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NEURO-COGNITIVE ENHANCEMENTS THROUGH YOGA TECHNIQUES: A FOCUSED ANALYSIS ON MEMORY AND ATTENTION IN MEDICAL STUDENTS

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Background:
The rigorous demands of medical education often lead to high levels of stress, which can adversely affect cognitive functions such as memory and attention. Yoga, an ancient practice integrating physical postures, controlled breathing, and meditation, has been associated with various psychological benefits, including improvements in cognitive function. This study focuses on analyzing the effects of two specific yoga techniques, Sudarshan Kriya Yoga (SKY) and Raja Yoga, on the memory and attention of undergraduate medical students.

Objective:
The primary objective of this study was to evaluate the effects of Sudarshan Kriya Yoga and Raja Yoga on improving memory and attention among medical students, compared to a control group that did not engage in any structured physical or mental exercises.

Methods:
A total of 150 medical students were randomly allocated into three groups: Sudarshan Kriya Yoga (n=50), Raja Yoga (n=50), and a control group (n=50). Both intervention groups practiced their respective yoga techniques for 30 minutes daily over a 20-week period, while the control group continued with their usual routines without any additional interventions. Cognitive assessments were conducted at baseline and after 20 weeks using the Mini-Mental State Examination (MMSE) and the Stroop test.

Results:
At baseline, MMSE scores and Stroop test times were comparable across all groups. Post-intervention, significant improvements were observed in both intervention groups. The SKY group's MMSE scores increased from 27.20 ± 2.16 to 29.02 ± 0.8 ($p < 0.001$), while the Raja Yoga group's scores improved

from 26.68 ± 2.15 to 29.02 ± 0.82 ($p < 0.001$). Stroop test times significantly decreased in the SKY group from 10.17 ± 1.04 seconds to 7.29 ± 1.12 seconds ($p < 0.001$) and in the Raja Yoga group from 10.53 ± 1.02 seconds to 7.43 ± 0.83 seconds ($p < 0.001$). The control group showed no significant changes in either MMSE scores or Stroop test times. Both yoga techniques were similar in efficiency.

Conclusion:

The findings from this study suggest that both Sudarshan Kriya Yoga and Raja Yoga are effective in significantly enhancing cognitive functions related to memory and attention among medical students. These yoga practices could be beneficial as part of a regular routine for students in managing stress and improving academic performance.

Keywords:

Sudarshan Kriya Yoga, Raja Yoga, cognitive function, medical students, memory, attention, stress management.

1. Introduction

Medical education is widely recognized as one of the most challenging and stressful academic pursuits. Medical students are routinely exposed to high levels of academic pressure, long hours of study, and the emotional strain associated with clinical training. These stressors can significantly impair cognitive functions, particularly memory and attention, which are critical for both academic success and future clinical practice (1,2). Given these challenges, there is a growing interest in interventions that can mitigate stress and enhance cognitive function among medical students.

Yoga, an ancient practice rooted in Indian philosophy, has gained global recognition for its holistic benefits on physical, mental, and emotional health. Among various forms of yoga, Sudarshan Kriya Yoga (SKY) and Raja Yoga have been studied for their potential to enhance cognitive functions and reduce stress (3,4). Sudarshan Kriya Yoga, characterized by rhythmic breathing techniques, is known to influence the autonomic nervous system and reduce stress levels (5). Raja Yoga, which focuses on meditation and mental discipline, is believed to improve mental clarity, concentration, and emotional stability (6).

Despite the recognized benefits of yoga, there is a paucity of research specifically targeting its impact on cognitive functions such as memory and attention in medical students. This study aims to fill this gap by conducting a focused analysis of the effects of Sudarshan Kriya Yoga and Raja Yoga on these cognitive functions. The study hypothesizes that regular practice of these yoga techniques will lead to significant improvements in memory and attention compared to a control group that does not engage in any structured physical or mental exercises.

2. Methodology

This study was designed as a randomized controlled trial (RCT) to evaluate the effects of Sudarshan Kriya Yoga (SKY) and Raja Yoga on cognitive functions among medical students. The study was conducted over a 20-week period and included pre- and post-intervention assessments to measure the impact of the interventions.

The study was conducted at the Physiology Department of Moti Lal Nehru Medical College, Prayagraj. A total of 150 undergraduate medical students were recruited. Participants were randomly allocated into three groups, with 50 students in each group: Sudarshan Kriya Yoga (SKY) group, Raja Yoga group, and a control group. The inclusion criteria for participants were as follows: (1) undergraduate medical students aged between 18-25 years, (2) willingness to participate in the study, and (3) no prior regular practice of yoga or other structured mental or physical exercises. Exclusion criteria included: (1) any history of neurological or psychiatric disorders, (2) ongoing use of medications that could affect cognitive functions, and (3) any medical condition contraindicating physical activity.

Ethical approval for the study was obtained from the Institutional Review Board of MLNMC, Prayagraj. Written informed consent was obtained from all participants before enrollment in the study. Participants were informed about the study procedures, potential risks, and benefits, and were assured of their right to withdraw from the study at any time without any consequences.

Interventions – Participants were divided into three groups, 50 in each group.
Sudarshan Kriya Yoga (SKY) Group: Participants in this group practiced Sudarshan Kriya Yoga for 30 minutes daily, guided by a certified instructor. The practice involved specific rhythmic breathing techniques designed to regulate the autonomic nervous system and promote mental well-being.
Raja Yoga Group: Participants in the Raja Yoga group engaged in 30 minutes of daily practice, which included meditation, breath control, and mental focus exercises. The sessions were also conducted under the guidance of a trained instructor.

Control Group: The control group did not participate in any structured physical or mental exercises during the study period. They were advised to continue with their usual routines without any additional interventions.

Outcome Measures - Cognitive functions were assessed using two primary measures. The Mini-Mental State Examination (MMSE) was used to evaluate general cognitive function, including memory, attention, language, and visuospatial abilities. The MMSE is a widely used tool in clinical and research settings to assess cognitive impairment. The Stroop test was administered to assess attention and cognitive flexibility. This test measures the time taken by participants to name the color of the ink in which a word is printed, where the word itself may denote a different color. The Stroop test is considered a reliable measure of cognitive control and executive function. Assessments were conducted at baseline (pre-intervention) and after 20 weeks (post-intervention). The primary outcome measures were changes in MMSE scores and Stroop test times between the pre- and post-intervention assessments.

Statistical Analysis - Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0. Baseline characteristics of the groups were compared using one-way analysis of variance (ANOVA) for continuous variables and the Chi-square test for categorical variables. The effects of the interventions on cognitive outcomes were analyzed using repeated measures ANOVA to assess within-group and between-group differences over time. Post hoc pairwise comparisons were performed where significant main effects were found. A p-value of less than 0.05 was considered statistically significant.

3. Results

This randomized controlled trial evaluated the impact of Sudarshan Kriya Yoga (SKY) and Raja Yoga on cognitive functions, specifically memory and attention, in undergraduate medical students. The study included 150 participants divided into three groups: the SKY group (Group A), the Raja Yoga group (Group B), and the control group (Group C). The primary outcomes were measured using the Mini-Mental State Examination (MMSE) and the Stroop test at baseline and after 20 weeks of intervention.It is important to mention that there were a total of 9 dropouts from the study ; 3 dropouts from group A, 3 dropouts from group B and 3 dropouts from group C.

Cognitive Function: MMSE Scores

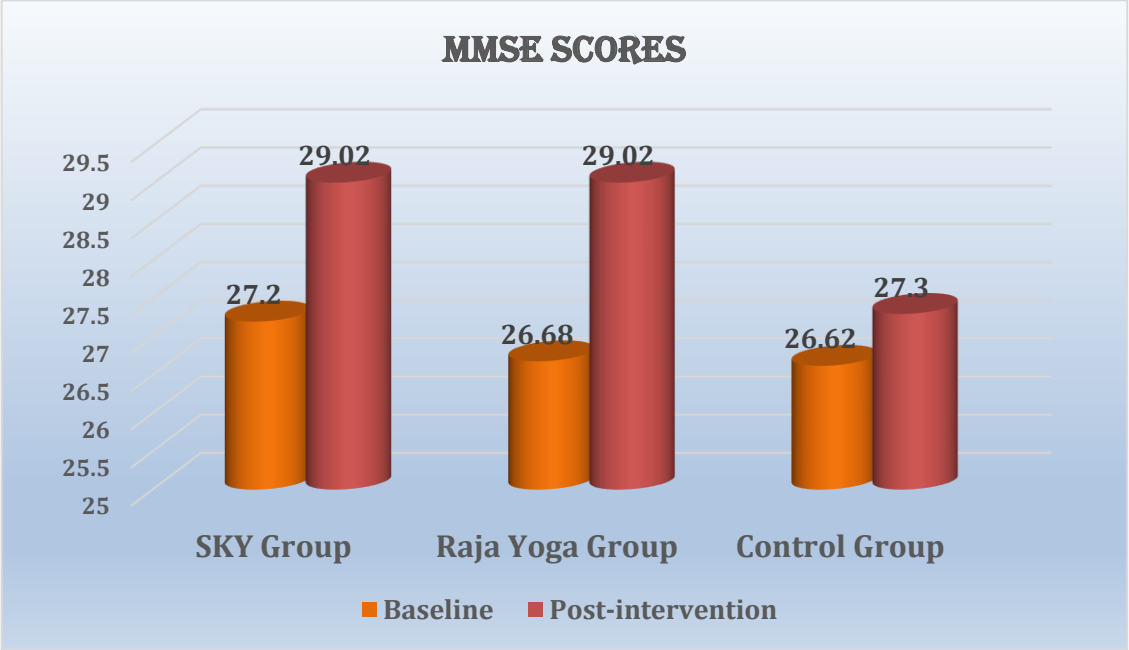
At baseline, the MMSE scores were similar across the three groups, indicating no significant differences in initial cognitive function. The mean MMSE score for the SKY group was 27.20 ± 2.16, for the Raja Yoga group was 26.68 ± 2.15, and for the control group was 26.62 ± 2.15. These baseline scores suggest that all groups started with comparable cognitive abilities.

After the 20-week intervention, significant improvements in MMSE scores were observed in both the SKY and Raja Yoga groups. The post-intervention MMSE score for the SKY group increased to 29.02 ± 0.8, and for the Raja Yoga group, it increased to 29.02 ± 0.82. Both improvements were statistically significant, with p-values of less than 0.001, indicating that the interventions had a strong positive effect on general cognitive function.
In contrast, the control group showed only a slight increase in MMSE scores, with a post-intervention mean of 27.3 ± 1.5. This change was not statistically significant ($p > 0.05$), suggesting that the absence of structured mental or physical exercises did not lead to any meaningful improvement in cognitive function over the study period as seen in Table 1 and graph 1.

Table 1: MMSE Scores at Baseline and Post-Intervention

Group	Baseline MMSE Score (Mean ± SD)	Post-Intervention MMSE Score (Mean ± SD)	p-value
SKY Group	27.20 ± 2.16	29.02 ± 0.8	< 0.001
Raja Yoga Group	26.68 ± 2.15	29.02 ± 0.82	< 0.001
Control Group	26.62 ± 2.15	27.3 ± 1.5	> 0.05

Graph 1: MMSE Scores at Baseline and Post-Intervention



Cognitive Function: Stroop Test

The Stroop test was used to measure attention and cognitive processing speed. At baseline, the mean Stroop test times were similar across the groups, with the SKY group recording a mean time of 10.17 ± 1.04 seconds, the Raja Yoga group recording 10.53 ± 1.02 seconds, and the control group recording 10.57 ± 2.02 seconds. These baseline results indicate that the attention and processing speed were comparable among the participants at the start of the study.

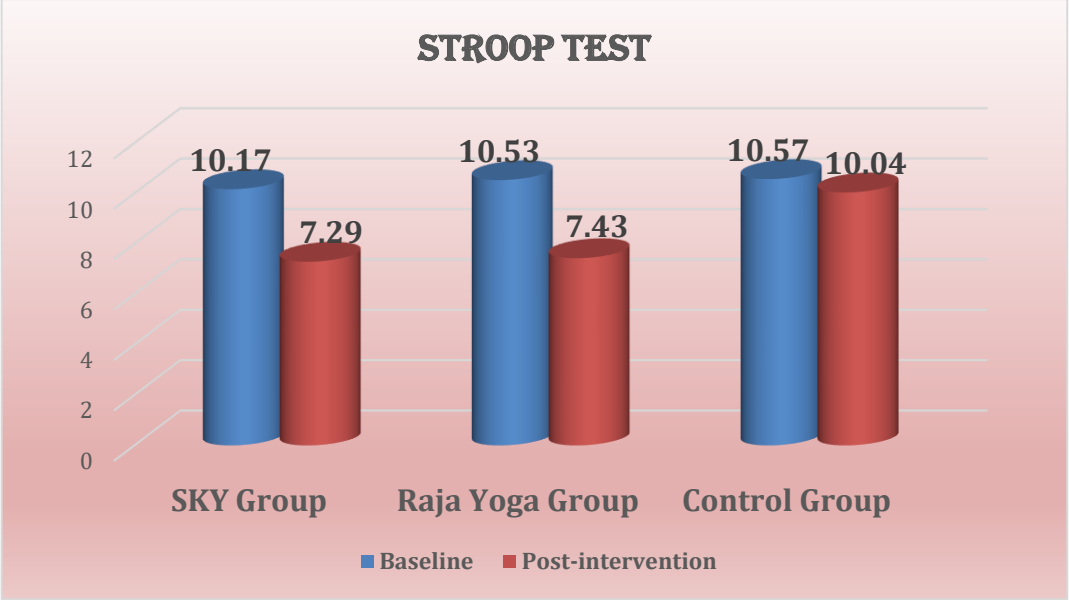
After the 20-week intervention, significant reductions in Stroop test times were observed in both the SKY and Raja Yoga groups. The post-intervention mean Stroop test time for the SKY group decreased to 7.29 ± 1.12 seconds, while the Raja Yoga group saw a reduction to 7.43 ± 0.83 seconds. Both reductions were statistically significant, with p-values of less than 0.001, indicating a marked improvement in cognitive flexibility and processing speed as a result of the interventions.

The control group, however, showed a minimal reduction in Stroop test time, with a post-intervention mean of 10.04 ± 1.56 seconds. This change was not statistically significant ($p > 0.05$), reinforcing the finding that the absence of structured interventions did not lead to significant cognitive improvements.

Table 2: Stroop Test Times at Baseline and Post-Intervention

Group	Baseline Stroop Time (Mean ± SD)	Post-Intervention Stroop Time (Mean ± SD)	p-value
SKY Group	10.17 ± 1.04 seconds	7.29 ± 1.12 seconds	< 0.001
Raja Yoga Group	10.53 ± 1.02 seconds	7.43 ± 0.83 seconds	< 0.001
Control Group	10.57 ± 2.02 seconds	10.04 ± 1.56 seconds	> 0.05

Graph 2: Stroop Test Times at Baseline and Post-Intervention



The significant improvements observed in both the MMSE scores and Stroop test times for the SKY and Raja Yoga groups suggest that these yoga practices effectively enhance cognitive functions in medical students. The marked increase in MMSE scores indicates overall cognitive enhancement, particularly in areas like memory, attention, and visuospatial abilities. The substantial decrease in Stroop test times highlights improved attention, cognitive flexibility, and processing speed.

These findings are particularly relevant for medical students who face intense academic pressures and could benefit from interventions that enhance cognitive performance. The lack of significant changes in the control group underscores the importance of structured physical or mental exercises in promoting cognitive health.

4. Discussion

The results of this study underscore the significant impact of Sudarshan Kriya Yoga (SKY) and Raja Yoga on enhancing cognitive functions, particularly memory and attention, among medical students. These findings are noteworthy, especially in the context of medical education, where students are often subjected to high levels of stress, which can impair cognitive abilities and overall academic performance.

The significant improvements observed in both the MMSE scores and Stroop test times in the SKY and Raja Yoga groups highlight the efficacy of these yoga practices in enhancing cognitive functions. These results are consistent with existing literature that suggests yoga practices, particularly those involving rhythmic breathing and meditation, can lead to improved cognitive function and reduced stress (7,8). The absence of significant improvements in the control group further reinforces the potential cognitive benefits of yoga, as the control group, which did not engage in any structured physical or mental exercises, showed no meaningful changes in cognitive performance over the 20-week period.

Memory (as assessed by MMSE)

The MMSE scores, which provide a general measure of cognitive function including memory, attention, language, and visuospatial skills, showed significant improvement in both the SKY and Raja Yoga groups. At baseline, the MMSE scores were relatively similar across all groups, indicating that the students started with comparable cognitive abilities. However, after 20 weeks, the SKY group's MMSE score increased from 27.20 ± 2.16 to 29.02 ± 0.8, while the Raja Yoga group's score increased from 26.68 ± 2.15 to 29.02 ± 0.82. These improvements suggest that both yoga practices were effective in enhancing memory and other cognitive functions. The improvement in memory could be attributed to the stress-reducing effects of yoga, as stress is known to negatively impact memory (9). Additionally, the meditative components of Raja Yoga and the breathing techniques in SKY may enhance neuroplasticity, leading to better memory retention and recall (10,11).

In contrast, the control group exhibited minimal change in MMSE scores, from 26.62 ± 2.15 at baseline to 27.3 ± 1.5 post-intervention. This lack of significant improvement in the control group underscores the importance of engaging in activities that stimulate cognitive function and suggests that mere academic engagement may not be sufficient to maintain or improve cognitive abilities under high stress conditions.

Attention and Processing Speed (as assessed by Stroop Test)

The Stroop test, which measures attention, cognitive flexibility, and processing speed, also showed significant improvements in the SKY and Raja Yoga groups. The baseline Stroop test times were similar across all groups, with the SKY group at 10.17 ± 1.04 seconds, the Raja Yoga group at 10.53 ± 1.02 seconds, and the control group at 10.57 ± 2.02 seconds. After the intervention, the SKY group's Stroop time decreased to 7.29 ± 1.12 seconds, and the Raja Yoga group's time decreased to 7.43 ± 0.83 seconds. These reductions indicate that both yoga practices were effective in enhancing attention and cognitive processing speed.

The improvements in Stroop test times could be linked to the increased focus and mental clarity associated with yoga practices. The meditative aspects of Raja Yoga, in particular, are designed to improve concentration and cognitive control, which are directly measured by the Stroop test (12). Similarly, the rhythmic breathing exercises in SKY may enhance autonomic nervous system regulation, leading to improved attention and reduced cognitive interference, as evidenced by the shorter Stroop test times (13).

The control group, on the other hand, showed only a slight reduction in Stroop test time, from 10.57 ± 2.02 seconds to 10.04 ± 1.56 seconds, which was not statistically significant. This suggests that the cognitive benefits observed in the SKY and Raja Yoga groups are specifically related to the interventions rather than a general effect of time or participation in the study.

The observed improvements in cognitive functions can be attributed to several mechanisms associated with yoga. First, both SKY and Raja Yoga are known to reduce stress through their effects on the autonomic nervous system, particularly by enhancing parasympathetic activity and reducing

sympathetic overactivity. This shift in autonomic balance is crucial in mitigating the detrimental effects of stress on the brain, particularly in areas responsible for memory and attention (14).
Moreover, yoga practices have been shown to increase levels of brain-derived neurotrophic factor (BDNF), a protein that supports the survival of existing neurons and encourages the growth of new neurons and synapses. This neuroplasticity is likely a key factor in the cognitive improvements observed in the study, particularly in memory and attention tasks (15).

Additionally, the focused breathing techniques in SKY may enhance oxygenation and blood flow to the brain, which could further support cognitive function. The meditative practices in Raja Yoga, which emphasize mental discipline and focus, are likely to improve executive functions, including cognitive control and flexibility, as demonstrated by the improved Stroop test performance (16).
The findings of this study have significant implications for medical education. Given the high levels of stress that medical students face, incorporating yoga practices like SKY and Raja Yoga into their daily routines could serve as a valuable tool for enhancing cognitive performance. Improved memory and attention are not only beneficial for academic success but are also critical skills for clinical practice, where quick and accurate decision-making is essential.

Furthermore, the study suggests that yoga could be a low-cost, accessible intervention to enhance cognitive resilience in high-stress environments. Institutions may consider integrating yoga programs into their wellness initiatives to support the mental and cognitive health of students.
The results of this study are in line with previous research that has highlighted the cognitive benefits of yoga and meditation practices. For instance, studies by Gothe et al. (17) and Hariprasad et al. (18) have demonstrated similar improvements in memory and executive function among older adults and high-stress populations following yoga interventions. Additionally, Telles et al. (19) observed improvements in attention and cognitive processing speed in school children following a yoga program, further supporting the current findings.

Limitations and Future Research
While the results of this study are promising, there are some limitations that should be acknowledged. First, the study was limited to a specific population of medical students, and the findings may not be generalizable to other populations. Second, the study relied on self-reported compliance with the yoga practices, which could introduce bias. Future research could benefit from objective measures of compliance, such as the use of wearable devices to monitor adherence to the yoga practices.
Additionally, while the study focused on the cognitive benefits of SKY and Raja Yoga, it would be valuable to explore their effects on other aspects of mental health, such as anxiety and depression. Long-term studies are also needed to assess the durability of the cognitive benefits observed and to determine whether continued practice leads to sustained improvements.

5. Conclusion
In conclusion, this study provides robust evidence that Sudarshan Kriya Yoga and Raja Yoga significantly enhance cognitive functions, particularly memory and attention, in medical students. The improvements observed in MMSE scores and Stroop test times highlight the potential of these yoga practices as effective interventions for cognitive enhancement in high-stress academic environments. The findings suggest that integrating yoga into the daily routines of medical students could be a valuable strategy for mitigating the cognitive impact of stress and improving academic and clinical performance.
By addressing the cognitive needs of medical students through such holistic interventions, educational institutions can contribute to the overall well-being and success of their students, ultimately leading to better outcomes in medical education and practice.

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