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**ORIGINAL ARTICLE**

# Evaluation of sleep architecture in practitioners of Sudarshan Kriya yoga and Vipassana meditation*

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**Abstract**

Yoga is an ancient Indian science and way of life that has been described in the traditional texts as a systematic method of achieving the highest possible functional harmony between body and mind. Yogic practices are claimed to enhance the quality of sleep. Electrophysiological correlates associated with the higher states of consciousness have been reported in long-term practitioners of transcendental meditation during deep sleep states. The present study was carried out to assess sleep architecture in Sudarshan Kriya Yoga (SKY) and Vipassana meditators. This was to ascertain the differences, if any, in sleep architecture following yogic practices. Whole night polysomnographic recordings were carried out in 78 healthy male subjects belonging to control and yoga groups. The groups studied were aged between 20 and 30-years-old (younger) and 31 to 55-years-old (middle-aged). The sleep architecture was comparable among the younger control and yoga groups. While slow wave sleep (non-REM (rapid eye movement) $S_3$ and $S_4$) had reduced to 3.7 percent in the middle-aged control group, participants of the middle-aged yoga groups (both SKY and Vipassana) showed no such decline in slow wave sleep states, which was experienced by 11.76 and 12.76 percent, respectively, of the SKY and Vipassana groups. However, Vipassana practitioners showed a significant enhancement ($P < 0.001$) in their REM sleep state from that of the age-matched control subjects and also from their SKY counterparts. Yoga practices help to retain slow wave sleep and enhance the REM sleep state in the middle age; they appear to retain a younger biological age as far as sleep is concerned. Overall, the study demonstrates the possible beneficial role of yoga in sleep–wakefulness behavior.

**Key words:** sleep architecture, slow wave sleep and REM sleep, Sudarshan Kriya yoga, Vipassana meditation.

## INTRODUCTION

The science of yoga has been practiced in India over thousands of years. The word "yoga" originates from the Sanskrit word "*Yuj*", meaning union; a union of *jeevatma*, the individual consciousness, with that of *paramatma*, the universal consciousness. Yogic practices were devised in ancient times to achieve the highest possible functional harmony between body and mind.[1]

The practice of yoga appears to bring significant physiological and biochemical changes which contributes

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towards a better physical health and mental well-being.[2–5] Khalsa[6] in a recent review has compiled the scientific studies carried out on yoga since 1925. Most of these studies have assessed the regulatory role of yoga on autonomic, cardiovascular, respiratory and central nervous system functions. Parallel to the studies mentioned on yoga, the practice of other procedures such as Vipassana meditation[7–14] and Sudarshan Kriya (SKY) yoga[15–17] have also revealed the possibilities and potentialities of these practices on physical and mental health through their promotive and therapeutic benefits. All these scientific researches on yoga and allied methods have been restricted to associate the potential benefits of these practices on physical and mental health during the waking, conscious state. The possible beneficial role of yoga on other behavioral states such as sleep and dream states warrant further investigation to elucidate the importance of such techniques on the brain and mind or the relationship between brain and behavior. Yogic interventions including asanas (physical postures), pranayama (voluntarily regulated breathing) and relaxation techniques, together with lectures on yoga, have shown to improve sleep quality and provide an overall enhancement of subjective feelings of well-being in an institutionalized group of geriatric population.[18] Carlson *et al*.[9–11] have reported similar effects of a mindfulness-based stress reduction program on the enhancement of sleep quality in terminally ill cancer patients. Mason *et al*.[19] have studied the electrophysiological correlates associated with the higher states of consciousness in practitioners of transcendental meditation who have been practicing it for more than 15 years. The practitioners showed enhanced theta-alpha and delta power, along with reduced EMG during deep sleep states, together with an enhanced REM sleep state. These electrophysiological changes are believed to be associated with attaining a highly stabilized state of higher states of consciousness or "transcendental consciousness" in the practitioners. The present study was aimed to ascertain the differences, if any, in sleep architecture following yogic practices. Accordingly, polysomnographic recordings were carried out in long-term practitioners of Vipassana meditation and Sudarshan Kriya yoga.

## METHODS

Polysomnographic recordings were carried out in 78 healthy male subjects. However, the data of only 67 subjects were included in the present study. They were divided into control and yoga groups. Subjects from both groups were matched for demographic characteristics such as age, gender and socioeconomic status. The average height, weight and age of the different groups are; $168 \pm 2.1$ cm, $57.4 \pm 2.6$ kg and $26 \pm 2.8$ years, respectively, for the control group and $166 \pm 6.2$ cm, $59.6 \pm 2.8$ kg and $27.4 \pm 2.4$ years for the SKY group in the group aged between 20 and 30 years. Similarly the average height, weight and age for the middle-aged group are $170 \pm 4.8$ cm, $65.5 \pm 4.8$ kg and $44.5 \pm 8.62$ years for the control group, $172 \pm 2.4$ cm, $66.7 \pm 5.2$ kg and $42.14 \pm 6.48$ years for the SKY group and $170 \pm 3.2$ cm, $66 \pm 5$ kg and 44. $12 \pm 8.8$ years, respectively, for the Vipassana group. The age-based grouping of subjects has been done according to the study of Landolt *et al*.[20] The younger control group (20–30 years of age, $n = 14$), comprised postgraduate students of the National Institute of Mental Health while the younger SKY group ($n = 14$) were graduates and residents of the Bangalore Art of Living Foundation (AOL), the headquarters of Shri Shri Ravisankar, who introduced the technique of SKY. The middle-aged control group (31–55 years of age, $n = 13$) were employees of our Institute as well as from other public sectors. The middle-aged practitioners of SKY ($n = 13$) and Vipassana ($n = 13$) were employed either in the public sector or with government institutions. In addition, the practitioners were teachers of the respective yogic techniques and were recruited for the present study through their respective yoga centers, Bangalore.

### Details of yoga practice

We have studied the sleep architecture of yoga practitioners belonging to two schools of yoga, those practicing Sudarshan Kriya yoga, which is a pranayama-based technique and the other practicing Vipassana meditation techniques, utilizing the mindfulness-based meditation program. The younger SKY group had practised SKY for more than three years whereas the middle-aged SKY group are long-term practitioners of SKY, with more than five years of regular practice. All participants (both young and middle aged) practice SKY techniques for 2–3 h daily, in the morning and evening. The Vipassana practitioners have also practiced regular meditation for more than five years. They spend a total of 6–8 h daily in meditation, both in the morning and evening.

SKY is a variant of pranayama and has three sequential components of breathing interspersed with normal breathing, the *Ujjai* (slow breathing, 2–3 cycles/min), *Bhastrika* (rapid, forced expiration, 20–30 cycles/min) and medium to fast cyclical breathing (going through increasing frequencies of 20–40, 40–60, 60–80 cycles/

min). These variations of rhythmic breathing are practiced over a period of 30 min, while sitting with eyes closed and with awareness focused on the incoming and outgoing breath. The end of the last round of cyclical breathing is followed by *yoga nidra* (tranquil state) in a supine position for 10–15 min. SKY is offered in several countries as a popular weekend stress management course.

Vipassana meditation has its origin in Theravada and Mahayana Buddhism. Vipassana in the Pali language means "insight", seeing things as they really are. Vipassana meditation is one of the India's most ancient meditative techniques involving the strategy of mindfulness to achieve the absorption of the mind. In mindfulness, meditators learn to notice and witness the perceptions of the senses and the thoughts arising in the mind without reacting to them, like onlookers, and can focus their attention on their bodily activities in their true perspective, in their true nature.[21]

## Inclusion/exclusion criteria

The inclusion criteria for enrollment in this study were (i) the subject is free from physical illness; and (ii) is not on any chronic medication, particularly those acting on central nervous system. Subjects with a personal or family history of a sleep disorder, respiratory or cardiovascular problems, psychiatric illness, neurological illness and diabetics were not included. None of the subjects took any central nervous system stimulants or caffeine prior to the study. The subjects who fulfillled the inclusion criteria were apprised of the investigational nature of the study and their informed consent was obtained for polysomnography. All participating subjects in the study visited the sleep laboratory to acquaint themselves with the laboratory set up prior to the actual recording session and were informed about their habitual sleep–wake timings in the week prior to the study to rule out any discrepancies in their sleep timing. The study was initiated after obtaining the approval of the Institute's human ethics committee.

## Polysomnographic recordings

Whole night polysomnographic recordings (PSG) were accomplished in a semi-soundproofed sleep cabin in the sleep laboratory during subject's normal, habitual night-time hours, under video-monitored supervision. Electrodes were placed according to the 10–20 system of electrode placement of Jasper, 1958.[22] Electroencephalograms (EEG) were recorded from silver disc electrodes placed bilaterally at frontal (F3, F4), central (CZ) and occipital (O1, O2) and A1, A2 (ear lobe). Monopolar referential montage was used for recording with each area referred to the contra lateral ear. The forehead of the subject was connected to the floating ground on the EEG input box. An electrooculogram (Bottom of Form EOG) recorded monopolarily from both canthi with a sensitivity of 5 microvolts, time constant of 0.3 s, and a high frequency filter of 70Hz. The chin electromyogram (EMG) was recorded with a sensitivity of 3 microvolts, time constant of 0.03 s and high frequency of 70Hz by 32 channel digital Neurofax equipment (model EEG-2110). The electrical impedance was kept below 3 Ohms.

We analyzed the sleep architecture of those subjects with a sleep efficiency index of more than 85%. Out of 78 participants, the sleep architecture of only 67 subjects (85% of total number participated) met the selection criteria and 15% (11 subjects) were eliminated from the study. The sleep efficiency index-based selection criterion was adopted from previous reports.[20,23] The sleep efficiency index (SEI) was obtained by the formula ($TST/TIB \times 100$), where TST is the total sleep time and TIB is total time spent in bed. The SEI-based selection criterion helps to eliminate the possible sleep-related problems of subjects and thus helps to ensure that the participants had a good night sleep both in terms of quality and quantity in the control and yoga groups.

The sleep stages were assessed using a Polysmith software program. In addition, the sleep stages were also scored manually epoch by epoch (1 epoch = 30 s) by a trained scorer according to Rechtshaffen and Kales' manual.[24] The scorer was blinded as to which group the subjects belonged to, to avoid bias in the analysis.

## Statistical analysis

All statistical analysis was carried out on SPSS Ver.11.0 software. The data were expressed using descriptive statistics such as mean ± SEM and percentages. The comparison of sleep stages across the groups for the different stages of sleep were studied by a repeated measure ANOVA followed by LSD *post hoc* test.

# RESULTS

All the participants reported sound, undisturbed sleep during the test session in the sleep cabin. Figure 1 depicts the representative hypnogram of various groups studied. The sleep architecture and the sleep variables

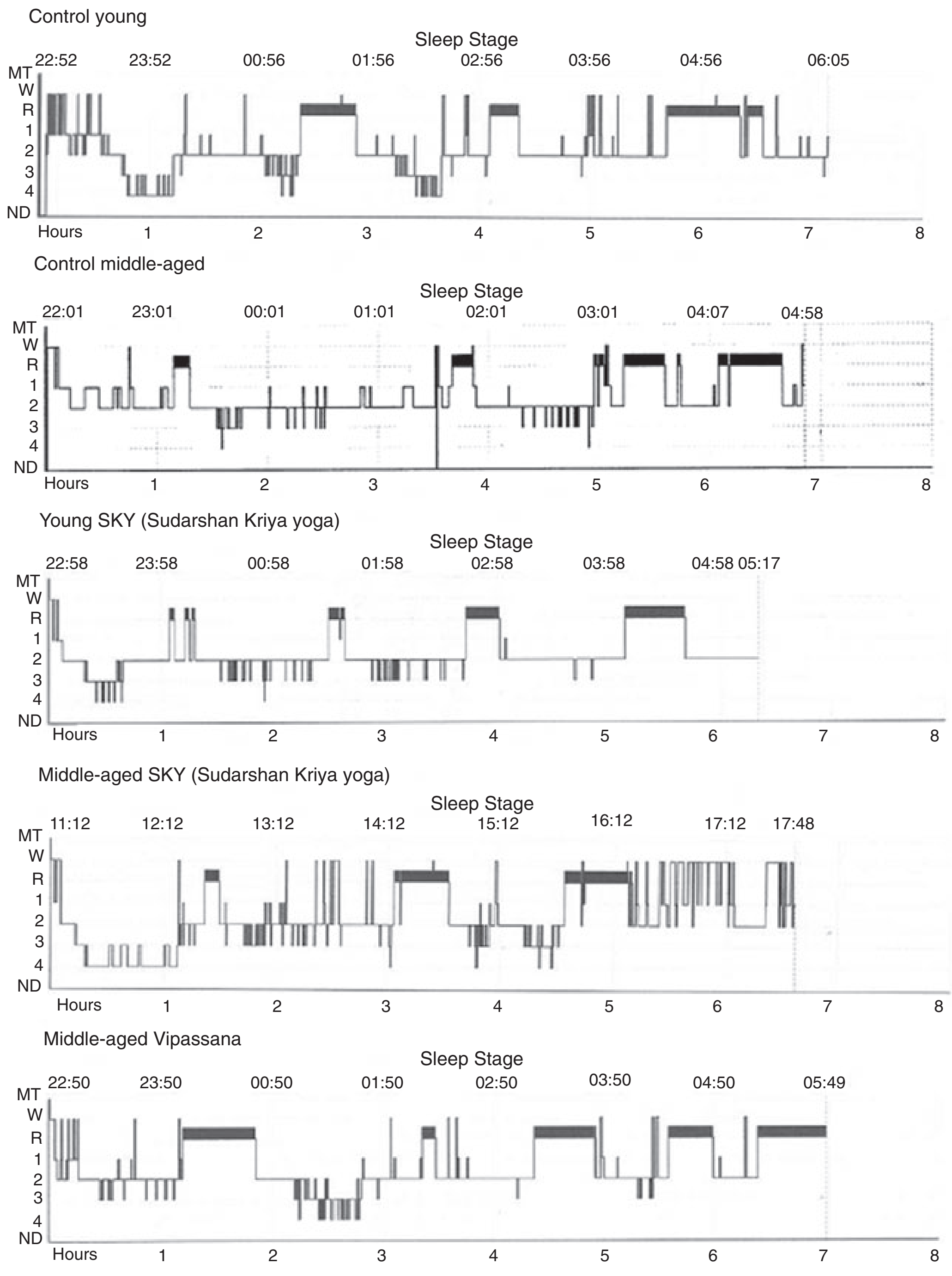


**Figure 1** Representative sleep stage plots of the whole night polysomnography carried out in various groups. From top to bottom; control subject aged 25 years, control subject aged 42 years, SKY practitioner aged 26 years, SKY practitioner aged 43 years and subject practicing Vipassana, aged 43 years. Note the reduced deep sleep states in the middle-aged control subject. Also note the enhanced deep sleep state in the middle-aged SKY and Vipassana subjects. The hypnogram of the Vipassana subject shows a very prominent REM sleep state. The sleep states have been scored by a Polysmith software program, edited manually according to Rechtshaffen and Kales manual (1968).[24]

**Table 1** All-night sleep parameters in control and yoga subjects when recorded during their habitual bedtimes

| | Younger group (20–30 years) | | Middle-aged group (31–55 years) | | |
|---|---|---|---|---|---|
| | Control ($n = 14$) | SKY ($n = 14$) | Control ($n = 13$) | SKY ($n = 13$) | Vipassana ($n = 13$) |
| Sleep variables | Mean ± SEM | Mean ± SEM | Mean ± SEM | Mean ± SEM | Mean ± SEM |
| Sleep latency (min) | 5.82 ± 2.36 | 6.12 ± 1.76 | 8.12 ± 2.86 | 4.65 ± 1.16 | 6.12 ± 1.24 |
| REM latency (min) | 99.32 ± 14.44 | 78.96 ± 11.28 | 116.14 ± 12.56 | 75.28 ± 5.68† | 63.48 ± 11.94† |
| Total recording time (min) | 362.62 ± 12.99 | 348.10 ± 10.86 | 373.68 ± 12.12 | 388.42 ± 7.57 | 388.22 ± 18.26 |
| Total sleep time (min) | 332.07 ± 11.80 | 329.64 ± 0.28 | 338.28 ± 17.98 | 358.10 ± 6.98 | 371.18 ± 15.22 |
| Wakefulness (min) | 30.61 ± 6.20 | 28.04 ± 4.64 | 32.12 ± 9.18 | 35.62 ± 6.02 | 30.62 ± 6.24 |
| Stage 1 (%) | 12.49 ± 2.08 | 14.12 ± 1.12 | 14.46 ± 1.34 | 12.11 ± 4.10 | 8.54 ± 1.88 |
| Stage 2 (%) | 51.80 ± 1.99 | 48.36 ± 5.24 | 61.14 ± 1.12‡ | 48.98 ± 4.12 | 40.12 ± 6.98 |
| Stage 3 (%) | 8.69 ± 0.84 | 8.18 ± 1.04 | 3.24 ± 0.14 | 7.94 ± 1.20 | 8.98 ± 1.05 |
| Stage 4 (%) | 4.35 ± 1.21 | 3.64 ± 1.29 | 0.46 ± 0.16* | 3.82 ± 0.94 | 3.78 ± 0.98 |
| Slow wave sleep (%) | 13.04 ± 2.05 | 11.82 ± 2.33 | 3.7 ± 0.3§ | 11.76 ± 2.14 | 12.76 ± 2.03 |
| REM sleep (%) | 22.60 ± 2.02 | 24.71 ± 1.83 | 20.28 ± 1.34 | 25.98 ± 2.66 | 38.42 ± 6.34** |

Non-REM $S_4$ was reduced significantly (*$P < 0.05$) in the middle-aged control group when compared to the middle-aged yoga groups, the SKY and Vipassana. The Vipassana practitioners showed a significant increase (**$P < 0.001$) in their REM sleep state when compared to the middle-aged SKY and control groups. REM latency is reduced significantly (†$P < 0.05$) in the middle-aged SKY and Vipassana practitioners when compared to the middle-aged control group. The non-REM $S_2$ state has been significantly (‡$P < 0.05$) increased in the middle-aged control group from that of younger control group. Slow wave sleep (both non-REM $S_3$ and $S_4$) in the middle-aged control group was significantly reduced (§$P < 0.05$) from that of the middle-aged yoga groups (SKY and Vipassana) and also from that of the younger groups. Variables are expressed as mean ± SEM. Repeated measures ANOVA followed by LSD *post hoc* test has been used for the statistical analysis.

among the younger groups (SKY and control) were comparable (Table 1). The middle-aged control subjects (31–55 years) showed changes in the slow wave sleep states. Their non-REM $S_4$ was reduced significantly ($P < 0.05$) and their non-REM $S_3$ was decreased considerably (but not significantly) from that of the age-matched yoga groups (SKY and Vipassana) and also from the younger groups. Altogether, the slow wave sleep (both non-REM $S_3$ and $S_4$) in the middle-aged control subjects was significantly reduced ($P < 0.05$) from that of the middle-aged yoga groups (SKY and Vipassana) and also from that of the younger groups (Table 1). Additionally the non-REM $S_2$ state had been significantly ($P < 0.05$) increased in the middle-aged control group while their REM sleep state was comparable to that of younger control group, whereas other sleep variables, such as total sleep time (TST), REM latency and sleep latency, were comparable to that of younger control group (Table 1). The sleep efficiency index was above 85 percent in all of the groups studied.

Distinct changes in sleep stages and other variables have been observed in the practitioners of yoga (Table 1). The middle-aged SKY and Vipassana groups retained slow wave sleep (non-REM $S_3$ and $S_4$) similar to that of the younger groups. Slow wave sleep constitutes 11.76 and 12.76 percent, respectively, for the SKY and Vipassana groups (middle-aged yoga groups) against that of 3.7 percent exhibited by the middle-aged control group (Table 1). In addition, Vipassana practitioners showed a significant increase ($P < 0.001$) in their REM sleep state when compared to the SKY and middle-aged control groups. Their REM sleep state constitutes 38.42 percent when compared to the middle-aged SKY and control groups with a REM sleep state of 25.98 percent and 20.28 percent, respectively (Table 1). The REM latency was reduced significantly ($P < 0.05$) in both the practitioners when compared to that of the middle-aged control group (Table 1).

## DISCUSSION

The present study compared the sleep architecture in the practitioners of Vipassana meditation and Sudarshan Kriya yoga with that of control non-practitioners of yoga. This was to ascertain the differences, if any, in their sleep architecture following yogic practices.

The results suggest that there was a decrease in slow wave sleep among the middle-aged control group while such reduction was not seen in both the yoga groups, that is, the middle-aged Vipassana and SKY practitioners. Reduced slow wave sleep is an age-associated phenomenon as has been reported.[25–27] It is considered that reduced slow wave sleep and the slow wave activity reduce the homeostatic drive for sleep.[25,28] The homeostatic process is thought to reflect the need or pressure for sleep which builds up during sustained wakefulness and dissipates during sustained sleep. We cannot also rule out the possibility of a stress-induced decrease in slow wave sleep in the middle-aged control group. The practioners of yoga, however, showed a marked increase in slow wave sleep. The regulatory role of yogic practices on the homeostatic process or on stress management would have helped the yoga group to maintain slow wave sleep, though we need to elucidate this further in future studies.

Vipassana meditators showed a pronounced enhancement in their REM sleep state, while the SKY group did not show such an enhanced REM sleep state. However, both Vipassana and SKY practitioners exhibited a relatively shorter interval to the occurrence of their first REM sleep episode, that is, they had a very short REM onset latency. The REM density (measure of frequency of REMs) is an index of sleep satiety or sleep need and increased REM density accompanies prolonged periods of sleep.[29–33] Extended sleep periods and a systematic reduction in the duration of prior wakefulness leads to increased REM, and sleep deprivation reduces the REM density.[31,33,34] The enhanced REM duration observed in the Vipassana practitioners could be an index of heightened orientation and inner alertness associated with enhanced brain activity during REM. Mason *et al.*[19] have also reported such enhanced REM sleep states in long-term practitioners of transcendental meditation. Growing evidence suggests that the circadian rhythm of melatonin contributes to the endogenous circadian rhythm of sleep propensity in humans[35–37] and the practice of meditation in general has shown to enhance melatonin secretion.[38–40] Though the functions of REM sleep remains to be elucidated, it is hypothesized that REM sleep is associated with memory consolidation.[41] The physiological mechanisms of reduced REM latency with increased REM sleep state observed in the yoga practitioners needs to be elucidated further.

Over all, our study demonstrates that the sleep architecture of a yoga practitioner is comparable to that of the non-yoga group when they are young, between 20 and 30 years of age. However, differences such as enhanced slow wave sleep and REM duration have been observed in Vipassana practitioners between 31 and 55 years of age. This indicates that, as we advance in age, age-associated changes in sleep quality and structure could be compensated for through yoga practices. This could correlate with the positive, regulatory role of yoga on sleep functions or it could be associated with its regulatory role on homeostatic and circadian mechanisms. "Yoga may be of great value, through its capacity to awaken altered states of consciousness, and may profoundly reorient an individual's identity, emotional attitude and sense of well-being and purpose in life."[8] Meditation techniques have been reported to enhance hormonal and immune-system functioning, thereby ensuring a healthy state of relaxation.[42,43] However, more studies need to be carried out to elucidate the mechanisms by which the practice of Vipassana meditation and SKY regulate the various aspects of sleep and how yogic practices foster a balance between the endocrine–immune system and sleep–wakefulness behavior.

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