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Association Of Sudarshan Kriya Yoga - A Yogic Breathing Practice With Improved Cognitive Abilities: A Cross-Sectional Study On Adolescents Yogic Breathing And Cognitive Abilities: Study On Adolescent

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ABSTRACT

Background: There exist a strong inverse correlation between stress and cognitive abilities in adults and children. This effect is pronounced in adolescents as their stress coping mechanisms are developing.
Objective: The present study aims to explore the effects of yogic breathing practice on cognitive abilities of adolescents.

Methods: The is cross-sectional study comprised of 455 students of 14 (13-17) years mean age. Four schools matching in curriculum, demography and other education related aspects were selected from Bengaluru, India for the study. A total of 218 students were included in the experimental group practicing Sudarshan Kriya Yoga (SKY) for over one year, and 237 were enrolled in control group who did not practice any form of yoga or meditation. Cognitive abilities were tested using RPM, RAVLT and TMT.

Results: The results demonstrated that the SKY group performed significantly better than control group in all the tests. The RPM scores demonstrates a greater percentage population (N) in grade 1 and Grade 2 among the study (SKY) group demonstrating intellectually better. Students from the SKY group scored significantly better in RAVLT immediate recall demonstrating good working memory and verbal learning skills. The students of SKY group performed the tasks in the trail making test better than the control group with good accuracy demonstrating good visual motor skills.

Conclusion: Our study demonstrates better cognitive skills among the SKY practicing group compared to the non-practitioners of same demographic background. The findings could be attributed to lower stress levels and therefore better cognition among children.

Keywords: Sudarshan Kriya Yoga, SKY, Cognition, Adolescent, Stress.

1. INTRODUCTION

Stress has become a ubiquitous part of life. Chronic stressful conditions impair several physiological conditions, leading to poor quality of life. Several research studies state a strong correlation between high levels of stress, anxiety and poor cognitive abilities in adults and children (Bourne Jr, Yaroush RA, 2020; Sandi C, 2013; Taylor L, Watkins L, et.al., 2016; Juster RP, McEwen BS, et.al., 2010). Though a mild amount of stress is shown to have positive correlation with cognition, such as with implicit memory; in long term, excess stress has detrimental effects in the cognitive response of an individual (Sandi C, 2013). Excessive amount of acute or chronic stress impairs hippocampus and prefrontal cortex related functions such as complex flexible reasoning and explicit memory (Sandi C, 2013). The intensity and duration of stress correlates with the severity of cognitive decline (Alkadhi K, 2013). This correlation of stress and poor cognition particularly effects adolescents who have underdeveloped coping mechanisms and are increasingly facing novel stressful situations (Lupien St, at.al., 2007). WHO quotes 10-20% of children by the age of 14 years start experiencing mental illness and about 75% of them suffer from anxiety by the age of 20 years (WHO-21st June 2020). The pandemic situation has added to stressors among the youths with limited contact with the near and dear ones with increased isolation, loss of structure and routine in life (Rosen ML, et.al., 2021). Previous research studies on yoga demonstrate its positive effects on mental health. Yoga improves the executive functions in children, such as higher order cognitive processes, which in turn are associated with academic ability, regulation of emotions, conscience, and moral development (Daly LA, et.al., 2015; Hagins M, Rundle A, 2016). Yogic breathing and Pranayama have shown positive effects on neuro-cognitive, psycho-physiological, respiratory, biochemical and metabolic functions of the participants when practiced under the supervision of a trained teacher (Saoji AA, Raghavendra BR, et.al., 2019). In a study, where effects of yogic breathing and working memory training on cognitive communicative abilities of middle aged adults were studied, it was found that yogic breathing enhanced training effects and improved the cognitive communicative abilities (Shao GN, Kim H, Imran SM, 2020). Our study explores the benefits of a unique rhythmic breathing technique, Sudarshan Kriya Yoga (SKY) which has its roots in yoga. SKY is usually taught through a 4-day workshop. Participants learn SKY breathing technique and meditation designed to reduces stress and increase well-being. Numerous research studies on SKY technique in the past have highlighted its benefits on mental (Chandra S, et.al., 2017; Sharma A, et.al, 2017; Toschi-Dias E, et.al., 2017) emotional (Gootjes L, Franken H, Van Strien JW, 2011; Warner A, Hall K, 2012) and overall well-being (Bhatia M, et.al., 2003; Kiellgren A, et.al., 2007) exploring its role in modulating the parasympathetic nervous system and hence influencing brain and other organ systems to improve human performance (Brown RP, Gerbarg PL, 2005). Studies also reflect the role of SKY in reducing the stress

levels during examination period among college going students (Subramanian S, et.al., 2012). Undergraduate medical students have demonstrated decrease in serum cortisol levels post SKY workshop (Kanchibhotla D, et.al,2020; Kumar S, 2017). However, there exists no study that correlates the effect of SKY on the cognitive abilities of adolescents. A study evaluated the effects of Youth empowerment seminar (YES) program, which incorporates SKY technique, on the impulsive behavior of adolescents. The study results demonstrated an improvement in the mental health and reduction in impulsive behavior post SKY workshop (Ghahremani DG, et.al, 2013). Another study on the same participants demonstrated decreased stress levels and improved emotional and social well-being among children (Kanchibhotla D, et.al., 2021). However, no study, so far, has explored the effect of SKY breathing on the executive functions of an adolescent. Although yoga is gaining popularity in the world, studies on yogic breathing are fewer in number. Breathing is an important physiological function and the impact of its modulation on mind-body systems is increasingly being studied in adults. There is less information on how the breathing modulation impacts the executive functions in adolescents. This is the first study on SKY, a yogic breathing technique, which demonstrates its effects on cognitive abilities of adolescents.

2. MATERIALS AND METHODS

2.1 Study Design

The purpose of the study was to examine the benefits of SKY on the cognitive performance of adolescents. This is a cross-sectional study consisting of a control and a study arm. To minimize interference, separate schools, similar in demography and other education aspects were selected for the study and control arm. A total of four schools were selected. Two schools which had incorporated regular practice of SKY as a part of their curriculum (morning assembly) were enrolled in study group. Students in the age group 12-15 years from these two schools, who regularly practiced SKY breathing for the last one year daily, were enrolled in the study. Other two schools did not have any yoga or meditation technique as a part of their curriculum. Students in the age group 12-15 years from these two schools were enrolled in control group. It was also ensured that they did not have a personal practice of yoga or meditation. Cognitive abilities such as visual-motor skills, memory and non-verbal intelligence were tested using standard test instruments. Instructions for all the measures were clearly mentioned before administrating the test. The tests were administered at a single time point.

2.2 Subjects

455 students were enrolled for the study. 237 students from the two schools practicing SKY breathing formed the study group, while 218 students formed the control group. Average age of students from all four schools was 14 (13-17) years. All the four schools were from Bengaluru, India and had similar curriculum and student teacher ratio. It was ensured that all students came from similar socio-economic background. Students with any learning disabilities were excluded from the study. All students were provided an informed consent explaining the purpose and procedure of the study, to be signed by their parents.

2.3 Intervention

The study group had undergone a four-day workshop to learn the SKY technique at the start of academic year. The workshops were facilitated by experienced instructors trained by the Art of Living Foundation. The participants were given a home practice and were encouraged to practice daily. SKY is a cyclic rhythmic breathing technique having its roots in traditional yoga. SKY is a 25 minutes' procedure including three yogic components – pranayama (Ghahremani DG, et.al, 2013). Om chanting and Sudarshan Kriya. The pranayama uses Ujjayi breath. Ujjayi involves experiencing the conscious sensation of the breath touching the throat (Tomar R, et.al., 2011). This slow breath technique is performed at a rate of 2–4 breaths per minute (bpm). This technique improves lung capacity allowing more passage of air through the lungs (McCraty R, Zovas MA, 2014). Om is chanted three times with prolonged exhalation. Lastly, Sudarshan Kriya rhythmic breathing is done with slow (20 bpm), medium (40–50 bpm), and fast (60–80 bpm). A SKY session is done in a seated posture and eyes closed during the session. In our study, the adolescents in the SKY group were practicing SKY breathing daily as a part of the morning assembly in their schools.

2.4 Test Measures

2.4.1 Raven's standard progressive matrix (RPM): This test measures non-verbal intelligence of an individual. The test has sixty diagrammatic puzzles divided into five sections of twelve puzzles each. A part is missing from each puzzle. The subject needs to identify the missing part correctly among the four options provided. In each set, the level of difficulty increases as the questions progress. Subjects were timed for 30 minutes and instructed to perform the test to the best of their ability. Instructions were given as per Raven's standard progressive manual (Raven J, JH Court, 1938; Raven J, et.al, 1994). Every correct answer was awarded one point while incorrect answer was not awarded any point. The total score was calculated by adding all the correct responses and ranged from 0-60. The total score was converted into percentile score and further graded into five grades.

Grade 1 was awarded if an individual's score was at or above the 95th percentile for people of his/her age. Grade 1 indicates intellectual superiority.

Grade 2+ and grade 2 were awarded if the score was placed at or above the 90th percentile and at or above the 75th percentile and respectively. They indicate above average intelligence.
Grade 3+ and 3 indicate average intelligence and were awarded if the score was greater than the median or 50th percentile and fell between the 25th and 75th percentiles for their age respectively.
Grade 4 and 4- indicate below average intelligence and were awarded if the score was placed at or below the 25th percentile at or below the 10th percentile respectively. Finally grade 5 indicates defective intelligence and was given if the score was placed at or below the 5th percentile for their age-group.

2.4.2 Trail Making Test: Trail making test (TMT) measures the cognitive parameters such as speed processing, mental flexibility and visual-motor skills. The test was conducted in two parts Part A and Part B. Part A consisted of numbers encircled from one to twenty-five. The participant had to join the points from one to twenty-five without lifting their pen from the paper. Part B consisted of numbers and alphabets in numerical and alphabetical order respectively. The

participant had to start from point one and join the points alternating between alphabets A to N and numbers one to thirteen. Part A assessed the visual search and motor speed skills while part B judged higher cognitive skill such as mental flexibility. The time taken by each student to finish part A and part B was recorded in seconds. The students were scored on the basis of time taken to perform the test.[29]

2.4.3 Rey Auditory Verbal Learning test: Rey Auditory verbal learning test (RAVLT) measures cognitive abilities like memory and verbal learning skills. The test was a neurophysiological assessment in which the subject was presented with two list of fifteen unrelated nouns (List A and List B) (Gale SD, et.al, 2007). The first list, also known as the stimulus list, was read to the subjects who thereafter verbally recalled the list. The list was read for five times and free recall was given to the participants each time. Further, List B also known as distractor list was read to the participants to intervene the memory of subjects following the five trials. Finally, the subjects were asked to recall the initial stimulus list verbally without the list being repeated to the participants. Mean value of correct responses recalled for each trial were calculated and classified as immediate recall (trial 1-5), delayed recall (after the distractor list, Trial 6) and recognition (Trial 1-5+6).

2.4.4 Data Analysis:

Data entry was done in Microsoft Excel and analyzed using IBM SPSS Statistics, Version 23.0. Demographic variables were tabulated and represented using proportions (%). Quantitative data was presented with mean and SD and analyzed using Student's T (paired and unpaired) test wherever applicable to obtain p values. Difference between scores was noted as significant if the p value was less than 0.05. Apart from the descriptive statistical tools, Univariate analysis and ANOVA (single factor) was used to determine the significance. Reliability and internal consistency were calculated using Cronbach alpha.

3. RESULTS

Table 1 depicts demography of the participants from two groups. Male to female ratio in the study group and control group was 45:55 and 48:52 respectively.

Table 1 Participants Demography (N=455) n(%)

Characteristics	**Type**	**SKY GROUP (N=237)**	**CONTROL GROUP (N=218)**	**All Participants**	**P value**
Gender n(%)	Male	107 (45.1%)	105 (48%)	212	0.34
	Female	129 (54.9%)	113 (52%)	242	
Age (years)	Mean (SD)	14 (0.77)	14 (0.74)	14	0.05

	Min.	13	13	13	
	Max.	16	17	17	

3.1 Raven's Progressive Matrix

Table 2 demonstrates the average accuracy scores obtained by two groups in RPM test. Table 3 demonstrates the grades obtained by the percentage population in both the groups. SKY group had higher average scores than control (p value <0.05). The percentage population in the grade 1 and grade 2 are higher in the study group compared to the control group demonstrating better intelligence in the study group. Females in the study group perform better than the control group. Reliability score for the tool was calculated using cronbach alpha which was 0.868.

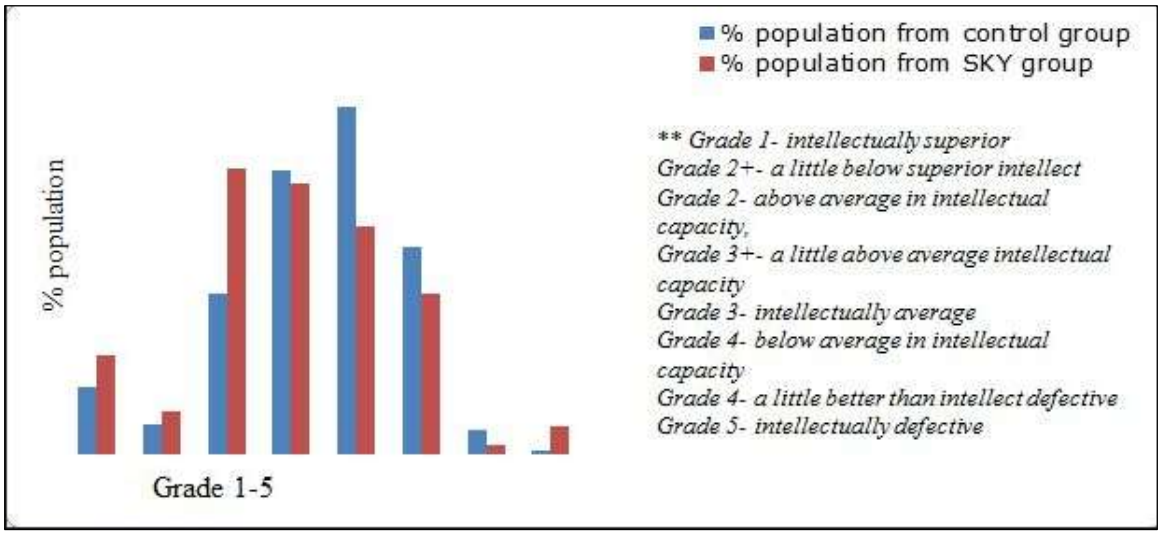

Figure 1 demonstrates grading of students as per their intelligence for both control and study population. The scores obtained in the Raven's Progressive matrix are grouped into grades in decreasing order of intellect to analyze intelligence among the students. Lower grades indicate high levels of intelligence. SKY population performed at a level of grade 1, 2 and 2+ whereas control group scored mostly on grades 3,3+, 4.

TABLE 2: Overall RPM Scores - mean (SD) and p value

Average accuracy : Mean (SD)	**SKY (n= 237)**	**Control(n=218)**	**p value**
Total	44.2 (7.7)	42.9 (6.5)	0.04*

Male	42.8 (8.7)	43.2 (6.14)	0.8
Female	45.4 (6.7)	42.4 (6.8)	0.001**

Paired t test: <0.05 – significant

<0.001- Highly significant

TABLE 3: Study and Control Population grading between groups		
	Number of students from SKY group N(%)	Number of students from Control group N(%)
Grade 1	20 (8.4%)	4 (1.8%)
Grade 2	54 (22.8%)	38 (17.5%)
Grade 3	110 (46.41%)	130 (59.9%)
Grade 4	35 (14.77%)	45 (20.7%)
Grade 5	4 (1.68%)	1(0.46%)

Paired t test: <0.05 – significant

<0.001- Highly significant

3.2 Rey Auditory Verbal Learning Test (RAVLT)

Table 4 depicts the average RAVLT scores between the two groups indicating their performance in visual motor skills and memory. As noted in the table recognition mean values, immediate and delayed recall scores of the students practicing SKY are significantly higher in comparison to control group. Table 5 demonstrates the differences in RAVLT scores between the two genders. Both the genders show higher scores in SKY group, however male SKY group have significantly higher scores than their counterparts in control group.

TABLE 4: Overall RAVLT Scores - mean (SD) and p value

	SKY group	Control group	P value
RAVLT- Recognition	63.6(11.5)	59.5(13.4)	<0.001**
RAVLT- Immediate Recall	52.2(9.6)	48.7(11.4)	<0.001**
RAVLT- Delayed Recall	11.5(2.6)	10.8(2.6)	0.01*

Table 5 : Distribution of RAVLT scores between the study groups and genders			
Males			
	SKY group	**Control group**	**P value**
RAVLT- Recognition	61.0(10.9)	55.9(13)	0.003*
RAVLT- Immediate Recall	50.16(8.9)	45.9(10.9)	0.005*
RAVLT- Delayed Recall	10.9(2.6)	9.9(2.7)	0.009*
Female			
RAVLT- Recognition	65.4(11.6)	62.7(12.9)	0.092
RAVLT- Immediate Recall	53.6(9.8)	51.1(11.3)	0.066
RAVLT- Delayed Recall	11.8(2.5)	11.6(2.3)	0.433

Paired t test: <0.05 – significant

<0.001- Highly significant

3.3 Trail Making Test

Table 6 demonstrates the mean time taken by the students from both the groups to perform the Trail making test representing mental flexibility and visual-motor skills (Bowie CR, Harvey PD, 2006). SKY group performed significantly better in task A p value 0.032 however both groups performed same in task B. Both males and females of SKY group perform better than control group but failed to show any significance. Further,

error made by the participants were also marked between the groups. In both the tasks, the study group made less errors than the control group signifying the accuracy of the task performed.

Table 6: Mean Time analysis to complete TMT task A and task B

OVERALL	**SKY**	**Control**	P **value**	**SKY**	**Control**	P **value**
	Task A			**Task B**		
Mean (Time in mins) (SD)	0.39 (0.3)	0.45 (0.4)	0.032*	1.14(3.6)	1.14 (0.7)	0.99
MALE						
Mean (Time in mins) (SD)	0.41 (0.2)	0.49 (0.5)	0.156	1.02 (0.8)	1.16 (0.8)	0.215
FEMALE						
Mean (Time in mins) (SD)	0.37 (0.3)	0.42(0.23)	0.120	1.23 (4.7)	1.12 (0.6)	0.807

Paired t test: <0.05 – significant

<0.001- Highly significant

TABLE 7: Errors among the study and control population

	No. of Participant (N)	
TMT	**Error**	
	Task A	Task B
SKY group	16	70

Control group	29	79

4. DISCUSSION

The present study explores association of SKY practice with improvement in cognitive abilities in adolescents. To the best of our knowledge this is a pioneer study which demonstrates the long-term impact of a breathing technique on the visuo-spatial, visuo-motor, verbal and non-verbal learning skills, as well as mental flexibility and memory in an educational set up. Our finding indicates the practice of Sudarshan Kriya may be the reason for improved cognitive abilities among the SKY group. The scores of SKY group have been consistently higher compared to the control group for all three tests, suggesting SKY technique might have a role in improving cognition. A proposed model to understand the effect of SKY on cognitive functions include balance of central nervous system.

4.1 Implications of SKY technique on non-verbal intelligence.

The SKY group showed higher scores for fluid intelligence as measured by Raven's standard progressive matrix (RPM). Students who practice yoga and meditation are more alert, have better sense of perception and therefore can minimize errors during visuo-motor performance, as well have an improved speed of performance (Carter KS, Carter III, 2016). A review on the neurophysiologic mechanism of the SKY technique states its ability to activate the autonomic nervous system, which produces a state of alertness and calmness which further modulates the structures within the brain (Sharma VK, et.al, 2006). Another study suggested variation in cognitive functions is not only proportional to brain size but also modifiable with breath based trainings such as SKY. The author adds that physical and mental training of mind is responsible for optimized cognitive performance of an individual.[31] A study highlighted the significance of yoga and meditation practices in increasing the gray matter volume and better cognitive performances (Brown RP, Gerbarg PL, 2005). Gender wise analysis for fluid intelligence highlights that females SKY practitioner perform significantly better than their female counter parts from control group.

4.2 Implications of SKY technique on memory and verbal learning skills

The results from Rey Auditory Verbal Learning Test (RAVLT) imply that students practicing SKY have better verbal memory than their peers who do not practice any holistic techniques. Our results indicated better recognition and retention in SKY practitioners. Under stress, glucocorticoids are known to impair the declarative memory performance affecting the cognitive functions, which are dependent on the hippocampus (WHO-21st June 2020). Improved cognitions could be explained by increased mental processes and faster information processing in children post intervention (Froeliger B, et.al, 2012). A randomized control study among college going students demonstrated the benefits of SKY in reducing stress, depression and anxiety with improved positive emotions such as mindfulness and social connectedness. Studies have observed that there is a direct relation between stress, working memory and learning capacity of an

individual (Kanchibhotla D, Subramanian S, Kulkarni S, 2020). Another study demonstrated positive effects of yoga practices on cognitive abilities of 82 children in the age group of 11 to 15 years studying in residential schools located in rural India. Results highlighted significant improvement in memory quotient of students who practiced the twelve-week yoga intervention (Qin S, et.al, 2009).

4.3 Implications of SKY technique on visuo-spatial, visuo-motor and mental flexibility skills

The Trail making test evaluates a student's visuo-spatial, visuo-motor and mental flexibility skills by means of two tasks. Our results demonstrate that the students in the SKY group have improved visuo-motor skills. However, there was no difference among the two groups in case of mental flexibility. A study evaluated the effect of yoga practices on children and the results demonstrated statistically significant results using Stroop Color-Word Task, Digit Symbol Substitution Test, digits Span Test and Trial Making Test in the favor of yoga practices, in comparison to children's performance at the beginning of the study (Verma A, et.al, 2014). Irrespective of gender, our results still demonstrate a significantly higher performance by the SKY group. A possible explanation for above results could be improved meta-awareness and alertness as a result of yogic practice, that may result in faster executive and cognitive processing without the distraction of mind wandering (Purohit SP, Pradhan B, 2017). The study in its all novelty does not rule out the option of self-selection among the subjects of study. Since it is a single time point study, further studies are required to ensure the reproducibility of the intervention among the students. This will help the educational policy makers to standardize the tool in large educational set ups. Also, a pre-post analysis of the students 'mental health will validate the results in support of the intervention alone.

5. CONCLUSION

The results indicate an association between improved cognitive abilities and SKY practice amongst adolescents. Yogic breathing techniques like SKY have a role to play in improving brain functions and hence the ability to perceive, understand and learn. Increased mind-management with such holistic techniques can facilitate growth of intellectual potential among the youngsters which may benefit the individual and society as whole.

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