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# Heart Rate Variability During Sleep Following the Practice of Cyclic Meditation and Supine Rest

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**Abstract** Day time activities are known to influence the sleep on the following night. Cyclic meditation (CM) has recurring cycles. Previously, the low frequency (LF) power and the ratio between low frequency and high frequency (LF/HF ratio) of the heart rate variability (HRV) decreased during and after CM but not after a comparable period of supine rest (SR). In the present study, on thirty male volunteers, CM was practiced twice in the day and after this the HRV was recorded (1) while awake and (2) during 6 h of sleep (based on EEG, EMG and EGG recordings). This was similarly recorded for the night's sleep following the day time practice of SR. Participants were randomly assigned to the two sessions and all of them practiced both CM and SR on different days. During the night following day time CM practice there were the following changes; a decrease in heart rate, LF power (n.u.), LF/HF ratio, and an increase in the number of pairs of Normal to Normal RR intervals differing by more than 50 ms divided by total number of all NN intervals (pNN50) ($P < 0.05$, in all cases, comparing sleep following CM compared with sleep following SR). No change was seen on the night following SR. Hence yoga practice during the day appears to shift sympatho-vagal balance in favor of parasympathetic dominance during sleep on the following night.

**Keywords** Sleep · HRV · Meditation

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## Introduction

The recovery experiences during leisure time, sleep, and affect the next morning are inter-related (Sonnetag et al. 2008). Psychological detachment from work on the preceding day predicted negative activation and fatigue the next morning, whereas mastery experiences during the evening predicted positive activation, while relaxation predicted serenity. Also, the quality of sleep showed a relation with all affective variables. The results hence suggest that events on a particular day impact the quality of sleep at night and the affect the following day. Various factors of diverse behavioral and chemical origins are known to influence sleep (Jurkowski and Bobek-Billwicz 2007). Among the well recognized factors are sleep deprivation and high intensity exercise (Dworak et al. 2007).

Yoga is an ancient science, originating in India, which has components of physical activity, instructed relaxation and interoception (Vivekananda Kendra 2005). Yoga includes a number of practices such as physical postures (*asanas*), regulated breathing (*pranayama*), meditation, and lectures on philosophical aspects of yoga (Taimini 1986). In persons with sleep-onset and/or sleep-maintenance insomnia, as well as those with primary or secondary insomnia, 8 weeks of yoga practice improved the sleep efficiency, total sleep time, total wake time, sleep onset latency, and the wake time after sleep onset (Khalsa 2004).

Also, a combination of yoga practices (i.e., physical postures, voluntarily regulated breathing, relaxation techniques, and lectures on yoga philosophy), improved the self-rated quality of sleep in older persons, compared to a group receiving an ayurveda poly-herbal preparation and another wait-list control group (Manjunath and Telles 2005). The following benefits were self-rated by the older participants after 6 months of yoga practice viz., a decrease in the time taken to fall asleep, an increase in the total number of hours slept and in the feeling of being rested in the morning.

Among yoga techniques, meditation particularly has been shown to reduce stress and increase feelings of calm (Oman et al. 2008). However our unpublished observations were that many individuals, particularly those with high baseline levels of stress, find it difficult to begin their practice of yoga with meditation (Nagendra and Nagarathna 1997). In fact, in traditional yoga texts meditation is described as the seventh, out of eight stages required to reach a stage of final mental liberation (Taimini 1986). Some people find it easier to practice those techniques which are described as earlier stages, such as yoga postures (*asanas*). Based on this a technique was evolved, called cyclic meditation, which combines yoga postures with periods of supine rest when the person is given instructions to help them reach a meditative state (Telles et al. 2000).

In normal volunteers practicing cyclic meditation reduced psychophysiological arousal based on a decrease in oxygen consumption (Telles et al. 2000; Sarang and Telles 2006a); and changes in the heart rate variability suggestive of a shift towards vagal dominance (Sarang and Telles 2006b). In another study correlating cyclic meditation and heart rate variability, a 2-day cyclic meditation program decreased occupational stress levels and baseline autonomic arousal (Vempati and Telles 2000). This was more apparent when participants were categorized based on the occupational stress index (OSI) at baseline. Those with high OSI levels showed a change in heart rate variability suggestive of vagal dominance, while those with low OSI levels to begin with showed no change.

There have been studies which have shown that day time stress influences the sympathetic/parasympathetic balance during sleep. For example, reduced parasympathetic activity, based on the heart rate variability was recorded during sleep in the symptomatic phase of severe premenstrual syndrome (Baker et al. 2008).

Hence, considering that (1) day time activities influence sleep, including the level of parasympathetic activity during sleep, and (2) cyclic meditation is a relatively easy to learn technique which influences the heart rate variability, with specific changes associated with the levels of mental stress, the present study was designed to compare the effects of practicing cyclic meditation in the day time with the effects of supine rest practice, on the heart rate variability during sleep.

## Methods

### Participants

Thirty male volunteers with ages ranging from 20 to 33 years (group mean age ± SD, 22.3 ± 4.6 years) participated in the study. Autonomic and respiratory variables have been shown to vary with the phases of the menstrual cycle (Yildirir et al. 2002), hence the study was restricted to males. All of them were undergoing training at a residential yoga center in the south of India and had a minimal experience of practicing cyclic meditation and relaxation in a position of supine rest (*shavasana*, the corpse posture), which was the 'control' intervention, at least once a day for 4 days in a week, for a year. All of them were in normal health based on a routine clinical examination and none of them had a history of smoking or consuming alcohol or caffeinated beverages. Also none of them were taking medication and they did not use any other wellness strategy. The electrocardiogram (EKG) recording of all volunteers was free of extra systoles. The design of the study was explained to the participants and their signed consent was taken. The study was approved by the Institution's Ethical Committee.

### Design of the Study

Participants were assessed on three separate nights in the sleep laboratory. The first night was for acclimatization to the laboratory environment. Electrodes and transducers were connected as for a standard recording but no recording was taken. The other two recording sessions were 3 days apart. On 1 day participants were asked to practice cyclic meditation two times a day, i.e., at 06:00 h and 18:45 h. Their practice was supervised by a trained yoga instructor. After that they were asked to report to the sleep laboratory at 21:00 h and a whole night recording was taken. On the other day of recording participants were asked to practice unguided supine rest in *shavasana* (SR), as a control for cyclic meditation, twice in the day, and at the same time and for the same duration as the cyclic meditation sessions. This practice was also supervised by the same yoga instructor, though no instructions were given. Each session lasted for 22 min 30 s. For this session also, participants reported to the sleep laboratory at 21:00 h and a whole night polysomnography recording was taken. A minimum duration of 6 h of recording was made for all the participants even if they continued to sleep for longer than that. The 6 h of recording did not include 'wakefulness before sleep onset' but may have included periods of wakefulness in between. Throughout the night standard polysomnography measures (EEG, EOG, EMG) were recorded but in the present study they were used to distinguish between wakefulness and sleep, not between the different stages of sleep. All readings for heart rate variability taken during sleep were averaged into one value for analysis.

For all participants on each recording day there were two separate recordings. The first recording was for 10 min while the participants lay supine but awake. After this the lights were switched off and participants were told that they could go to sleep. The order of the sessions was randomized using a random number table. On both recording days [i.e., cyclic meditation (CM) and supine rest (SR)], participants were asked to avoid all other physical activity (e.g., walking, jogging, or other yoga practices). However they continued with the rest of their routine (e.g., listening to lectures on yoga). Since all of them were residing in the same yoga center, the rest of their routine was relatively comparable. As described above, for each of the two recordings the average of all readings taken during sleep was obtained as one value.

## Assessments

Autonomic and respiratory variables were acquired using a four channel polygraph (Medicaid, Chandigarh, India). The EKG was recorded using Ag/AgCI electrodes with conducting gel (Electrode Gel, Medicaid Systems, Chandigarh, India) and recording was made using standard limb lead II configuration. Data were acquired at the sampling rate of 1,024 Hz and were analyzed offline. Noise free data were included for analysis. Records of six participants had artifact and these recordings were excluded but repeat recordings were taken on the same participants and included for analysis. The R waves were detected to obtain a point event series of successive response-response intervals, from which the beat-to-beat heart series was computed. The data were analyzed with an HRV analysis program developed by the Biomedical Signal Analysis Group, University of Kuopio, Finland (Niskanen et al. 2004). The respiration was recorded using a stethograph connected to an AC amplifier and fixed around the trunk approximately 8 cm below the lower costal margin when the participants stood erect.

## Intervention

### *Cyclic Meditation (CM)*

CM lasted for 22 min 30 s. Throughout the practice, participants kept their eyes closed and followed pre-recorded instructions from an audiotape. The instructions emphasized carrying out the practice slowly, with awareness and relaxation. The five phases of CM consisted of the following practices.

Phase 1 (5 min): The practice began by repeating a verse (1 min) from the yoga text, the *Mandukya Upanishad* (Chinmayananda 1984); followed by isometric contraction of the muscles of the body ending with SR (1 min, 30 s); slowly coming up from the left side and standing at ease, called *tadasana*, and balancing the weight on both feet, called centering (2 min, 30 s).

Phase 2 (5 min): Then the first actual posture, bending to the right (*ardhakaticakrasana*, 1 min, 20 s); a gap of 1 min, 10 s in *tadasana* with instructions about relaxation and awareness; bending to the left (*ardhakaticakrasana*, 1 min, 20 s); and a gap of 1 min, 10 s in *tadasana.*

Phase 3 (5 min): Forward bending (*padahastasana*, 1 min, 20 s); another gap (1 min, 10 s); backward bending (*ardhacakrasana*, 1 min, 20 s); and a gap of 1 min, 10 s in *tadasana*.

Phase 4 (5 min): Slowly coming down to a supine posture for rest with instructions to relax different parts of the body in sequence.

Phase 5 (5 min): Supine relaxation and a prayer for 2 min, 30 s; followed by SR for 2 min, 30 s.

### *Supine Rest (SR)*

During the supine rest session, the participants lay supine in the corpse posture (*shavasana*) with eyes closed, legs apart and arms away from the body. This practice also lasted for 22 min 30 s.

## Data Extraction

The heart rate in beats per minute (bpm) was obtained by continuously counting QRS complexes in successive 60 s periods. The breath rate (in cycles per minute) was calculated by counting the breath cycles in 60 s epochs, continuously.

Heart rate and heart rate variability spectrum (HRV) as well as breath rate were recorded for 6 h during sleep and the first 5 min and the last 5 min of each hour was included for analysis. Hence in each 6-h sleep recording there were twelve epochs each of 5 min, for analysis. For the pre-sleep recording the first 5 min out of a 10 min period was used.

Following the European Guidelines of the Task Force of the European Society of Cardiology (18), the following components of time domain HRV were analyzed viz., the number of pairs of Normal to Normal RR intervals differing by more than 50 ms (NN50), NN50 divided by total number of all NN intervals (pNN50), and total index of NN intervals (TINN). In addition, the HRV power spectrum was obtained using Fast Fourier Transform analysis (FFT). The energy in the HRV series in the following specific frequency bands was studied viz., the very low frequency band (0.0–0.05 Hz), low frequency band (0.5–0.15 Hz), and high frequency band (0.15–0.50 Hz). The low frequency and high frequency band values were expressed as normalized units (Task Force of the European Society of Cardiology 1996).

Hence the HRV data were analyzed to obtain both time domain and frequency domain measures.

### Data Analysis

Data were analyzed using SPSS version 16.0. Repeated measures analyses of variance (ANOVA) were performed with two Within Subjects factors, i.e., (1) Sessions with two levels; Cyclic meditation (CM) and Supine rest (SR) and (2) States with two levels; i.e., Pre-sleep and During-sleep.

Post hoc tests with Bonferroni adjustment for multiple comparisons were used to detect significant differences between mean values recorded pre-sleep and during-sleep (for both 'CM Sessions' and 'SR sessions' separately). Also, comparisons were made with values recorded during sleep following CM compared with those recorded during sleep following SR.

## Results

The group mean values ± SD for heart rate, breath rate, time domain and frequency domain measures of HRV spectrum are given in Table 1. Time domain measures are given in rows 3–5 and frequency domain measures in rows 6–8.

### Repeated Measures Analysis of Variance (ANOVA)

There was a significant difference between Sessions for (1) heart rate [$F = 3.90$, for $df = 3.89, 71.89$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.983$]; (2) the square root of the mean of the sum of squares of differences between adjacent NN intervals [RMSSD; $F = 4.06$, for $df = 1.00, 79.41$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.875$]; (3) low frequency power [$F = 4.06$, for $df = 1.00, 73.09$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.934$]; and (4) the ratio between low frequency and high frequency power [$F = 3.47$, for $df = 1.00, 68.5$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.835$].

No significant changes were observed between States for any measures of HRV, heart rate or breath rate.

There was a significant interaction between Sessions and States for (1) the square root of the mean of the sum of squares of differences between adjacent NN intervals [RMSSD; $F = 4.42$, for $df = 1.10, 140.25$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.951$]; and (2) low frequency [$F = 3.78$, for $df = 3.79, 88.25$, $P < 0.05$; Huynh–Feldt $\varepsilon = 0.864$], suggesting that the two factors were not independent of each other for these variables.

### *Post Hoc Tests for Multiple Comparisons*

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment. Comparisons were made between During-sleep following CM with During-sleep following SR, Pre sleep CM with During-sleep CM, and Pre-sleep SR with During-sleep SR sessions.

A significant decrease in heart rate, LF and LF/HF power and an increase in the number of pairs of Normal to Normal RR intervals differing by more than 50 ms divided by total number of all NN intervals (pNN50) was observed when a comparison was made between During-sleep following CM with During-sleep following SR sessions ($P < 0.05$ in all the cases). No significant change was noticed in the comparison of Pre-Sleep with the respective During-Sleep.

## Discussion

In the present study, practicing cyclic meditation twice in the day time reduced the heart rate and breath rates during sleep, the following night, and also influenced time and

**Table 1** Heart rate, breath rate and measures of heart rate variability recorded pre and during-sleep following cyclic meditation (CM) practice and following supine rest (SR)

| Variables | Sessions | | | |
|---|---|---|---|---|
| | Cyclic meditation (CM) | | Supine rest (SR) | |
| | Pre-sleep | During-sleep | Pre-sleep | During-sleep |
| Heart rate (bpm) | 62.17 ± 5.74 | 60.98 ± 7.22* | 66.48 ± 7.68 | 65.92 ± 6.24 |
| Breath rate (cpm) | 19.67 ± 6.28 | 17.93 ± 3.50 | 18.48 ± 2.61 | 18.26 ± 2.91 |
| NN50 (count) | 91.64 ± 41.56 | 108.84 ± 43.44 | 101.77 ± 55.13 | 106.53 ± 53.47 |
| pNN50 (%) | 41.60 ± 25.11 | 52.44 ± 26.51* | 42.90 ± 22.43 | 46.27 ± 23.81 |
| TINN (ms) | 570.31 ± 302.49 | 571.26 ± 285.63 | 413.83 ± 229.60 | 573.85 ± 263.43 |
| Low frequency (LF) power (n.u.) | 48.76 ± 21.43 | 45.23 ± 18.03* | 55.11 ± 15.23 | 55.19 ± 16.83 |
| High frequency (HF) power (n.u.) | 49.38 ± 19.45 | 53.20 ± 19.87 | 51.09 ± 20.65 | 50.45 ± 18.01 |
| LF/HF ratio | 1.28 ± 0.80 | 1.06 ± 0.68* | 1.38 ± 0.84 | 1.36 ± 0.93 |

Values are group mean ± SD; * $P < 0.05$, using repeated measures analysis of variance (ANOVA), post hoc tests with Bonferroni adjustment, comparing During-sleep (CM) with During-sleep (SR) frequency domain measures of the heart rate variability recorded during sleep. Similar changes were not seen during sleep following the practice of supine rest twice a day on another day. The changes during sleep following CM were suggestive of reduced arousal and a shift in the autonomic balance towards parasympathetic dominance. These changes were a decrease in the low frequency power (normalized units) and a decrease in the LF/HF ratio among frequency domain measures. The LF band of the HRV is mainly related to sympathetic modulation when expressed in normalized units (Task Force of the European Society of Cardiology 1996), whereas efferent vagal activity is a major contributor to the HF band. However changes in autonomic tone are not the only factors which can vary LF.

Respiratory sinus arrhythmia is a commonly used non-invasive measure of cardiac vagal control (Wilhelm et al. 2004). Hence concurrent monitoring of respiration along with heart rate variability increases the accuracy of the HRV to predict autonomic control. This supposition is supported by an acute increase in LF and total spectrum HRV as well as vagal baroflex gain corrected with slow breathing during biofeedback periods (Lehrer et al. 2003). It was earlier shown that bio-feedback training to increase the amplitude of respiratory sinus arrhythmia maximally increases the amplitude of heart rate oscillations only at approximately 0.1 Hz (Lehrer et al. 2000). To achieve this, breathing is slowed to a point at which resonance occurs between respiratory-induced oscillations and oscillations that naturally occur at this rate. In the present study there was no change in the breathing rate during sleep following either CM or SR. This suggests that the change in LF activity was related to autonomic activity and not to the breath rate.

The LF/HF ratio is correlated with sympatho-vagal balance (Malliani et al. 1991). Apart from these changes in frequency domain measures of the HRV, there was an increase in the pNN50 among the time domain measures of the HRV measured during sleep following CM. The pNN50 is a time domain measure which is highly correlated with frequency domain measures and recognized to be strongly dependent on vagal tone (Massin et al. 1999).

Hence, these changes in frequency and time domain measures of the HRV suggest that the night sleep following day time practice of CM is associated with increased parasympathetic activity and a corresponding shift in the sympatho-vagal balance.

Cyclic meditation is best described as a moving meditation, in which physical postures are interspersed with supine rest (Sarang and Telles 2006a). In a previous study the frequency domain measures of the HRV were recorded in 42 volunteers before, during and after the practice of CM and SR. The results are relevant to the results of the present study (Sarang and Telles 2006b). During and after CM the LF power and LF/HF ratio decreased whereas HF power increased. However, while actually practicing yoga postures during CM, the LF power increased. Hence, it appeared that predominantly sympathetic activation occurred while practicing yoga postures during CM whereas parasympathetic dominance increased after CM.

The changes following CM suggesting a shift towards vagal dominance are similar to the HRV changes following a low velocity, low impact technique involving movements, called Wai Tan Kung, which is a traditional Taiwanese conditioning exercise (Lu and Kuo 2003). The study was conducted in elderly volunteers and suggested enhanced vagal activity and lower sympathetic activity associated with Wai Tan Kung.

In the present study changes in VLF have not been described though the VLF power accounts for more than 90% of the total power in the 24 h of the heart rate power spectrum. The physiological mechanism underlying the VLF power has not been conclusively identified (Hadase et al. 2004). The VLF power in part reflects thermoregulatory mechanisms and fluctuation in the activity of the renin-angiotensin function and the function of chemoreceptors (Malliani et al. 1991; Parati et al. 1995).

The exact mechanism by which CM leads to a state of physiological relaxation needs to be understood. Apart from the changes in the HRV, the practice of CM was associated with a decrease in the oxygen consumption, breath rate and breath volume which exceeded the decrease in the same variables after a comparable period of SR (Sarang and Telles 2006a). The benefits may be related to the fact that CM practice includes yoga postures (which involve stretching) and guided relaxation. In an earlier study by different authors when a body and mind program which included meditative stretching and guided relaxation, was practiced by persons with chronic toxic encephalopathy for 8 weeks, they showed improved physical and mental relaxation indicated by lower electromyography activity, higher alpha percentage and reduced state anxiety. Also in another study, guided relaxation was shown to be more effective in reducing physiological arousal than a control session in SR (Vempati and Telles 2002). Specifically yoga based guided relaxation which is a part of CM decreased LF power and increased HF power. This was not seen during a period of SR of the same duration. Guided relaxation includes visual imagery and muscle relaxation which may have contributed to the effect. However, the exact mechanism is not known. CM practice also includes interoception with awareness of internal body sensations. During the breath awareness phase of Vipassana mindfulness meditation, the LF/HF ratio decreased (Telles et al. 2005). Hence the changes associated with CM practice may be related to the fact that the practice includes mental imagery, muscle relaxation and internal awareness. The fact that the changes occurred during sleep following the practice of CM on the preceding day may be related to the fact that day time activities influence sleep in the night.

While attempts were made to control the other activities of the participants during the day, a further study in which participants' daily activities and diet are individually noted. These variations in the subjects' routine as well as inherent differences between individuals may have accounted for the fact the participants' baseline values differed widely, which is a limitation of the study. Accounting for these individual variations would be expected to substantiate the present findings. Also in the present study no attempt was made to correlate the HRV with the stages of sleep; as this presented certain technical difficulties. A future study with such a correlation would overcome this limitation and provide additional information.

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