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How Does Yoga Breathing Affect Prefrontal QEEG Quotients?*

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Abstract

The underlying changes in biological processes that are associated with reported changes in mental and physical health in response to yoga breathing (prāṇāyāma) have not been systematically explored yet. In this study, the effects of a yoga breathing program on prefrontal EEG were tested with middle-aged women. Participants were collected as volunteers and controlled into two groups. Two channel EEG was recorded in the prefrontal region (Fp1, Fp2) from the yoga breathing group (n=17) and control group (n=17). QEEG quotients were transformed from the EEGs and analyzed by the ANOVAs on gain scores. As a result, α/δ (left, right) and CQ (correlation quotient) for yoga breathing participants were significantly decreased compared to control group ($p<.05$). $\alpha/\beta_H + \alpha/\delta$ (left, right) were increased significantly ($p<.05$). For those significantly changed QEEG quotients, the interaction effects of Group x prefrontal alpha (α) and beta (β) asymmetry were tested. Only the α asymmetry showed main effect on the gain score of $\alpha/\beta_H + \alpha/\delta$ (right) with $F(1, 34) = 5.694$ ($p<.05$). Pearson's correlation coefficient between α asymmetry and gain score of $\alpha/\beta_H + \alpha/\delta$ (right) was .374 ($p<.05$). The gain score of $\alpha/\beta_H + \alpha/\delta$ (right) was increased for the right α dominance of yoga breathing group. On the contrary it was decreased for the left α dominance of yoga breathing group as well as the control regardless of the dominance. The result of this study implies that yoga breathing increases stress resistance and is effective in the management of physical stress. Emotionally relaxed people may have greater instantaneous stress reduction after yoga breathing. Moreover, yoga breathing could be also beneficial for depressed who may be more vulnerable to stress.

Key words : yoga breathing, electroencephalography (EEG), QEEG, prefrontal asymmetry, stress

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1. Introduction

Yoga breathing (prāṇāyāma)[1] has been used to control the inhalation and exhalation so as to calm and tone the nervous system (Satyananda, 2003). The yoga breathing pattern helps not only relax the sympathetic and energize the parasympathetic nervous system, but improve the cardiovascular function. Intentional control of the breath directly affect the limbic system, so emotional relaxation follows slow and smooth breath (Jerath & Barnes, 2009). That's why breathing techniques have been used as complementary interventions for high-blood pressure, emotional disturbance, and other therapies (Mehling 2001, 2006; Ernst, 2000; Kaminoff, 2006). Yoga breathing has been considered as one of main practices in yoga tradition, because only with the awareness of the breath, the practitioners may have calmer and relaxed mind (Riley, Ehling & Sancier, 2004).

Besides the usefulness of yoga breathing for emotional calmness, it is known to be useful for stress reduction (Field, Diego, & Hernandez-Reif, 2010; Jerath & Barnes, 2009; Jovanov, 2005; Singh et al., 1990; Singh et al., 2011). Lin et al. (2011) reported that yoga practice including yoga breathing was significantly effective for anger, depression, and stress as a result of a meta-analysis with 10 RCT (random-controlled trials) studies for 762 cancer patients.

On top of its psychological and physiological effects, yoga breathing might be used as a way of preparation for meditation (Coulter, 2001). Yoga breathing leads the practitioner to concentrate either on the breathing itself, sound, or on the body parts. So through yoga breathing, the practitioner is within reach of concentration (dhāraṇā) and absorption (samādhi) (Jung, 2007). For example, Vialatte et al. (2009) reported that paroxysmal gamma (γ) was observed during the practice of Bhramari[2], a type of yoga breathing. While doing Bhramari, practitioners mainly concentrate on the sound of the yoga breathing. The researchers also reported that theta (θ) increased during the yoga breathing. Both γ and θ are considered as characteristics of meditation (Joliot, Ribary & Llinas, 1994; Howard et al., 2003; Keizer, Verment & Hommel, 2010), implying that the state of yoga breathing is similar to that of meditation.

Among many yoga breathing techniques, nadi shodhana (alternate nostril breathing)[3] has been mainly explored due to its influence on the cerebral hemispheres. Since Kayser reported that the human nasal passages exhibited spontaneous changes in unilateral nasal airway resistance (Flanagan & Eccles, 1997) in 1895, the relationship between hemispheric activity and alternating nostril dominance has been investigated using electroencephalography (EEG) (Werntz et al., 1983). Stancák & Kuna (1994) showed that hemisphere asymmetry in the β1 band (12.1-16.0 Hz) was decreased in the second half of FANB (forced alternate nostril breathing), suggesting that FANB has a balancing effect on the functional activity of the left and right hemisphere. Telles et al. (2012) reported that P300 peak latency was significantly lower at C3 compared to that at C4, following right nostril yoga breathing ($p<.05$). They suggested that right nostril yoga breathing facilitates the activity of contralateral (left) hemisphere, in the performance of the P300 task.

Nowadays EEG has been used as psychophysiological measure in relation to emotion. Recent neuroimaging studies suggest while negative affect typically activates the right prefrontal cortex, amygdala, and insula, the left prefrontal cortex is associated with positive emotions (Davidson; 1993). The right prefrontal cortex is active for negative emotion, while left prefrontal cortex is involved in emotional relaxation and positive behavior (Davidson, 2004; Allen et al.; 1993). Henriques and Davidson (1991) reported that clinically depressed

1) Yoga breathing (prāṇāyāma) is comprised of prāṇa (vital energy, life force) and ayāma (extension, expansion). Prāṇāyāma means 'extention or expansion of the dimension of prāṇa'. In the prāṇāyāma, there are four important aspects of breathing: inhalation, exhalation, internal breath retention, and external breath retention.

2) Bhramari means 'bee' and the practice is so-called because a sound is produced which imitates that of the black bee.

3) Nadi shodhana (alternate nostril breathing) means that practice which purifies nadis. Nadi means 'channel' or 'flow' or energy and shodhana means 'purification'.

participants had less left-sided activation (i.e., more alpha activity) than did normal control participants. There was a significant Group x Hemisphere interaction in the midfrontal region for the α band only. Therefore, depression may be considered for people whose left α is greater than right α. According to Coan & Allen (2004), frontal asymmetry can represent not only the state of depression as a moderator but the trait as a mediator of emotion. Anxiety with depression can be suspected for those with greater right β than left β (Demos, 2009).

Moreover, studies have being done on EEG in relation to stress (Seo, & Lee, 2010). The prefrontal cortex may mediate the extent to which psychosocial stress affects mental and physical health (Segerstrom & Miller 2004; Cohen et al., 1993). Lewis et al. (2007) found a shift from relatively greater left frontal activity during the low examination session to relatively greater right frontal activity during the high examination session. Papousek and Schulter (2002) suggested that the extent of prefrontal asymmetry vary under chronic stress.

Although EEG has been widely used in meditation studies as well as yoga breathing, it's not easy to recognize and handle it. To compromise those shortcuts of EEG, quantitative EEG (QEEG) quotients have been developed and widely applied in many studies. For instance, α/δ, $\alpha/\beta_H + \alpha/\delta$, brain quotient were used to show body stress, stress resistance, and brain function (Lee, 2010). Among QEEG quotients, emotional and behavioral characteristics were reported to be useful to show α and β asymmetry (Lim, Chae, & Park, 2011). In the present study, prefrontal EEG was measured before and after yoga breathing program. Then QEEG quotients were analyzed to assess the effectiveness of yoga breathing on stress. α/δ (BS: body stress), α/β_H (MS: mental stress), $\alpha/\beta_H + \alpha/\delta$ (ASQ: anti-stress quotient) were selected as stress-related quotients. Correlation quotient (CQ) and brain quotient (BQ) were compared to decide whether hemispheric balance and brain function were affected by yoga breathing. Finally prefrontal α and β asymmetry were tested whether they have interaction effect with yoga breathing.

2. Materials and Methods

2.1. Participants

Two naturally formed groups were involved in this study. A total of 34 female adults were recruited to participate with an average age of 40.4 ± 7.25 (17 for yoga breathing group with mean age 39.35 ± 6.02, 17 for control group with mean age 40.59 ± 8.45). They were all free from cardiac, pulmonary, metabolic and other diseases that would cause autonomic nervous dysfunction. All subjects were right-handed and medication-free. Informed written consent was obtained from each subject after the experimental procedures had been explained.

2.2. Procedure

All of the participants were asked not to take caffeine or alcoholic beverages for at least 3 hr prior to the experiment. The participants of yoga breathing group reported to the laboratory at 13:00, and sat on a chair in a quiet, light-attenuated electrically shielded room with the temperature between 20 and 22 ℃. After the headbands were attached on the prefrontal area (Fp1, Fp2), the participants relaxed for 5 min for stabilization. Then the participants were asked to follow the instruction of the BQT[4)] software. EEG was recorded for 10 min as a baseline condition (pre-intervention). Subsequently, the participants left the room for 2 hr yoga breathing program. After the practice, they came back for the second EEG measurement (post-intervention). Participants of control group individually visited the laboratory, and their EEGs were measured twice a day with 2h interval.

2.3. Yoga Breathing Program

Two-hour yoga breathing program was designed (See Table 1). First half of the program was devoted for basic

4) BQT is a Brain-Computer Interface software using Neuroharmony, two channel wearable EEG system (Braintech Corp., Korea).

breathing, which was mainly composed of breathing awareness and abdominal breathing. Breathing awareness practice introduces practitioners to their own respiratory system and breathing patterns.

Table 1. Yoga breathing program

	Contents	Duration
Basic breathing (1h)	Warming-up	10 min
	Breathing awareness	10 min
	Abdominal breathing	20 min
	Relaxation	10 min
	Abdominal breathing	10 min
Yoga breathing (1h)	Break	10 min
	Nadi shodhana	20 min
	Relaxation	10 min
	Kapālabhāti	20 min

Participants sit in a comfortable meditation posture or lie in shavasana (See Figure 1) and relax whole body, then observe the natural breathing process, total awareness of the rhythmic flow of the breath (Satyananda, 2003). Abdominal breathing is practiced by enhancing the action of the diaphragm and minimizing the action of the rib cage. Participants lie in shavasana and relax whole body, placing the right hand on the abdomen just above the navel and the left hand over the center of the chest, and feeling the abdomen expanding and contracting (Satyananda, 2003).

Second half of the yoga breathing program consisted of nadi shodhana and kapālabhāti[5], as they are the most popular practices (Coulter, 2001; Iyengar, 2009). Hand position for nadi shodhana is shown in Figure 1. Participants sit in comfortable meditation posture keeping the head and spine upright and adopt the hand position. One round of nadi shodhana is practiced as follows: close the right nostril with the thumb and breathe in through the left nostril; close the left nostril with the ring finger, release the thumb, and breathe out through the right nostril; inhale through the right nostril; close the right nostril with the thumb, release the ring finger, and exhale through the left nostril. After practicing 10 rounds of nadi shodhana, take a rest for a while.

To practice the kapālabhāti, participants sit in meditation posture, inhale deeply through both nostrils, expanding the abdomen, and exhaling with a forceful contraction of the abdomen muscles. Then the next inhalation takes place by passively allowing the abdominal muscles to expand. Inhalation should be a spontaneous or passive, involving no effort. After practicing 10 rounds of kapālabhāti, take a rest for a while. Kapālabhāti may be joined to the yoga postures as shown in Figure 1.

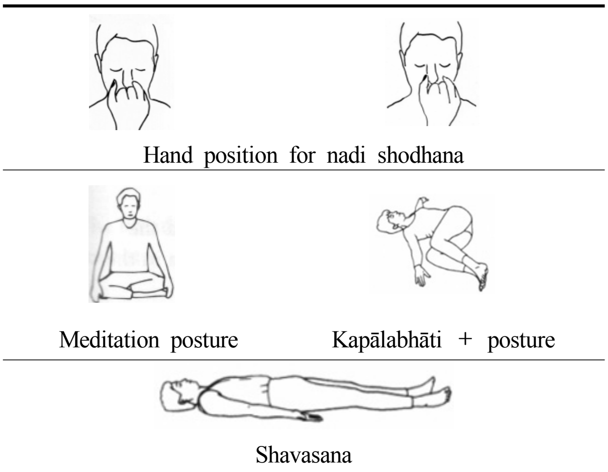

Figure 1. Postures used in this study

2.4. QEEG Techniques and Quotients calculations

EEG data were recorded at baseline (pre-intervention) and after yoga breathing program (post-intervention). Two channel wearable EEG system and BQT software (Braintech Corp., Korea) were used to record and store the brain wave signals in a computer. The EEG system was in the form of a headband with two active electrodes (Fp1, Fp2) and one reference electrode (Fpz) on the forehead, and one ground electrode on the earlobe. All electrodes were dry type, hence no gel was applied to attach the electrodes. The EEG was recorded with the participants under the instruction of BQT Software, with eyes open (40 sec), closed (40 sec), and

5) Kapālabhāti is the practice which brings a state of light or clarity to the frontal region of the brain. kapāl means 'cranium' or 'forehead' and bhāti means 'light' or 'splendor'.

open (40 sec) respectively. Detected signals were filtered with a notch and band pass (0.1~30 Hz) filters and converted to digital data at a 256 Hz sampling rate. A fast Fourier transform was used to calculate absolute relative power in each of five non-overlapping frequency bands: delta (δ: 0.1~3 Hz), theta (θ: 4~7 Hz), alpha (α: 8~13 Hz), low beta (β_L: 14~20 Hz), high beta (β_H: 21~30 Hz).

Table 2. Summary of QEEG Quotients

BQT	QEEG	Meaning
Emotional characteristic	α asymmetry	+: left α dominance - : right α dominance
Behavioral characteristic	β asymmetry	+: left β dominance - : right β dominance
BS	α/δ	Body stress
MS	α/β_H	Mental stress
ASQ	α/β_H + α/δ	Stress resistance
CQ	L/R	Hemispheric balance
BQ	Based on all quotients	Total brain function

Note. BQT = Brain-Computer Interface software (Braintech Corp., Korea); BS = Body Stress (left, right); MS = Mental Stress (left, right); ASQ = Anti-Stress Quotient (left, right); CQ = Correlation Quotient; BQ = Brain Quotient; L = left; R = right.

From the EEG data, QEEG quotients were calculated using the algorithm available at the www.braintech.in. Most of the quotients of stress, correlation, and brain function are presented as a score from 0 to 100. However, body stress and mental stress are shown in raw numbers. EEG asymmetries are recognized as characteristics. Table 2 shows the quotients used in this study to test the effect of yoga breathing.

2.5. Statistical Analysis

Statistical analyses were carried out using SPSS for Windows (version 12). To verify the homogeneity between two groups, χ^2 test and *t* test were performed. While χ^2 test dealt discrete values like age groups, α and β asymmetry, *t* test handled QEEG quotients. Analysis of variance (ANOVA) on gain scores of QEEG quotients were assessed to test possible differences between the conditions (yoga breathing and control). Two naturally formed groups were involved in this study, so it is better to analyze them with ANOVA on gain scores than repeated measures ANOVA (Huck & McLean, 1975). Data were presented by means ± SD. Unless otherwise specified, significant levels were set at $p \leq .05$.

3. Results

3.1. Homogeneity test

According to χ^2 test for discrete values like age groups, α asymmetry, and β asymmetry, the two groups are homogeneous as shown in Table 3.

Table 4 shows the result of t test for QEEG quotients, all of the quotients except α/β_H (L) being homogeneous. Baseline α/β_H (L) was significantly higher for the yoga breathing group, which means the participants were more stressed than the control. This may be caused by the fact that two naturally formed groups were recruited in this study. Nevertheless, the BQ was not significantly different between two groups, so they might be considered homogeneous in their brain function to be compared in this study (Park, 2005).

Table 3. Result of χ^2 test: discrete values

		Yoga breathing (n=17)	Control (n=17)	χ^2	*p*
Age groups	20's		1 (5.9%)	1.583	.663
	30's	9 (52.9%)	7 (41.2%)		
	40's	7 (41.2%)	7 (41.2%)		
	50's	1 (5.9%)	2 (11.8%)		
α asymmetry	LD	6 (35.3%)	6 (35.3%)	.000	1.000
	RD	11 (64.7%)	11 (64.7%)		
β asymmetry	LD	9 (52.9%)	6 (35.3%)	1.074	.300
	RD	8 (47.1%)	11 (64.7%)		

Note. *: p<.05; LD = left dominance; RD = right dominance.

Table 4. Result of *t* test: QEEG quotients

	Yoga breathing *M (SD)*	Control *M (SD)*	*t*	*p*
α/δ (L)	18.96 (11.89)	12.78 (5.82)	1.926	.063
α/δ (R)	16.66 (12.90)	13.91 (6.52)	.783	.440
α/β_H (L)	1.091 (0.65)	0.61 (0.36)	2.677	.012*
α/β_H (R)	1.38 (1.07)	0.77 (0.68)	1.975	.057
$\alpha/\beta_H + \alpha/\delta$ (L)	71.39 (14.61)	77.14 (8.68)	-1.402	.170
$\alpha/\beta_H + \alpha/\delta$ (R)	73.95 (15.63)	75.75 (9.59)	-1.405	.688
CQ	76.95 (10.02)	73.02 (8.10)	1.256	.218
BQ	70.47 (9.47)	67.67 (7.87)	.937	.356

Note. *: $p<.05$.

3.2. Changes in QEEG quotients due to yoga breathing

To analyze the effect of yoga breathing, gain scores of QEEG quotients were calculated first (Table 5). For the yoga breathing group, α/δ (L, R), α/β_H (L, R), and CQ were decreased, while $\alpha/\beta_H + \alpha/\delta$ (L, R) and BQ were increased. Meanwhile for the control group, α/δ (L, R) and CQ were increased, but $\alpha/\beta_H + \alpha/\delta$ (L, R) and BQ were decreased with respect to time.

Table 5. Gain scores of QEEG quotients

	Yoga breathing		Control	
	M	*SD*	*M*	*SD*
Δ α/δ (L)	-6.813	10.901	4.091	13.814
Δ α/δ (R)	-5.768	9.925	2.498	12.881
Δ α/β_H (L)	-0.393	1.063	0.055	0.847
Δ α/β_H (R)	-0.71	1.343	-0.071	0.845
Δ $\alpha/\beta_H + \alpha/\delta$ (L)	6.954	12.308	-5.269	16.688
Δ $\alpha/\beta_H + \alpha/\delta$ (R)	6.273	10.597	-3.401	15.891
Δ CQ	-1.768	14.253	7.786	9.461
Δ BQ	.192	6.800	-.388	10.610

Note. $\Delta = Q_2 - Q_1$; Q_2 = post-intervention; Q_1 = pre-intervention.

ANOVAs were tested with the gain scores of QEEG quotients as shown in Table 6. Gain scores of α/δ (L, R) and CQ were decreased significantly ($p<.05$), while gain scores of $\alpha/\beta_H + \alpha/\delta$ (L, R) were increased significantly for the yoga breathing group compared to control ($p<.05$).

Table 6. Result of ANOVAs on gain scores

		SS	*Df*	*MS*	*F*
Δ α/δ (L)	Between	1010.648	1	1010.648	6.528*
	w/in	4957.465	32	154.827	
Δ α/δ (R)	Between	580.761	1	580.761	4.393*
	w/in	4230.576	32	132.206	
Δ α/β_H (L)	Between	1.708	1	1.708	1.848
	w/in	29.567	32	.924	
Δ α/β_H (R)	Between	3.469	1	3.469	2.758
	w/in	40.251	32	1.258	
Δ $\alpha/\beta_H + \alpha/\delta$ (L)	Between	1269.780	1	1269.780	5.906*
	w/in	6879.433	32	214.982	
Δ $\alpha/\beta_H + \alpha/\delta$ (R)	Between	795.503	1	795.503	4.361*
	w/in	5837.168	32	182.411	
Δ CQ	Between	775.794	1	775.794	5.301*
	w/in	4682.743	32	146.336	
Δ BQ	Between	2.865	1	2.865	.036
	w/in	2541.145	32	79.411	

Note. *: $p<.05$.

3.3. Association between the changes in QEEG quotients and prefrontal asymmetry

Baseline prefrontal asymmetry was tested for the gain scores of α/δ (L, R), $\alpha/\beta_H + \alpha/\delta$ (L, R) and CQ which were significantly different between groups. Two-way ANOVAs (Group x α asymmetry, Group x β asymmetry) were tested on them. As a result, neither any quotients had main effect of β asymmetry, nor they showed significant interaction effect of Group x α or β asymmetry.

Two-way ANOVA of α asymmetry x β asymmetry didn't show any significant change for those QEEG quotients.

However, gain score of $\alpha/\beta_H + \alpha/\delta$ (R) proved to have main effect of α asymmetry with F (1, 34)=5.694 (p<.05). Pearson's correlation coefficient between α asymmetry and gain score of $\alpha/\beta_H + \alpha/\delta$ (R) was .374 (p<.05). For the right α dominance of yoga breathing, $\alpha/\beta_H + \alpha/\delta$ (R) was increased the most (See figure 2). On the contrary, they were decreased for the left α dominance of yoga breathing group as well as the control regardless of dominance. The decrease of $\alpha/\beta_H + \alpha/\delta$ (R) was the biggest for left α dominance of control.

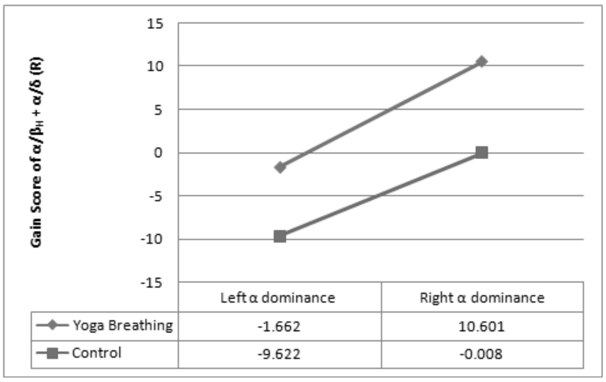

Figure 2. Group x α asymmetry for $\Delta\ \alpha/\beta_H + \alpha/\delta$ (R)

4. Discussion

This study has demonstrated that prefrontal QEEG quotients of yoga breathing participants changed compared to control participants. Especially gain scores of α/δ (L, R) and CQ were decreased significantly (p<.05), and that of $\alpha/\beta_H + \alpha/\delta$ (L, R) were increased significantly (p<.05). Gain scores of $\alpha/\beta_H + \alpha/\delta$ (R) showed main effect of α asymmetry, while none of the quotients had main effect of β asymmetry.

Clare (2004) reported that stress reduction is the most important effect of yoga among health-related ones. This has been verified in many previous studies (Field, Diego, & Hernandez-Reif, 2010; Jerath & Barnes, 2009; Jovanov, 2005; Singh et al., 1990; Singh et al., 2011; Lin et al., 2011). The result of our study was consistent with them.

α/δ representing body stress was significantly decreased after yoga breathing in this study, as may be predicted from the previous report by Wang (2010). She reported that yoga breathing was more effective in the physical stress reduction and stress response than yoga postures and relaxation. $\alpha/\beta_H + \alpha/\delta$ representing stress resistance was significantly increased after yoga breathing in this study. This is similar to the report of Mehling (2006), where stress response ability of yoga breathing group was significantly increased compared to physical therapy group.

Although the effect of yoga breathing on body stress and stress resistance was significantly positive, it didn't change mental stress significantly in this study. Baseline α/β_H (L, R) of the yoga breathing group was higher than the control. Especially α/β_H (L) was significantly higher in the yoga breathing group from the beginning. Hence the reduction of mental stress was not enough to show significant difference between groups despite it was decreased much for yoga breathing group.

This study showed that $\alpha/\beta_H + \alpha/\delta$ (R) had main effect of α asymmetry. This may be corresponded to the report by Henriques and Davidson (1991), showing only the α band had significant Group x Hemisphere interaction in the midfrontal region for depression. Our result shows that the stress resistance of right α dominance were the most positively affected by the yoga breathing. This result implies that people of right α dominance may be more emotionally relaxed and positively accept the yoga breathing intervention as supposed by Davidson (1993; 2004) that left prefrontal cortex is involved in emotional relaxation and positive behavior.

One more promising utility of yoga breathing is that it can also relieve the left α dominance who may be easily stressed or previously depressed. Left α dominance of control had lower stress resistance as time went by, implying that they may be easily stressed and negatively respond to outside stimulus. This is consistent with earlier reports saying that the right prefrontal cortex is active for negative emotion, while left prefrontal cortex is involved in emotional relaxation and positive behavior (Davidson, 2004; Allen et al.; 1993). Nonetheless the stress resistance of α dominance of yoga breathing group didn't fall as much as the control. Depression may be considered for people whose left α is greater than right α (Demos, 2009), this may partly account for the decrease of stress resistance for left α dominance regardless of yoga breathing and control group.

While α asymmetry of the participants had main effect on the gain scores of $\alpha/\beta_H + \alpha/\delta$ (R), β asymmetry didn't affect any prefrontal QEEG quotient. From this result, it may be said that yoga breathing affected α/δ (L, R), CQ, and $\alpha/\beta_H + \alpha/\delta$ (L, R) regardless of the behavioral attitude of the participants.

In conclusion, we quantitatively analyzed changes in psychophysiologial changes due to yoga breathing. The obtained results suggest that yoga breathing is effective for stress management, especially body stress. More relaxed people may have better instantaneous stress reduction from yoga breathing. Moreover, yoga breathing can be beneficial for people who may be easily stressed or previously depressed. Further integrated studies are needed to cast light on the mind-body interaction underlying the benefits of yoga breathing. Nevertheless, our findings may indicate the characteristics of individuals who are mostly likely exhibit alteration in psychophysiological changes due to yoga breathing, and QEEG quotients may be a promising tool in stress measurement for the yoga breathing.

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