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Original Research Article

Yogic Breathing as a Tool to Improve Working Memory among Rural School Children

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ABSTRACT

Background: Literature supports that for overall development of mental as well as physical health and academic success, working memory is an important necessity. Low childhood Socioeconomic status (SES) negatively affects the development of cognitive functions. Right nostril yoga breathing (RNB) and alternate nose breathing (ANB) are fairly simple and children can be taught to do this with practice easily.

Material and methods: It was a randomized pre -post study with a total of 48 students (25 boys & 23 girls) in an age group between 10 to 14 years. Each group comprising of 24 students were assigned to do RNB and ANB for 30 days. Model based on The Wechsler Intelligence scale for children in native language was used to test the working memory of the students before and after 30 days intervention.

Results: Average age of the students was 13.10 years. Modified B. G. Prasad was used to define socioeconomic status and all fitted into the Lower Socioeconomic class. There was an improvement in all the three subsets of working memory in the post test score of both the group. Using Cohen's D analysis, the effect size was large for Digi Span Forward with both RNB and ANB intervention. (1.12 vs 1.16) Both practices showed a medium effect size on Digi Span Backward assessment. (1.41 vs 1.20). In the more complex Letter Number Sequencing assessment , the effect size was larger after practicing ANB and medium after practicing RNB.(1.16 vs 0.91).

Conclusion: Support in the form of this inexpensive, simple intervention like yogic breathing techniques might help to improve the working memory skills among these impoverished children who have too many environmental and social stressors hampering their cognition.

Keywords: Working Memory, Yoga, Mindfulness, School Students, Rural Health, Socioeconomic Status

INTRODUCTION

A child's innocent world should be full of being playful, happy and inquisitive. They need to be encouraged to develop their unique personalities and achieve a balance between their own strengths and social expectations by using their cognitive skills. Cognition is a combination of skills that involves attention, learning, memory, language and visuospatial skills which help in carrying out our day-to-day activities .[1]Working memory is a part of this cognitive communication ability and is required for reasoning,

mathematic problem solving, language and many other aspects of learning.[2] Literature supports that for overall development of mental as well as physical health and academic success, working memory is an important necessity.[3]

According to the latest Annual Status of Education Report (ASER-2022) comprising of 616 rural districts, in spite of 11% increase in rural government school enrolment, there is a decline in basic reading and arithmetic skills of younger children.[4] Reasons for the poor academic performance among rural children who belong to low socioeconomic status (SES) seems to be multifactorial. Chronic stress, poverty, less stimulant environment at home, availability of schools in their village, teacher- student ratio, good infra structure in the school, language barriers are the main hurdles. Economic survey 2022-2023, notes that 65% of the country's population lives in rural areas and 75% among them earn less than Rs. 5000/per month.[5] Low childhood SES negatively affects the development of cognitive functions. A longitudinal study observed that children belonging to low socioeconomic status at birth showed lower Working Memory(WM) performance at middle school.[6] Lower SES adolescents were found to have poor working memory performance and smaller hippocampal and Dorso Lateral Prefrontal cortex (DLPFC) volumes than their higher SES peers.[7]A meta-analysis of 64 studies with 37,737 participants found that low socio economic status was significantly associated with both simple and complex working memory task involving both verbal and visuospatial tasks.[8] Felner et al in his study among students belonging to disadvantage background showed that these students suffered social, emotional and academic adjustments.[9]

Working memory has many interlinked components. It has an important component that helps us resist distractions and remain focused when completing a task. Children facing working memory problem have difficulty in staying focused. It has been proposed that attention is only minimally involved in working memory maintenance but very much required for encoding and manipulation of information in working memory.[10] Newby et al have shown that by increasing the power of attention, capacity of working memory can be increased.[11] Varied interventions like music therapy, computerized programmes, mindfulness meditation, Taekwondo and yoga have been used among children to focus on training direct attention. But most of the above-mentioned practices are beyond the scope of children growing up in below poverty line (low SES). The most easy and inexpensive among the abovementioned interventions suitable for these children can be yoga.

Yoga the ancient practice with its origin in India is known to help in sustaining the cognitive control especially in the area of memory and attention by its different asanas, breathing techniques and meditation. Pranayama, an art of regulating the breath is an integral part of yoga. They regulate breathing by altering rate, rhythm, depth and attend to the autonomic process of breathing. Attention to breathing brings this autonomic process under volitional control and renders this activity more controlled and goal directed by using cognitive resources like working memory, planning flexibility and inhibition. [12] Gamma oscillations are forms of cortical activity linked to cognition and higher cortical functions and which can be observed in consciously controlled breathing like yogic breathing.[13] A study in Pakistan analysing neural correlates of Cognitive function among disadvantaged children in rural Low Middle Income Countries (LMIC) showed that higher executive functions and verbal activity was linked to high frequency gamma neural oscillations.[14]Among the various components of Pranayama, right nostril yoga breathing (RNB) and alternate nose breathing (ANB) are fairly simple and children can be taught to do this with practice easily. Executive functions, Perceived Stress test, motor skills, Reaction time were significantly improved in respective study population performing RNB, LNB and ANB.[15,16,17] Awareness of breath while practicing ANB and RNB becomes a form of practising mindfulness technique. Literature on the effects of yoga on the brain health ,show an increase in hippocampus grey matter density, cortical thickness in left prefrontal lobe and in other areas like amygdala, cingulate gyrus.[18] A recent cross sectional study using fMRI found that there is a greater resting state anteroposterior functional brain connectivity between medial pre frontal cortex and right angular gyrus among yoga practioners compared to non-practicing controls.[19] These changes lead on increased relaxation, increased alertness and reduced stress and a greater

sense of subjective wellbeing which can increase the work performance.

With this background we decided to do a pilot study among school children in the age group of 10 to 14 years belonging to low SES to see the effects of right nostril breathing (RNB) and Alternate Nose Breathing (ANB) on few subsets of working memory.

MATERIALS AND METHODS

This was a randomized pre -post study approved by Institutional Ethics Committee. The study was conducted over a period of six months from May2019 to October 2019.Study was carried out among the students of a Zila parishad primary school in rural Maharashtra. Parents of students who participated in the study were mostly farmers and doing manual labour in construction sites. Modified B. G. Prasad classification which is based on monthly per capita income of the family was used to find the Socioeconomic status .[20] They all fitted into the social class - Class V (Lower Socioeconomic class). Non-probability convenience sampling was used to calculate the sample size. A written protocol explaining in detail the study plan in native language (Marathi) was sent to parents of class 4 comprising of 60 students. Out of 60, a total of 48 students (25 boy's & 23girl's) in an age group between 10 to 14 years participated in the study after getting a written consent from their parents. The inclusion criteria were (i) Students whose parents gave consent to let their children participate. (ii) those who were interested to learn and practice yoga after demonstration of the two-breathing technique by a certified yoga teacher. The following were excluded (i) having any systemic illness (ii) any physical disability or congenital deformity (iii) having ongoing treatment for any illness iv) Parents not giving consent.

Intervention:

The students were divided into two groups by random number table method each group comprising of twenty-four students. Each group was assigned one of the two types of yogic breathing such as Right Nostril breathing and Alternate nostril breathing the students were made to attend a 30-day yoga (5 days/a week) training course during their summer vacation in the school ground between 8.00 am to 8.30 am. First five days (not included in 30 days) the yoga teacher explained in detail the different types of breathing to the designated groups and watched them perform it. Before starting intervention, pre-assessment was taken on 0 day. During the 15 minutes session starting from day 6, initial 5 minutes was spent in again explaining the procedure to students, encouraging them. The actual breathing practice was followed by the students for 10 minutes. For both the groups they were asked to keep their eyes gently closed during the intervention. Both the sessions were conducted in different halls.

a) Right nostril breathing (Suryanuloma Viloma): The student sits comfortably with spine straight and closing the left nostril with ring and middle finger and inhales and exhales through right nostril alone.

b) Alternate nostril breathing (Nadisodhan pranayama): The student sits comfortably with spine erect and is first asked to exhale through both the nostrils. This was followed by inhaling though the left nostril (with the right nostril closed using right thumb) and then exhales through right nostril (with the left nostril closed using right the little finger and ring finger). The student then inhaled through the right nostril and exhaled through the left nostril. This completes one cycle with the approximate duration of six seconds.

Blinding: The statistician who did the randomization and analysed the data was blinded**.**

Assessments:

A model based on The Wechsler Intelligence scale for children, 4th edition subset Digit span forward (DSF) and Digit span backward (DSB) and Letter number sequencing (LNS) were used to test the working memory of the students before and after 30 days intervention.[21] These three subsets have been researched thoroughly and are known to have good psychometric properties. Pre and post yoga intervention test had separate numbers and letter sequence. DSF: In which the participant was read a sequence of numbers and then he/she recalled the numbers in the same order. DSB: In which the participant recalled the numbers in reverse order, thus assessing a higher load manipulation in WM. Each assessment had a sequence length of 2 to 4 numbers

with 2 trials each followed by the actual test LNS: Here the participant was read a series of numbers and letters and asked to recall the numbers in ascending order and the letters in alphabetical order. Each correct attempt was scored as 1 and if wrong 0. The final score was how many correct attempts out of 10 trials. Children were tested individually in a calm area of the school. Measures were administered in native Marathi by their school teacher who was trained by the first author.

Data analysis: Data coding and entry was done in Microsoft Excel spread sheets and descriptive and inferential statistical analysis was done by using SPSS version 21 (Statistical Package for Social Sciences) software. Descriptive analysis was done by Frequency, proportion, mean, median, and standard deviation. Significance of paired data was analysed by Paired t test. P value less than 0.5 was considered statistically significant. Size of the effect was quantified using Cohen's d (1998). Effect size of 0.2, 0.5 and 0.8 were considered as small, medium and large respectively.

RESULTS

Table 1: Demographic details along with anthropometric measurements

Age (Years)	13.10 ± 1.79
Total participants	48
Male	25
Female	23
Wight (Kg)	25.7 ± 2.72
Height (cm)	121.2 ± 3.69
BMI kg/ m^2	17.1 kg/m^2
Education	Class 4 students
Socio economic status	BG Prasad class V

Table 2: Pre and post-test values after practicing RNB, ANB on WM variables

	RNB-Mean ± SD	**ANB-** Mean ± SD
DSF		
DSF-Pre	4.95 ± 1.39	4.66±1.40
DSF-Post	6.08 ± 1.28	5.83±1.52
P value	0.05*	0.05*
DSB		
DSB-Pre	5.12±1.91	5.66±1.85
DSB-Post	6.54±2.02	6.88±2.00
P value	0.05*	0.05 *
LNM		
LNM -Pre	6.29±1.64	4.70±1.68
LNM - Post	7.20±1.48	6.37±1.49
P value	0.05 *	0.05*

RNB-Right nostril breathing ANB- Alternate nose breathing WM-Working Memory
DSF- Digi span forward DSB- Digi span backward
LNM- Letter number sequencing

Table 3: Summarised Effect Size

Method	**Assessment Technique**	**Paired Difference**	**Effect Size***
RNB	DSF	1.12	Large
ANB	DSF	1.16	Large
RNB	DSB	1.41	Medium
ANB	DSB	1.20	Medium
RNB	LNM	0.91	Medium
ANB	LNM	1.66	Large

*Cohen's D Small 0.2, Medium >0.5, Large >0.8
RNB-Right nostril breathing ANB- Alternate nose breathing
DSF- Digi span forward DSB- Digi span backward
LNM- Letter number sequencing

The purpose of this study was to assess if mindful breathing techniques (RNB and ANB) can be taught to students from low SES to improve their working memory. Average age of the students was 13.10 years. In the RNB group, the pre test scores for LNS (6.29) was slightly greater than the DSF, DSB tasks. Among the ANB group, pre-test score for DSB (5.66) was slightly more.

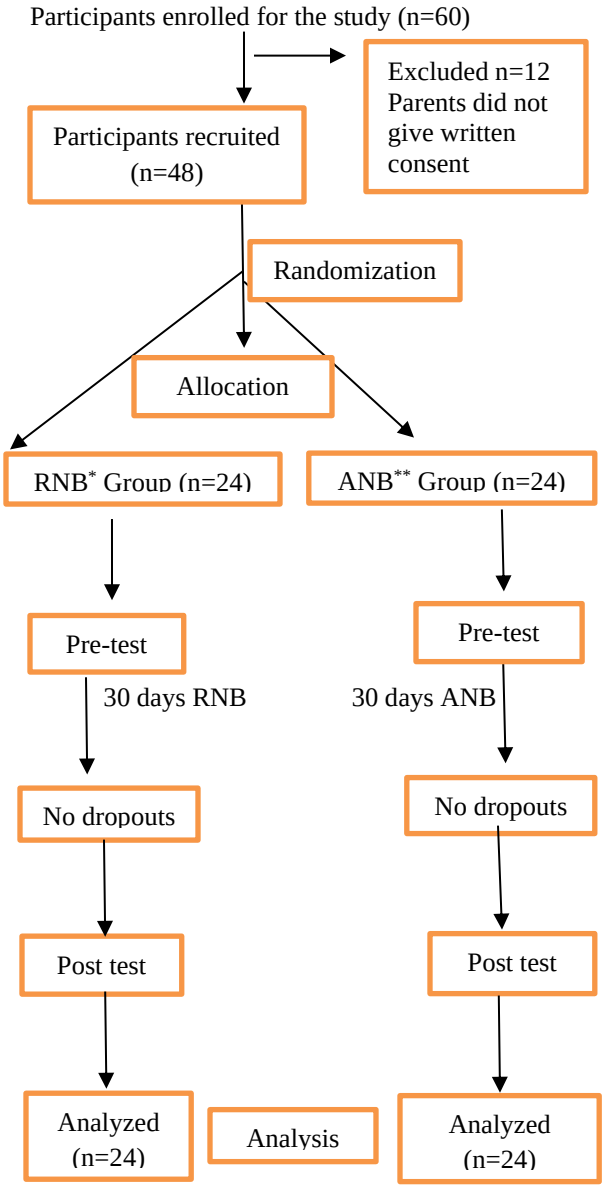

Fig 1: Flow Diagram of participants enrolment, allocation and intervention: *RNB: Right nostril breathing, **ANB: Alternate nose breathing

There was an improvement in all the three subsets of working memory in the post test score of both the group. Post intervention DSF task which primarily involves rote memory and auditory sequential processing significantly improved after both RNB and ANB practice. (6.88,5.83 p >0.05) Using Cohen's D analysis, the effect size was large for DSF with both RNB and ANB intervention. (1.12 vs 1.16) Post intervention DSB task which demands to transform and manipulate information while maintaining the same in storage, mean scores were greater than pre-test scores (6.54,6.88 p >0.05). Both practices showed a medium effect size on DSB assessment. (1.41 vs 1.20).In the more complex LNS assessment , the effect size was larger after practicing ANB and medium after practicing RNB (1.16 vs 0.91).

DISCUSSION

Breath controlled practice are known to help all the components of working memory Improved verbal and spatial memory in children were observed after practicing ANB, RNB and LNB.[22] Electroencephalography (EEG) and Magnetoencephalography and behavioural measures have shown that Unilateral nose breathing increases the activity in contralateral hemisphere. Imran Khan et al in their study on EEG signature change during unilateral yogi nasal breathing have reported that dominant airway unilateral nose breathing is associated with brain changes in frontal and parietal left hemisphere whereas non dominant breathing has diffuse bilateral effects in posterior and central cortices.[23] Karamjit Singh et al in their study have found that right nostril yoga breathing lead to an significant increase in the level of oxyHb and total Hb in the left prefrontal cortex(PFC) which indicates increased activity.[24] Evidence suggest that during selective updating of WM, functional MRI shows activation in the dorsolateral prefrontal cortex, cingulate and parietal cortex, substantia nigra and ventral tegmental area.[25] Thus the rhythm of cerebral hemispherical dominance with respect to right nostril breathing seems to play an important role in cognition and working memory. In our study, it was task DSF which showed more effectiveness after RNB practice. Practice of Alternate nostril breathing(ANB) is known to have improved cardiac functions, lowered systolic and diastolic blood pressure ,cognitive response and reaction time.[26] Telles et al in their study on hemisphere specific EEG changes related to ANB , showed a decrease in frontal theta band and a decrease in the amplitude of beta wave band over right occipital region after practicing ANB which suggested decreased mental activity .[27] This can be attributed to

the harmonizing or balancing effect associated with ANB .In our study the effect size was large following ANB intervention in the most complex LNS task and the simple DSF compared to RNB . An analysis of prospective cohort study on children's working memory and its association with socioeconomic disadvantages showed that children from lower SES scored less on all WM tasks and the biggest gap reflected in task involving executive control (DSB, LNM).[28] Another author has suggested an interesting link between working memory and yogic breathing due to the role of respiratory component in the phonological loop of verbal working memory tasks.[29]

Mindfulness meditation has been shown to improve working memory functioning and capacity by causing changes in the structure, neural activity and functional connectivity in various regions of the brain. A longitudinal study published in scientific reports nature research, showed that following 40 days of short-term mindfulness meditation training, there was an increase in cortical thickness in the left pre cuneus and left superior parietal lobe. In the same study the functional assessment using fMRI showed decreased amplitude of low frequency fluctuations(ALFF) and these structural and functional changes were accompanied by reduction in depressive scores and anxiety traits.[30] Hagen et al in their recent article have noted that after 8 weeks of yoga intervention , the study participants demonstrated increased awareness of importance of relaxation, stress reduction and improved sleep which are vital for learning and memory .[31]A recent review article on yoga effects on brain health suggests that practicing yoga helps in selectively disengaging from negative emotional information process which helps in increasing overall neurocognitive efficiency.[32] Results from a study by Eyre et al where yoga was used as an intervention, functional MRI showed changes in the areas of default mode network associated with improvement in verbal memory recall. [33] A review paper by Serwacki & Cook-Cottone on yoga practice in schools showed that yoga had a positive influence on cognitive performance, anxiety and emotional wellbeing among the participants .[34] So on exploring the other plausible reasons for improvement of scores in our study post intervention , it must be that the practice of this mindful breathing technique can be inducing a state where attention is more focused on the task at hand , facilitating a calm and relaxed mind leading to a sense of mental and emotional wellbeing. Verma et al in their study have demonstrated that even shorter duration of intervention in the form of yoga is beneficial in improving cognitive parameters among school children.[35] Studies have shown that experiencing poverty at an early age persistently has a negative impact on the cognitive abilities of the child. Any increase in childhood adversity without proper intervention can lead to future cognitive, social and physical problem. So, by encouraging these children to practice mindfulness at this early age can be a skill for life in years to come.

CONCLUSIONS

Literature suggests that practicing yoga in the form of postures, asanas and meditation in schools help in improving students' academic output by increasing their attention, concentration, impulse control, motor coordination and social skills. Support in the form of this inexpensive, simple intervention in schools as a part of curriculum might help to improve the working memory skills among these impoverished children who have too many environmental and social stressors hampering their cognition.

Limitations: One important limitation in our study is the small sample size. We had only one certified yoga teacher to conduct the programme effectively so we had to restrict ourselves to few participants. But it can definitely open the avenue for more scope in the rural set up where teachers can be taught and made to practise yoga in its various forms for the betterment of these children. Another major limitation in our study was the short time of intervention daily (10 minutes). As it was difficult to sustain the children's concentration time beyond 10 minutes, we opted for this. But even this short time of intervention can be used as a sensitising dose and gradually increased class wise as their age increases.

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Conflicts of Interest: Authors declare no conflict of interest.

Consent: Written Informed Consent was taken from the parents of the students who participated in the study before starting the study.

Ethical Clearance: The study was accorded Ethical Committee Approval vide Ethics Committee Reg No: PIMS/DR/RMC/2019/230 dated 27/12/2019 from Pravara Institute of Medical Sciences – Deemed University. The study was carried out in accordance with the principles as enunciated in the Declaration of Helsinki.

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