Short - Term Loosen Up Meditation Induced EEG and Autonomic Response in Healthy Japanese Students

Iwakuma M1*, Nakayama T2, Oshita D1 and Yamamoto A3

1Graduate School of Medicine, Department of Medical Communication, Yoshida-Konoecho, Sakyo-ku, Kyoto University, Kyoto, Japan
2Department of Physiology, Meiji University of Integrative Medicine, Hyoashi-cho, Nantan-shi, Kyoto, Japan
3Faculty of Nursing, Department of Nursing, 1-21 Mibu Higashi-takadacho, Nakagyo-ku, Kyoto College of Nursing, Kyoto, Japan

Abstract

Meditation has been practiced beginning of ancient times, and recently has gained more attention as something that can be utilized by anyone, regardless of their location, age, or gender for health benefits. The present study was aimed to produce some basic data on the effects of short-term meditation, as assessed by measuring brain waves during meditation, on 15 healthy Japanese students. Experiments were conducted with the subjects’ eyes closed. After watching a meditation video (of about nine minutes duration), subjects took a three-minute break before practicing voiceless self meditation.

Frequency analysis of brain waves of the subjects during the meditation revealed that the strength of α waves tends to increase during the meditation. In addition, the content rate of M1 (α + b) α waves during meditation tended to be higher than during the rest or recovery periods, although this difference was not statistically significant. The content rate of M2 (α + b) α waves during meditation was higher than that during rest, while that for δ waves was much lower than that during rest. Relative to that during recovery, the content rate during meditation was significantly lower for M2 α waves but significantly higher for δ waves. The α waves showed significantly more intermediate frequencies during M1 and M2 meditation as compared to those during the rest period, but fewer were noted during recovery. The LF/HF values, which reflect sympathetic nerve activity, were significantly higher during both M1 and M2 meditation than during the rest period. However, relative to that during recovery, LF/HF during M2 meditation was significantly lower.

One limitation of the present study is that the meditation period was comparatively short. In addition, many of the subjects were also inexperienced in meditation, which may have created more variability in the results. However, the present study clearly demonstrates that repeated practice of meditation may improve subject’s attention to task activities as well as the effectiveness of the neural network recruited for impulse control.

Keywords: Meditation; EEG; Sympathetic Nerve Activity; Median Power Frequency; Trait Anxiety; α- and δ-Wave Oscillation

Abbreviations

EEG: Electroencephalogram; ECG: Electrocardiogram; kΩ: Kilo-Ohm; Hz: Herz; LF: Low Frequency; HF: High Frequency; S.D.: Standard Deviation; M: Meditation; RESP: Respiration.

Introduction

A wide range of theories and health boosting schemes are adopted in programs to recover humanity in order for us to survive in modern, stressful society. Among them, meditation, which has been practiced a long time ago, has recently been attracting particular attention as a programme which can be practiced anywhere by anyone regardless of age or gender. Conventionally, meditation has been used to train the body and mind in religious traditions. Recently, however, it is widely practiced as part of human development, preventative medicine, alternative medicine, and health promotion programs in every corner of the globe without being restricted to a particular ethnic group, religion or region. The recent trend is to understand meditation from a holistic point of view and there is a growing tendency to use meditation medically and educationally: in therapies, stress reduction, awareness of illness, recovery of physical and mental health, and stress coping.

Seppala et al. noted that despite the inconsistent or low impact on anxiety, many studies on meditation research utilized mindfulness-based meditation, while far fewer studies examined breathing-based meditation [1]. These researchers also concluded that breathing-based meditation is superior to mindfulness meditation. One reason for this is that participants in mindfulness meditation are instructed to sit still, which could be “challenging for anxious people with high degree of physiological arousal, breathing may be preferable because it engages that participant in a structured activity that leads to immediately observable calming effects”. Therefore, manipulation of respiration and practicing certain postures are noted as differences between mindfulness and breathing-based meditation practices.

Many studies in a number of fields have reported meditation reduces stress, enhances physical and mental functions and is effective in calming the mind and promoting health. One study instructed Japanese students to perform simple meditation for five minutes before class, and found that students reported improved attitudes toward the class and concentration, promotion of mental and physical health, and prevention of mental problems [2]. Another study examined the effects of meditation on relieving anger in healthy students and concluded that the results of this study, which found a reduction in the tendency to ruminate over experiences and memories of anger, suggest the efficacy of mindfulness meditation as a technique for the midterm management of excessive anger and aggressive behavior [3]. Its efficacy against depression, eating disorders, and anxiety disorders is recognized, and some efforts have been made to use meditation therapy in clinical settings [4,5].

Recent studies in neuroscience have also investigated the meditation, and a meta-analysis of the relationship between meditation and brain structure has concluded an efficacy of meditation on emotions resulted from an altered brain structure. For example, a recent study [6] found a positive correlation between subjective happiness and gray matter volume in the brain. Sato and his colleagues note that “previous structural neuroimaging studies have shown that training in psychological activities, such as meditation, changed the structure of the precuneus gray matter”. Likewise, according to another study by De Prycker,
practicing meditation may also increase a sense of happiness, which is a better indicator than economic success [7]. In meta-analysis and systematic review of neuroimaging of meditation practice, meditation has been concluded to "indeed have positive effects on cognitive and emotional processes, these effect sizes are comparable to roughly 'medium' effects of many other behavioral, educational, and psychological interventions" [8]. Based on some previous meditation studies, the present study attempts to fill the research gaps in the area of effects of short-term meditation by examining how breathing-based meditation influences the electroencephalogram (EEG) and autonomic response of healthy Japanese students.

**Methods**

**Subjects**

Subjects for the present study were healthy men and women (14 males; mean age 19.7 ± 0.9) belonging to Japanese student community. This study received the approval of the Ethics Committee of Meiji University of Integrative Medicine (Approval No. 27-27-18). Experiments were done during November through December in 2015. The research was performed after explaining its motives and contents in detail to subjects and obtaining their written consent.

**Meditation training**

All subjects viewed a relaxation meditation tutorial DVD, which lasted for nine minutes, after recording electrodes were placed. Subjects then entered a shielded room, sat on a cushion placed on the floor, and closed their eyes before starting the experiment. Each subject meditated for nine minutes.

**EEG recording and Electrode placement**

EEG recording was performed following the International 10-20 System. Silver/silver-chloride disc electrodes were filled with electrode paste (Elefix, Nihon Kohden, Japan). Active electrodes were placed at C3 and C4 and reference electrodes at both earlobes. Inter-electrode impedance was restricted to ≤ 5 kΩ. EEG signals were recorded from precordial leads. A respiration sensor was attached to the left nostril, which transmitted breathing information through a multi-telemeter system (Ech2101; Nihon Kohden) to be amplified via a Bioamp Web5000 device (Nihon Kohden). Transmitted EEG and ECG signals were amplified using a high-sensitivity bioamplifier (Biotop 12R, NEC-Sanei, Tokyo). Each amplified signal was input into a personal computer after passing through an A/D converter, and monitored and recorded using Vital Recorder II measurement software (version 2.6.7.1103; Kissei Comtec, Nagano, Japan). Bioamplifier frequency bandwidths were set at 0.4 - 60 Hz for EEG signals, 0.016 - 30 Hz for ECG signals, and 0 - 30 Hz for respiratory signals; the sampling rate was 1 kHz. Bandwidths for EEG components were set at 1 - 3.5 Hz for δ waves, 3.5 - 7.5 Hz for θ waves, 7.5 - 12 Hz for α waves, and at 12–32 Hz for β waves [9]. (Note: δ waves-associated with the deep stage 3 and 4 of NREM; α waves-reduced with open eyes, drowsiness and sleep, β waves [9].)

**Statistical processing**

Testing was carried out on analysis results using PASW Statistics statistical software (Ver. 18.0; SPSS Inc., Chicago, IL, USA). All results are shown in terms of mean ± S.D. Brain wave appearance frequencies, α-wave median power frequency, and LF/HF ratio during the rest, meditation, and recovery stages were evaluated using paired t-tests. Statistical significance was set at ≤ 5%.

**Results**

Fourteen of the fifteen subjects completed the whole meditation procedure without any noted incident. Data from the one subject who contained excessive noise was not included in analysis. As seen in Figure 1, breathing rhythm changed greatly during meditation, as the heart rate increased during inspiration and decreased during expiration. (In figures, the meditation stage is divided into M1a and M1b (i.e. the first half) and M2a and M2b (i.e. the second half).

Concomitant changes in the α-wave component were also observed. Representative results of EEG frequency analysis of brain waves recorded during meditation are shown in Figure 2. Alpha waves exhibited a tendency to increase in power during meditation. As shown in Figure 3, the percentage of all brain waves comprised by α-waves was higher during the M1 (a + b) stage than during the
rest and recovery stages; however, neither of these differences was significant. Compared with during rest, the percentage of α-waves was significantly higher during the M2 (a + b) stage (41.70 ± 13.45, p = 0.036), and the percentage of δ-waves was significantly lower (21.97 ± 8.46, p = 0.025). In addition, the percentages of α-waves and δ-waves during M2 (a + b) were significantly higher and lower than during recovery (41.70 ± 13.45, p = 0.004; 19.27 ± 7.81, p = 0.020, respectively). Table 1 shows variation in α-wave median power frequency during meditation. α - wave median power frequency significantly increased during both M1 and M2 with respect to during rest (p = 0.041, p = 0.036), but was observed to decrease during recovery.

As shown in Table 2, LF/HF ratio based on the R-R interval obtained from ECG signals (which represents the balance between the parasympathetic and sympathetic nervous systems [10] and can be used as an indirect of cardiac autonomic balance index [11], was significantly higher during M1 and M2 than during rest (p = 0.011, p = 0.006, respectively). However, LF/HF ratio during M2 was significantly lower than during recovery (p = 0.004).

In the mood survey, administered at the conclusion of the experiment, the eight subjects who had no prior experience with
meditation responded with the following comments: “I calmed down” (4/8); “My mood was normal” (2/8); “I felt really relaxed” (1/8); and “I felt sleepy” (1/8). Except for one subject (who felt “normal”), the six subjects with previous meditation experience responded that they felt really relaxed, that they felt really good, and that tension throughout their body had been relieved.

Discussion

During meditation, the R-R interval increased during exhalation and decreased during inhalation, as seen in Figure 1. This observation reveals that exhalation slowly and completely causes excitation of the parasympathetic nervous system to temporarily dominate, while inhaling again causes excitation of the sympathetic nervous system to temporarily dominate. In this way, subjects repeating rhythmic breathing movements while envisioning the “relaxation” of parts of their body caused transient increases in α-wave activity and decreased during inhalation, as seen in Figure 1. This phenomenon is believed to be activated by the rhythmic breathing movements of meditation, which are deeply associated with a series of downward inhibitory signals that elicit reduction of trait anxiety [14,20] and promoted happy emotions [6].

It is widely recognized that peak α frequency varies by age group: 20 year old youth average is about 10.89 Hz, while 70-year-old elderly average is about 8.24 Hz. Peak frequency decreases with advancing age [21]. In addition, the typical α-wave median power frequency is ~10.04 Hz for healthy, 19 - 21 year old males [22]. Here, the series of changes in the brain due to meditation produced a significant increase in α-wave median power frequency (M1 = 10.059 Hz; M2 = 10.056 Hz). We believe a heightened awareness of sensory signals [15] is one reason for the positive feelings of our subjects reported after meditation. Increased α-wave median power frequency is considered to be due to reduced anxiety [23]. In the subjective feeling survey, many subjects (10 out of 14) reported positive feelings at the conclusion of meditation, regardless of whether they had prior experience with meditation or not. Experienced subjects reported slightly more positive feelings and increased α wave, but decreased δ wave percentage content compared with inexperienced subjects. However, these group differences were not statistically significant (p = 0.687).

In the present study the meditation exercise was performed only for a short time; further, many subjects also lacked experience with meditation, and even those with experience had only done meditation a few times. These factors may be partially responsible for the large variation in the results of our study. Likewise, as meditation techniques are numerous, the existing findings may also differ from researcher to researcher: Therefore, the interpretation of our findings is limited only to the contents of the one which we employed herein. However, a related study performed on regular meditators and non-meditators suggests that repeated meditation training may be able to raise the efficiency of neural networks mobilized for task based attention and impulse control [24]. These neural activities recruited may activate default-mode network [25,26] that is an important role of depression [26], and promote preconcous structural changes [6] to elicit happy emotions and lead to improvement of negative, passive mood [17]. Among these, the reported increased α-wave activity during meditation is consistent with our findings; however, Yu et al. failed to find α-δ anticorrelation [17]. This phenomenon is believed to be activated by the rhythmic breathing movements of meditation, which are deeply associated with a series of downward inhibitory signals that elicit reduction of trait anxiety [14,20] and promoted happy emotions [6].

Table 2: Changes in LF/HF ratio during the rest, meditation and recovery stages. Data are mean ± S.D., LF: Low Frequency, HF: High Frequency, M: Meditation, *p < 0.05 versus the rest, **p < 0.01 versus the rest and the recovery.

<table>
<thead>
<tr>
<th></th>
<th>LF/HF (ratio) (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>1.00 ± 0.0</td>
</tr>
<tr>
<td>M1</td>
<td>2.56 ± 1.95 *</td>
</tr>
<tr>
<td>M2</td>
<td>3.65 ± 3.02 **</td>
</tr>
<tr>
<td>Recovery</td>
<td>1.73 ± 1.65 **</td>
</tr>
</tbody>
</table>

Many reports have demonstrated that meditation activates the prefrontal cortex [17-19] and anterior cingulate gyrus [18,19], promotes increased α-wave and decreased δ-wave activity [17], significantly elevates whole-blood serotonin concentration [17], and leads to improvement of negative, passive mood [17]. Among these, the reported increased α-wave activity during meditation is consistent with our findings; however, Yu et al. failed to find α-δ anticorrelation [17]. This phenomenon is believed to be activated by the rhythmic breathing movements of meditation, which are deeply associated with a series of downward inhibitory signals that elicit reduction of trait anxiety [14,20] and promoted happy emotions [6].

References


