PAPER 213

ELECTROPHYSIOLOGIC CHARACTERISTICS OF RESPIRATORY SUSPENSION PERIODS OCCURRING DURING THE PRACTICE OF THE TRANSCENDENTAL MEDITATION PROGRAM

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The combination of inner alertness, respiratory suspension, and high EEG coherence was found to characterize the state of transcendental consciousness experienced during the practice of the Transcendental Meditation technique.—EDITORS

In a study designed to identify the electrophysiologic characteristics of the Transcendental Meditation program, 52 periods of spontaneous respiratory suspension (RS) were observed in 18 subjects during the practice of this program. These periods were correlated with some but not all the subjective experiences of pure consciousness. Nineteen RS periods (belonging to 11 subjects) free from any artifact were selected for EEG analysis. The mean total EEG coherence over all frequencies and over nine derivations for TM subjects showed a significant increase during the RS periods as compared to pre- and post-RS control periods. There was no significant change in mean total EEG coherence in a control group of 30 subjects voluntarily holding their breath. The heart rate showed a significant decrease during the RS periods in both the experimental and control groups, whereas there was no significant change in EEG alpha power in either group. These findings extend those of previous studies and help characterize the physiologic correlates of the state of pure consciousness during the TM program.

INTRODUCTION

A number of early studies on the Transcendental Meditation (TM) technique have noted overall changes in respiratory and electrophysiologic activity during the technique (1 – 7). More recent studies, using continuous measurements of specific physiologic parameters that were highly correlated with meditation experiences, have shown even more marked physiologic changes in participants of the TM and more advanced TM-Sidhi program (8,9). One study, involving four independent experiments, reported a total of 565 episodes of respiratory suspension in 40 subjects observed during practice of the TM technique and showed that respiratory suspension is highly correlated with the subjective experience of pure consciousness (9). The study controlled for the possibility that either voluntary control or sleep onset were responsible for the periods of respiratory suspension. Further, the frequency and length of these breath suspensions were noted to be substantially and significantly greater for TM subjects than for control subjects relaxing. Eleven of the subjects were instructed to press an event marker after the subjective experience of pure consciousness, which has been defined by these and other researchers as a least excited state of consciousness, a state of complete mental quiescence in which thoughts are absent although consciousness is main-

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tained (8,9). The temporal distribution of button presses was found to be significantly related to the distribution of breath suspension. Further, an extensive analysis of periods of respiratory suspension associated with the experience of pure consciousness in one advanced TM meditator showed significant differences between respiratory suspension and control periods in a number of measures. For example, the following characteristics were observed during periods of respiratory suspension: high EEG coherence in the alpha and theta frequencies, reduced heart rate, high basal skin resistance, stable phasic skin resistance, markedly reduced respiration rate, mean minute ventilation, and mean metabolic rate (9).

In order to follow up and extend the electrophysiologic findings in this one advanced TM subject, we undertook a study with a similar experimental approach using a larger number of subjects and additional controls.

METHODS

Subjects

Two main groups of subjects were studied: an experimental group of 54 TM meditators (36 males and 18 females) with a mean age of 27.9 years (range 21 – 43 yrs.) who had been practicing the TM technique for a mean of 77 months (range 16 – 144 months); and a non-meditating control group (control group 1) of 31 subjects (18 males and 13 females) with a mean age of 24.6 years (range 18 – 48 yrs.). One additional control group was also studied: subjects were asked to voluntarily hold their breath (control group 2). This control group consisted of 30 TM meditators (23 males and 7 females) with a mean age of 24.8 years (range 19 – 32 yrs.) who had been practicing the TM technique for a mean of 55.8 months (range 1 – 113 months). (See Table 1.) All subjects reported that they were physically and mentally healthy with no history of brain disorders.

TABLE 1. Summary of Characteristics of Subject Groups

	Experimental	Control I	Control II
Number of subjects	54	31	30
Age	27.9 yrs (mean)	24.6 yrs	24.8 yrs
Type of subject	TM subjects	Nonmeditating	TM subjects
Condition	Practicing TM	Relaxing with eyes closed	Voluntary breath holding
Type of measurement taken	Number of RS periods	Number of RS periods	Number of RS periods
	Total EEG coherence		Total EEG coherence
	EEG power spectrum		EEG power spectrum
	Heart rate		Heart rate
	Phasic skin resistance		

Procedure

The procedure for the experimental group and control group 1 involved an initial eyes-closed period of 2 – 5 min followed by an experimental period of 10 – 15 min in which TM subjects were instructed to meditate while nonmeditating control subjects were asked to relax with eyes closed. While the experimental period was slightly shorter than the normal period, it was felt from previous research (1, 4, 9) that it was adequate to observe periods of respiratory suspension.

The procedure for the subjects in control group 2 involved several steps. The subjects were initially asked to meditate for 5 min; during the fifth minute the average breath length was calculated. After a 2 – 3 min rest following meditation, the subjects were told, when given the instruction to "start," to take a normal inhalation and then hold it until instructed to stop. Each subject performed this breath holding for three predetermined periods separated by a minute of rest. The periods of breath holding were equal to one, two, and three times the average breath length. The different lengths of time were randomized as to order, but each subject held his breath for all three times.

Subjects were comfortably seated in a dimly lit quiet room equipped with closed circuit TV and intercom adjacent to the instrument room. Sixteen subjects were given an event marker button connected to the EEG paper record, and were instructed to press the button after each experience of transcendental or pure consciousness. This allowed a correlation of the subjective experience with the electrophysiologic measurements.

Data Acquisition

The polygraphic recording was performed on a 16-channel Grass Model 78 Polygraph with a Megatek Laboratory Interface connected to a Data General Nova computer. The data were digitized and recorded on a digital magnetic tape recorder. EEGs were taken in 69 subjects (including all experimental and 15 nonmeditating control subjects) from electrodes F3, F4, C3, Cz, C4, T3, T4, O1, O2, of the 10 – 20 International System, and in 46 subjects (including all control group 2 and 16 nonmeditating control subjects) from electrodes F3, F4, C3, C4, O3, and O4, with linked ear for the reference electrode in all subjects. Electrocardiograms (ECG) were recorded in all subjects and electrooculograms (EOG) and phasic skin resistance (GSR) were recorded in 85 subjects. Respiration was monitored with a thermocouple placed at the edge of the nostril.

The criteria used for a respiratory suspension were the following: (1) absence of fluctuation in the respiratory pattern exceeding one tenth of the mean amplitude of this pattern measured during the first 2-min period of eyes closed, (2) a duration of longer than twice the mean interval of time between two respirations during the first eyes-closed period, and (3) no hyperventilaton, as defined by unusual rapid and deep breathing, at the beginning or the end of the RS period. The coherence spectrum, a measure of the correlation between two signals, was computed for the following pairs of electrodes: F3F4, C3C4, O1O2, F3C3, F4C4, T3C3, T4C4, C3O1, C4O2 in 69 subjects, and F3F4, C3C4, O3O4, F3C3, F4C4, C3O3, C4O4 in the remaining 29 subjects via Fast Fourier Transform, using epochs of 2.56 sec according to the methods of Levine (6).

The mean of the total coherence over the whole frequency range was computed during the RS period and during control periods immediately before and after the RS. The length of each pre- and post-RS control period was determined as being equal to the length of the corresponding RS period. In the experimental group two precontrol periods immediately before and two postcontrol periods immediately after the RS period were examined, whereas in control group 2 only one pre- and one postcontrol period were examined. The mean power was computed for each lead during each RS period and its respective control periods, for each frequency band (Delta: 1 – 4 Hz; Theta: 4 – 8 Hz; Alpha: 8 – 12 Hz; Beta: 12 – 50 Hz), and over the entire spectrum. The heart rate was also measured over the same periods.

RESULTS

In the experimental group, 18 TM subjects showed 52 RS periods with a mean duration of 15.4 sec (range 10 – 44 sec). We did not observe any respiratory suspension meeting our criteria in control group 1 (relaxing with eyes closed). In control group 2 (voluntary breath holding), 30 subjects showed 90 predetermined periods of RS. The following results are an analysis of the electrophysiologic changes during RS periods in the TM group and in control group 2.

Subjective Experience of PC and RS Periods

Out of the 16 TM subjects who were asked to indicate with an event marker periods of pure consciousness, six of these subjects also showed periods of respiratory suspension. Twenty periods of respiratory suspension were seen in these six subjects and sixteen of these periods corresponded to a press-button signal. Subjects indicated the subjective experience of transcendental or pure consciousness by a press-button signal within 10 sec of the offset of one of the breath suspension episodes.

Coherence

In the experimental group, the mean coherence over all frequencies and all derivations was computed for 19 RS periods (11 subjects) free of artifacts (EEG, EOG, ECG, movements, or technical problems) and for their pre- and postcontrol periods. In control group 2, it was computed for 39 RS periods (13 subjects) free of artifacts, and for their pre- and postcontrol periods. (See Table 2.) In both groups an analysis of variance with repeated measures of the means of coherence was performed (10).

In the TM group, there was a significant difference between the RS and the pre- and postcontrol periods ($F = 4.4$, $p < 0.005$ with 4 and 40 *df*). In the two-tailed paired *t*-test, the RS periods had a significantly higher coherence than each of the control periods but a significant difference was not found between the control periods, although the first postcontrol period tended to have a lower coherence than the other control periods. Figures 1 and 2 show the mean coherence over all frequencies for each derivation and the total mean coherence over all frequencies and all derivations.

The voluntary breath holding group did not show significant differences in coherence in any derivation between the RS and pre- and postcontrol periods. The total coherence showed a slight, but not significant decrease during the RS period, and then a tendency to increase back to precontrol levels.

TABLE 2. Characteristics of Respiratory Suspension

	Precontrol 1	Precontrol 2	Respiratory Suspension	Postcontrol 1	Postcontrol 2
Total Coherence (Mean over all derivations)					
Experimental group ($N = 11$)[a]	0.792 $p^b < 0.05$	0.790 $p < 0.05$	0.810	0.774 $p < 0.005$	0.794 $p < 0.06$
Control group II (voluntary breath holding) ($N = 13$)	—	0.605 NS	0.601	0.605 NS	—
Heart rate (beats per minute)					
Experimental group ($N = 17$)	72 $p < 0.01$	70.8 $p < 0.001$	67.2	70.8 $p < 0.05$	69 NS
Control group II ($N = 13$)	—	66.1 $p < 0.002$	63.2	64.6 NS	—

[a] N = number of subjects
[b] p values for RS versus each control period, two-tailed paired t-test

Coherence Changes with Respect to Mean Coherence during Control Periods

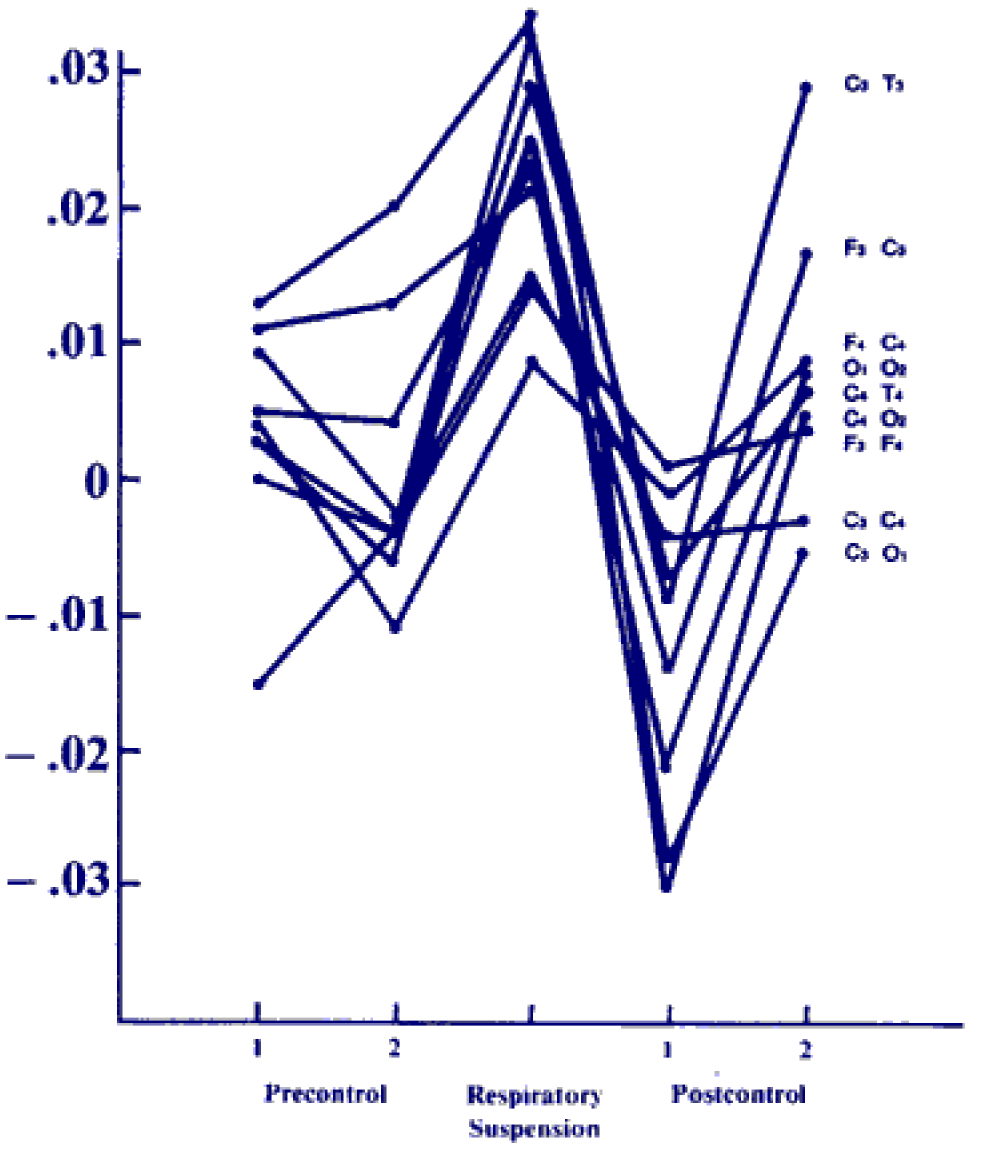

Fig. 1. Mean total coherence over all frequencies for 11 subjects, for each derivation is shown here. There was a significant increase of coherence during the RS periods as compared to each of the pre- and postcontrol periods.

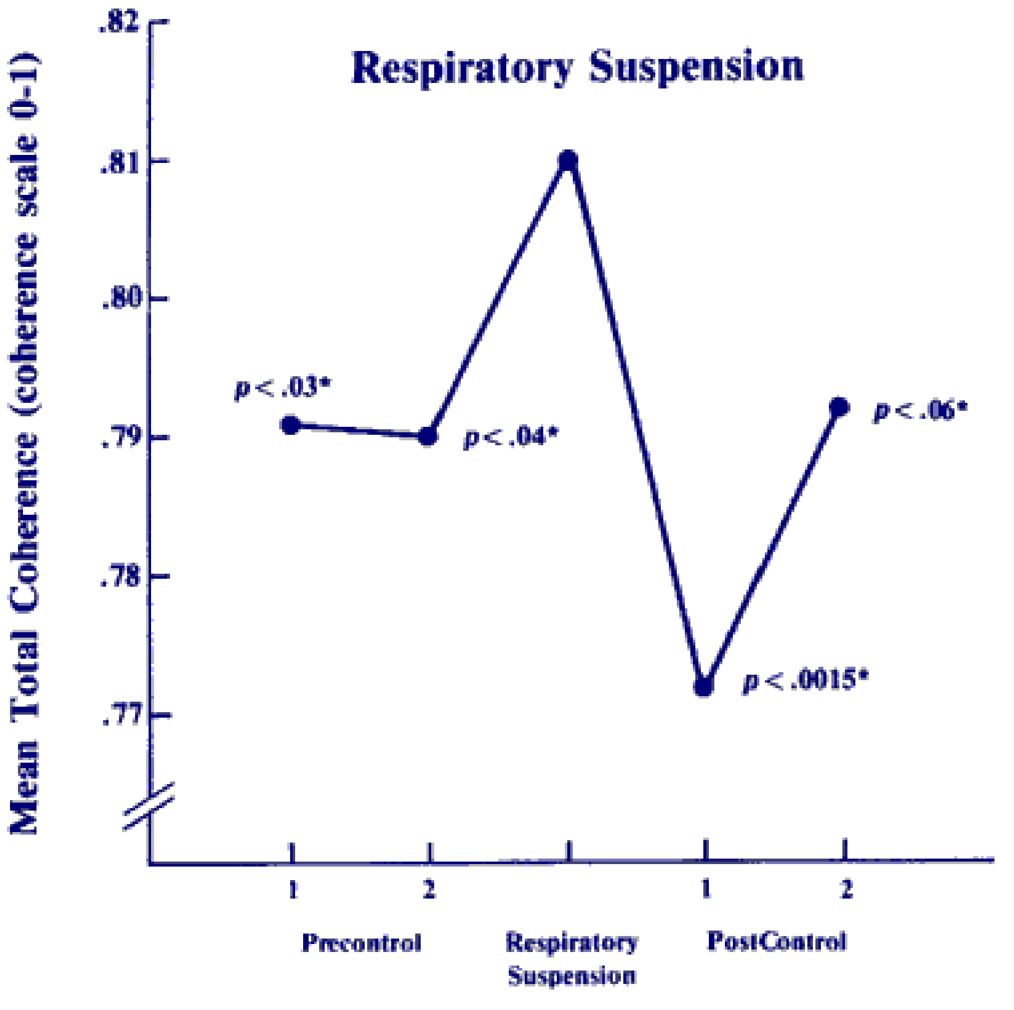

Fig. 2. Mean total coherence over all derivations for all frequencies for 11 subjects. * RS versus each control period, two-tailed paired t-test.

Power Spectrum

In the TM group, an analysis of variance with repeated measures of the power spectrum of all subjects showed a significant decrease in mean theta power during the RS period, as compared to the control periods ($F=12.64$, $p<0.005$ with 4 and 40 df) with no significant decrease in other frequency bands. We did observe the following tendencies: during the RS period, the power in the alpha band increased and in the delta and beta decreased; and during the postcontrol period, the power in beta and theta increased and the power in alpha and delta decreased.

The intentional breath holding group showed no significant changes in measurements of power spectrum for the different periods, frequency bands, and EEG leads. During the RS period, there was a tendency for alpha and theta power to increase, and delta and beta to decrease, whereas following the RS period, beta increased and delta, theta, and alpha decreased.

Heart Rate

Of the 52 RS periods observed in the experimental TM group, 50 periods belonging to 17 subjects were free of ECG artifacts. The analysis of variance with repeated measures of the heart rate of the TM group showed a significant change ($F=4.79$, $p<0.002$ with 4 and 64 df). The mean heart rate during the precontrol periods was 71.4 beats/min; it decreased 4.2 beats/min to a mean of 67.2, and then increased to 69.9 in the postcontrol periods. A two-way analysis of variance of the heart rate for control group 2 showed a significant change ($F=5.52$, $p<0.01$ with 2 and 24 df) between RS and control periods, and no significant difference for the factor of length of time holding breath. The mean heart rate during the precontrol period was 66.1 beats/min; it decreased significantly 2.9 beats/min to a mean of 63.2, and then increased to 64.6 in the postcontrol period. (See Table 2.)

Phasic Spontaneous Skin Resistance Responses

The mean number of spontaneous skin resistance responses per minute was computed for the RS periods, and pre- and postcontrol periods for each subject in the experimental TM group. Periods containing artifacts were excluded, and 6 of the 18 subjects were excluded because of technical problems in the recording of their spontaneous skin resistance responses.

The analysis of variance with repeated measures showed that there was no significant change in the number of phasic spontaneous skin resistance responses. The number of spontaneous skin resistance responses per minute tended to be lower during RS (0.78) than during TM (1.03), and lower during TM than during the precontrol periods (1.50). Phasic skin resistance was not recorded in control group 2.

DISCUSSION

In general, the results of our investigation support and extend Farrow and Hebert's findings (9) as well as those of previous studies (1 – 8). We will briefly summarize the similarities and differences between our study and that of Farrow and Hebert before elaborating more fully on the significance of these findings.

In both studies, the most important observation noted was the existence of periods of respiratory suspension that are associated with the subjective experience of pure consciousness in certain subjects during the practice of the Transcendental Meditation technique. The second important observation noted in both studies is that these periods of respiratory suspension are accompanied by an increase in EEG coherence. Farrow and Hebert reported that changes in EEG coherence were found in individual frequency bands. In our study, changes were found in total coherence over all frequency bands. We further extended Farrow and Hebert's findings by showing these changes in coherence to be specific to periods of respiratory suspension during the Transcendental Meditation technique and not to be present in control subjects voluntarily holding their breath. Unlike Farrow and Hebert we did not find significant changes in phasic spontaneous skin resistance associated with periods of respiratory suspension in TM subjects. Although we did confirm Farrow and Hebert's finding of a significant decrease in heart rate during periods of respiratory suspension in subjects practicing the TM technique, we also found a significant decrease in the heart rate in subjects voluntarily holding their breath.

While there were certain methodologic differences in the two studies, the most important difference between them is the number of subjects involved. Farrow and Hebert involved only one section of their study in electrophysiologic analysis of periods of respiratory suspension, and, in that section, extensive periods of measurement were made on one expert subject. Our study involved a larger group and the results, therefore, represent the characteristics of the group as a whole rather than findings that may have been aspects peculiar to one individual. A larger group is, indeed, essential for the generalization of original findings; however, it may unfortunately result in an averaging out of important physical details that may be specific to more advanced stages of the practice of the TM technique. Nevertheless, the important finding of both studies, which should be emphasized, is the discovery of an objective criterion for the physiologic analysis of the subjective experience of pure consciousness.

Many investigations of the TM technique have attempted to identify and physiologically characterize the subjective experience of transcendental or pure consciousness described as a fourth major state of consciousness (1 – 6, 11). One methodologic difficulty commonly experienced, especially in earlier studies on the TM technique, is the absence of objective criteria to distinguish the state of pure consciousness from other states that also occur during the technique. Our findings, and those of Farrow and Hebert, reveal that rather than using average values of physiologic parameters over the entire period of the TM technique, it is necessary to isolate periods of pure consciousness from other possible states. Objective measures and subjective reports of others' studies and of ours indicate that the following different types of states may be experienced: wakefulness with varying degrees of relaxation, occasional drowsiness or even sleep stages, and periods of pure consciousness.

For example, electrophysiologic activity such as increased alpha power, the appearance of high voltage theta spindles, and increases in basal skin resistance along with specific biochemical changes such as decreased levels of plasma cortisol, are often associated with subjective reports of a wakeful state of deep relaxation during the TM technique (5, 7, 12 – 16). Occasional periods of drowsiness have been reported by some investigators and even various sleep stages as defined by standard EEG and EOG criteria have been observed particularly with certain experimental conditions such as the use in one study of white noise as a constant auditory background condition (17). Finally, high intra- and interhemispheric EEG coherence in alpha and theta frequencies, especially in frontal areas of the brain, accompanied by periods of low metabolic rate, respiratory suspension, and stable autonomic activity, have been reported (1 – 4, 6) and have been found to be highly correlated with the subjective experience of transcendental or pure consciousness (8, 9).

The results of our study and those of Farrow and Hebert suggest that a simple and effective approach to isolating and characterizing the subjective experience of pure consciousness during the TM technique is a fine structure analysis of periods of respiratory suspension. Although not all subjects who report experiencing the state of pure consciousness show respiratory suspension periods, they are present in a number of subjects and are easily identified. Through an analysis of compensatory hyperventilation, these respiratory suspension periods during the TM technique have been shown by Farrow and Hebert to be significantly different from voluntary breath holding. Their results also indicate that respiratory suspension periods during the TM technique are different from those seen during sleep apnea again because they are not followed by periods of compensatory hyperventilation (9).

Our analysis of the electrophysiologic changes during periods of respiratory suspension confirms the findings of earlier studies (6, 8, 9) that the experience of pure consciousness is characterized by a significant increase in EEG coherence. During voluntary breath holding no such increase in EEG coherence was found. The electrophysiologic analysis also suggests that neither heart rate, skin resistance, nor EEG alpha power are in themselves useful discriminators of the state of pure consciousness. The significant decrease in heart rate found in both respiratory suspension periods during the TM technique and in voluntary breath holding suggests that this change was not an effect specific to the state of pure consciouness. In addition, no significant decrease was seen in phasic skin resistance response. In the study of Farrow and Hebert and in ours, no significant changes in EEG alpha power were seen in the respiratory suspension period as compared to pre- and postcontrol periods. This finding is of importance since it confirms the results of recent studies (8, 18) that EEG coherence is a more reliable measure in characterizing the state of pure consciousness than EEG alpha power, which has been widely used in earlier studies on the TM technique (1 – 3, 5, 7).

In conclusion, we would suggest that the methods and results of this study and that of Farrow and Hebert offer a new more powerful approach to the study of states of consciousness. The application of such an approach to better understand the underlying physiologic mechanisms during the TM and TM-Sidhi program is significant, especially in the light of the reported beneficial effects of this program on physical and mental health (19 – 26), biologic aging (27, 28) and psychophysiologic performance (29 – 32). We would suggest that this experimental approach be expanded through the addition of other physiologic measurements such as organ blood flow and biochemical analysis of blood samples taken during periods of respiration suspension in the TM and TM-Sidhi program so that a more detailed and complete understanding can be gained of the physiologic basis of the state of pure consciousness.

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