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Comparing cognition, coping skills and vedic personality of individuals practicing yoga, physical exercise or sedentary lifestyle: a cross-sectional fMRI study

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ABSTRACT

Background: Nature and intensity of physical activity may influence cognition, coping mechanisms and overall personality of an individual. The objective of this cross-sectional study was to compare cognition, coping styles and vedic personality among individuals practicing different lifestyle.

Methods: Thirty-nine healthy young adults of both gender (27.63±4.04 years) were recruited and categorized into three groups; i.e. yoga, physical activity or sedentary lifestyle groups. Participants were assessed on cognition, coping styles and Vedic personality inventory (VPI). Verbal-n-back and Stroop tasks were performed using 3 Tesla MRI scanner. Task Based Connectivity (TBC) analysis was done using CONN toolbox in SPM.

Results: There were no significant differences in the cognitive domains across the groups. The planning (p=0.03) and acceptance domain (p=0.03) of the Brief COPE scale showed difference across the groups. Post-hoc analysis revealed that planning and acceptance scores were distinctly higher in the physical activity group, however, there was no difference between physical activity group and yoga practitioners. Similarly, in the VPI, *Sattva* (p=0.003), *Rajas* (p=0.05) and *Tamas* (p=0.01) were different across the groups, and the post hoc analysis showed superiority in *Sattva* scores in Yoga group, meanwhile, both *Rajas* and *Tamas* were higher in the physical activity group. Yoga practitioners preferentially recruited left Superior Frontal Gyrus in relation to the physically active group and precuneus in relation to the sedentary lifestyle group.

Conclusion: The study revealed that yoga practitioners had a distinct higher *sattva guna* and preferentially recruited brain areas associated with self-regulation and inhibitory control.

1. Introduction

The modern work life has become stressful and requires optimum coping mechanisms, especially the ones which are affordable and adoptable by the communities. Coping involves thoughts and behaviors used to manage the internal and external demands of varied stressful situations.[1,2] Apart from coping skills, personality traits also play a substantial role in the adjustments to stress in daily life. Personality is a "dynamic organization within the person of the psychological and physical systems that underlie that person's patterns of actions, thoughts, and feelings".[3] Personality traits, in the vedic context comprises three qualities, termed as Trigunas; i.e., Sattva, Rajas, Tamas, that regulate the dynamism from

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subtle to gross level including the body, mind, and environment.[4,5] From a modern perspective using the polyvagal theory, Sattva may be described as a state that activates the social engagement system. Ancient philosophical texts, Samkya Karika and Bhagawat Gita described Sattva as the force of equilibrium that translates in quality as good, harmony, happiness and light.[4–6] Rajas, the state that activates the fight or flight response in the polyvagal theory, is explained as the force of kinesis and translates in quality as struggle, effort, passion, and action. Tamas is a state of shutdown or immobilization which is correlated with the force of in conscience and inertia, translated as obscurity or incapacity or inaction as per classical texts of yoga.[4–7]

Physical exercise and mind-body therapies such as yoga and meditation have been shown to induce structural and functional changes in the brain that improve cognitive functioning, personality traits, and general well-being.[8,9] Yoga, a mind-body practice originating from ancient Indian philosophy, aims at obtaining the functional harmony between mind and body using physical postures, breathing, and meditation techniques, all performed with mindfulness. Indulging in yoga may also benefit an individual who fosters self-regulation and resilience than physical exercises alone.[6]

There were several attempts to understand the pattern of cognitive correlations associated with the different lifestyles using functional neuroimaging. [10,11] The physical activity showed improvements in working memory and attention, as well as benefits in concentration and behavioral inhibition. Activation of the supramarginal gyrus and superior parietal lobule, which is associated with feelings of empathy and overcoming emotional egocentric biases, during emotionally arousing conditions were reported to be associated with emotional regulation in yoga practitioners.[12,13] Despite the increasing number of studies in this area, the functional task based connectivity for attention based upon the engagement of individuals with different lifestyles has not been explored. Moreover, it is well-acknowledged that a sedentary lifestyle has an adverse impact on physiological functioning and health. [14] Previous studies have used fMRI to investigate the effects of acute physical exercise and cerebral hemodynamics and cognition. [8,9,15] These studies have not explored the effect of yoga and physical exercises than those leading a sedentary lifestyle and have a few methodological limitations. Vedic personality and coping mechanisms have also not been explored in previous studies. The current study aimed to assess the functional task based neural connectivity, coping behavior, cognitive functioning, and personality of individuals practicing yoga, physical exercises, and sedentary lifestyles. To the best of our knowledge, this is the first study that compares these effects of yoga, physical exercise, and sedentary behavior.

2. Methods

2.1. Study design

The current study was an observational cross-sectional study conducted at a tertiary care hospital in North India between December, 2018, and 2019. The study was approved by the institutional ethical committee, and written informed consent was obtained from all participants.

2.2. Participants

Convenient sampling was adopted, and 39 healthy young adults of either gender between the age group of 18-35 years with a minimum education of high school were recruited from centers providing yoga therapy, local gymnasium, and professionals working in tertiary care health settings. The participants were categorized into three groups equally based on their lifestyle practices, i.e. either to yoga group (YG), physical exercise group (PE) or to the sedentary lifestyle group (SED). The inclusion criteria for the yoga and exercise group were at least one hour of yoga or physical activity, three days per week for a minimum of three years. For a sedentary lifestyle, the inclusion criteria were lack of any kind of physical exercise for the past three years. The exclusion criteria for the participants were previous medical history of any neurological or psychiatric illness, history of substance abuse or sleep difficulty in the past 3 months. Those who did not give written consent for the trial were also excluded.

2.3. Neuropsychological assessment and data collection

A socio-demographic and case report profile sheet were used for screening along with Hamilton anxiety and depression scale to rule out the presence of anxiety and depression among the participants. The detailed cognitive assessment included different cognitive tests i.e. Digit Symbol Substitution Test (DSST), [16] visual 1 and 2 back test, Color trail 1 and 2,[17] and Post Graduate Institute Memory Scale (PGIMS).[18] The psychological assessment for coping mechanisms and personality included, namely, Brief COPE[2] and the Vedic Personality Inventory (VPI).[19]

2.4. Functional MRI Tasks

The functional magnetic resonance imaging (fMRI) tasks were developed and presented using SuperLab software (Cedrus Corporation, San Pedro, USA). MR compatible headphones and LED monitor (M/s. Philips Healthcare, The Netherlands) were used for the cue presentation of the auditory and visual cues. Inverted mirror mounted on the head coil was used to project the visual cues with position adjusted to suit subject viewing. MR compatible response pads (Lumina 3G, Cedrus Corporation, San Pedro, USA), connected to the Lumina controller were used for subject's response feedback. The following tasks were conducted during the fMRI imaging:

Verbal 1-back Task: The task comprised 30 seconds of active and 30 seconds of rest in block design. During the active period, verbal cues ('Hindi' alphabets) were presented and participants were instructed to respond when the same verbal cue was presented one after the other (1 back or preceding) (Fig. 1).

Verbal 2-back Task: The task in block design comprised 24 seconds of rest and 30 seconds of active period presenting verbal cues ('Hindi' alphabets). Participants were instructed to respond when the same verbal cue was presented leaving one different cue in between two same cues (2 back) during the active block (Fig. 2).

Stroop Colour Word Task (SCWT): The active block with stroop effect represented congruent and incongruent stimuli for 20 seconds and 40 seconds (with two repetitions), respectively, interleaved by the rest blocks for 20 seconds. The task was initiated by a non-stroop block of 80 seconds (color words in 'black and white' font and '+ (neutral sign)' in different colours with rest blocks in-between) to make the participants acclimatize with task and response pads (Fig. 3).

2.5. Magnetic Resonance Imaging (MRI)

The MR imaging was done on a 3T MRI scanner (Philips Medical Systems Ingenia) using 32-channel head coil. Blood oxygen level dependent (BOLD) fMRI data was acquired using Echo-planar imaging (EPI) sequence with Field of View (FOV)= (230×230) mm, TR/ TE=2000/30ms, number of slices= 35, slice thickness= 4.5mm, slice gap=0mm and dynamics= 185 for verbal-1-back and verbal-2-back and 220 for SCWT. Three dimensional T1 weighted imaging (3DT1) data was acquired using TR/ TE = 8/ 4 ms, FOV= (240×240) mm, slice thickness= 0.5 mm, number of slices=360. The voxel

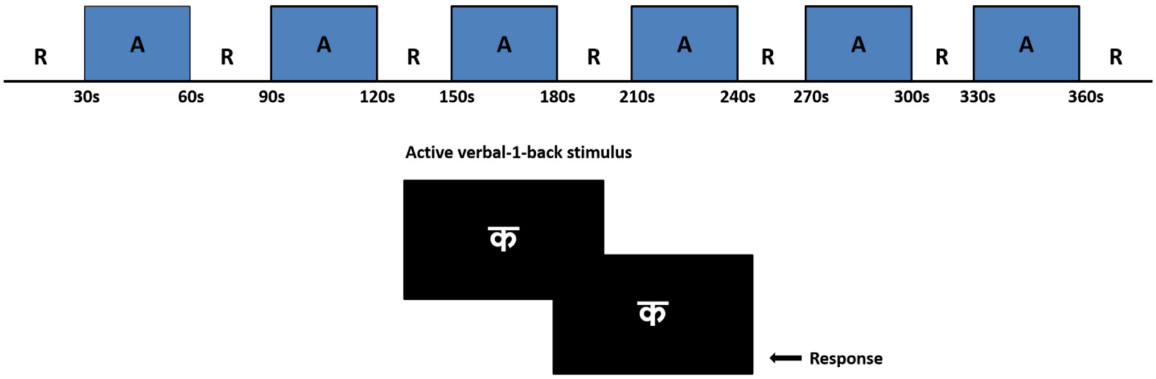

Fig. 1. Paradigm for verbal 1-back task.

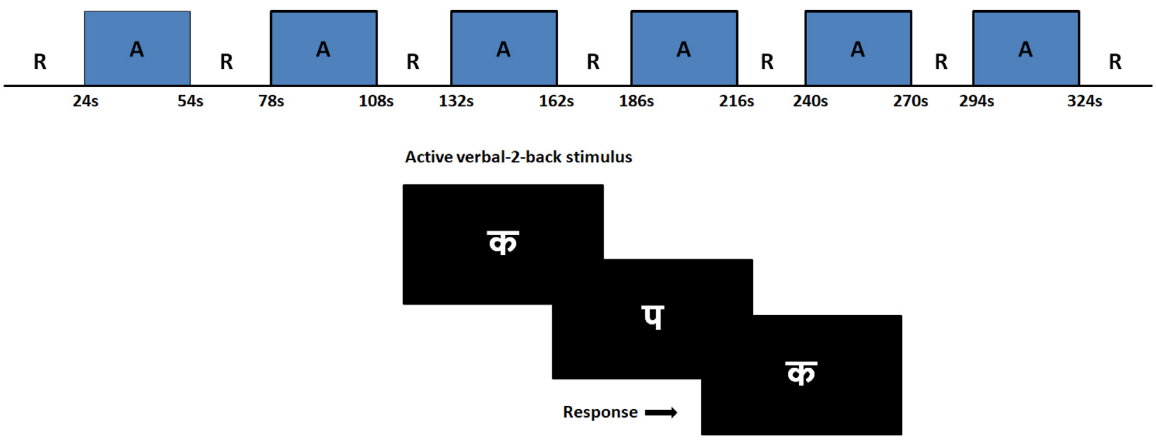

Fig. 2. Paradigm for verbal 2-back task.

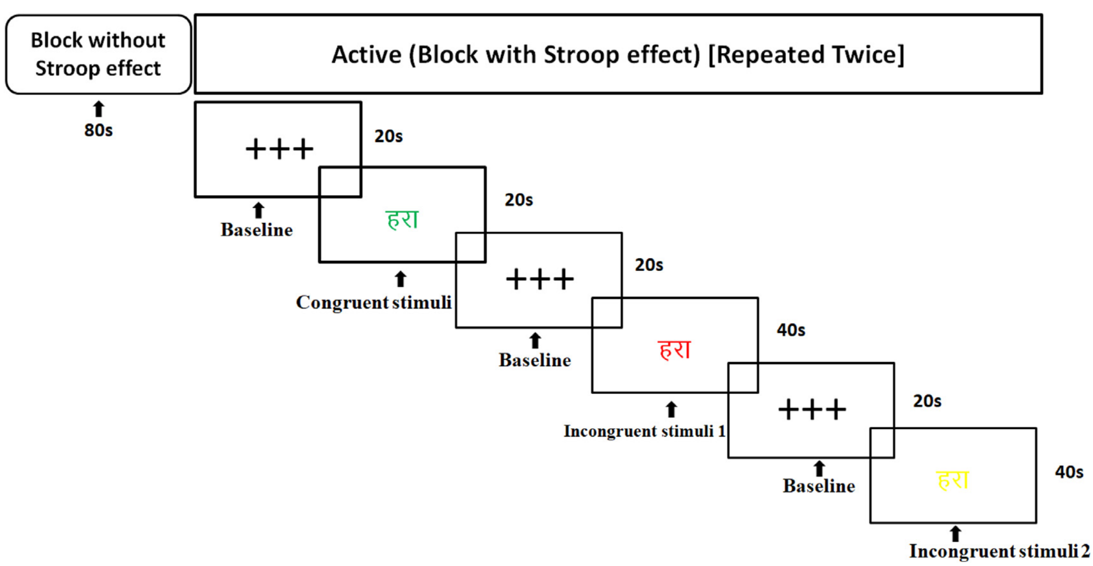

Fig. 3. Paradigm for SCWT.

size for fMRI was 2.8×2.8×4.5 (mm) and T1 was 1×1×0.5 (mm) with a flip angle of 90 for BOLD and 8 degrees for T1.

2.6. MRI data analysis

2.6.1. Anatomical (3DT1) data analysis

SPM computational anatomy toolbox CAT12 was used for volumetric analysis using 3DT1 data. Keeping the default parameters during preprocessing (reorientation, segmentation and normalization) modulated gray and white matter maps were generated. Group difference for the total intracranial volume (TIV), gray matter (GM), white matter (WM), white matter hyper-intensity (WMH) difference was estimated using analysis of variance (ANOVA).

2.6.2. fMRI data analysis

fMRI data was analysed using 'Statistical Parametric Mapping' (SPM version 12) using standard preprocessing pipeline. Briefly, BOLD data was first reoriented and corrected for motion artefact using realignment and unwarp.[20] Data with greater than 2mm translation and greater than 1° rotational movement were discarded. Supplementary table S1 presents mean motion per subject, calculated as mean root-mean-square of translation and mean absolute Euler angle. [21] Further, data was normalized to standard echo planar imaging (EPI) template followed by smoothing with 6mm Gaussian kernel. First level model definition (including motion parameters as nuisance variable) followed the generation of active>rest contrast for verbal-n-back tasks and incongruent for SCWT. The subject level contrasts were analysed using ANOVA for group level differential inferences. The findings are presented at the liberal $p<0.001$ uncorrected, k=5 (no voxels survived the stringent condition family-wise error correction (FWE)).

2.6.3. Functional connectivity analysis

SPM connectivity toolbox CONN (version 18.a) was used for task-based connectivity analysis, keeping the preprocessing as mentioned above. Additionally, the T1 anatomical data were reoriented, segmented into gray matter, white matter and CSF, and normalized to MNI common atlas space. First-level covariates included standard motion parameter time course and time course of artefact detection tool–based “scrubbed” signal artefacts. Linear regression of confounding effects was then conducted including, cerebrospinal fluid and white matter masked BOLD time series and all first-level covariates (e.g., motion correction and “scrubbing”), along with effect of experimental condition. Resulting data were band-pass frequency filtered (Inf to 0.01Hz). Bivariate correlation analysis using hrf weighting on the band-pass frequency–filtered fMRI BOLD time series was done to estimate task specific functional connectivity measures. The Fisher z transformed correlation coefficient created the group/task-specific seed to voxel functional connectivity (FC) maps. The connectivity analyses were restricted to the networks (seeds/ region of interest (ROIs)) with intergroup differential BOLD activity as well as adapted from earlier literature [21] and the ROIs analysed were: Right and Left Dorsal Attention Frontal Eye Field (FEF), Right and Left Dorsal Attention Inferior parietal sulcus (IPS), Right and Left Fronto Parietal Lateral Prefrontal Cortex (LPFC), Right and Left Fronto Parietal Posterior parietal cortex (PPC). The analysis focused on the connectivity measures during the “active” block for verbal tasks and SCWT, “incongruent” blocks. To account for false positives due to multiple comparisons across 8 seeds (ROIs) and 3 groups, connectivity results are presented with $p<0.002$ (0.05/24) uncorrected for height/ peak level statistics *and* $p<0.05$ FWE corrected for cluster level statistics. Among the presented findings, the connectivity surviving stringent $p<0.002$ false discovery rate (FDR) correction on height/ peak level statistics *or* $p<0.002$ FWE correction statistics on cluster level are marked. [22]

2.7. Statistical analysis

Statistical Analysis was done by Stata (ver. 14.2.). Continuous variables were reported as mean ± SD (Standard deviation) or Median (minimum, maximum), whereas frequencies with percentage (%) reported for categorical variables. Kruskal–Wallis and Chi-Square test were used to compare between group characteristics with continuous and categorical outcomes, respectively. Post-hoc analysis was performed for the variables showing statistically significant differences between groups. Pearson product-moment correlation coefficient was used to ascertain the relationship between Vedic personality traits and coping skills. p-value < 0.05 was considered as significant for various comparisons.

3. Results

The mean age of the study participants in all the groups (n=13 for each group) was 27.63±4.04 years with years of education between 16.6±2.3 years. There were no significant differences in age, education, and gender observed in the groups (Table 1).

3.1. Comparison of cognitive domains, coping skills and VPI across groups

The results of different domains of the coping styles, cognition and Vedic personality across the groups are described inTable 2. There was no difference in the broad categories of coping skills in relation to different lifestyles. In the individual domains, only planning (p=0.03) and acceptance (p=0.03) domains were different across the groups while no statistical significance was observed in other domains across the groups. Later, a post-hoc analysis was carried out to appreciate the superiority, which revealed that the PE had distinctly higher planning (p=0.04) compared to the YG and acceptance (p=0.03) compared to the SED. There was no significant difference between YG and PE when compared for acceptance (p=1.00) domain.

The vedic personality scores were calculated in percentage for each of the dominant traits (*gunas*). Differences between three study groups was seen in all the three personality domains; *Sattva* (p=0.003), *Rajas* (p=0.05) and *Tamas* (p=0.01). The post-hoc analysis showed significant differences in *sattva* score, which was distinctly superior in the YG in comparison with the PE ($p<0.001$) and SED (p=0.02), whereas *rajas* and *tamas guna* were predominantly higher in the PE and SED when compared with YG. There were no differences in the *rajas* and *tamas* scores in PE and SED. There were no differences in cognitive functioning in individuals with nature and intensity of physical activity.

3.2. Correlation of Triguna with the coping skills

Pearson correlation was calculated between *triguna* and coping skills (Table 3). *Sattva guna* was positively correlated with the emotion focused coping strategy across the groups however statistical significance was only observed in the PE ($p<0.05$). On a contrary, the *Tamas guna* was negatively correlated with emotion-focused coping across the groups but was statistically significant only in PE and YG. *Sattva guna*, also showed statistically significant positive correlation with the problem focused coping category of the Brief COPE scale. Figure 4 depicts the interplay between personality and coping mechanisms.

3.3. MRI data findings

No statistical difference was observed in the TIV, gray matter, white matter, CSF and white matter hyperintensity between the three groups (Table 4).

3.4. fMRI BOLD activations across groups

The fMRI data (BOLD activation and connectivity) was analysed with reduced sample size of n=10, 13, 10 (verbal-1-back), n=10, 12, 11 (verbal-2-back), and n=6, 12, 11 (SCWT) for PE, SED and YG, respectively.

For the *verbal 1-back task*, the YG exhibited activations in the right declive, inferior semi lunar lobule, precentral gyrus, insula, superior temporal gyrus, parahippocampal gyrus and left middle temporal gyrus. The PE exhibited activations in the left middle temporal gyrus. No activations were observed for the SED group on the one back task.

For the *verbal 2-back task*, the YG exhibited activations in the right postcentral gyrus, middle temporal gyrus, superior temporal gyrus and left cerebellar tonsil. The PE exhibited activations in the right postcentral gyrus and middle frontal gyrus. The SED exhibited activations in the left superior temporal gyrus, medial frontal gyrus, insula.

Table 1
Socio-demographic details of the study participants.

Characteristics	Groups			p value
	Yoga practitioners (n=13)	Sedentary lifestyle (n=13)	Physical exercise (n=13)	
Age (in years)	27.2 ± 2.7	28.6 ± 4.4	27.6 ± 4.6	0.88*
Education(in years)	17.3 ± 1.3	16.3 ± 0.9	16.3 ± 2.3	0.27*
Gender				0.66**
Male/	6(46.15)/	6(46.15)/	8(61.54)/	
Female	7(53.85)	7(53.85)	5(38.46)	

p-values obtained by *ANOVA and ** Chi-square test.

Table 2
Comparison of cognitive domains, vedic personality type and coping skills of yoga practitioners, sedentary lifestyle and physical exercise individuals.

Domains		Yoga practitioners (n=13)	Sedentary Lifestyle (n=13)	Physical exercise (n=13)	$\chi 2$ value	p value
Coping Skills	Emotion focused	25(0,32)	25(0,29)	25(0,36)	0.75	0.68
	Problem focused	17(0,22)	18(0,21)	18(0,22)	0.48	0.78
	Dysfunctional	22(0,27)	23(0,30)	22(0,30)	0.40	0.82
Coping Skills- individual domains	Self-distraction	5.5(3,8)	6(3,8)	7(3,8)	3.2	0.20
	Active coping	6(4,8)	7(5,8)	7(5,8)	0.64	0.73
	Denial	3.5(2,6)	3(2,6)	2(2,6)	1.12	0.57
	Substance Use	2(2,5)	2(2,2)	2(2,6)	3.49	0.17
	Use of Emotional support	5(3,7)	5.5(2,8)	4(3,7)	1.71	0.43
	Use of instrumental support	5(2,8)	5.5(3,7)	5(3,7)	1.36	0.51
	Behavioral disengagement	2.5(2,6)	3.5(2,8)	3(2,5)	0.75	0.69
	Venting	4(2,7)	3.5(3,6)	4(3,6)	0.90	0.64
	Positive reframing	7(4,8)	6(4,8)	7(3,8)	1.89	0.39
	Planning	6(3,7)	6.5(4,8)	7(5,8)	6.87†	**0.03**
	Humor	4(2,8)	4(2,7)	4(2,8)	0.32	0.85
	Acceptance	6.5(4,8)	5(4,7)	7(5,8)	6.87‡	**0.03**
	Religion	6.5(2,8)	3.5(2,8)	4(2,8)	0.32	0.85
	Self-blame	2(2,5)	4.5(2,6)	4(2,7)	5.53	0.06
Vedic Personality Inventory	Sattva	47(43,60)†,§	40(30,47)	45(36,49)	11.84	**<0.01**
	Rajas	28.5(17,34)	31(28,39) §	29.5(27,34)	5.83	**0.05**
	Tamas	22(17,29)	26(20,37) §	27(18,32)	8.65	**0.01**
Cognition	Digit Symbol Substitution	160.5(130,210)	150.5(115,173)	149(100,195)	2.63	0.27
	Color Trails 1	52.5(28,71)	53.5(37,74)	50.5(28,111)	0.05	0.98
	Color Trails 2	88(12,120)	84(56,124)	101.5(64,149)	1.15	0.56
	One Back- hits	8(6,10)	9(7,10)	9(7,10)	2.39	0.30
	One Back- Errors	2.5(0,5)	1(0,5)	2(0,5)	1.59	0.45
	Two Back- hits	6(3,8)	5(2,7)	5(1,8)	0.26	0.88
	Two Back- Errors	4(0,6)	3(0,6)	3(0,5)	0.06	0.96
	Post graduate Institute Memory Scale	93(88,99)	93(85.5,99.5)	91.25(87,99)	1.48	0.47

† Yoga vs. Physical activity; ‡Sedentary lifestyle vs. Physical activity
§ Yoga vs. sedentary lifestyle ($p<0.01$); p values obtained by Kruskal –Wallis test

Table 3
Product moment Correlation of Triguna with the coping skills.

Groups	Triguna	Emotion focused coping	Problem focused coping	Dysfunctional coping
Yoga Practitioners (n=13)	Sattva	0.37	0.26	-0.04
	Rajas	-0.10	-0.64	-0.53
	Tamas	-0.53*	0.11	-0.08
Sedentary Lifestyle (n=13)	Sattva	0.30	-0.12	-0.43
	Rajas	-0.43	-0.15	0.07
	Tamas	-0.43	0.10	0.42
Physical activity (n=13)	Sattva	0.74*	0.51*	0.25
	Rajas	-0.13	-0.29	-0.39
	Tamas	-0.72*	-0.42	-0.07

* $p < 0.05$, Karl-pearson coefficient of correltion is reported.

Table 4
Total Intracranial volume, GM, WM, WMH, CSF comparison across groups.

	Group			F	p-value
	YOGA	PE	SED		
TIV	1336.86 ± 177.49	1368.83 ± 102.38	1304.53 ± 108.14	0.54	0.58
GM	623.01 ± 66.92	635.37 ± 32.56	601.31 ± 46.74	1.08	0.35
WM	462.35 ± 54.95	466.76 ± 34.14	447.10 ± 37.50	0.55	0.58
CSF	250.80 ± 71.51	266.15 ± 54.87	255.50 ± 50.06	0.16	0.85
WMH	0.702 ± .348	0.54 ± 0.24	0.615 ± 0.31	0.61	0.55

†TIV: Total Intracranial Volume;, ‡ GM: Grey Matter, § WM: White Matter, ¶ WMH: White Matter Hyperintensities, #CSF: Cerebrospinal Fluid; ANOVA was used to obtained p-values.

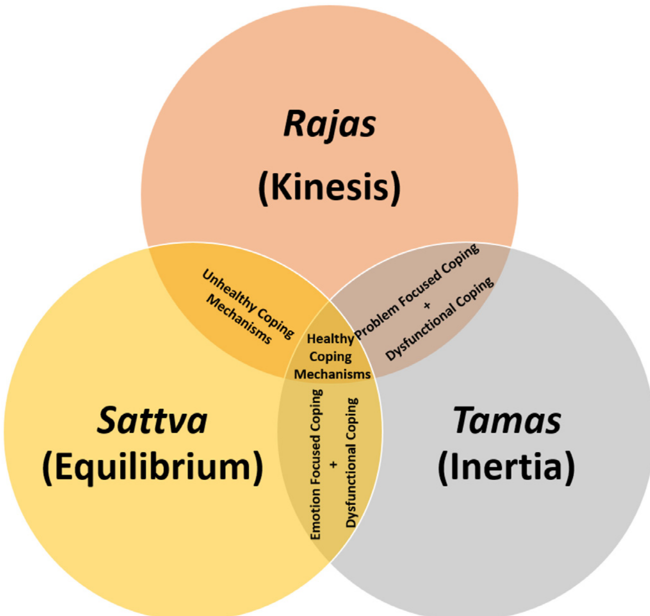

Fig. 4. An Interplay between Vedic Personality (Trigunas) and Coping Mechanisms.

For the *SCWT*, the YG exhibited activations in the left culmen, fusiform gyrus, inferior occipital gyrus, subgyral, precentral gyrus, inferior parietal lobule, precuneus, parahippocampal gyrus, inferior semi-lunar lobule, cerebellar tonsil, superior temporal gyrus, lentiform nucleus, inferior frontal gyrus and right declive, middle frontal gyrus, precentral gyrus, lentiform nucleus, and medial frontal gyrus. The PE exhibited activations in the bilateral middle occipital gyrus. The SED exhibited activations in the left culmen, middle frontal gyrus, interior frontal gyrus, middle occipital gyrus, lentiform nucleus, precentral gyrus and right insula, middle occipital gyrus, superior parietal lobule, inferior parietal lobule middle frontal gyrus, postcentral gyrus, declive and fusiform gyrus. (Supplementary data S2-S9)

3.5. Task based functional connectivity analysis across the groups

Task based functional connectivity analysis revealed differences in connectivity across the three groups for verbal-1-back, verbal-2-back and SCWT (Table 5-7, with most significant connectivity marked in '*'). For verbal-1-back tasks (Table 4), increased functional connectivity was observed for inferior parietal and fronto-parietal regions (Fig. 5: A, B) and reduced functional connectivity in bilateral lateral prefrontal regions (Fig. 5: C, D) in PE compared to SED.

In comparison of YG with PE, for verbal 1-back task, increased functional connectivity was evidenced in inferior parietal attention network (Fig.5: G) with bilateral fronto-parietal network showing reduced connectivity (Fig.5: E, F). YG also showed enhanced bilateral inferior parietal dorsal attention network connectivity with precuneous (Fig.5: H) and fusiform gyrus (Fig.5: I).

For verbal 2-back task (Table 6), enhanced connectivity for right frontoparietal attention network was observed (Fig. 6: A, B), while reduced connectivity between left fronto-parietal and cerebellar regions (Fig. 6: C) was observed in PE with respect to SED group Further, frontal and inferior parietal attention networks showed enhanced connectivity in YG compared to both PE as well as SED (Fig. 6: D, E, F, G). Left posterior parietal connectivity with cerebellum was found reduced in YG compared to SED (Fig. 6: H). For SWCT (Table 7), the fronto-parietal attention network showed enhanced connectivity in YG compared to SED (Fig. 7: A, B, –C).

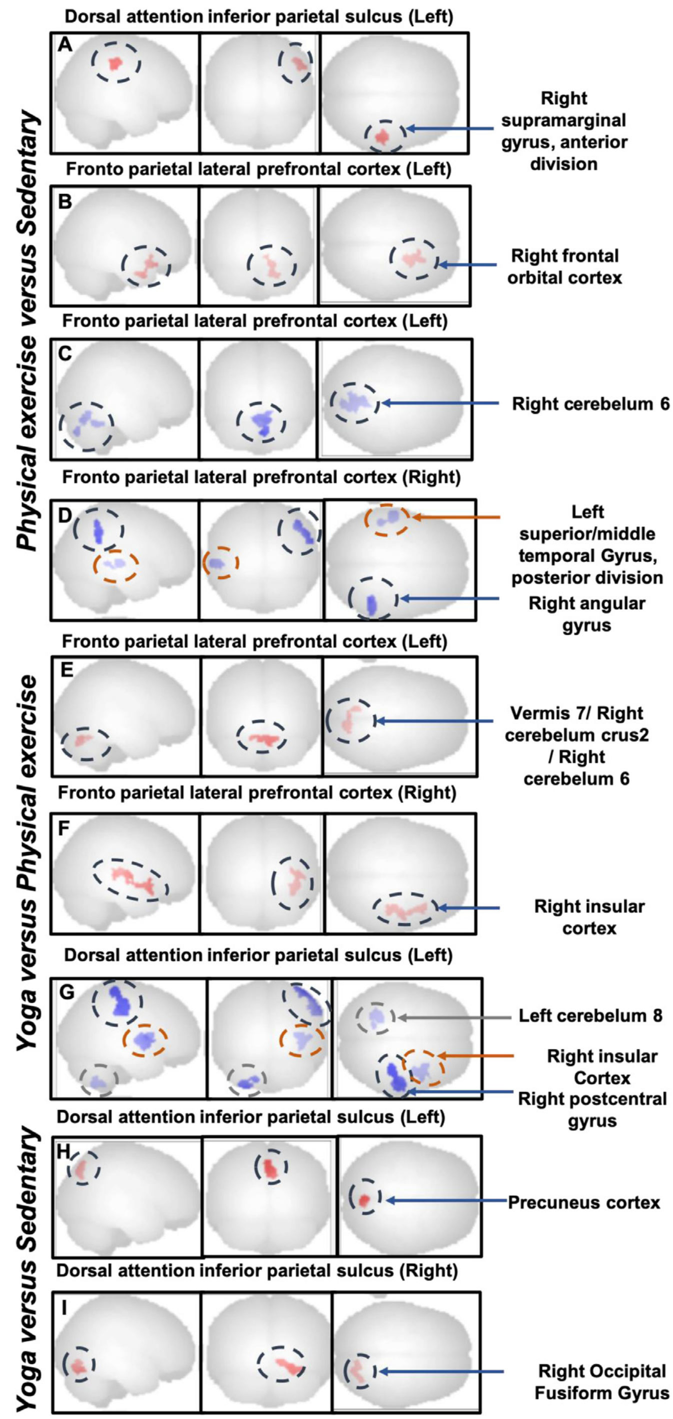

Fig. 5. Verbal-1-back task based functional connectivity for PE versus SED (Sedentary) for the seed: (A) Dorsal attention IPS (Inferior parietal sulcus) (Left), (B) Fronto parietal LPFC (Lateral prefrontal cortex) (Left), (C) Fronto parietal LPFC (Lateral prefrontal cortex) (Left), (D) Fronto parietal LPFC (Lateral prefrontal cortex) (Right); YG versus PE for the seed: (E) Fronto parietal LPFC (Lateral prefrontal cortex) (Left), (F) Fronto parietal LPFC (Lateral prefrontal cortex) (Right), (G) Dorsal attention IPS (Inferior parietal sulcus) (Left); YG versus SED for the seed: (H) Dorsal attention IPS (Inferior parietal sulcus) (Left), (I) Dorsal attention IPS (Inferior parietal sulcus) (Right), at the significance level of height threshold $p<0.002$ uncorrected and cluster threshold $p<0.05$ FWE-corrected (one-sided contrast). The clusters in 'Red' blobs indicate 'increased connectivity' and 'Blue' blobs 'decreased connectivity' for the respective comparison. PE: Physical exercise, SED: Sedentary lifestyle, YG: Yoga group.

Table 5
Task based connectivity difference across the groups for one back task at the significance level of height threshold p<0.002 uncorrected and cluster threshold p<0.05 FWE-corrected (one-sided contrast).

Cluster location	MNI Coordinates x, y, z (mm)	Cluster size (k)
PE>SED		
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Left)		
Right Supramarginal Gyrus, anterior division	+50 -26 +44	222
Seed: Fronto parietal LPFC (Lateral prefrontal cortex)(Left)		
Right Frontal Orbital Cortex	+20 +06 -36	280
PE<SED		
Seed: Fronto parietal LPFC (Lateral prefrontal cortex)(Left)		
Right Cerebelum 6*	+12 -72 -26	542
Seed: Fronto parietal LPFC (Lateral prefrontal cortex)(Right)		
Right Angular Gyrus	+54 -48 +38	313
Left Superior/middle Temporal Gyrus, posterior division	-52 -38 -04	254
YOGA<PE		
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Left)		
Right Postcentral Gyrus / Right Supramarginal Gyrus, anterior division	+52 -24 +44	596
Right Insular Cortex*	+42 +04 +02	464
Left Cerebelum 8*	-28 -52 -58	300
YOGA>PE		
Seed: Fronto parietal LPFC (Lateral prefrontal cortex) (Left)		
Vermis 7/ Right Cerebelum Crus2 / Right Cerebelum 6	+12 -72 -26	275
Seed: Fronto parietal LPFC (Lateral prefrontal cortex) (Right)		
Right Insular Cortex*	+42 -28 +04	478
YOGA>SED		
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Left)		
Precuneous Cortex	+02 -78 +46	230
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Right)		
Right Occipital Fusiform Gyrus	+24 -80 -16	277

'*' indicates connectivity surviving the height/ peak level p<0.002 FDR-correction or cluster level p<0.002 FWE-correction.
†PE- Physical exercise group;, ‡YOGA- Yoga group;, § SED- Sedentary lifestyle group.

Table 6
Task based connectivity difference across the groups for two-back task at the significance level of height threshold p<0.002 (uncorrected) and cluster threshold p<0.05 FWE corrected (one-sided contrast).

Cluster location	MNI Coordinates x, y, z (mm)	Cluster size (k)
PE>SED		
Seed: Dorsal attention FEF (Frontal eye field) (Right)		
Right Cerebelum 6	+10 -56 -22	332
Seed: Fronto parietal PPC (Posterior parietal cortex) (Right)		
Left Frontal Orbital Cortex*	-38 +00 +00	396
PE<SED		
Seed: Fronto parietal LPFC (Lateral prefrontal cortex) (Left)		
Left Cerebelum 8*	+06 -80 -42	1160
YOGA>PE		
Seed: Dorsal attention FEF (Frontal eye field) (Right)		
Left Superior Frontal Gyrus*	-16 +16 +48	407
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Right)		
Right Cuneal Cortex	+04 -74 +38	550
Seed: Fronto parietal LPFC (Lateral prefrontal cortex) (Left)		
Left Cerebelum 8	-08 -78 -44	321
YOGA>SED		
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Right)		
Precuneous Cortex*	+04 -74 +36	1095
Left Inferior Temporal Gyrus, anterior division	-50 -06 -44	266
YOGA<SED		
Seed: Fronto parietal PPC (Posterior parietal cortex) (Left)		
Left Cerebelum 8*	-28 -50 -52	604

'*' indicates connectivity surviving the height/ peak level p<0.002 FDR-correction or cluster level p<0.002 FWE-correction.
†PE- Physical exercise group;, ‡YOGA- Yoga group;, § SED- Sedentary lifestyle group.

4. Discussion

Practicing regular yoga and physical exercises has been shown to help in improving executive functions, memory and other higher-level cognitive functioning. [23,24] Yoga has been studied as an intervention that promotes the cognitive functions in healthy as well as diseased individuals.[23–25] In the current study, the study participants in the three arms - Yoga, Physical Activity and sedentary, did not differ in the cognitive profile and depicted intact cognitive functioning. A previously conducted study revealed that watching television was associated with lower scores on executive function tests while computer use resulted in better performance on executive function and verbal memory tests which is suggestive that not all sedentary behaviors are similar or have negative implications. [26,27] Interestingly, cognitively-engaging exercise seems to depict enduring effects than exercises that are non-cognitively-engaging on executive functions. [28,29] It can be speculated that due to the similar age, educational and professional status of the study participants there was no difference which was observed in the cognitive functions. In addition, no difference was observed in the TIV, gray matter, white matter, white matter, CSF and WMH between the three groups.

Table 7
Task based connectivity difference across the groups for SCWT task at the significance level of height threshold $p<0.002$ uncorrected and cluster threshold $p<0.05$ FWE-corrected (one-sided contrast).

Cluster location	MNI Coordinates x, y, z (mm)	Cluster size (k)
YOGA>SED		
Seed: Dorsal attention IPS (Inferior parietal sulcus) (Right)		
Left Paracingulate Gyrus	+02 +44 -04	262
Seed: Fronto parietal PPC (Posterior parietal cortex) (Left)		
Left Superior Frontal Gyrus*	-20 +00 +50	358
Right Frontal Pole	+44 +56 +14	237
Seed: Fronto parietal PPC (Posterior parietal cortex) (Right)		
Left Paracingulate Gyrus	-12 +08 +50	208

'*' indicates connectivity surviving the height/ peak level $p<0.002$ FDR-correction or cluster level $p<0.002$ FWE-correction.
†PE- Physical exercise group;, ‡YOGA- Yoga group;, § SED- Sedentary lifestyle group..

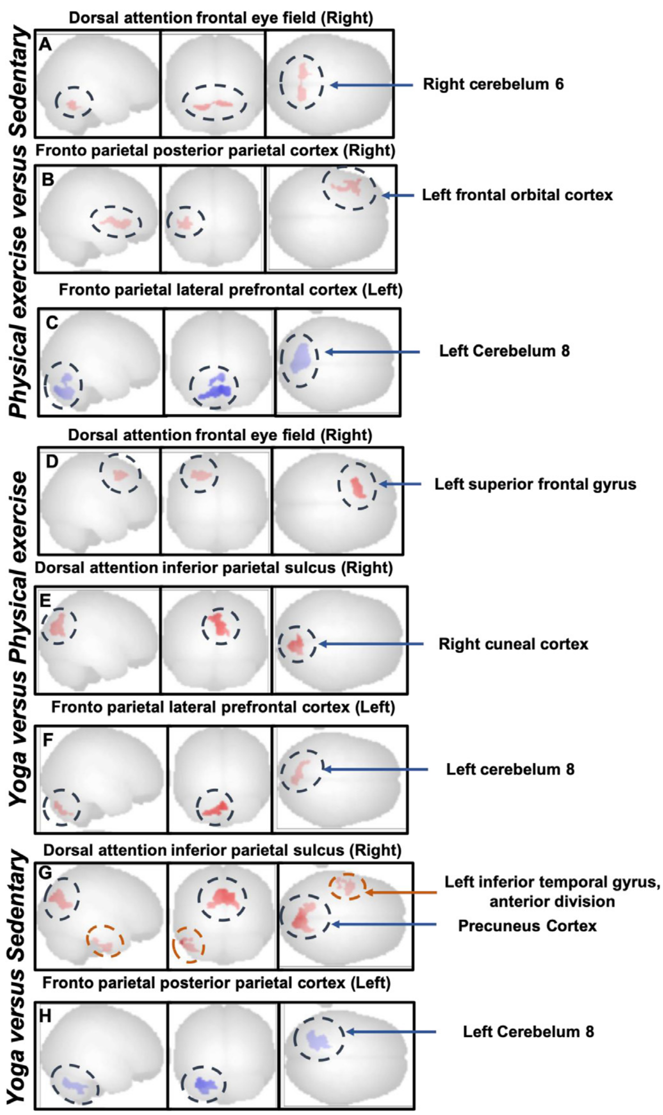

Fig. 6. Verbal-2-back task based functional connectivity for PE versus SED for the seed: (A) Dorsal attention FEF (Frontal eye field) (Right), (B) Fronto parietal PPC (Posterior parietal cortex) (Right), (C) Fronto parietal LPFC (Lateral prefrontal cortex) (Left); YG versus PE for the seed: (D) Dorsal attention FEF (Frontal eye field) (Right), (E) Dorsal attention IPS (Inferior parietal sulcus) (Right), (F) Fronto parietal LPFC (Lateral prefrontal cortex) (Left); YG versus SED for the seed: (G) Dorsal attention IPS (Inferior parietal sulcus) (Right), (H) Fronto parietal PPC (Posterior parietal cortex) (Left), at the significance level of height threshold $p<0.002$ uncorrected and cluster threshold $p<0.05$ FWE-corrected (one-sided contrast). The clusters in 'Red' blobs indicate 'increased connectivity' and 'Blue' blobs 'decreased connectivity' for the respective comparison. PE: Physical exercise, SED: Sedentary lifestyle, YG: Yoga group.

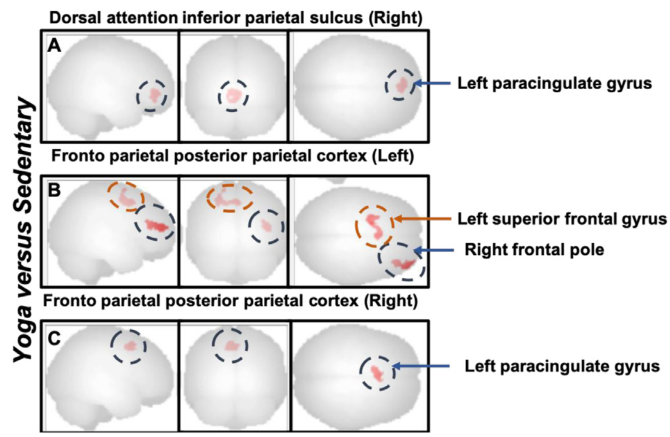

Fig. 7. Stroop Color Word Task (SCWT) based functional connectivity for YG versus SED for the seeds: (A) Dorsal attention IPS (Inferior parietal sulcus) (Right), (B) Fronto parietal PPC (Posterior parietal cortex) (Left), (C) Fronto parietal PPC (Posterior parietal cortex) (Right), at the significance level of height threshold $p<0.002$ uncorrected and cluster threshold $p<0.05$ FWE-corrected (one-sided contrast). The clusters in 'Red' blobs indicate 'increased connectivity' and 'Blue' blobs 'decreased connectivity' for the respective comparison. SED: Sedentary lifestyle, YG: Yoga group.

Our study findings shows greater activity in the YG as compared to the other groups across tasks. The YG on the verbal 1-back task had greater activations of the right hemisphere in comparison to the other groups. Specific brain regions in the right hemisphere such as the right inferior semilunar lobule, precentral gyrus, superior temporal gyrus, parahippocampal gyrus, declive and insula were active during the task for attention in the yoga practitioners. The cerebellum, a brain structure known for decades as integral to the precise coordination and timing of body movements, has more recently been acknowledged to be involved in cognition, specifically executive function. [30] Yoga practitioners in the current study also displayed greater activity of the cerebellum across all tasks.

Differences in patterns of brain connectivity were observed during the fMRI tasks between individuals with different physical activity. Current study observed, in the auditory one back task for the dorsal attention IPS; PE functionally connected with right supramarginal gyrus with enhanced strength compared to the SED and YG groups. And, for fronto parietal LPFC; right frontal orbital cortex was found to be connected in PE compared to the other two groups. The right supramarginal gyrus and right frontal orbital cortex may play a role during the processing of the working memory for individuals who practice regular physical exercise. For the yoga practitioners with respect to both the groups, right insular cortex and right cerebellum were found to be functionally connected with fronto parietal LPFC pathway during *1-back task*. For both, yoga and PE groups there were greater activations in the frontal regions as compared to the SED. The frontal lobe is the hub of higher cognitive functions—including planning, discriminating, abstract thinking, personality, and behavior. Certain breathing practices such as kapalabhati are also referred to as "frontal brain purification," due to the rejuvenating effects it has on the frontal area of the brain. Therefore, engaging in either PE or yoga helps in improving the activity of the frontal brain regions. [30, 31] The parietal lobe is associated with limb movement, understanding speech, and sensing pain. According to recent studies published, the brain scans of this region demonstrated that mindfulness meditation can dramatically reduce sensitivity to pain. [32] The same can be seen in the yoga practitioners in our study.

In addition, Yoga practice is believed to increase the *Sattva guna* and thereby to improve the sense of the internal visceral state supporting homeostasis. Increased connectivity of the insular cortex in the yoga practitioners compared to the other groups is supported by previous literature that states that insula is said to play a wide role in interoception.[32]

For the *2- back task*, when the yoga practitioners were compared to the PE, the dorsal attention pathway FEF exhibited increased connectivity with the left superior frontal gyrus, the dorsal attention IPS pathway with the right cuneal cortex and the fronto parietal LPFC with the cerebellum. The right SFG activity mediates the counteracting processes of inhibitory control and motor urgency. [33] Our results also support a unique role of the right SFG for proactive control of impulsivity and cognitive control that can be seen in the yoga practitioners.

During the *SCWT*, the yoga practitioners in comparison to SED, exhibited increased connectivity of the left paracingulate gyrus with the dorsal attention IPS pathway, left superior frontal gyrus and right frontal pole with the fronto parietal PPC pathway, and the left para cingulate gyrus with the fronto-parietal PPC. Previous studies have also reported the activation of the SFG in old and new yoga practitioners. [33,34] Practicing yoga helps in uniquely activating the SFG which plays a crucial role in cognitive and motor control tasks.[35] However, there was no difference in the cognitive tasks across the groups.

Recent studies have stated the practice of Yoga or other Mindfulness based meditation is associated with larger gray matter volume and long-term yoga has beneficial effects on the integrity of white matter. [36] Contrary to the literature, our study has shown no significant differences in the gray matter, white matter or the CSF levels of the three groups. This could be attributed to the young age of the study participants, years of yoga practice, variation in the type of yoga practice and similarity in their cognitive profiles.

In our study we also evaluated the *Triguna* using the VPI where we found that the yoga practitioners had a higher percentage of *Sattva* trait or *guna* in relation to the other two groups. Regular yoga practice might help develop the *Sattva*(force of equilibrium), which helps in cultivating traits such as calmness, safety, and connection, which is similar to an earlier study that exhibited an improvement in *sattva* in YG. [37] The characteristics of ventral vagal complex are attributed to *sattva guna*, which implies that the practice of yoga may strengthen the social engagement system. [6] The percentage of *rajas* and *tamas* traits were low in the yoga practitioners when compared to the PE and SED. A similar finding was reported by Deshpande et al. that *Rajas* (force of kinesis) was reduced in the YG but significantly better in PE. This depicts that regular practice of yoga will restore equilibrium of the *trigunas that* contributes towards health and wellness. The improvement of *Rajas guna* was found to be higher in those engaging in regular physical exercise suggesting the activation of sympathetic nervous system and the ventral vagal complex. [6]*Tamas guna* was found to be higher in PE and SED in relation to the yoga practitioners.

In the PE individuals, *sattva guna* was positively correlated with all the three broad category of the Brief COPE scale but statistical significance was observed only in the emotion and problem focused coping categories, meanwhile, *tamas guna* was negatively correlated with all the coping categories, but statistical significance was observed only in the emotion focused coping. The reduction of *tamas guna* reflects positive coping mechanisms of individuals engaged in regular physical exercises. A similar trend was observed in the yoga practitioners where *tamas* were negatively correlated with emotion focused coping. *Rajas* were found to be negatively correlated to all the broad categories across the groups which may be attributed to the sympathetic dominance associated with rajas. [6] Yoga and mindfulness meditation in employees has shown to foster positive coping mechanisms which reduce burnout. [38] Exercise is considered vital for maintaining mental fitness, and it can reduce stress. Applying interventions based on mindfulness-based stress reduction may further improve patients' lifestyle and coping strategies with hypertension. [39] Balance of the trigunas helps in cultivating positive coping mechanisms. Exercise is prescribed as an adjunctive treatment for anxiety and depressive disorders. [40] There is only a single study available which have reinforced that the triguna can significantly predict wellbeing dimensions across cultures. [41] Adding the component of triguna in the assessment of mental health disorders can help in understanding the role of inherent human nature in the development of the mental health issues. [42]

Sattva, Rajas and Tamas work together for the purpose of illumination and fostering positive mental health. Disequilibrium in any one of these factors may have an adverse effect on one's health and psychological well-being. [43-45] The balance achieved in the yoga practitioners group may reflect the effect of meditation component of yoga in addition to the physical postures (asananas).

The limitations of the current study are the cross-sectional nature of study and small sample size, making it difficult to generalize the findings. The years of practice of yoga or physical exercise is comparatively less when compared with the existing literature. The yoga participants did not follow a similar school of yoga practices, which may be a confounding factor. The people in SED group also engaged in cognitively engaging activities which could be one of the confounding variable in understanding the effects of yoga and PE on cognition in comparison to the SED. Though such a group has not been studied in the previous literature.

In conclusion, our study revealed that practicing yoga and physical exercise has a significant role in influencing individuals' personality, coping skills, and cognitive functioning. The yoga practitioners had a distinct higher *sattva guna (equilibrium trait)* and preferentially recruited brain areas associated with self-regulation and inhibitory control when compared with other groups.

CRediT authorship contribution statement

Harsimarpreet Kaur: Conceptualization, Methodology, Investigation, Data curation, Writing - original draft, Project administration. **Shefali Chaudhary:** Software, Formal analysis, Resources, Data curation, Validation. **Sriloy Mohanty:** Methodology, Resources, Writing - original draft. **Gautam Sharma:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition. **S Senthil Kumaran:** Conceptualization, Methodology, Software, Validation, Resources, Data curation, Writing - review & editing, Supervision, Funding acquisition. **Nirmal Ghati:** Writing - review & editing. **Rohit Bhatia:** Writing - review & editing. **Ashima Nehra:** Methodology, Writing - review & editing. **RM Pandey:** Formal analysis.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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Ethical statement

This research was reviewed and approved by the institutional review board of All India Institute of Medical Sciences (AIIMS), New Delhi. Informed consent was obtained from all participants.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.imr.2021.100750.

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