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Clinical utility of paced breathing as a concentration meditation practice

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Summary
Objectives: The present study examined changes in electroencephalogram (EEG) and heart rate variability (HRV) parameters during paced breathing (PB) and their relationships with self-reported personality traits.
Methods: Fifty-eight meditation-naive subjects (36 men, 22 women) ranging in age from 20 to 30 years completed the Temperament and Character Inventory (TCI). After a spontaneous breathing session, participants were asked to breathe in 6-s cycles, guided by an acoustic stimulus. EEG, HRV, and respiratory data were recorded during spontaneous and paced breathing. We calculated the powers for the EEG and HRV parameters based on the most regular respiratory curve observed over a 5-min period.
Results: In terms of HRV parameters, the high-frequency power increased and the low frequency-to-high frequency ratio decreased during PB. The low-frequency power did not change. In terms of EEG parameters, low-frequency alpha power, a marker of internal attention, globally increased and theta power, a marker of an advanced meditative state, locally decreased. This indicates that parasympathetic activity and internal attention increased, whereas an advanced meditative state was inhibited during PB. Of the personality traits, harm avoidance, novelty seeking, persistence, self-directedness, and self-transcendence were related to changes in low- and high-frequency alpha powers.
Conclusions: Our results suggest that PB can be utilized as a concentration meditation practice for novices, and that individual differences such as personality traits should be considered when PB is offered for clinical or experimental purposes.

Introduction

Meditation is associated with the attainment of a deeply restful, yet fully alert state.[1] It is generally accepted that breathing is an important practice for meditation, and this type of breathing is divided into two distinct categories: involuntary breathing and voluntary breathing.[2] Involuntary breathing, controlled by the respiratory center in the lower

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brain, maintains homeostasis of the arterial blood gases, whereas voluntary breathing, governed by a higher brain system such as the neocortex or lymbic system, is controlled mainly by abdominal expiratory activity.[2]

There are differences in breathing practices between novice and expert meditators. For example, Su-soku is a meditation practice in which novice practitioners silently count their breaths so as to focus their attention.[3] With ongoing practice, counting is omitted and practitioners simply remain aware of their present experience, including their breathing. Dunn et al.[4] proposed that it is a useful technique to divide the practice of meditation into four components: form, object, attitude, and behaviors of the mind. Among the four components, behaviors of the mind can be conceptualized as meditative concentration, which is mindfulness to internal or external stimuli occurring concurrently with meditation. Concentration has been defined as the focus of awareness on a single point or object.[4] According to Dunn's classification, Su-soku meditation is a type of concentration meditation because the single point or object of focus is the breath itself.[1,3,4]Paced breathing (PB) is voluntary breathing to synchronize the breathing rhythm with an acoustic or visual signal that oscillates at a specific frequency.[5–8] In the current study, we propose that PB, like Su-soku meditation, can be utilized as a method of meditation based on the following features. First, many studies have reported that PB induces an increase in parasympathetic activity,[7,9,10] which is directly related to an increase in respiratory sinus arrhythmia (RSA).[11] Parasympathetic activity related to psychological or somatic relaxation is generally regarded as a marker of successful meditation.[1,12,13] For example, during Su-soku, the percent change in theta power is positively correlated with the percent change in the normalized high frequency (HF) of heart rate variability (HRV), a marker of parasympathetic activation.[1] Thus, PB-induced parasympathetic activation is a possible method of meditation therapy. Second, PB may be defined as concentration according to Dunn et al.[4] because it focuses awareness on a single point or object: an acoustic or visual signal.[5–8]

Together with parasympathetic activation, the alpha- and theta-band powers of electroencephalogram (EEG) parameters are generally accepted as markers of successful meditation.[3] It has been reported that Su-soku results in an increase in low-frequency alpha and theta powers.[1] However, unlike Su-soku, changes in EEG parameters during PB are not consistent. One study has found that mean power in the beta band increases during PB,[6] whereas another has found that the power in beta-, alpha-, and theta-bands during slow PB are higher than those during fast PB.[5] To estimate the clinical utility of PB as a concentration meditation practice, it may be helpful to examine the effects of PB on autonomic and neurophysiological characteristics. Accordingly, the primary aims of the present study are to replicate parasympathetic activation during PB and to clarify the effects of PB on neurophysiological changes.

Another aim of the present study is to examine whether personality traits are related to autonomic and neurophysiological changes during PB. Personality is usually defined as a sum of the stable and habitual patterns of behavior that are characteristic of an individual.[14] A combination of these patterns of behavior leads to individual differences in personality, which is considered to be composed of temperament and character.[15] The former refers to tendencies to react to emotional stimuli and has some genetic basis. The latter reflects individual differences in self-object relationships and is more environmentally influenced than is temperament.[15] The Temperament and Character Inventory (TCI) is a common self-report questionnaire used to measure four dimensions of temperament, novelty seeking (NS), harm avoidance (HA), reward dependence (RD), and persistence (P), and three dimensions of character, self-directedness (SD), cooperativeness (C), and self-transcendence (ST).[16]

Dunn et al.[4] have theorized that personality can be regarded as an attitude or mental state regarding meditation because personality accounts for individual differences in autonomic and neurophysiological changes observed during meditation. Since temperament and character dimensions are related to brain function,[17] it is possible that individual differences in temperament and character dimensions are related to changes in HRV and EEG parameters during PB. Takahashi et al.[1] have found that changes in EEG and HRV parameters during Su-soku meditation are related to the personality traits measured by the TCI. However, few studies have examined whether personality mediates such changes during PB. Therefore, to examine which frequency bands and regions among the EEG and HRV parameters are more indicative of PB and to determine whether one's personality traits are related to those changes during PB, 58 meditation-naive subjects completed the TCI and the changes in their HRV and EEG parameters during PB were measured.

Methods

Participants

A total of 58 meditation- or qigong-naive college students (36 men, 22 women) volunteered for the study. Men ranged in age from 20 to 30 years (mean $\pm$ SD = 24.8 $\pm$ 1.8 years), and women ranged in age from 21 to 30 years (mean $\pm$ SD = 24.5 $\pm$ 2.0 years). There was no significant difference in age between genders. We excluded subjects with self-reported arrhythmia, hypertension, ischemic heart disease, pneumonia, infections of the upper respiratory tract, or mental illness. The study protocol was approved by the Kyung Hee University's Institutional Review Board. Informed consent was obtained from all participating subjects.

Psychological measures

Participants completed the Korean version of the TCI-revised short version (TCI-RS) for which reliability and validity were verified.[18] The TCI-RS is composed of 140 items that assess the four temperaments (NS, HA, RD, and P) and three characters (SD, C, ST). This questionnaire is rated on a 5-point Likert scale ranging from 0 (totally disagree) to 4 (totally agree). We summed the score of each subscale for the TCI-RS to examine which subscales among the seven subscales were indicative of the percent changes in HRV and EEG parameters during PB.

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Physiological measures

PB consisted of inspiration and expiration periods. As per the study by Strauss-Blasche et al.,[19] we set the one-cycle respiration time at 6 s, i.e., 10 breaths/min. We defined the inspiratory duration as the time between the onset of inhalation to the completion of inhalation (2.4 s) and defined the expiratory duration as the time between the completion of one inhalation and the beginning of the next inhalation (3.6 s). Therefore, the expiratory phase encompassed the inspiratory and expiratory pauses, as well as the expiration time. During the PB period, subjects synchronized their breathing rhythms according to 6 s auditory signals presented in stereo through personal computer speakers. The auditory signal was an electronic piano sample in which E (''mi'') corresponded to the inspiration period and C (''do'') corresponded to the expiration period.

The experiment consisted of training, spontaneous breathing, and paced breathing sessions. Participants were instructed not to smoke, exercise or consume caffeinated beverages in the 24-h period before the experiment. They emptied their bladders immediately before the placement of the EEG electrodes, ECG, and nasal thermistor. Each participant was seated in a comfortable recliner in a quiet room with his or her eyes closed. The EEG collected data from six electrodes: left frontal (F3), right frontal (F4), left temporal (T3), right temporal (T4), left parietal (P3), and right parietal (P4) regions, according to the international 10—20 system.

The ECG electrode was placed on V4 of the precordial leads, sampled at a rate of 256 Hz and notch-filtered at 60 Hz. The nasal thermistor was placed beneath one of the nostrils to generate a respiratory curve. All physiological measurements were recorded using the HSYS-REC-LD system (Stellate Systems Inc., Canada). After registering the EEG and ECG electrodes and the nasal thermistor, participants were instructed on how to synchronize their breathing with the auditory signals and were allowed to practice this for 15 min. After the training session, the participants rested for 10 min with the speakers turned off and then engaged in successive spontaneous breathing and paced breathing sessions for 15 min. For these two sessions, participants were asked to remain awake while their eyes were closed. All data were recorded in text format and were then exported to Complexity software (Laxtha Co., Korea). We cropped the 5 min period for EEG and ECG-data corresponding to the most regular respiratory curve before calculating EEG and ECG-parameters during the spontaneous and paced breathing sessions. The absolute spectral power of the EEG was calculated into the following spectral bands using fast Fourier transformation: theta (4.0—7.9 Hz), low-frequency alpha (8—9.9 Hz), high-frequency alpha (10—11.9 Hz), and beta (12—29.9 Hz). The spectral power of the EEG was assessed separately in different regions. The detection of R peaks in the ECG data, re-sampling at 4 Hz using the Hanning window, and generation of RR-interval tachograms were accomplished using Complexity software. Based on the 5-min RR-interval tachograms, the mean heart rate (HR) and the absolute spectral power of the ECG was calculated in low frequency (LF, 0.04—0.15 Hz) and high frequency (HF, 0.15—0.4 Hz) bands using fast Fourier transform. Using LF and HF, we also calculated the low frequency to high frequency ratio (LF/HF). Finally, respiration parameters during spontaneous and paced breathing were calculated using MATLAB 7.1 (MathWorks, Natick, MA, USA). We detected peak-to-peak intervals of the 5-min respiratory curve and calculated mean values and standard deviations of respiration times. The respiratory peak detection algorithm used in this study was based on the algorithm suggested by Billauer.[20]

Statistical analyses

All statistical analyses were performed using SPSS 15 for Windows (SPSS, Chicago, IL, USA). Because the distributions of EEG and HRV power parameters were skewed, each parameter was log-transformed, which provided a normal distribution. We used a *t*-test to compare the effects of pacing for paired EEG and HRV samples in the spontaneous and paced conditions. Changes in HRV and EEG parameters during PB were normalized using the following equation: (parameter in paced breathing/parameter in spontaneous breathing) $\times$ 100%. Pearson's correlations between the scores for the seven TCI subscales and the percent changes in EEG and HRV parameters during PB were performed. In all analyses, the significance threshold was set at $P < 0.05$.

Results

The mean values of the TCI subscales are listed in Table 1. Table 2 lists changes in the theta, low- and high-frequency alpha, and beta powers for the EEG from the six regions and changes in the mean HR, LF, and HF powers and LF/HF for HRV, and respiration times. The respiration time during PB

Table 1 Descriptive characteristics of TCI subscales.

Scale	Subscale		Mean ± SD
TCI	Trait (score)	Novelty seeking	36.28 ± 10.44
		Harm avoidance	36.36 ± 11.54
		Reward dependence	44.43 ± 10.96
		Persistence	45.78 ± 10.94
	Character (score)	Self-directedness	47.69 ± 11.43
		Cooperativeness	54.10 ± 9.05
		Self-transcendence	31.45 ± 12.63

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Table 2 Differences between spontaneous and paced breathing with regard to EEG, respiration and HRV parameters.

Region	Breathing pattern	EEG parameter			
		Theta (ms^2)	Low-frequency alpha (ms^2)	High-frequency alpha (ms^2)	Beta (ms^2)
Lt. frontal	Spontaneous	**3.51 ± 0.90**	**2.05 ± 0.70**	**1.87 ± 0.60**	2.31 ± 0.50
	Paced	**$3.27 \pm 0.70^{**}$**	**$2.27 \pm 0.82^{**}$**	**$2.12 \pm 0.66^{**}$**	2.34 ± 0.49
Rt. frontal	Spontaneous	3.36 ± 1.04	**1.99 ± 0.73**	**1.78 ± 0.61**	2.21 ± 0.54
	Paced	3.19 ± 0.69	**$2.23 \pm 0.85^{**}$**	**$2.07 \pm 0.68^{**}$**	2.25 ± 0.45
Lt. temporal	Spontaneous	2.74 ± 0.70	**1.73 ± 0.77**	**1.79 ± 0.57**	2.63 ± 0.76
	Paced	2.61 ± 0.71	**$1.90 \pm 0.87^{*}$**	**$2.03 \pm 0.63^{**}$**	2.61 ± 0.63
Rt. temporal	Spontaneous	**2.36 ± 0.73**	1.25 ± 0.77	**1.37 ± 0.60**	2.21 ± 0.86
	Paced	**$2.11 \pm 0.62^{**}$**	1.36 ± 0.82	**$1.51 \pm 0.65^{*}$**	2.14 ± 0.72
Lt. parietal	Spontaneous	**3.02 ± 0.69**	**2.27 ± 0.94**	**2.39 ± 0.76**	2.61 ± 0.64
	Paced	**$2.78 \pm 0.49^{**}$**	**$2.49 \pm 1.02^{**}$**	**$2.75 \pm 0.86^{**}$**	2.54 ± 0.50
Rt. parietal	Spontaneous	2.93 ± 0.67	**2.18 ± 0.92**	**2.26 ± 0.78**	**2.36 ± 0.46**
	Paced	2.86 ± 0.67	**$2.51 \pm 1.03^{**}$**	**$2.75 \pm 0.89^{**}$**	**$2.48 \pm 0.51^{*}$**
Respiration time (s)					
	Spontaneous	**3.86 ± 0.86**			
	Paced	**$5.98 \pm 0.09^{**}$**			

	HRV parameter			
	Mean HR (bpm)	LF (ms^2)	HF (ms^2)	LF/HF (ratio)
Spontaneous	71.78 ± 10.05	6.16 ± 0.84	**5.94 ± 0.67**	**1.04 ± 0.13**
Paced	70.45 ± 8.80	6.10 ± 0.49	**$6.72 \pm 0.69^{**}$**	**$0.91 \pm 0.08^{**}$**

Values are means ± standard deviation. Significant differences between spontaneous and paced breathing are in bold.
* $P < 0.05$.
** $P < 0.01$.

was 5.98 s, and the standard deviation was 0.09, indicating that the subjects' breathing corresponded to the acoustic signal. The mean HR and LF values did not change, whereas HF increased and LF/HF decreased during PB, indicating that our paradigm replicated parasympathetic activation during PB. In terms of EEG parameters, theta band power decreased locally, whereas the low- and high-frequency alpha band power increased globally during PB. Beta band power did not change during PB, except for that of P4.

Table 3 lists correlation coefficients between scores for the seven TCI subscales and percent changes in the power for EEG and HRV parameters between spontaneous and paced breathing sessions. NS was inversely correlated with powers for theta (P3), low-frequency alpha (P3), high-frequency alpha (F3, F4, T4, P3, and P4), and beta bands (T4, P3, and P4). HA was positively correlated with powers for low-frequency alpha (P3), high-frequency alpha (F3 and F4), and beta bands (P3). P was inversely correlated with powers for theta (P3 and P4), low-frequency alpha (P3 and P4), high-frequency alpha (F3 and F4), and beta bands (P3 and P4). SD was inversely correlated with powers for low-frequency alpha (P3) and high-frequency alpha bands (P3). ST was inversely correlated with powers for high-frequency alpha (T3 and P3) and beta bands (T3, T4, P3, and P4). These results indicate that, during PB, the increase in alpha power was more prominent in participants high in HA, whereas the increase in alpha power was inhibited in participants high in NS, P, SD, and ST. In terms of TCI subscales and percent change in HRV parameters, C was inversely correlated with HF, and ST was inversely correlated with LF and HF. These results suggest that, during PB, parasympathetic activation was inhibited in the participants high in C and ST, and the overall autonomic changes during PB were inhibited in participants high in ST. The effects of personality traits on autonomic changes during PB were less prominent than those on neurophysiological changes during PB.

Discussion

In our study, we found that PB resulted in global increases in low- and high-frequency alpha power and local decreases in theta power. These global changes in alpha band power are consistent with the results from Bušek's study.[5] Low-frequency alpha power reflects internal attention or non-task-related cognitive processes, whereas high-frequency alpha power reflects external attention or task-related processes.[1,21] Theta power frequently indicates drowsiness, states of low-level alertness, mental calculation, working memory, and an advanced meditation-state.[22,23] It is generally accepted that, during meditation, there is a shift to a higher power in frequencies of slower alpha and theta, particularly in the frontal area.[1,24] Thus, our findings suggest that PB results in an increase in internal attention, a marker of a successful meditation, yet also results in an increase in external attention, which inhibits

Table 3 Correlations between TCI subscales and percent changes in HRV and EEG parameters.

Scale	Percent change in the subscale	TCI						
		Temperament (score)			Character (score)			
		Novelty seeking	Harm avoidance	Reward dependence	Persistence	Self-directedness	Cooperativeness	Self-transcendence
HRV	Mean HR (%)	0.091	−0.096	0.101	−0.063	0.136	0.072	0.165
	LF (%)	−0.112	0.014	−0.247	−0.091	−0.158	−0.252	**−0.299**[*]
	HF (%)	−0.204	0.084	−0.208	−0.136	−0.036	**−0.369**[**]	**−0.277**[*]
	LF/HF (%)	0.006	−0.069	−0.102	0.018	−0.128	0.024	−0.150
EEG	*Theta (%)*							
	Lt. frontal	−0.001	−0.022	0.024	−0.144	−0.001	−0.034	0.031
	Rt. frontal	0.242	−0.199	0.071	0.000	0.069	−0.078	0.108
	Lt. temporal	−0.107	−0.089	0.196	0.030	0.059	0.018	−0.231
	Rt. temporal	−0.058	−0.085	0.198	−0.076	−0.030	−0.084	−0.172
	Lt. parietal	**−0.276**[*]	0.252	−0.001	**−0.349**[**]	−0.247	−0.023	−0.208
	Rt. parietal	−0.067	0.093	0.141	**−0.315**[*]	−0.132	−0.035	−0.075
	Low-frequency alpha (%)							
	Lt. frontal	−0.147	0.190	0.012	−0.245	−0.107	0.120	−0.003
	Rt. frontal	−0.119	0.186	0.026	−0.253	−0.106	0.111	0.024
	Lt. temporal	−0.114	−0.021	0.106	0.028	0.029	0.080	−0.149
	Rt. temporal	−0.115	0.172	−0.018	−0.043	−0.083	−0.004	−0.078
	Lt. parietal	**−0.299**[*]	**0.298**[*]	−0.048	**−0.300**[*]	**−0.267**[*]	0.113	−0.214
	Rt. parietal	−0.243	0.216	0.011	**−0.338**[*]	−0.161	0.059	−0.096
	High-frequency alpha (%)							
	Lt. frontal	**−0.280**[*]	**0.312**[*]	−0.214	**−0.278**[*]	−0.230	−0.140	−0.147
	Rt. frontal	**−0.284**[*]	**0.298**[*]	−0.176	**−0.271**[*]	−0.234	−0.111	−0.120
	Lt. temporal	−0.219	−0.018	0.071	−0.006	0.039	0.025	**−0.286**[*]
	Rt. temporal	**−0.261**[*]	0.135	0.088	−0.093	−0.057	−0.017	−0.248
	Lt. parietal	**−0.397**[**]	0.249	−0.106	−0.224	**−0.267**[*]	0.066	**−0.356**[**]
	Rt. parietal	**−0.282**[*]	0.233	−0.082	−0.250	−0.254	0.036	−0.162
	Beta (%)							
	Lt. frontal	−0.134	0.156	−0.005	−0.126	−0.138	−0.124	−0.232
	Rt. frontal	−0.118	0.161	0.044	−0.139	-0.124	−0.106	−0.230
	Lt. temporal	−0.087	−0.050	0.085	−0.013	0.073	−0.047	**−0.267**[*]
	Rt. temporal	**−0.292**[*]	0.037	0.116	−0.159	0.049	−0.058	**−0.381**[**]
	Lt. parietal	**−0.403**[**]	**0.294**[*]	−0.069	**−0.317**[*]	−0.213	−0.016	**−0.377**[**]
	Rt. parietal	**−0.265**[*]	0.205	0.073	**−0.351**[**]	−0.130	−0.065	**−0.262**[*]

Significant correlations are in bold.
[*] $P < 0.05$.
[**] $P < 0.01$.

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advanced meditation.[3] Our findings also suggest that PB is suitable for meditation-novices because it resulted in local decreases in theta power, a marker of an advanced meditative state.[22,23] In terms of HRV parameters, HF increased, whereas LF did not change during PB. HF is a parasympathetic marker and LF is dually influenced by both sympathetic and parasympathetic activities.[25] Therefore, it is possible that sympathetic activity together with parasympathetic activity increased during PB. This sympathetic activation is consistent with the increase in the high-frequency alpha power of the EEG.

Of the personality traits that we assessed, only HA was positively correlated with percent changes in low- and high-frequency alpha power during PB. It has been theorized that HA reflects a heritable tendency to avoid punishment, non-rewards, and novelty.[16] HA is known to be positively correlated with mood and anxiety in normal volunteers, as well as in patients with anxious personality disorders.[26,27] Thus, this finding suggests that individuals high in HA can effectively perform concentration meditation practice.

NS was inversely correlated with percent changes in theta, low- and high-frequency alpha, and beta band powers, suggesting that participants high in NS performed PB less effectively. Individuals high in NS tend to be excitable, exploratory, curious, and easily bored, whereas those low in NS are typically slow-tempered, unemotional, and tolerant of monotony.[26,27] These results suggest that, in clinical cases, PB would be beneficial for concentration meditation in individuals with a low NS score.

Individuals low in P manifest low levels of perseverance and repetitive behaviors, even in response to intermittent reward, and individuals low in ST tend to be proud, unimaginative, and unable to tolerate ambiguity.[28,29] It appears that the repetitive acoustic signal may have been monotonous for the more creative participants, whereas participants who tend to be unimaginative may have been able to perform PB more effectively. It is also of note that NS, P and ST were inversely correlated not only with low- and high-frequency alpha powers, but also with beta power. There is some evidence suggesting that activity in the beta band is associated with increased alertness and cognitive processes.[30] Thus, it is likely that participants low in NS, P and ST were not only in an aware state, but also in an alert state.

HRV parameters were also related to personality traits. Participants low in C and ST showed a higher increase in HF, suggesting that they performed PB more effectively. Individuals low in ST tend to be proud, unimaginative, and intolerant of ambiguity, and those low in C tend to be self-absorbed.[28,29] More unimaginative or self-absorbed participants may more effectively perform PB because it is a concrete and simple practice that does not require skill. Unlike prior studies,[1] we did not find any significant relationship between NS and LF, indicating that the effects of personality traits on autonomic changes during PB were less prominent than those of personality traits on neurophysiological changes during PB.

Although our study makes novel contributions to the study of meditation, several limitations should be noted. First, we did not use a structured psychiatric interview in our assessment, and therefore we cannot completely exclude the possibility that some subjects may have had clinical depression or an anxiety disorder, which are known to influence the scores of temperament dimensions such as HA and SD.[31] Second, our study protocol was limited to a single respiratory frequency, and we could not evaluate the effect of different respiratory frequencies on EEG and HRV parameters during PB. Although one study has reported that differences in changes in EEG parameters between normal respiration frequency and low respiration frequency are not prominent,[5] it is a challenge to examine the effect of respiration frequency on EEG and HRV parameters during PB.

Conclusions

Autonomic and neurophysiological changes during PB result from an increase in parasympathetic activity directly related to an increase in RSA and personality traits related to HA, NS, P, ST. Our study suggests that personality traits mediate neurophysiological changes more prominently during PB than do autonomic changes. In contrast to other meditative practices, PB has several advantages as a concentration meditation practice. The methodology of PB is direct and simple and a novice can perform it without any difficulty. In meditation-naive adults, PB resulted in an increase in low-alpha band powers of the EEG, which is a hallmark of successful meditation. PB also resulted in an increase in high-alpha band powers and a decrease in theta powers. These results indicate that PB maintains alertness and external awareness in meditative practitioners, which hinders them from entering advanced meditative states. Thus, individual differences such as personality traits should be considered when PB is offered for clinical or experimental purposes.

Conflict of interest

The authors have no personal or financial conflicts of interest associated with this work.

References

1. Takahashi T, Murata T, Hamada T, Omori M, Kosaka H, Kikuchi M, et al. Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. *International Journal of Psychophysiology* 2005;**55**:199–207.
2. Fumoto M, Sato-Suzuki I, Seki Y, Mohri Y, Arita H. Appearance of high-frequency alpha band with disappearance of low-frequency alpha band in EEG is produced during voluntary abdominal breathing in an eyes-closed condition. *Neuroscience Research* 2004;**50**:307–17.
3. Chiesa A. Zen meditation: an integration of current evidence. *Journal of Alternative and Complementary Medicine* 2009;**15**(5):585–92.
4. Dunn BR, Hartigan JA, Mikulas WL. Concentration and mindfulness meditations: unique forms of consciousness? *Applied Psychophysiology and Biofeedback* 1999;**24**(3):147–65.
5. Bušek P, Kemlink D. The influence of the respiratory cycle on the EEG. *Physiological Research* 2005;**54**:327–33.
6. Stančák Jr A, Pfeffer D, Hrudová L, Sovka P, Dostálek C. Electroencephalographic correlates of paced breathing. *Neuroreport* 1993;**4**:723–6.
7. Driscoll D, DiCicco G. The effects of metronome breathing on the variability of autonomic activity measurements.

Journal of Manipulative and Physiological Therapeutics 2000;**23**(9):610—4.
8. Kobayashi H. Does paced breathing improve the reproducibility of heart rate variability measurements? *Journal of Physiological Anthropology* 2009;**28**:225—30.
9. Sakakibara M, Hayano J. Effect of slowed respiration on cardiac parasympathetic response to threat. *Psychosomatic Medicine* 1996;**58**:32—7.
10. Yuen AWC, Sander JW. Can slow breathing exercises improve seizure control in people with refractory epilepsy? A hypothesis. *Epilepsy and Behavior* 2010;**18**:331—4.
11. Grossman P, Taylor EW. Toward understanding respiratory sinus arrhythmia: relations to cardiac vagal tone, evolution and biobehavioral functions. *Biological Psychology* 2007;**74**:263—85.
12. Cysarz D, Büssing A. Cardiorespiratory synchronization during Zen meditation. *European Journal of Applied Physiology* 2005;**95**:88—95.
13. Pal GK, Velkumary S, Madanmohan. Effect of short-term practice of breathing exercises on autonomic function in normal human volunteers. *Indian Journal of Medical Research* 2004;**120**:115—21.
14. Gana K, Trouillet R. Structure invariance of the Temperament and Character Inventory (TCI). *Personality and Individual Differences* 2003;**35**:1483—95.
15. Cloninger CR, Bayon C, Svrakic DM. Measurement of temperament and character in mood disorders: a model of fundamental states as personality types. *Journal of Affective Disorders* 1998;**51**:21—32.
16. Cloninger CR. A unified biosocial theory of personality and its role in development of anxiety states. *Psychiatric Developments* 1986;**3**:167—226.
17. Cloninger CR, Przybeck TR, Svrakic DM, Wetzel RD. *The Temperament and Character Inventory (TCI): a guide to its development and use*. St. Louis: Center for Psychobiology of Personality, Washington University; 1994.
18. Lee SH, Hwang ST. Construct validity of the TCI-RS (Temperament and Character Inventory-Revised-Short Version): comparing temperament and character with depression and anxiety in Korean undergraduates. *Korean Journal o Clinical Psychology* 2009;**28**(2):533—48.
19. Strauss-Blasche G, Moser M, Voica M, McLeod DR, Klammer N, Marktl W. Relative timing of inspiration and expiration affects respiratory sinus arrhythmia. *Clinical and Experimental Pharmacology and Physiology* 2000;**27**:601—6.
20. Billauer E. *Peakdet: peak detection using MATLAB*. http://billauer.co.il/peakdet.html [last modified 17.05.12].
21. Klimesch W, Doppelmayr M, Russegger H, Pachinger T, Schwaiger J. Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters* 1998;**244**:73—6.
22. Fell J, Axmacher M, Haupt S. From alpha to gamma: electrophysiological correlates of meditation-related states of consciousness. *Medical Hypotheses* 2010;**75**:218—24.
23. Sammler D, Grigutsch M, Fritz T, Koelsch S. Music and emotion: electrophysiological correlates of the processing of pleasant and unpleasant music. *Psychophysiology* 2007;**4**: 293—304.
24. Tassi P, Muzet A. Defining the states of consciousness. *Neuroscience and Biobehavioral Reviews* 2001;**25**:175—91.
25. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation, and clinical use. *Circulation* 1996;**93**:1043—65.
26. Ampollini P, Marchesi C, Signifredi R, Gianaglia E, Scardovi F, Codeluppi S, et al. Temperament and personality features in patients with major depression, panic disorder and mixed conditions. *Journal of Affective Disorders* 1999;**52**:203—7.
27. Tanaka E, Sakamoto S, Kijima N, Kitamura T. Different personalities between depression and anxiety. *Journal of Clinical Psychology* 1998;**54**:1043—51.
28. Cloninger CR, Syrakic DM, Przybeck TR. A psychological model of temperament and character. *Archives of General Psychiatry* 1993;**50**:973—90.
29. Kose S. A psychobiological model of temperament and character: TCI. *Yeni Symposium* 2003;**41**(2):86—97.
30. Steriade M. Cellular substrates of brain rhythms. In: Niedermeyer E, Lopes da Silva FH, editors. *Electroencephalography — basic principles, clinical applications, and related fields*. 4th ed. Baltimore: Williams & Wilkins; 1999. p. 28—75.
31. Jylhä P, Isometsä E. Temperament, character and symptoms of anxiety and depression in the general population. *European Psychiatry* 2006;**2**:389—95.

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