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Original Article

Modulation of sleep quality, cardiac autonomic activity, and cognition by yoga in medical students

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ABSTRACT

Objectives: The disturbed sleep quality among medical students due to their hectic schedule may negatively impact the cognition, consequently affecting their academic performance. With the hypothesis that short duration of simple yogic exercises may improve sleep quality and heart rate variability (HRV), and thus may improve cognitive abilities, the study aims to evaluate the outcome of short duration yoga training on HRV, cognition, and sleep in medical students.

Material and Methods: The participants of the study were young and apparently healthy medical students. The study commenced after the Institutional Scientific Re- search and Ethics Committee approval. The informed consent was taken from all the participants in writing. All parameters (height, weight, age, body mass index [BMI], systolic blood pressure [SBP], diastolic blood pressure [DBP], heart rate [HR]) along with HRV, sleep quality (using Pittsburgh Sleep Quality Index [PSQI]), and cognitive ability (using Trail Making Tests Parts A & B [TMTs-A&B]) were assessed in the participants at baseline. Thereaf- ter, the students practiced yoga (asanas, pranayama, and meditation) under supervision of a yoga instructor and a faculty for the duration of one hour every day for six weeks. Measurements were repeated after six weeks. Depending on the normality of data and data distribution, the comparison was done using Wilcoxon Signed Rank Test or dependent samples t-test. The level of significance was kept as $p < 0.05$.

Results: Following six weeks of yoga sessions, a significant improvement in the high frequency power normalized unit (HFnu) and total power in comparison to baseline values was observed: 53.25± 10.14 versus 59.57 ± 9.61 and 3238 ± 1133 versus 3473 ± 1130, respectively. Significant difference at six weeks between baseline and post yoga values was observed in TMT-A (30.16 ± 5.04 vs 19.84 ± 2.76) and TMT-B (69.96 ± 12.99 vs 49.24 ± 10.99). Sleep quality also improved significantly after yoga sessions (baseline PSQI score of 10.68 ± 1.79 and post-PSQI score of 4.12 ± 1.67).

Conclusion: It was concluded that one hour of supervised yoga session every day for six weeks can improve HRV, sleep quality, and cognitive ability among medical students. Medical students should practice yoga regularly to improve cognitive function and sleep and to reduce cardiovascular morbidity.

Keywords: Cognition, Heart rate variability, Meditation, Sleep quality, Yoga

INTRODUCTION

Good quality sleep is an important indicator of a healthy life. Inadequate sleep has deleterious effects on mental as well as physical health. Inadequate sleep is a predisposing factor for cardiovascular morbidity,[1] and sleep deprivation may lead to drastic deficits in cognitive processing and academic performance.[2] Yoga intervention has proved to be beneficial in managing sleep-related problems in diseased as well as healthy individuals.[3] Various aspects of yoga like asanas, meditation, and mindfulness have been implemented at universities and higher education institutions for improving mental health.[4] Research has shown that Long Sudarshan Kriya, a form of yoga and meditation technique, may be helpful in improving heart rate variability (HRV) as it increases parasympathetic and decreases sympathetic activity.[5] Research has proved that simple yogic exercises for a duration of six weeks decreases heart rate (HR) and blood pressure in young women.[6] HRV, a noncomplex, nonintrusive index of cardiac autonomic activity, is widely used to identify risk of cardiovascular morbidity.[7] HRV has also been used as a biomarker of cognitive impairment in apparently healthy population, as presented in the Systematic review by Forte *et al*., (2019).[8]

Medical students have poor sleep pattern due to their hectic schedule.[9] In the pandemic time, a sequence of national lockdowns forced the students to stay inside their houses,

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which has further deteriorated or altered the sleep cycles of the medical students, and the pattern is continuing till date.[10] The disturbed sleep quality may negatively impact the cognition, consequently affecting their academic performance.[11] This could also have a negative impact on the students' mental and physical health. We hypothesize that a short duration of simple yogic exercises may improve sleep quality and HRV, thus leading to improved cognitive abilities. The studies on yoga training in medical students are sparse; hence we planned this study to evaluate how short-term yoga influences sleep quality, HRV, and cognitive function in medical students.

MATERIAL AND METHODS

This study commenced in the Department of Physiology after approval from the Institutional Ethics Committee was granted. All participants provided written informed consent. A sample of 50 participants was selected based on the willingness of the students to participate in the research. Young, apparently healthy adults of both gender 18–25 years of age who consented to participate were included in the study. Individuals actively involved in physical activity, yoga, or meditation; individuals with physical disability to perform pranayama/yoga postures, color vision deficiencies, significant physical or mental health conditions, and individuals on regular medications; individuals who drink alcohol, smoke, or used recreational drugs regularly were excluded from the study. The participants with body mass index (BMI) < 18 kg/m^2 or > 25 kg/m^2 were also excluded.

After recording all baseline parameters, the selected participants were trained in yoga for six weeks, 60 minute/day in the evening at 6 PM by a trained yoga expert under the supervision of a department faculty to ensure compliance. The sequence of yoga asanas and pranayam was adapted from the Common Yoga Protocol given by the Ministry of AYUSH.[12] The asanas practiced were SukṣmaVyāyāma (Loosening Practices), Uttanasana (Standing Forward Bend), Badhakonasana (Butterfly pose), Parivrtta Sukhasana (Easy Seated Twist Pose), Setu Bandha Sarvangasana (Bridge Pose), Halasana (Plough Pose), Viparita Karani (Legs Up the Wall Pose), variation of Sukhasana (Easy Forward Bend), Balasana (Child Pose), Janu Sirsasana (Head to Knee Pose), and Savasna (Corpse Pose). Among the Pranayamas, Anuloma Viloma, Bhramari, and Kapalbhati were practiced.

The following parameters were recorded at baseline and after six weeks of yoga training:

- Age, height, weight, arterial blood pressure, and HR. BMI was calculated from height and weight using Quetelet's Index.
- Sleep quality was assessed using the freely available Pittsburgh Sleep Quality Index (PSQI).[13] PSQI is a self-reported test using pencil and paper. It usually takes between 5 and 10 min for completion. Each of the 19 self-reported items in the questionnaire falls into one of seven subdivisions: subjective sleep quality, sleep duration, sleep latency, sleep disturbances, habitual sleep efficiency, use of sleep medication, and daytime dysfunction.
- HRV was measured after the participants were comfortable and relaxed for at least ten minutes. Following the standard procedure recommended by the Task Force on HRV,[14] electrocardiogram (ECG) recordings were performed for 10 minutes to analyze short-term HRV. HRV was then evaluated using both the time domain and frequency domain analyses. The ECG was captured using a computer-based digital data acquisition system with PowerLab® electrocardiographs (ADInstruments, Australia). Recordings were processed and stored with LabChart® v. 8.0 software (ADInstruments) at a sampling rate of 500 Hz and a time resolution of 1 ms. Artifacts were visually inspected on the computer display, and only segments with more than 90% pure sinus beats were included in the final analysis. The HRV data were analyzed using the Kubios HRV® software (version 2.2, Finland), with a signal sampling rate set at 1 kHz to ensure the precise detection of parameter changes.
- The paper and pencil Trail Making Cognitive tests (TMT-A&B) were used to assess cognitive function.[15] The participants were asked to perform practice sessions before the start of the test. In Trail Making Tests Parts A (TMT-A), the participants were asked to draw a straight line to connect 25 consecutive numbered circles. In Trail Making Tests Parts B (TMT-B), participants were directed to draw lines connecting numbers and letters in a specific sequence, alternating between numbers and letters. For both tests, the score was based on the total time (in seconds) required to complete the tasks. The time for the tests was measured with a stopwatch. The result was interpreted as given in Table 1.

Statistical Analysis: Data was analyzed using GraphPad Prism (GraphPad Software version 8 for windows, San Diego,

Table 1: Trail making test interpretation

Trail making test	Average time (seconds)	Time suggestive of defective cognition (s)
TMT-A	29	> 78
TMT- B	75	> 273

TMT-A: Trail making tests parts A, TMT-B: Trail making tests parts B

California, USA). For each parameter, the data was tested for normal distribution and expressed as mean ± standard deviation. For baseline and post yoga comparison, depending on the normality of the data, paired t-test or Wilcoxon Signed Rank Test was used. The significance level was kept at $p < 0.05$ in the study.

RESULTS

During the training, a trained yoga instructor led the yoga sessions while an investigator was present. There was no loss to follow-up. All 50 students reported for the yoga session daily and for baseline and post yoga assessment of the required parameters. The average age, height, and weight of the participants were 21.86 ± 2.6 years, 162.90 ± 9.9 cm, and 61.09 ± 10.8 kg, respectively. The calculated mean BMI was 22.47 ± 3.9 kg/m^2.

The cardiovascular parameters are shown in Table 2. A significant difference was witnessed in the systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR after six weeks of yoga training in comparison to the baseline values. Mean blood pressure did not show any significant changes.

The baseline and post-intervention values of HRV parameters are shown in Table 3. There was a significant difference in the high frequency power normalized unit (HFnu) and total power (TP) between the two recordings (baseline and post yoga).

The participants demonstrated a significantly enhanced performance on the TMT-A&B tests after six weeks of yoga practice. Additionally, the PSQI revealed a notable improvement in sleep quality following yoga practice compared to baseline values. These results are detailed in Table 4.

Table 2: Cardiovascular parameters in the participants at baseline and after six weeks of yoga training

S.No	Parameters	At baseline	After six weeks of yoga	p-value
1.	SBP (mmHg)	116.6 ± 2.04	111.8 ± 8.10	0.049*
2.	DBP (mmHg)	80.88 ± 2.17	78.72 ± 2.3	0.0026*
3.	MBP (mmHg)	92.77 ± 3.34	92.00 ± 1.77	0.23
4.	HR (BPM)	83.44 ± 3.81	80.88 ± 4.23	0.010*

The values are in Mean ± SD. In the table, Systolic blood pressure (SBP), Diastolic blood pressure (DBP), Mean blood pressure (MBP), and Heart rate (HR) refers to systolic blood pressure, diastolic blood pressure, mean blood pressure, and heart rate, respectively. A p-value of less than 0.05 was taken as statistically significant. The data were compared using dependent samples t-test. The significant values are marked as '*'. SD: Standard deviation.

Table 3: HRV parameters in the participants (n = 50)

S.No.	Parameters	Values		p-value
		Baseline	Post Yoga	
1.	Standard deviation of normal to normal interval, SDNN (ms)	61.10 ± 8.71	59.36 ± 8.87	0.19
2.	Square root of the mean of squares of the differences between adjacent NN intervals, RMSSD (ms)	56.55 ± 8.76	56.08 ± 7.7	0.81
3.	Proportion derived by dividing NN50 by the total number of NN intervals, PNN50 (ms)	45.84 ± 9.5	44.74 ± 9.66	0.35
4.	Low-frequency power normalized unit, LFnu	49.48 ± 9.12	48.12 ± 7.87	0.31
5.	High-frequency power normalized unit HFnu	53.25 ± 10.14	59.57 ± 9.61	0.03*
6.	LF/HF	0.96 ± 0.33	0.87 ± 0.26	0.12
7.	Total power	3238 ± 1133	3473 ± 1130	0.015*

The values are in Mean ± SD. A p-value of less than 0.05 was taken as statistically significant. The pre-and post-intervention data was compared using the Wilcoxon Signed Rank Test. SD: Standard deviation, HRV: Heart rate variability, The significant values are marked as '*'.

The correlation between HRV parameters (HFnu and TP) with PQSI and TMT-A&B score is given in Table 5. No significant correlation was found among these parameters except in TMT-B score, which was found to have a significant negative correlation with TP.

DISCUSSION

As a lifestyle intervention, yoga has shown to ease stress and reinstate disturbed autonomic nervous system balance. This study examined the impact of six weeks of yoga training on autonomic activity (HRV), sleep quality, and cognition in medical students. We hypothesized that a short duration of simple yogic exercises may improve sleep quality and HRV, thus leading to improved cognitive abilities. This study

Table 4: Values of trail test and the PSQI in the participants (n = 50)

S.No.	Parameters	Values		p-value
		Baseline	Post yoga	
1	Trail A (s)	30.16 ± 5.04	19.84 ± 2.76	≤0.0001*
2	Trail B (s)	69.96 ± 12.99	49.24 ± 10.99	0.0008*
3	PSQI	10.68 ± 1.78	4.12 ± 1.67	≤0.0001*

The values are in Mean ± SD. PQSI: Pittsburgh Sleep Quality Index. A p-value of less than 0.05 was taken as statistically significant. The pre- and post-intervention data was compared using Wilcoxon Signed Rank Test. The significant values are marked as '*'. SD: Standard deviation.

Table 5: Correlation of significant HRV parameters with PSQI and trail test scores

Scores	HRV parameters	Baseline		Post yoga	
		R	P	r	P
PSQI		-0.17	0.43	−0.25	0.21
Trail A	HFnu	0.07	0.74	−0.07	0.75
Trail B		0.07	0.73	−0.29	0.15
PSQI	Total power	0.18	0.27	−0.32	0.12
Trail A		0.39	0.19	−0.27	0.18
Trail B		0.03	0.89	−0.41	0.04*

A p-value of less than 0.05 was taken as statistically significant. PQSI: Pittsburgh Sleep Quality Index; HFnu: High frequency power in normalized unit, HRV: Heart rate variability, TP: Total power. Correlation was calculated using Spearman's Rank Correlation test. The "*" denotes significant value.

found a significant reduction in cardiovascular parameters, including SBP, DBP, and HR, after six weeks of yoga practice. Of all the recorded HRV parameters assessed, only HFnu and TP showed a significant increase.

Similar to our study, fall in blood pressure and HR following yoga training was observed by other researchers also.[16,17] Om chanting and yoga nidra have shown to lower blood pressure and improve lipid profile in hypertensive patients.[16] Simple yogic exercises for the duration of six weeks have shown to lower blood pressure and HR in young women.[6] Papp *et al.* (2013) have observed that eight weeks of hatha yoga increased HRV but has no effect on blood pressure.[18] Some of yogic asanas have proved beneficial in elderly patients with essential hypertension where the possible mechanism could decrease stress-induced sympathetic hyperactivity and plasma renin activity after yoga training.[19] Hagins *et al.* (2013), in a systematic review, suggested yoga to be an effectual intervention for reducing blood pressure.[20]

The improved HFnu and TP in this study are suggestive of increased parasympathetic activity after practicing yoga for six weeks. However, no changes were observed in other parameters which could be due to less duration of the training. Most of the researchers have shown improvement in HRV of healthy and diseased adults after yoga sessions(asana, breathing exercise & meditation) ranging from four weeks to six months.[21–23] Similar to this study, Papp *et al.* (2013) observed significant increase only on pNN50 after hatha yoga of eight weeks duration, suggesting an improved parasympathetic tone.[18] The study by Bhasker *et al.* (2017) found that pranayama and meditation in Long Sudarshan Kriya significantly increased parasympathetic activity and decreased sympathetic activity in the heart.[5] This suggests that these practices may be effective in improving HRV. Additionally, a six-month study of yoga breathing practice in healthy adolescents showed a continued shift toward parasympathetic dominance in their cardiac autonomic tone. While the exact mechanism by which yoga influences autonomic activity is still being researched, some yoga practices appear to directly stimulate the vagus nerve, leading to increased parasympathetic output and improved HRV. These effects have been observed after just a few weeks of yoga practice.

The sleep quality improved significantly after six weeks of yoga practice, as suggested by the decreased scores of the subjective PSQI. The benefit of yoga on sleep has been studied by many researchers. Consistent with our study, yoga training resulted in improvements in the sleep-wake cycle and PSQI scores in the yoga-trained group compared to the nontrained control group.[9] A systematic review and meta-analysis found that yoga interventions are more effective than nonactive control groups in addressing sleep-related issues in women.[4] Another trial with the eight-week Kundalini yoga intervention has proved that yoga may benefit patients with insomnia as an adjunctive therapy to cognitive behavioral therapy.[24] Sleep deprivation is akin to stress-like situation that may activate the sympathetic nervous system and increase cortisol secretion, leading to a rise in blood pressure.[25] By activating the sympathetic nervous system, sleep leads to decreased HRV.[26] One possible explanation for improved sleep quality in terms of improved sleep latency and more deep sleep without disturbances after yoga could enhance physical and mental relaxation due to stretching and relaxing of muscles and brief meditation. Another possible mechanism by which yoga improves sleep could be a decrease in the sympathetic nervous system activation.

Cognitive ability as tested by the TMTs-A&B was found to significantly improve after practicing yoga for six weeks. Various studies have also shown a direct relation between mindfulness training, yoga, meditation, and improved cognition.[27,28] In a meta-analysis by Gothe and McAuley (2015), it was concluded that both the short and long duration of yoga practice leads to better cognitive functions. However, the sample size, characteristics of the sample population,

type of yoga asanas and breathing exercises, and cognition tests in these studies were different, which limits the positive association.[29] Yoga training improves HRV by enhancing vagal activity.[10] The improvement in cognitive abilities by enhancing the vagal tone can be explained on the basis of the neurovisceral integration model.[30] Yoga, meditation, and cardio training for over five weeks have enhanced cognitive functions, including attentiveness and decision-making capacity, in young adults.[31] HRV has many implications in psychophysiological research. Thayer *et al*. (2010) recognized the existing functional association between the prefrontal lobe and heart via the central autonomic connections involved in stress regulation, emotional reactions, limbic system, cognition, and reward and punishment responses.[7] Resonance breathing, a type of pranayama, when practiced for a short duration of 20 minutes daily for a month has shown to enhance parasympathetic tone and depress sympathetic activity. Resonance breathing has also shown to enhance cognitive abilities and reduced apparent stress in adults.[32]

Yoga, meditation, and cardio training for over five weeks have enhanced cognitive functions, including attentiveness and decision-making capacity, in young adults.[31] HRV plays a significant role in psychophysiological research. Thayer *et al*. (2010) demonstrated a practical link between the prefrontal cortex and the heart through the central autonomic network, which is involved in stress regulation, emotional responses, limbic system functions, cognition, and reward and punishment mechanisms.[7] Additionally, practicing resonance breathing, a form of pranayama, for 20 minutes daily for over four weeks has been found to increase parasympathetic activity, decrease sympathetic activity, improve cognition, and reduce perceived stress levels in young adults.[32]

In this study, significant correlation was observed in TP and cognitive ability by TMT-B test. This shows that with the increase in HRV, there is improvement in cognitive abilities. It has been postulated that HRV is an important biological marker of health, disposition, and adjustment,[14] and hence improvements in HRV due to yogic practice may lead to improved health, cognition, and sleep quality. This study corroborates this postulation.

This study is limited by its study design. Further, we did not test autonomic reactivity through the Conventional Autonomic Function Tests. This study can further be extended as a randomized control trial with greater sample and detailed autonomic assessment and electrophysiological assessment for cognition.

CONCLUSION

This study demonstrated that daily one-hour yoga sessions including asana, pranayama, and meditation over six weeks enhanced heart rate variability (HRV) among medical students, as indicated by increases in HFnu and TP values. Regular yoga sessions also improved sleep quality and cognitive function in these students. These findings suggest that regular yoga is an effective approach for managing stress, improving sleep quality, enhancing cognition and cardiovascular health in young adults. Hence, regular yoga practice is recommended for young medical students for better physical and mental health.

Authors' contributions

All authors have made substantial contributions to the conception and design of the work; in the acquisition, analysis, or interpretation of data; and in drafting and revising the manuscript and all authors have approved the submission.

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Ethical approval

The research/study approved by the Institutional Review Board at the Government Institute of Medical sciences, Greater Noida, number GIMS/IEC/HR/2022/25, dated 22nd July 2022.

Declaration of patient consent

The authors certify that they have obtained all appropriate participants consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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