

## Research article

**Assessment and comparison of cognitive function tests in abacus trained and untrained students aged 8-12 years in the South-Indian population**Bhavya R.L.<sup>1</sup>, Y. Dhanalakshmi<sup>2</sup>, Ria Ann Philip<sup>3</sup><sup>1</sup>Department of Physiology, SRM Medical College Hospital and Research Centre, SRM Nagar, Potheri, Kattankulathur, 603203, Kancheepuram, Tamil Nadu, India<sup>2</sup>Department of Physiology, <sup>3</sup>JIPMER, Puducherry 605006, India

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**ABSTRACT**

**Introduction and Aim:** During childhood period, cognitive decline could manifest as learning disability. Cognitive abilities, which have a strong relationship with synaptic plasticity an amazing property of the brain is mandatory for the growing demands and challenges. Our study focuses on the effect of memory tasking (abacus training) on cognitive abilities in children. The aim of the study is to assess the cognitive functions of children who had undergone level one abacus training in the age group of 8-12 years and to compare the cognitive functions between children trained and untrained in abacus.

**Materials and Methods:** The study was approved by ICMR-STC 2018 and institutional ethics committee. It was conducted in children aged 8-12 years, who were age and BMI matched and were untrained and trained in abacus level one, between June-July 2018. Seventy participants, majority being females (fourth-fifth standard), were recruited from a school in Puducherry. Anthropometric indices were recorded, and baseline cognitive parameters were assessed by MoCA.

**Results:** The total median scores for MoCA were 28 (27-29) and 26 (23-28) in study and control groups respectively ( $p=0.016$ ). Values for trail making test A was 44.89 sec (study group), 56.20 sec (control group) ( $p=0.04$ ) and trail making test B was 94.7 sec (study group) and 125.3 sec (control group), ( $p=0.03$ ) respectively. In letter cancellation test, the scores were 31.8 (study group) and 31 seconds (control group) ( $p=0.019$ ).

**Conclusion:** Abacus training improves all three domains of cognition and learning abilities in children.

**Keywords:** Abacus; BMI (body mass index); Montreal cognitive assessment test (MoCA); Neural plasticity.

**INTRODUCTION**

A part from motor, social developmental skills, language and communication skills, cognitive development is an essential part of brain development in growing children, as it plays an important role in acquisition of knowledge, problem solving abilities and thinking power, which is mandatory for the growing minds to cope up with and understand the world around them and enhance their ability to think laterally. Around 5-10% of school children are found to have learning disabilities (1) and furthermore the average global prevalence of neurological impairment among children aged 0-14 years are found to be 5% (2). Cognitive impairment is one among the neurological impairment which needs attention in the present scenario. The components of cognition like learning and memory, attention, concentration, language, and communication skills that are interlinked with each other, has a positive impact on daily routine that

boosts the confidence of a learner's mind. Hence it is mandatory to foster a child's cognitive development

with certain programs on brain training like abacus, which deals with mental arithmetic and serves as a cognitive stimulus. Abacus based mental calculations have been found to be stress free and play way method of learning which enhances the synaptic efficacy and developmental plasticity which underlies the cognitive abilities, like learning and memory (3). From time immemorial counting was done using stones, by carving notches on wood or bone and counting with fingers, which paved way for sign language and written numbers (4,5). But then these methods of counting were time consuming and hence it progressed with the use of abacus for calculations. But with the evolution of computer and other gadgets there is a downplay with the use of abacus.

The term abacus originates from the Latin word 'abax' meaning a 'flat board' or 'tablet'. It is an ancient tool used for fast and accurate calculation by

China, Japan, Korea, and India since 1200 A.D. (6) An abacus consists of a rectangular frame, holding in place a number of beads on vertical rods. There are two horizontal rows. The top row contains one or two beads per column while the bottom row may have four to five beads. By moving the bottom row beads upwards and the top row beads downwards, numbers are counted. Each vertical column represents place value starting from the right as ones, tens, hundreds, etc. (7).

A study conducted in by Lizhu *et al.*, shows that abacus promotes the use of multiple senses including visual, auditory, and sensory system to solve problems. This integrated approach leads to an improvement in short term memory, reading efficiency, intelligence quotient and a general improvement in all academic subjects including mathematics (8). The trainees in abacus showed enhanced usage of posterior superior parietal cortex as when compared to the untrained individuals who use the language centers of their brain for problem solving. This plays an important role in both working and photographic memory which is essential for visuospatial intelligence (9).

In 2002, a research project by Chen *et al.*, showed that the abacus trained group not only had a better performance in arithmetic operation than the untrained group but also had better ability to store visual-spatial information (10). The ability to process visual information in more than one dimension is called the visuospatial intelligence. This enables one to excel in abstract and mechanical reasoning as well as space relations along with lateral thinking. These abilities are mandatory in scientific and technical fields like Physical science, engineering, computer science and mathematics. Visuospatial intelligence which is important in scientific and technical fields is found to increase in abacus training (11). With advancing stages in abacus training, students start to use imaginary abacus for calculations which boosts working memory and photographic memory which in turn enhances the visuospatial learning (12). Thus, early exposure and structured training motivate non-addictive means of brain training programs which will enhance competency in cognitive tasks more than merely skill acquisition. While there are many studies on abacus training, documentations on cognitive function tests in abacus learners as a whole entity is lacking. Our study is the first of its kind to assess the effectiveness of abacus training in improving cognitive functions in south Indian children aged 8-12 years. We hypothesize that abacus training will improve the basic cognitive abilities like memory, concentration, coordination, analytical skills, processing speed, visuospatial abilities, naming skills, attention, alertness, and awareness in children.

## **MATERIALS AND METHODS**

### **Study design**

This is a cross-sectional study in which cognitive functions were assessed in level one abacus trained and abacus untrained children aged 8-12 years, conducted in a school within the campus. This study was selected by ICMR-STs 2018, approved by research monitoring and institutional ethics committee. The study period was conducted between June–July 2018. The participants were divided into two groups; study group being trained and control group untrained in abacus level one. Recordings obtained from abacus untrained children were considered as baseline cognitive scores. Sampling was nonrandomized, with 35 participants in each group. Sample size was calculated with the mean and S.D. values from data published earlier for the cognitive test scores of both the groups in memory tasks (89.63 – 23.82) and (36.89 – 5.50) respectively. It was calculated based on two samples' test with 80% power and 5% level of significance. All the participants were enrolled based on inclusion and exclusion criteria.

### **Inclusion criteria**

#### **Study group:**

- Age between 8 to 12 years
- Children trained in abacus (level 1)

#### **Control group:**

- Age between 8 to 12 years
- Children who did not receive any training in abacus

### **Exclusion criteria**

Participants with a history of neurological disorder, head injury in the recent past. i.e., within 3 to 5 years.

After obtaining approval from the Institutional research monitoring committee and Ethics committee for human studies, informed and written consent was obtained from the parents/guardians of all the participants who were willing to participate in the study along with assent for students.

### **Recruitment of study and control group**

Age and gender matched children of the age group 8-12 years studying in fourth and fifth standard with majority from fourth standard belonging to different sections were enrolled for participation in the study with many amongst them being females. There are 10 stages in abacus training and each stage goes for 3 months, of which we chose children, who had undergone level one abacus training and then compared them with children who did not undergo abacus training at all. Then they were enrolled under the study group and control group respectively based on the inclusion and exclusion criteria as mentioned

above. Thirty- five students were selected for the study under each group based on the sample size calculation. The participants were from a school in the Puducherry. After obtaining the informed and written consent from the parents/guardians and assent for the students, the procedure was explained to them following which the anthropometric parameters like weight, height and BMI were measured. Then the students were subjected to neurocognitive test battery. Baseline cognitive scores were assessed in both the abacus trained and untrained participants where in the untrained participants (matched for age and BMI) serve as controls and the cognitive parameters tested in them serve for the baseline cognitive scores (MoCA).

## **PROCEDURE**

Anthropometric parameters measured were weight, height and BMI

### **Measurement of Height**

Height of each study subject was measured with a wall mounted stadiometer. The students were asked to stand with both heels and knees together on a flat surface with straight legs. With the occiput, shoulder blade, hips and heels pressed against the vertical bar, the height of each study subject was measured in centimeters by bringing the slider and pressing on to the top of the head.

### **Measurement of weight**

The study subjects were asked to wear light clothing. They were made to stand with bare foot on a standardized weighing machine with legs positioned on either side of the digital scale and the weight was measured in kilograms.

### **Measurement of body mass index (BMI)**

BMI was calculated using Quetelet's index.

Quetelet's index = weight / [height]<sup>2</sup>

Weight - in kilograms.

Height- in meters.

### **Cognitive function tests**

The cognitive function tests include Montreal cognitive assessment test, letter cancellation test, trail making tests A and B.

### **Montreal Cognitive Assessment Test (MoCA)**

It is a highly sensitive screening test for cognitive impairment. It consists of seven domains namely- visuospatial function, naming, attention, language, abstraction, delayed recall, and orientation- distributed over 22 questions. It is scored out of 30 points and a score of less than 26 indicates mild

cognitive impairment. The forward and reverse digit spans are two of the many components of MoCA (13).

### **Forward digit span test**

This test is used to determine the immediate verbal memory span of the subject. The examiner reads out a sequence of digits which contain any numbers from 3 to 8. The sequence will be read out only once which the subject must repeat. Two chances are given for each digit and the score is based upon the number of digits recalled correctly. (14).

### **Reverse digit span test:**

The subject is asked to repeat the reverse of the sequence dictated by the examiner. The score is calculated based on the number of digits the subject manages to repeat in the reverse order (14).

### **Trail making test**

Part A: The subject is asked to connect the numbers which are randomly scattered on the sheet. The score is based on the time taken for the subject to finish the test.

Part B: The subject is asked to connect numbers to the letters. For example, 1 to A, 2 to B etc. Scores are decided by the time taken by the individual to finish the test. (14)

### **Letter cancellation test**

This test helps in evaluating the attention span of the subject. It is a pencil and paper test where the subject is asked to strike out the letter H placed at random intervals in a series of letters. The subject will be scored based on the time taken to complete the test and the number of errors made by the subject (15).

### **Statistical analysis**

Normality of the data was tested using Kolmogorov-Smirnov test. The normally distributed data has been expressed as mean  $\pm$  S.D. 'p' value < 0.05 is considered statistically significant. Non-normally distributed data has been expressed as median and interquartile range. The data was analyzed using unpaired 't' test with SPSS version 19. Sample size was calculated with the differences in cognitive test scores between the abacus untrained and abacus trained children, from the data published earlier. The mean and S.D. values for the cognitive test scores for children untrained and trained in memory tasks, as per the previous studies were found to be (36.89- 5.50) and (89.63- 23.82) respectively. Hence our study includes 35 subjects in each group. Sample size calculation was based on two sample 't' tests with 80% power and 5% level of significance.

## RESULTS

The anthropometric parameters measured include age, height, and weight. BMI was calculated using these values. The mean age for the study group was 10 years and that for the control group was 9.8 years ( $p= 0.2$ ). The difference was not found to be statistically significant. Similarly, the mean height for the study group and control group being 139.49 cm and 137.77 cm, which was also not statistically significant ( $p= 0.4$ ). The average weight in this age group was found to be 33.83 Kg in the study group and 31.09 Kg in the control group. This was statistically insignificant ( $p= 0.17$ ). The BMI was 17.19 for the study group and 16.25 for the control group. The variation was not statistically significant. ( $p= 0.188$ )

Visuospatial skills reported a median score of 5/5 in the study group and 4/5 in the control group. Though there was no statistical significance ( $p=0.106$ ), the

two groups showed difference in score with the abacus trained children showing better performance than the untrained. Naming skill scores are normally distributed and are expressed as mean  $\pm$  standard deviation. The study and control group reported mean scores of 3/3 and 2.83/3 respectively for naming skills, which was found to be statistically significant ( $p=0.01$ ). The median score for attention in study and control group was 5/6 each having an interquartile range of 5 to 6 percentile and 4 to 6 percentiles respectively. This difference was not significant ( $p=0.115$ ). The median score for language was 2/3 in both study and control groups with an interquartile range of 2 to 3 percentile and 1 to 3 percentiles respectively. This difference was statistically significant ( $p=0.017$ ). The median score for abstraction was 2/2 in both study and control groups with an interquartile range of 1 to 2 percentile for both. It was not statistically significant ( $p=0.44$ ).

**Table1:** Comparison of demographic and anthropometric data between study group (children trained in abacus level one) and control group (children untrained in abacus)

Sr. No.	Parameter	Study group (n=35)	Control group (n=35)	'p' Value
1.	Age (years)	10.2 $\pm$ 1.28	9.83 $\pm$ 1.15	0.206
2.	Height (cm)	139.49 $\pm$ 11.43	137.77 $\pm$ 8.69	0.482
3.	Weight (Kg)	33.83 $\pm$ 7.92	31.09 $\pm$ 8.54	0.168
4.	BMI (Kg/m <sup>2</sup> )	17.19 $\pm$ 2.30	16.25 $\pm$ 3.51	0.188

Note: The parameters were found to be normally distributed and were hence represented as mean  $\pm$  S.D. (Standard deviation) cm- centimeter, Kg- kilogram, m<sup>2</sup>- meter square

**Table 2:** Comparison of Montreal cognitive assessment test (MoCA) data between study group (children trained in abacus level one) and control group (children untrained in abacus).

Sl. No.	Parameter	Study group (n=35)	Control group (n=35)	p value
1	Visuospatial skills (x/5)	5(4-5)	4(4-5)	0.106
2	Naming skills (x/3)	3.00 $\pm$ 0.00	2.83 $\pm$ 0.38	0.01*
3	Attention (x/6)	5 (5-6)	5 (4-6)	0.115
4	Language(x/3)	2 (2-3)	2 (1-3)	0.017*
5	Abstraction(x/2)	2 (1-2)	2 (1-2)	0.444
6	Delayed recall(x/5)	4 (3-5)	4 (4-5)	0.623
7	Orientation(x/6)	6	6	0.079
8	Total MoCA(x/30)	28 (27-29)	26 (23-28)	0.016*

Note: Orientation is a constant value. The parameters 1,3,4 - 8 was found to be non-normally distributed and have been expressed as median with interquartile range. \* values are statistically significant. x/30 – numerator denotes score obtained by the participant; denominator denotes maximum score

The median score for delayed recall was 4/5 in both study and control groups with an interquartile range of 3 to 5 and 4 to 5 percentile respectively. It was not statistically significant ( $p=0.6$ ). The score for orientation in study group was a constant of 6/6. The median score in control group was 6/6. The difference was statistically insignificant ( $p= 0.07$ ). The total median scores for MoCA were 28 (27-29) and 26 (23-28) in study and control group respectively. It was statistically significant ( $p=0.016$ ).

The time taken for completion of trail making test A was 44.89 seconds for the study group and 56.20 seconds for the control group. It was found to be statistically significant ( $p=0.04$ ). Similarly, the time taken for completion of trial making test B was 94.7 seconds for the study group and 125.3 seconds for the control group. It also shows statistical significance with a  $p$  value of 0.03. In letter cancellation test, the mean of time taken for the completion of task was 31.83 seconds for the study group as when compared to 31 seconds for the control group. This difference is not statistically significant ( $p = 0.19$ ).

**Table 3:** Comparison of trail making test A and B, letter cancellation test data between study group (children trained in abacus level one) and control group (children untrained in abacus).

Parameter	Study group (n=35)	Control group (n=35)	'p' value
Trail making A	44.89± 19.66	56.20± 26.68	0.047*
Trail making B	94.74± 50.02	125.31± 65.09	0.031*
Letter cancellation test (x/35)	31.83± 2.89	31.00± 2.43	0.199

The parameters were found to be normally distributed and are expressed as mean ± S.D

\* values are statistically significant. x/35– numerator denotes score obtained by the participant; denominator denotes maximum score

## DISCUSSION

In an individual's life early growth period plays a vital role. Studies show that for the neural system, developmental plasticity may change at a time which is referred to as the critical period (16). Hence during this period, activity dependent modification and strengthening of synapse is possible in children if they are given memory tasks which serves as cognitive stimulus. This is likely to improve the cognitive efficiency of the developing brain, which in turn will enhance the work efficiency. Abacus is one such play way method of memory tasking, which when practiced regularly can lead to structural as well as

functional reorganization of brain (17). Our study has proved that long term abacus training, apart from improving the precision and speed of mental arithmetic skills, also stimulates various functions like visual organization, visual and verbal attention, and visual and verbal memory. Thus, the students trained in abacus have better visuospatial skill when compared to the untrained students. Though it showed no statistical significance, abacus trainees came up with a better score. This goes hand in hand with the study done by Hanakawa *et al.*, (9). During abacus training students are ought to create an imaginary abacus for computation. This imaginary abacus replaces the object as such and serves as a tool for computing in both forward and backward directions. This enhances coordination as well as visuospatial ability of the learner. This is essential for the perception of distance, depth and movement which is essential for understanding and recollecting, the spatial relationship between the objects which acts as a platform for excelling in space studies and spatial navigation which needs mental computational capacity to visualize and solve the problems of navigation. Apart from visuospatial abilities abacus learners showed a better score in both naming skill and language which was statistically significant. Total MoCA showed a better score in abacus trainees when compared to the untrained. This is consistent with the research work of Tanaka *et al.*, (18). Naming skill and language is an essential part of our day to day lives which is a measure of cognitive flexibility. Naming is crucial for communication, language comprehension and for learning. Regular abacus training serves as a stimulation program for cognition as the developing brain has the excellent ability of activity dependent modification of the strength and efficacy of the preexisting synapses. This plays a vital role in transforming short term memory and experiences into long term memory. Thus, change in synaptic strength on a long-term basis helps in storage of memories which helps the developing brain to achieve and excel in the cognitive domain of learning (19,20). Abacus learners took less time for completing both trial making test (TMT) A and B. Trail making test A tests awareness, alertness and speed of processing data which is inversely proportional to the time taken to finish the task. Trail making test B tests mental elasticity and cognitive shifting which is found to be better in students trained in abacus as when compared to the students untrained in it. This is in accordance with the study conducted by the Japanese psychological research (21). This denotes those children who are undergoing abacus training show much better attention and concentration capacity as when compared to the untrained. Also, the visuomotor, visuospatial abilities along with conceptual tracking seems to be better in abacus trained students as when compared to the students untrained in abacus. Along with cognitive domain

even psychomotor skill seems to be good in students skilled in abacus. In letter cancellation test which measures the attention span, visual scanning of an individual, the time taken to complete task shows no statistical significance between the two groups. Though there is no statistical significance between the two groups, the omission and commission errors were found to be less in the study group when compared to the control group. This shows that there is a good hand eye coordination along with a good scanning ability in abacus trained children. This is attributable to enhanced usage of posterior superior parietal cortex in abacus users. Studies show that people without problems of spatial neglect are also prone for fall in attention span and target detection as in letter cancellation test. This has a strong correlation with age (22). Hence memory tasks can be encouraged to be practiced by all irrespective of age.

## CONCLUSION

Education and cognition play an important role from childhood through adolescence. To create sharp minds with ability of creativity and invention, the education system must focus on the cognitive ability of the developing brain, as cognitive decline is posing threat now a days.

We conclude that abacus training at initial level itself enhances cognitive skills like naming skills, visuospatial skills, attention, processing speed, alertness, awareness, memory, concentration, coordination, and analytical skills when compared to untrained individuals. This reinforces the utility of memory tasks like abacus in enhancing synaptic plasticity at a very young age. Abacus training is a non-addictive stress-free way of memory tasking when compared to advanced method of memory games with gadgets which poses the threat of digital eye strain leading to computer vision syndrome. Hence abacus training can be one of the steppingstones for achieving the goals of Right to sight /Vision 2020 along with enabling the individual to achieve all the three domains of learning.

## Limitations

If the proposal would have been funded, inclusion of biomarkers would have enabled us further to correlate biomarker with cognitive function test parameters to give further insights.

## Future perspectives

Abacus the play way boredom free brain game may be inducted into regular school curriculum making learning a stress-free environment. This memory tasks can be taken in as a parallel treatment option along with medications for neurological disorders like attention deficit hyperactivity disorder (ADHD), Alzheimer's disease and Autism.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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