PSYCHOPHYSIOLOGY
Copyright © 1977 by The Society for Psychophysiological Research

Vol. 14, No. 1
Printed in U.S.A.

Physiological Changes in Yoga Meditation

BARRY D. ELSON, PETER HAURI, AND DAVID CUNIS
University of Connecticut School of Medicine, Farmington, CT, Dartmouth Medical School and Dartmouth College, Hanover, NH

ABSTRACT

A group of 11 meditators using Ananda Marga Yoga techniques were matched individually with non-meditating controls. Controls were instructed to remain "wakefully relaxed" for 40 min, while the others meditated for the same amount of time. Six of the 11 controls fell asleep during the 40 min (defined by K-complexes and spindles in the EEG), while none of the meditators fell asleep. Rather, meditators remained in a relatively stable state of alpha and theta EEG activity. Meditation was also characterized by a marked increase in basal skin resistance and by a decrease in respiratory rate, changes which were not observed in the controls. Some physiological changes observed during meditation continued into the post-meditation resting periods. These findings suggest that Ananda Marga meditation produces a physiological effect different from that observed in controls who try to relax with their eyes closed.

DESCRIPTORS: Meditation, Sleep, Relaxation, EEG, Alpha, Theta, GSR. (Elson)

Experimental studies indicate a relative predominance of alpha and theta activity in the EEG during Yoga meditation, coupled with physiological changes that characterize a "state of hypometabolic relaxation" (Bagchi & Wenger, 1958; Anand, Chhina, & Singh, 1961; Wallace, Benson, & Wilson, 1971). However, there is disagreement concerning the specific contribution that meditation makes to this state. Most studies to date do not contain control groups of non-meditators sitting and relaxing for similar time periods. Thus, it is unknown whether relaxing non-meditators could achieve similar effects as are obtained during meditation.

A second controversy in this field relates to the state of awareness during meditation. Wallace et al. (1971) assert that there is no evidence of sleep in practitioners of Transcendental Meditation (T.M.). On the other hand, Younger, Adriance, and Berger (1973) found that in a group of 8 meditators (7 of whom were instructors of T.M.), "on the average almost half of a typical meditation period was spent in waking alpha, *slightly less asleep* and the remainder alert [p. 99]" (italics added). In addition, Pagano, Rose, Stivers, and Warrenburg (1976) tested "five experienced practitioners of T.M." and found that they spent "appreciable parts of meditation sessions in sleep stages 2, 3, and 4 [p. 308]." The current study attempts to clarify both of the above issues for Ananda Marga Yoga meditation.[1]

To resolve the controversy on sleep during meditation, the moment of sleep onset needs to be defined. As adults fall asleep, they usually pass first through a state of high alpha production (8–12 Hz) and slowly rolling eye movements. They then enter a stage of low voltage, mixed frequency EEG with a predominance of activity in the 2–7 Hz range. This EEG is defined by Rechtschaffen and Kales (1968) as stage 1 "sleep." It is usually followed within a few minutes by stage 2 sleep (spindles and K-complexes on a low voltage background) and later on by stages 3, 4, and REM.

Judging from the literature, it appears that both the alpha state and Rechtschaffen and Kales' (1968) stage 1 "sleep" are *transitional* phases between full wakefulness and unambiguous sleep. For example, Rechtschaffen and Foulkes (1965) found "functional blindness" already in the alpha state: subjects with their eyes taped open no longer saw pictures held in front of their eyes during the later parts of the alpha state. This would suggest that sleep onset occurs already during the alpha state (if

Address requests for reprints to: Peter Hauri, Dartmouth Medical School, 703 Remsen Building, Hanover, NH 03755.

[1]Ananda Marga (The "Path of Bliss") is a socio-spiritual organization founded in India in 1955 by followers of Sri Sri Anandamurtijii. Ananda Marga meditation is one part of a set of practices that also include yogic postures, adherence to moral principles, and engagement in social service. It is now practiced throughout many parts of the World. U.S. headquarters are at 854 Pearl St., Denver, Colorado.

sleep is defined as a relative lack of reactivity to the environment). On the other hand, Johnson (1973) concluded that "stage 1, with its fluctuating behavioral and EEG activity, appears to be a transition period between awake and asleep [p. 328]." He based his conclusion mainly on a careful computer analysis of the power spectra in the EEG. The bulk of the current sleep literature seems to agree with Johnson's view. In particular, people who have been aroused from this state are very likely to report that they have been awake, not asleep (Agnew & Webb, 1972).

Since the exact moment of sleep onset is still a matter of debate, it appears unnecessarily confusing to call stage 1 a "sleep" stage. For purposes of this paper, therefore, we have renamed this EEG stage "the theta state." (By definition, our "theta state" is thus identical to Rechtschaffen & Kales' stage 1 "sleep.") The name "theta state" was selected because theta waves are the most prominent characteristic of this stage, even though faster frequencies are also frequently present.

Being unable to confidently select an exact moment of sleep onset confuses the question of sleep during meditation, especially since *two* transitional stages ("alpha" and "theta") can apparently be distinguished. To simplify matters somewhat, only three states of arousal are distinguished in this paper: a) *full arousal* (low voltage random fast, beta EEG), b) "*alpha-theta,*" the transitional stages between wake and sleep (characterized either by more than 50% alpha waves or by a predominance of theta activity on a low voltage mixed background), and c) *unambiguous sleep* (stage 2 sleep, characterized by spindles and K-complexes). Since the alpha-theta stage usually lasts ½ to 5 min before leading to stage 2 sleep (Vogel, Foulkes, & Trosman, 1966), two types of alpha-theta activity were defined for this study: "descending" or hypnagogic alpha-theta (leading to stage 2 sleep within 5 min or less) and "non-descending" alpha-theta (not leading to sleep).

Method

Subjects

Two groups were studied: meditators and non-meditators. Meditators were selected first. Non-meditators were then matched to them in terms of age (±4 yrs), height (±10 cm), weight (±15 kg), and sex. All subjects were interviewed to exclude persons with obvious psychological and/or medical problems, and to match non-meditators to meditators as closely as possible in terms of customary and recent levels of physical activity. Everyone selected for this study was in good health, none was on any drug medication, none had ever taken part in any previous EEG or psychophysiological study, and all claimed to be good sleepers.

All meditators selected for this study had been practicing the Ananda Marga techniques at least twice per day. This form of meditation (like T.M.) features the mental repetition of a sound (the "Mantra") while the eyes are closed. However, unlike T.M., in Ananda Marga meditation the mantra has a specific meaning, and specific techniques are used for "mental withdrawal" and concentration.

Ten of the meditators had practiced between 9 and 31 months (mean 18.8 months). The eleventh meditator was a yogic monk and teacher with special advanced training and 54 months of meditative experience. However, all meditators performed the same basic Ananda Marga technique during the study. With the possible exception of the yogic monk (whose title suggested that he was possibly a "superior" meditator), there was no way of assessing proficiency, or depth of meditation, as performed by the various subjects in this study.

By contrast, none of the non-meditators had any experience whatsoever with any form of meditation. The final groups of meditators and non-meditators each included 7 men and 3 women in their late teens and early twenties, and one woman about 60 years old.

Measurements

The following measures were recorded continuously on a Grass 78 polygraph:

EEG (C_4/ear), *EMG* (mental/submental) and *EOG* (2 channels, electrodes placed 1 cm lateral to right and left outer canthus, referred to opposite ear). Placement and recording of these four channels was done in every detail according to the standardized procedures for sleep research described by Rechtschaffen and Kales (1968).

Basal Skin Resistance (BSR). Non-polarizing Beckman Biopotential Skin Electrodes (silver/silver chloride) were attached to palm and dorsum of the right hand, using KY jelly as contact medium. BSR was assessed by a Grass 7P1 preamp, designed to pass a constant 50 μA current through the electrodes. According to the manufacturer's specifications and according to pilot work in our own lab (at the resistances typical for this study), this electrode/amplification system shows less than 10K Ω drift and polarization changes over the 1-hr period for which it was employed in this study.

Heart Rate was monitored by an EKG lead placed on the dorsal thoracic area and referred to the right ear.

Respiration was measured by a YSI thermistor #427 placed into the airstream in front of the left nostril.

Forehead and Finger Temperature were measured with two YSI thermistors #427 and read at 5-min intervals from a YSI telethermometer. The thermistors were placed in the middle of the forehead and on the volar surface of the distal segment of the right index finger. Because of baseline drifts in the recording equipment over the course of the experiment, only changes in the difference between the two temperature measurements could be reliably compared.

Procedure

All recordings were done between 10 am and 3 pm, i.e., close to the peak of the circadian cycle. Subjects were only recorded if they felt they had slept well during the previous night. Each of the subjects was requested to choose a comfortable sitting position. All of the non-meditators chose to sit in an upholstered upright chair; all of the meditators chose to sit in a cross-legged position on the floor.

One might argue that the different sitting positions of the two groups might have influenced our results. This is essentially an unsolvable problem. Had we required the meditators to sit in a chair, this would have interfered with their accustomed form of meditation. Had we required the non-meditators to sit cross-legged on the floor, this would have been quite painful for them. It seemed most appropriate to let each person choose the sitting position most typical for his activity: the floor for meditation, the chair for relaxing.

Following a 20-min period for habituation to the experimental situation, the measures described above were all recorded continuously for 70 min. The following schedule was observed during the experimental time:

10 min—Eyes Closed
5 min—Eyes Open
40 min—Meditation or "Wakeful Relaxation"
5 min—Eyes Open
10 min—Eyes Closed

During the 40 min period, the non-meditators were instructed to remain "wakefully relaxed" with their eyes closed.

Quantification of Data

Each 30 sec epoch of the record was scored by a technician experienced in using standardized sleep stage criteria (Rechtschaffen & Kales, 1968) and blind to the activity of the subjects. One addition was made: whenever the central EEG showed more than 50% alpha, "predominantly alpha" was scored. After scoring, the measures of descending and nondescending alpha-theta were computed.

Data samples of the physiological variables not used for sleep scoring were taken during 1 min at 5 min intervals. All data were then subjected to three-way analyses of variance (repeated measures design), using groups (meditators vs non-meditators), time (in 5-min intervals) and subjects nested within groups as the three dimensions. When either main effects or interactions (groups × time) showed significance, differences were further clarified by using the appropriate *t*-tests adjusted for multiple comparisons. Linear trends during meditation or "wakeful relaxation" were assessed by regression analyses.

The .05 rejection region was adopted in all statistical tests.

Results

EEG

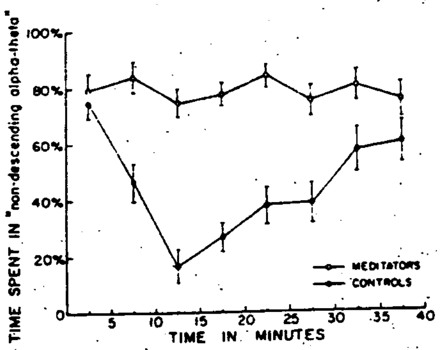

Fig. 1. Percentage of time spent in non-descending alpha-theta during meditation (relaxation for controls). Indicated values represent total percentages of time for each successive 5-min period. Standard errors of the mean are plotted for each data point.

As Fig. 1 shows, meditators had significantly more non-descending alpha-theta than controls throughout the 40-min meditation (wakeful relaxation) period. In addition, the alpha-theta level of meditators remained at a relatively constant level (around 75%) throughout this period. In contrast, non-descending alpha-theta of non-meditators fell from 76% to less than 20% after 10 min of sitting wakefully relaxed and then gradually recovered to the initial level of alpha-theta.

None of the meditators entered stage 2 sleep at any time during meditation, while 6 of the 11 controls showed stage 2 sleep at some point during the relaxation period. Thus, a major difference between the two groups was the fact that meditators remained in alpha-theta, while many controls passed through that state quickly, either on their way to stage 2 sleep or on their way to complete arousal (beta waves).

Comparing EEG at the end of the 5-min "eyes-open" periods before and after meditation (or relaxation), meditators nearly *doubled* their non-descending alpha-theta from the "before" to the "after" period. Controls had significantly less alpha-theta during eyes open periods than the meditators, and they showed no change from "before" to "after" (Table 1).

Looking at the theta state (traditionally called stage 1 "sleep") alone, only 1 control showed theta activity not immediately followed by stage 2 sleep. By contrast, 7 of the 11 meditators (all non-sleeping) showed theta activity during meditation. For 6 of the 7 meditators, time spent in theta activity ranged from 4 to 32%, while the Ananda Marga teacher spent 86% of his meditation time in the theta state. In addition, while no other subject showed theta activity in either the "before" or the "after" eyes open period, the teacher had 30% theta wave activity in the eyes-open period following meditation.

Basal Skin Resistance (BSR)

Analysis of variance indicated a significant group × time interaction for BSR. In the course of meditation, the mean BSR of meditators *increased*

TABLE 1

Comparison of 5 min eyes-open periods before and after meditation (or relaxation for controls)

Physiological Variables	Eyes Open Before Meditation or Relaxation Mean (SD)	Eyes Open After Meditation or Relaxation Mean (SD)	*F*	% change
Non-descending alpha-theta (%time)				
Meditators	26(38)	46(38)	3.24*	+77%
Controls	6(13)	5(12)	0.36	− 8%
Basal skin resistance (K Ω)				
Meditators	170(82)	205(81)	1.97	+21%
Controls	219(72)	190(61)	3.38*	−13%
Heart rate (bpm)				
Meditators	72.3(9.8)	71.2(7.7)	0.57	− 2%
Controls	57.2(9.1)	55.5(9.0)	1.81	− 3%
Forehead minus finger temperature (°C)				
Meditators	3.0(3.1)	2.3(2.8)	1.51	−23%
Controls	1.0(1.7)	1.2(1.9)	−0.64	+20%
Respiratory rate (breaths/min)				
Meditators	17.7(3.6)	16.1(5.2)	1.20	− 9%
Controls	16.2(2.2)	16.8(2.4)	1.80	+ 3%

Note. Data were obtained during the last of the 5 min for heart rate and respiratory rate, at the conclusion of the 5 min for basal skin resistance and temperature. Alpha-theta was scored in 30 sec epochs throughout the 5 min period.
*$p<.05$.

almost continuously. On the other hand, the BSR of the control group *decreased* during all but the first 5 min of the relaxation period (Fig. 2). Linear regression slopes of BSR during these periods were significantly different from each other.

Comparing BSR for the eyes-open periods before and after meditation or relaxation (Table 1) analysis of variance showed a significant group × time interaction. Meditators showed a slight trend to increase, while the BSR of controls was significantly lowered.

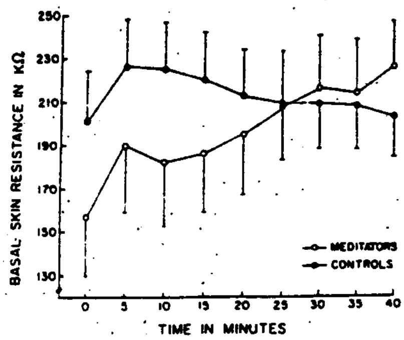

Fig. 2. Progression of basal skin resistance during the 40-min meditation period (relaxation for controls). Standard errors of the mean for each data point are plotted in one direction only to avoid overlap.

Heart Rate

Mean heart rate was 71 bpm for meditators, significantly different from the 54 bpm for controls. In each group, 7 of the 11 subjects showed a heart rate decrease from the initial eyes open period to the final one.

Forehead-Minus-Finger Temperature

Although the difference between forehead and finger temperature became progressively smaller for meditators and larger for controls, none of the temperature data reached statistical significance (Table 1).

Respiratory Rate

Analysis of variance showed a significant group × time interaction for respiratory rate. While controls showed a relatively stable respiratory rate during their 40-min rest period, meditators lowered their respiratory rate by an average of 2.3 breaths/min while meditating.

Discussion

The main result from the current study is the demonstration that some yoga meditators are able to maintain a stable alpha-theta state during meditation. Controls, put into the same environment, either fall asleep or become aroused. The alpha-theta state during meditation is accompanied by a steadily increasing basal skin resistance and a decreasing respiratory rate, while neither skin resistance nor respiratory rate changes significantly in non-meditators.

The findings of this study add to the evidence that stage 1 "sleep" is a transitional phase, unlike full wakefulness and unlike unambiguous sleep. With appropriate training one can apparently learn to "hold on" to this stage, a feat which has not been demonstrated for any other "sleep" stage. Obviously, our conclusion disagrees with the view proposed by Younger et al. (1973) on meditation. Their highly trained meditators, according to our view, did *not* fall asleep as Younger et al. (1973) claim, but rather entered the non-descending theta state (scored sleep by them) typical for advanced meditation. However, our results do not explain the findings of Pagano et al. (1976), whose meditators entered stages 2, 3, and 4 of sleep. Differences in meditation techniques (Ananda Marga vs T.M.), subjects, and procedures might account for the fact that their meditators slept while ours did not.

It seems noteworthy that the most advanced meditator in our group (the yogic teacher) showed an amount of theta wave activity far in excess of that shown by any other subject. This finding is in agreement with the study of Zen Meditation by Kasamatsu and Hirai (1966). These workers found that there is a relationship between the amount of experience and "ability" in meditation and changes in EEG activity: the more advanced the meditator, the more theta waves he showed. If the normal process of falling asleep involves a sequential series of neurophysiological events, as postulated by Freemon (1972), then meditation might be seen as stimulating earlier events, while inhibiting the occurrence of later ones. In this very limited sense, regular meditation might be described as a program involving repeated practice in "freezing" the hypnagogic process at later and later stages (first in the predominantly alpha wave stage, later in the predominantly theta wave ranges).

Data recorded during the initial baseline period with eyes open show that the meditators of this study were different from controls in heart rate and "non-descending" alpha-theta. Heart rate was within the normally expected range for the meditators, but abnormally low for controls. This finding probably reflects the extreme athletic fitness of the Dartmouth College students who volunteered as controls for this study. There is no reason to believe that the superb physical shape of these controls (as indicated by their low heart rate) should have biased any of the other results in this study.

The fact that meditators had significantly more alpha-theta in their initial eyes-open period could be interpreted to mean that the continuing practice of meditation has a lasting effect on the EEG, or, it might indicate that people who have originally more alpha-theta in their eyes-open EEG are more attracted to Ananda Marga meditation. Our study does not resolve this issue. In any case, the EEG difference discussed here is found only in the eyes-open period. With eyes closed, both groups initially showed similar levels of alpha-theta (see initial period in Fig. 1).

Comparing basal skin resistance (BSR) between meditators and controls (Fig. 2), we first note a difference of 49K Ω at the onset of the meditation (rest) period. This difference seems of little importance because it is not statistically significant, and because absolute BSR values are very dependent on minute variations of the outer skin and electrode application. Important for our study were the *changes* in BSR from the beginning to the end of meditation.

Most researchers agree that a fall of BSR is associated with arousal while a rise of BSR suggests increased relaxation (Silverman, Cohen, & Shmavonian, 1959; Hyman & Gale, 1973; Katkin, 1965). To our knowledge only Monroe's (1967) study on good and poor sleepers disagrees on this point: he found poor sleepers generally more aroused during sleep, but with higher BSR than good sleepers. However, we note that Monroe himself found these results "inconsistent," that his results have not been replicated, that all his subjects showed a dramatic rise in BSR during sleep onset (indicating relaxation) and that, different from our study, Monroe dealt with a highly abnormal group (his poor sleepers showed excessive neuroticism and excessive physiological arousal). This latter point becomes important because Tart (1967) reported highly idiosyncratic BSR patterns even in apparently normal subjects during sleep.

Based on the above discussion, the BSR data reported here (Fig. 2) appear to show progressive physiological relaxation during meditation, but show no such relaxation during the comparable rest period in non-meditators. The data on respiratory rate during meditation support this view: a significant lowering of the parameter among meditators suggests physiological relaxation; the non-meditators' data showed no significant changes.

The measure of "forehead minus finger temperature" needs explanation. A rise in finger temperature appears to indicate a decrease in sympathetic vasoconstrictor tone in the extremities (Barcroft, 1960). No such change is expected in the forehead, where little or no vasoconstrictor tone develops (Hertzman, 1959). Thus, a decrease in the difference between forehead and finger temperature would have suggested a decrease in sympathetic tone. However, no significant developments were found in this variable during the meditation (or rest) period. The same was true for heart rate. It is impossible to know from our data whether temperature and heart rate are two variables that had already reached a hard-to-change low baseline during the previous 35 min in the experimental situation, or whether Ananda Marga meditation inherently does not influence these two parameters.

Summarizing our data, we found significant changes in non-descending alpha-theta wave activity, in BSR, and in respiration. Based on this, we conclude that Ananda Marga meditation produces a physiological effect different from that produced in non-meditating controls who try to relax (with eyes closed) for the same length of time.

REFERENCES

Agnew, H. W., Jr., & Webb, W. B. Measurement of sleep onset by EEG criteria. *American Journal of EEG Technology*, 1972, *12*, 127–134.

Anand, B., Chhina, G., & Singh, B. Some aspects of electroencephalographic studies in yogis. *Electroencephalography & Clinical Neurophysiology*, 1961, *13*, 452–456.

Bagchi, B. K., & Wenger, M. A. Simultaneous EEG and other recordings during some yogic practices. *Electroencephalography & Clinical Neurophysiology*, 1958, *10*, 193.

Barcroft, H. Sympathetic control of vessels in the hand and forearm skin. *Physiological Reviews*, 1960, *40*, 81–92.

Freemon, F. R. Sleep research. Springfield, Ill.: Charles C Thomas, 1972.

Hertzman, A. B. Vasomotor regulation of cutaneous circulation. *Physiological Reviews*, 1959, *39*, 280–306.

Hyman, E. T., & Gale, E. N. Galvanic skin response and reported anxiety during systematic desensitization. *Journal of Consulting & Clinical Psychology*, 1973, *40*, 108–114.

Johnson, L. C. Are stages of sleep related to waking behavior? *American Scientist*, 1973, *61*, 326–338.

Kasamatsu, A., & Hirai, T. An electroencephalographic study of the Zen meditation (Zazen). *Folia Psychiatrica et Neurologica Japonica*, 1966, *20*, 315–326.

Katkin, E. S. Relationship between manifest anxiety and two indices of autonomic response to stress. *Journal of Personality & Social Psychology*, 1965, *2*, 324–333.

Monroe, L. Psychological and physiological differences between good and poor sleepers. *Journal of Abnormal Psychology*, 1967, *72*, 255–264.

Pagano, R. R., Rose, R. M., Stivers, R. M., & Warrenburg, S. Sleep during transcendental meditation. *Science*, 1976, *191*, 308–309.

Rechtschaffen, A., & Foulkes, D. Effect of visual stimuli on dream content. *Perceptual & Motor Skills*, 1965, *20*, 1149–1160.

Rechtschaffen, A., & Kales, A. (Eds.) *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*. Washington, D.C.: Public Health Service, U.S. Government Printing Office, 1968.

Silverman, A. J., Cohen, S. I., & Shmavonian, B. M. Investigation of psychophysiologic relationships with skin resistance measures. *Journal of Psychosomatic Research*, 1959, *4*, 65–87.

Tart, C. T. Patterns of basal skin resistance during sleep. *Psychophysiology*, 1967, *4*, 35–39.

Vogel, G., Foulkes, D., & Trosman, H. Ego functions and dreaming during sleep onset. *Archives of General Psychiatry*, 1966, *14*, 238–248.

Wallace, R., Benson, H., & Wilson, A. A wakeful hypometabolic state. *American Journal of Physiology*, 1971, *221*, 795–799.

Younger, J., Adriance, W., & Berger, R. Sleep during transcendental meditation. In M. H. Chase, W. C. Stern, & P. L. Walter (Eds.), *Sleep research*. Vol. 2. Los Angeles: Brain Information Service/Brain Research Institute, UCLA, 1973. P. 99. (Abstract)

(Manuscript received October 28, 1975; accepted for publication August 25, 1976)