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ORIGINAL ARTICLE

Practitioners of vipassana meditation exhibit enhanced slow wave sleep and REM sleep states across different age groups

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Abstract

Intense meditation practices influence brain functions in different ways and at different levels. Earlier studies have shown that meditation practices help to organize sleep–wake behavior. In the present study, we evaluated the sleep architecture of vipassana meditators across different age groups. Whole-night polysomnography was carried out in healthy male subjects between 30 and 60 years of age from control (n = 46) and meditation (n = 45) groups. They were further divided into younger- (30–39 years), middle- (40–49 years), and older-aged (50–60 years) groups. Sleep variables were evaluated from subjects who had a sleep efficiency index more than 85%. The sleep architecture of vipassana meditators was different from that of control groups. Vipassana meditators showed enhanced slow wave sleep and rapid eye movement sleep states with an enhanced number of sleep cycles across all age groups. When compared to meditators, the control groups exhibited pronounced age-associated decrease in slow wave sleep states. Our study suggests that vipassana meditation helps to establish a proper sleep structure in old age, probably through its capacity to induce neuronal plasticity events leading to stronger network synchronization and cortical synaptic strengthening.

Key words: REM sleep, sleep cycles, slow wave sleep, vipassana meditation.

INTRODUCTION

Intense yoga practice leads to inner evolution and awareness of one's own inner self, leading to a total transformation of individual consciousness. According to ancient Indian texts,[1] one can attain such a state of mental emancipation and self-realization through meditation or dhyana. Meditation demands a long-term commitment to daily practice and has the potential to induce neuronal and cortical plasticity.[2–4] Simultaneous evaluation of electroencephalogram (EEG) and autonomic functions during meditation has shown to produce large Fm (frontal midline) theta activity (indicative of relaxed concentration) and co- activation of both sympathetic and parasympathetic limbs of the autonomic nervous system.[5] Studies have shown that regular practice of meditation aids in the retention of younger biological age as far as autonomic, sensory, and cardiovascular functions are concerned.[6] Meditation is known to have neuroprotective effects and reduces the cognitive decline associated with normal aging.[7]

Reduced slow wave sleep, enhanced non-rapid eye movement (NREM) stage 1, and increased intermittent

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awakenings are associated with less sleep quality.[8] Meditation either alone or as a part of multi-component treatment has shown to be very effective in the management of insomnia.[9] Studies have reported the positive effect of yoga practices on sleep quality in geriatric populations.[10] Mindfulness meditation practices are known to have beneficial effects on various psychophysiological and cognitive attributes and to improve coping skills and overall quality of life.[11] A mindfulness-based stress reduction program was shown to improve sleep quality among cancer patients.[12] Additionally, long-term practice of transcendental meditation is reported to enhance slow wave sleep and REM sleep states as behavioral correlates of attaining higher states of consciousness.[13] In our previous study we also observed such enhanced levels of both slow wave sleep and REM sleep states among senior vipassana meditators.[14]

In the present study, we compared sleep architecture among healthy control subjects and senior vipassana meditators across different age groups. Additionally, the possible ways by which vipassana meditation helps to retain a proper sleep structure among older subjects is discussed.

METHODS

Subjects

Healthy male volunteers (n = 105) with an age range between 30 and 60 years participated in the study. Of these, data from 91 subjects with a sleep efficiency index more than 85% were included in the present analysis. These subjects include the controls (n = 46) with no experience in any kind of meditation or yoga practices and vipassana meditators (n = 45), senior vipassana meditators with more than 3 years of daily (>2–4 h/day) meditation practice. Before recruitment, subjects were assessed for their routine sleep habits using a sleep questionnaire and were examined physically for medical, psychiatric, neurological, and other disease conditions. Only those subjects with regular sleep habits, not on shift work or on any medications, and with no tobacco and alcohol abuse, were recruited for the study. The control subjects were recruited from various private and public sector institutions.

Vipassana meditators were recruited from all over the country through the Vipassana Research Institute, the world head quarters of vipassana meditation in Igatpuri, India. Most of them were teachers of vipassana meditation. The technical details of vipassana meditation have been described in our previous study.[14] In short, vipassana meditation involves the strategy of mindfulness, wherein meditators learn to notice and witness the perceptions of the senses and the thoughts arising in the mind without reacting to them, like an onlooker, and to focus their attention on their bodily activities in their true perspective, in their true nature. This practice of meditation follows the tradition of Sayagyi U Ba Khin as taught by S.N. Goenka in all vipassana meditation centers throughout the world.

Both controls and meditators were categorized into three subgroups based on age: younger- (30–39 years), middle- (40–49 years), and older-aged (50–60 years) groups. The age-based grouping of subjects was done as per an earlier study.[15] Subjects of all groups were matched for demographic characteristics such as age, socioeconomic, and educational status. The study was approved by the Institute Human Ethics Committee and informed consent was taken from the participants.

Polysomnographic recordings

Whole-night polysomnographic recordings were obtained during subjects' habitual bedtime for two consecutive nights; the first being the adaptation night and the second for the analysis of sleep states. In order to avoid any possible first-night effects on the sleep states analyzed, subjects with a sleep efficiency index (SEI) more than 85% for both nights were considered for data analysis. The participants were allowed to sleep until they woke up in the morning by themselves. Sleep efficiency index (SEI) was obtained by using the formula $\frac{TST}{TIB} \times 100$, where TST is the total sleep time and TIB is total time spent in bed. The SEI-based selection criteria help to exclude possible sleep-related problems and to ensure a good night's sleep both qualitatively and quantitatively. Additionally, the sleep schedule was evaluated over a period of 7 days prior to the study, with the help of a sleep log (UCLA sleep log). Subjects who were sleep-deprived the previous night were excluded.

Polysomnographic recordings were carried out in a semi-soundproof sleep cabin in the sleep laboratory under video-monitored supervision using 32-channel digital Neurofax equipment (EEG-2110; Nihon Kohden, Tokyo, Japan). Electrodes were placed according to Jasper's 10–20 system of electrode placement.[16] EEG was recorded from silver disc electrodes placed bilaterally at frontal (F3, F4), central (Cz), occipital (O1, O2), and monopolar referential montage.

A1 and A2 were used for recording: each area referred to the contra lateral ear, and the forehead of the subject was connected to a floating ground. Monopolar electrooculography was recorded from both canthi with a sensitivity of 5 microvolt, time constant of 0.3 s, and high-frequency filter of 70 Hz. The chin EMG was recorded with a sensitivity of 3 microvolt, time constant of 0.03 s, and high frequency of 70 Hz. The electrical impedance was kept below 5 K Ohms.

Sleep stages were assessed using the Polysmith software program (version 1.7.8R16H; Nihon Kohden). In addition, sleep stages were also scored manually epoch by epoch (1 epoch = 30 s) according to the Rechtshaffen and Kales manual[17] by a trained scorer who was blind to the details of the study.

Statistical analysis

All statistical analyses were carried out using SPSS version 13 software (SPSS, Chicago, IL, USA). Two-factor ANOVA was carried out to analyze age, groups, and their interaction effect on sleep variables. The main effects were further explored using pair-wise comparison between levels of the factors using Bonferroni corrections for multiple comparisons. $P < 0.05$ was considered to be significant.

RESULTS

The sleep variables were evaluated from subjects who had a sleep efficiency index more than 85% for both nights (adaptation as well as second night), although the second night's data was used for analysis. All participants reported having good sleep and felt refreshed on waking.

Table 1 provides the details of sleep variables between controls and meditators across different age groups. The sleep onset latency, sleep efficiency, sleep duration, and total time in bed were comparable across the age groups studied in both the controls and meditators. However, meditators showed enhanced slow wave sleep (NREM S3 and S4) and REM sleep states when compared to controls. Representative hypnograms from controls and meditators are given in Figure 1.

Slow wave sleep constituted about 17.95%, 11.3%, and 10.63% of total sleep among meditators, whereas that of controls was 11.29%, 6.65%, and 3.94% across younger-, middle-, and older-aged groups, respectively. Two-factor ANOVA revealed a significant difference between groups ($F^{1,77} = 11.03$, $P = 0.001$) and age ($F^{2,77} = 3.13$, $P = 0.049$). The interaction ($F^{2,77} = 3.17$, $P = 0.057$) between age and group was not significant. These main effects were further explored with pair-wise comparisons within the levels of group and age factors with Bonferroni's corrections for multiple comparisons. Controls exhibited a progressive significant reduction of slow wave sleep across age groups (younger- *vs* middle-aged, $P < 0.05$; middle- *vs* older-aged, $P < 0.05$; younger- *vs* older-aged, $P < 0.001$; Table 1, Fig. 2a). This is mainly due to a progressive decrease in both the NREM S3 and S4 states. Meditators showed a significant decrease in slow wave sleep up to the middle-aged group (younger- *vs* middle-aged, $P < 0.05$) and remained stable thereafter (middle- *vs* older-aged, $P = 0.805$). Significant decrease ($P < 0.05$) was found between younger- *vs* older-aged meditators (Fig. 2b). When the percentage of slow wave sleep was compared between two groups, meditators had significantly more slow wave sleep than controls in the respective age group (younger-aged controls *vs* meditators, $P < 0.05$; middle-aged controls *vs* meditators, $P < 0.05$; older-aged controls *vs* meditators, $P < 0.01$; Table 1).

REM sleep was 21%, 20%, and 18% among younger-, middle-, and older-aged controls, respectively, in comparison with meditators who had 33%, 30%, and 30% in the respective age groups. Two-factor ANOVA revealed a significant effect for group ($F^{1,81} = 26.18$, $P = 0.0001$) with no significant effect of age ($F^{2,81} = 1.26$, $P = 0.287$) or the interaction between group and age ($F^{2,81} = 0.71$, $P = 0.932$). Pair-wise comparisons with Bonferroni's corrections showed that REM sleep was significantly more in meditators in each of the age groups when compared with respective controls (younger-aged controls *vs* meditators, $P < 0.001$; middle-aged controls *vs* meditators, $P < 0.05$; older-aged controls *vs* meditators, $P < 0.005$; Table 1, Fig. 2c).

Two-factor ANOVA for REM onset latency showed no influence of age ($F^{2,82} = 0.369$, $P = 0.693$) whereas the effect of group was highly significant ($F^{1,82} = 14.23$, $P = 0.0001$). The interaction between age and groups ($F^{2,82} = 0.336$, $P = 0.716$) was not significant. The pair-wise comparison with Bonferroni's corrections showed significantly less REM onset latency in meditators in the older-aged group when compared with respective controls ($P < 0.001$).

Meditators also showed a higher number of sleep cycles compared to that of control subjects. Two-factor ANOVA showed a significant main effect of group [$F^{1,81} = 18.34$, $P = 0.0001$], but no significant effect of age ($F^{2,81} = 0.972$, $P = 0.383$) or the interaction between group and age ($F^{2,81} = 0.748$, $P = 0.476$). Pair-wise comparison with Bonferroni's corrections showed that meditators

Table 1 Sleep variables between controls and meditators across different age groups

	Younger-aged group (30–39 years)		Middle-aged group (40–49 years)		Older-aged group (50–60 years)	
Sleep variables	Controls (n = 19) Mean ± SEM	Meditators (n = 17) Mean ± SEM	Controls (n = 12) Mean ± SEM	Meditators (n = 11) Mean ± SEM	Controls (n = 17) Mean ± SEM	Meditators (n = 17) Mean ± SEM
Sleep onset latency (min)	7.24 ± 1.24	9.72 ± 2.06	8.60 ± 1.38	5.10 ± 1.76	7.24 ± 1.61	4.28 ± 1.03
REM onset latency (min)	104.08 ± 9.59	76.66 ± 10.28	120.50 ± 26.67	73.00 ± 8.49	105.65 ± 11.30	65.41 ± 7.32####
Total sleep Time (min)	379.58 ± 14.17	391.69 ± 14.07	345.25 ± 14.88	355.45 ± 18.84	341.53 ± 13.95	360.75 ± 15.21
Total time in bed (h)	5.75 ± 0.27	6.02 ± 0.24	5.7 ± 0.30	6.21 ± 0.24	5.34 ± 0.22	5.74 ± 0.26
Wakefulness (min)	27.33 ± 4.35	30.33 ± 7.00	32.30 ± 4.38	25.37 ± 3.90	43.65 ± 6.44	27.35 ± 4.67
Number of sleep cycles	3.47 ± 0.22	4.82 ± 0.23####	3.11 ± 0.53	4.73 ± 0.48#	3.29 ± 0.25	4.63 ± 0.25####
Sleep Efficiency Index (%)	93.23 ± 0.81	93.78 ± 0.86	91.45 ± 1.25	93.12 ± 1.22	90.11 ± 1.05	92.88 ± 1.08
NREM stage 1 (min)	52.58 ± 5.73	36.73 ± 7.24	62.40 ± 11.37	54.64 ± 8.31	71.74 ± 7.18	51.19 ± 7.72
NREM stage 2 (min)	182.00 ± 16.55	154.73 ± 12.34	191.10 ± 11.02	155.37 ± 16.74	189.12 ± 15.88	159.97 ± 9.91
NREM stage 3 (min)	35.14 ± 4.49	38.10 ± 4.78	20.50 ± 5.96*	32.80 ± 6.69	12.37 ± 3.27*	39.10 ± 5.56
NREM stage 4 (min)	11.57 ± 3.41	21.33 ± 6.44	11.83 ± 11.08	15.94 ± 3.21	0 ± 0	7.33 ± 4.84
SWS (min)	46.61 ± 5.06	57.25 ± 7.51#	29.52 ± 7.8*	48.74 ± 8.3*#	11.86 ± 3.4*,***	46.43 ± 6.00**,##
REM (min)	83.13 ± 8.26	121.90 ± 10.49####	69.65 ± 8.86	113.45 ± 14.41#	65.21 ± 7.60	110.84 ± 10.67###

Significant differences in sleep variables across different ages within groups: *$P < 0.05$, non-rapid eye movement (NREM) S3 of younger-controls *vs* middle-aged controls, middle-controls *vs* older-aged controls; slow wave sleep (SWS) of younger- controls *vs* middle-aged controls, middle-controls *vs* older-aged controls, younger-meditators *vs* middle-aged meditators. **$P < 0.05$, SWS in younger- meditators *vs* older-aged meditators. ***$P < 0.001$, SWS in younger- controls *vs* older-aged controls. Significant differences in sleep variables between the groups: #$P < 0.05$, SWS in younger-aged controls *vs* meditators, middle-aged controls *vs* meditators; REM sleep in middle-aged controls *vs* meditators; sleep cycle in middle-aged controls *vs* meditators. ##$P < 0.01$, SWS in older-aged controls *vs* meditators. ###$P < 0.005$, REM sleep in older-aged controls *vs* meditators. ####$P < 0.001$, REM sleep in younger-aged controls *vs* meditators; REM onset latency in older-aged controls *vs* meditators; sleep cycles in younger-aged controls *vs* meditators, older-aged controls *vs* meditators.

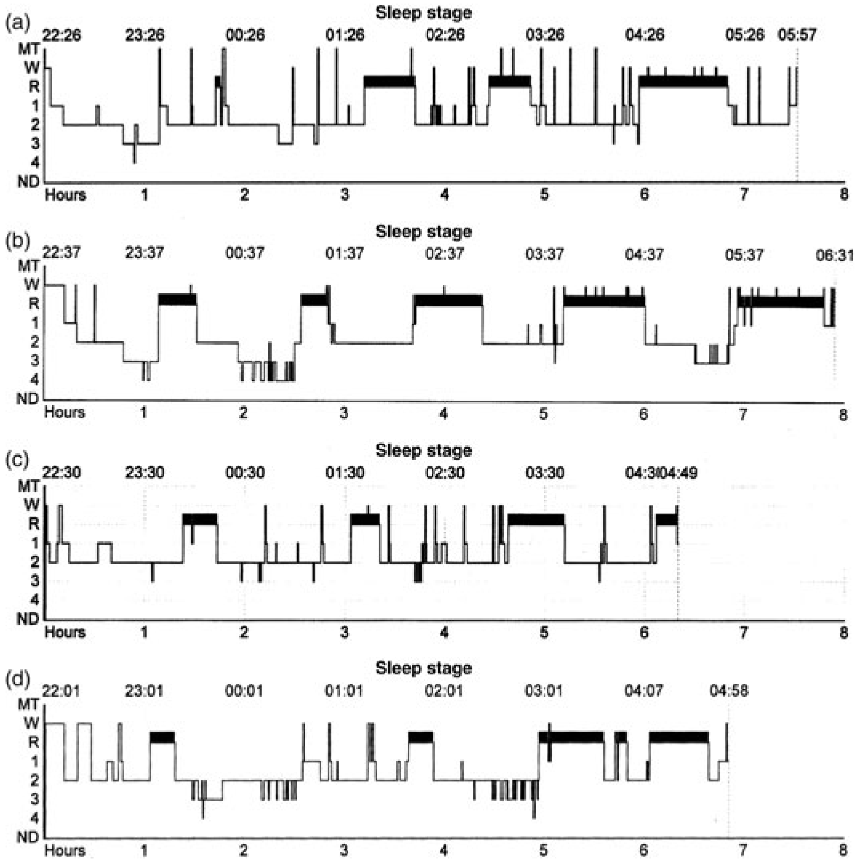

Figure 1 Representative hypnograms from controls and vipassana meditators across different age groups. The hypnograms from control subjects aged 36 (a) and 57 years (c) and meditators aged 36 (b) and 58 years (d) are depicted. Note a decrease in non-rapid eye movement (NREM) S3 with a total absence of NREM S4 in control Subject C. Both the non-rapid eye movement (NREM) S3 and S4 sleep states are present in the meditator Subject D. Meditator subjects (b,d) showed more REM compared to control subjects (a,c). The total sleep time between the control and meditators are comparable.

had a significantly higher number of sleep cycles in each of the age groups when compared to their respective controls (younger-aged controls *vs* meditators, $P < 0.001$; middle-aged controls *vs* meditators, $P < 0.05$; older-aged controls *vs* meditators, $P < 0.001$; Table 1).

In summary, the sleep architecture of vipassana meditators was distinct from that of control subjects. Vipassana meditators showed enhanced slow wave sleep and REM sleep states with reduced REM onset latency and enhanced number of sleep cycles across all age groups. When compared to meditators, the control groups exhibited pronounced age-associated decrease in slow wave sleep states.

DISCUSSION

The present study demonstrated the differences in sleep structure among control and vipassana meditators across different age groups. Vipassana meditators demonstrated a distinct sleep pattern with enhanced slow wave sleep and REM sleep states with a higher number of sleep cycles across the ages.

The control subjects showed a marked age-associated decrease in slow wave sleep states. Other sleep variables did not show any such age-associated changes. The slow wave sleep state was reduced by 65% among the older control group compared with the younger group. Alteration of sleep patterns as a function of normal aging has previously reported.[18–20] Decline in NREM Stage 4 and EEG slow wave activity reduce markedly the slow wave sleep states and is reported to begin by 30–40 years of age. The homeostatic process is thought to reflect the need or pressure for sleep,[21] and the decrease in slow wave sleep leads to a reduced homeostatic drive for sleep.[18,22,23] It has been hypothesized that aging affects slow wave sleep owing to alterations in endocrine and neural functions.[24–26] In the present study, we observed a pronounced age-related decrease in NREM S3 sleep together with a total absence of the NREM S4 state among the older-aged controls. These changes may be considered a consequence of local changes in cerebral circuits sub-serving sleep.

Vipassana meditators showed a different pattern of sleep architecture altogether. They showed enhanced

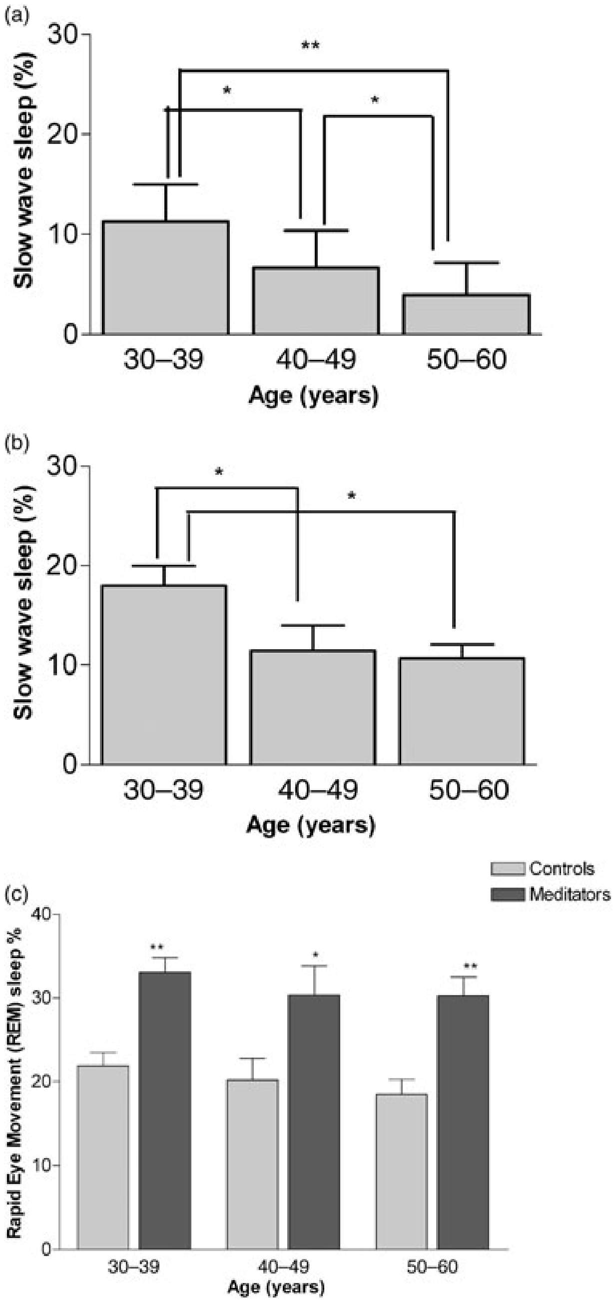

Figure 2 (a,b) Slow wave sleep among controls (a) and meditators (b) across age groups. Data represented as mean ± SEM. *$P < 0.05$; **$P < 0.001$. (c) Percentage of rapid eye movement (REM) sleep across different ages between controls and meditators. Data represented as mean ± SEM. *$P < 0.05$; **$P < 0.001$.

slow wave sleep and REM sleep states compared to controls. Enhanced slow wave sleep states can be correlated with various attributes of meditation; meditation helps to preserve slow wave sleep in old age as a means of combat the aging process. Mindfulness meditation involves intense sensory, emotional, and cognitive processing, and such practices help to strengthen thalamocortical and cortico-cortical interactions,[27] induce neuronal plasticity, and enhance cortical thickness.[4,28] Vipassana meditation practice also helps to reduce anxiety, negative affect, and increases positive affect and mental poise.[29] All these aspects perhaps aid in preserving slow wave sleep states and thereby contribute towards better sleep organization. Mason *et al.*[13] have correlated enhanced slow wave sleep states to a stabilized state of higher consciousness achieved through long years of intense meditation practice. Enhanced slow wave sleep observed among vipassana meditators appears to be an outcome of intense meditation practice, which may be a means to preserve proper sleep organization and a state wherein one experiences a higher state of consciousness and thereby better psychological and physical health[30,31] and well-being.[30]

Additionally, vipassana meditators showed enhanced REM sleep states across all ages studied. Long-term practitioners of transcendental meditation were reported to have more REM density when compared to short-term practitioners and the control group.[13] An enhanced REM sleep state thus appears to be an index of meditation practice, and is attributed to a heightened orientation and inner alertness achieved through meditation practice.[14] Enhanced REM density has been correlated to lucid dreaming which occurs during phasic REM periods.[13] The present study further affirms our earlier findings,[14] and enhanced REM sleep states together with reduced REM onset latency may be attributed to a measure of meditation proficiency. We need to elucidate the details of REM sleep characteristics in future studies. Mindfulness meditation practice involves enhanced attention and awareness of ongoing experience with perceptual clarity about one's emotional states.[32–34] Enhanced REM sleep observed among meditators could be associated with reactivation of neural circuitry active during wake, and linked with synaptic potentiation occurring during previous wakefulness.[33,34] This suggests the potential capabilities of REM sleep in activating the neural mechanisms associated with memory consolidation.[35] Additionally, the circadian rhythm of sleep propensity and REM sleep is correlated with the circadian rhythm of melatonin,[36,37] and meditation practice in general enhances melatonin secretion.[38–40] Thus enhanced REM sleep states associated with vipassana meditation may be correlated with enhanced brain activity related to synaptic plasticity, endocrine regulations, etc. Meditators also had a higher number of NREM–REM sleep cycles which are good indicators of sleep organization.[41] Vipassana meditators are hence endowed with all features of good sleep organization: high sleep efficiency index, enhanced slow wave sleep and REM sleep states, reduced REM onset latency, and a higher number of sleep cycles. Considering the potential capabilities of mindfulness meditation practice in inducing various aspects of neuronal plasticity events[4,27,28] together with its positive regulatory role on other neuroendocrine axes,[42] it appears that vipassana meditation helps to foster proper sleep–wakefulness behavior in old age.

The present findings highlight the implications of vipassana meditation in sleep medicine. However, more focused studies are needed to clearly delineate how meditation practice helps to regulate the neuroendocrine circuitry associated with proper sleep organization, the mechanisms by which meditation helps to combat the age-associated changes in sleep in addition to its positive effects on sleep per se.

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