frequency oscillations of heart rate changes. However, a statistical evaluation was not done to determine whether there were significant differences between the control and slow-breathing paced exercises due to the insufficiency of the sample size. Subjects indicated (when queried) that the metronome-guided breathing technique was relatively intrusive compared with the mindful slow breathing practice. Nonetheless, metronome-guided breathing produced similar effects on HRV.

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 HRV as a possible contributor to cardiovascular health, among other benefits. It is noteworthy that commercial devices are on the market to aid people with moderate hypertension to learn slow-breathing exercises[10]. These slow-breathing training devices need to be tested over longer periods of time (greater than 9 weeks) and there is the need to address other methodological issues[11].

Other economical methods to learn slow-breathing exist. Exercises such as yoga, tai chi, mindfulness meditation and other forms of "mind training" which can slow down breathing can be beneficial for stress reduction. The technique of HRV measurements can be employed, alongside biochemical markers, to measure levels of stress and stress reduction. Also, regular physical exercise would also have favourable influences on HRV[12].

A recent study has shown that slow, paced breathing during daytime rest at 0.1 Hz (equivalent to 6 breaths per minute respiration rate) showed improvements in night time sleep among self-reported insomniacs (SRIs) who demonstrated an increase in total power of HRV, compared to SRIs who performed spontaneous breathing and those who did paced breathing at 0.2 Hz, equivalent to 12 breaths per minute[13]. The authors suggested an increase in vagal activity, based on the increase in HRV, in SRIs which did perform slow-paced breathing at 0.1 Hz.

HRV measurements are a window to the functions of the autonomic nervous system, possibly a measure of levels of stress as well as possible markers for heart and other diseases[14]. In addition, it can provide markers for measuring outcomes for stress reduction interventions. Mindfulness meditation usually employs attentional tasks involving nonjudgmental awareness of inner and outer experiences, which usually starts with breath and body sensations while sitting quietly, or moving the body through yoga postures. Often this involves spontaneous slowing down of breathing. In a related study, the effects of mindfulness meditation on smoking cessation outcomes could be predicted by an increase in high frequency component of HRV during meditation[15].

It is thus important to examine the clinical application of slow breathing exercises associated with Tai Chi, Yoga and other forms of meditation, including mindfulness meditation, as complementary interventions for general stress reduction for healthy subjects, as well as for people at risk for heart disease and other chronic illnesses, 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. ■

DISCLOSURE

The author hereby declares that he has been conducting free yoga classes at the De La Salle Health Sciences Institute since 2007 as a community outreach project, with the end in view of understanding its potential as a stress reduction technique.

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