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RESEARCH ARTICLE

A COMPARATIVE STUDY OF PAPER AND PENCIL NEURO COGNITIVE TEST AND REACTION TIME IN ADOLESCENT CHESS PLAYERS AND NON-PLAYERS

[1]Elamaran, I., *[,1]Velkumary Subramanian, [1]Suchitra Balasubramanian and [2]Chandrasekaran Kathiresan

[1]Department of Physiology, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER)
[2]Directorate of Physical Education and Sports, Pondicherry University, Puducherry, India

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ABSTRACT

Introduction: Chess is considered as a cognitive game because of the engagement of mental resource &playing chess is believed to improve some of the cognitive domains.
Aim: The study was aimed to assess & compare the cognitive functions and reaction time in adolescent chess players and non-players
Materials and Methods: This was a cross sectional study conducted in 30 healthy adolescent chess players and non-chess players of either sex between age 12 and 17. The cognitive function of the subjects were assessed by the conventional paper and pencil neurocognitive test battery which includes two target letter cancellation test (LCT), trail making test A (TTA), trail making test B (TTB) and visual & auditory reaction time was assessed using reaction time apparatus.
Statistical analysis: Statistical analysis was done using SPSS version 20 and the neurocognitive test parameters and visual reaction time (VRT) and auditory reaction time (ART) between the two groups were compared using unpaired t test.
Results: Neuro cognitive test scores in the chess group was found to be improved significantly compared to non- chess group (TTA ($p=0.002$), TTB ($p<0.0001$), LCT(<0.0001). We also observed improvement in visual reaction time in chess players compared to non-chess players (<0.001) & no statistically significant difference observed in ART between study & control group($p=0.293$)
Conclusion: Chess players showed a significant improvement in the tested cognitive parameters like attention, executive function, working memory, visual scanning, psychomotor speed, shift strategy & visual reaction time compared to non-chess players, as assessed by the conventional paper & pencil neurocognitive tests and reaction time apparatus. Hence students can be encouraged to play chess to improve their cognitive skills which in turn will improve their scholastic abilities.

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INTRODUCTION

In today's modern world, children are much more involved in playing videogames, watching TV, movies and exploring internet leading a sedentary lifestyle. With modernisation, neither they are physically active nor are they mentally active. Due to this most of the children find it difficult to concentrate on a particular defined task due to decreased attention span. This can be overcome by including tasks like playing chess, Sudoku, etc.that will help to improve their cognitive skills. Chess & Sudoku are considered as the game for the brain. The game of chess has a long history in Western intellectual culture.

Corresponding author: Velkumary Subramanian,
Department of Physiology, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Puducherry, India.

Chess is considered as a cognitive game because of rigorous engagement of the mental resources during playing. Chess involves many aspects of high level cognition and requires sophisticated problem solving skills and it is considered one of the most mentally taxing pursuits. During chess playing, many kinds of cognitive processes are involved, e.g. attention, visuo-spatial perception, motivation, working memory, and decision making (Atherton *et al.,* 2003; Sharma *et al.,* 2014). Imaging studies of the brain have reported that the human brain is organized into multiple distinct, but functionally related networks to support these processes. It needs a complex processing involving the frontal lobe, parietal lobe and the occipital lobe (Sharma *et al.,* 2014; Grishma *et al.,* 2013). Activation in the frontal lobe for higher order reasoning, activation in the parietal lobes for control of attention and spatial orientation, activation in the occipital lobes for processing of visual stimuli, activation in the prefrontal cortex

for executive functions (Xujun *et al.,* 2012; Nejati, 2012; Schweinsburg *et al.,* 2015). Neurocognitive tests (NCT) are widely used tool to assess various cognitive domains including attention span, concentration, memory and various executive functions (Sharma *et al.,* 2006 and 2014). These tests can be performed by using either conventional paper and pencil NCT or computerized cognitive assessment tests. While the use of computer assisted cognitive tests is increasing due to reduced testing time, it is expensive and expertise is required (Mihalik *et al.,* 2012). In field studies, it is not feasible to carry them and administer them to an adolescent population in chess training centers and schools, therefore conventional testsare preferred over them. Reaction time (RT) denotes the time taken by an individual to react to an external stimulus and it is an indirect index of measuring the processing capability of central nervous system. It is a simplenon-invasive tool to determine the sensorimotor coordination and performance (Deora *et al.,* 2012). Reaction time can be described into three types (Bhavanani *et al.,* 2013). Simple reaction time – here there is one stimulus and one response, 2) Recognition reaction time – here there are some stimulus that should be responded to and other that should not get response and 3) Choice reaction time – here there are multiple stimulus and multiple responses (Madanmohan *et al.,* 2005). Reaction time involves stimulus processing, decision making, response programming and execution, these processes follow one another in a chain of reactions and make what we call the reaction time. It reflects the speed of the flow of neurophysiological, cognitive and information processes which are created by the action of stimulus on the person's sensory system (Grishma *et al.,* 2013).

In the current study, we have selected those paper and pencil tests which are valid for the age group of 12 to 17 years and are routinely administered as a part of various cognitive test batteries which include two target Letter Cancellation Test (LCT), Trail making Test A& B (TTA &TTB). These tests measure the following cognitive domains: Attention span, concentration, psycho-motor speed, visual scanning, shift strategy, various executive functions & memory (Sharma *et al.,* 2014; Lezak *et al.,* 2004). Literature search revealed a paucity of data on these commonly used NCT & RT in Indian adolescent chess players, therefore we planned to undertake the present study. This study will provide the scientific data on neuro cognitive functions in adolescent chess players. This will help in depicting the impact of chess on cognitive functions, if improvement is appreciated then chess could be included on a regular basis in the sports curriculum of schools for improving the scholastic abilities of the students.Therefore the objective of the present study was to assess the cognitive function using conventional paper and pencil neurocognitive test and reaction time in adolescent Chess players andnon-Chess players and to compare the cognitive function and reaction timebetween them.

MATERIALS AND METHODS

This was a cross sectional field study conducted in the Chess training centre and the Government high school at Puducherryin collaboration with the Department of Physiology, JIPMER, Puducherry during the period May to August 2015.The study was conducted after getting approval from the institutional ethics committee and prior permission from both the Chess training centre& the Government high school.The subjects were divided into two groups, the study group and the control group based on their ability to play chess.

Chess group: Thirtyright handed chess players of either sex with the age range between 12 and 17 years were recruited from the chess training centre located in Lawspet, Puducherry.

Non-Chess group: Thirty age and BMI matched non-chess players were recruited as the control group from Government school located near JIPMER.

Inclusion criteria

Study group

- Both Genders
- Age between 12 and 17 years
- Regular Chess players for at least 3 times a week for more than 1 year

Control group

- Both Genders
- Age between 12 and 17 years
- An adolescent who is not a regular chess player (< 2times in a month) or who does not know to play chess at all.

Exclusion criteria

- Neurological deficit, Psychiatric illness, Endocrine disorders, specifically hypothyroidism, any recent illness, drug intake or substance abuse, all these were excluded by taking history.

METHODOLOGY

The whole study procedure was explained to the participants, written informed assent from the subjects and written consentfrom the parent or local guardianwas obtained. All the tests were conducted in the chess training centre and in the Government school, respectively for the cases and control in a well-lit, quiet & an isolated room. The subjects were asked to fill in the proforma having their personal details and then the data sheet having their family and medical history was filled by the investigator.The anthropometric measurements like height, weight and Body mass index were noted and recorded in the data sheet.

Neurocognitive tests

The cognitive function of the subjects was assessed by the conventional paper and pencil Neurocognitive test battery which includes

a) Two target Letter Cancellation Test (LCT): (Sharma and Subramanian, 2014)

The subject was made to sit comfortably in a chair. The test procedure was explained and a copy of the LCT worksheet having five 30 character rows of letters of the English alphabet and a pencil was given to the subject. The test demonstration was done and then they were instructed to cancel out randomly placed letters 'E' and 'R'. The scores were calculated as the time taken (in seconds) by the subject to complete this task.

The numbers of different errors (omissions and commissions) done by the subject were also counted. This test assesses the person's ability for visual scanning, response speed and sustained attention for an identifiable target in which they are instructed to cancel all such target items in an array.

b) Trail making Test A (TTA): (Sharma and Subramanian, 2014; Corrigan and Hinkeldey, 1987; Gaudino *et al.,* 1995)

Trail making test has been extensively used in the neuropsychological research for the assessment of psychomotor speed, attention, and executive functions. The Trail Making Test A worksheet consists of circles numbered 1 – 25 distributed over a sheet of paper and the subject was instructed to draw lines to connect all the 25 numbered circles consecutively in ascending order. The subject was instructed to connect the circles as quickly as possible, without lifting the pencil from the paper. The score was the time taken in seconds by the subject to complete the task.

c) Trail making Test B (TTB) (Sharma and Subramanian, 2014; Lezak *et al.,* 2004; Collie *et al.,* 2003)

In TTB, similar to TTA there were 25 circles but they include both numbers (1 – 13) and letters (A – L), the subject was made to draw lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The subject was instructed to connect the circles as quickly as possible, without lifting the pencil from the paper. The score was the total time taken in seconds by the subject to complete the task. If the subject makes an error, it was pointed out immediately and he was allowed to correct it every now and then. Errors affect the subjects' final score in the completion time for the task.

The cognitive domain assessed in this test apart from attention & executive functions were, the subjects' ability to shift strategy, response set, planning, and flexibility. In all the three tests the time taken to complete the task was measured in seconds & then compared with those for the non-chess players.

Reaction Time (RT) (Deora *et al.,* 2012)

In the present study we assessed the recognition reaction time. Reaction times for the detection of auditory and visual signals were recorded by the RT apparatus (supplied by Ananda agencies Pune, India). Each individual was explained about the test procedure and sufficient trials were given for proper understanding as the subjects had no prior experience in working with the reaction time apparatus. First Visual (VRT) and then auditory reaction time (ART) were recorded. For visual reaction time red light was used as the stimulus target and for auditory reaction time beep sound was used as the stimulus target. The subjectswere asked to press the response key immediately upon seeing or hearing the stimulus, with their index finger of the dominant hand. Stimulus signal was given from front side, to avoid the effect of lateralised stimulus on reaction time. The reaction time values were directly read from the digital display. Ten trials each for visual and auditory reaction times were recorded, extreme values were deleted and the average of lowest three closer values was taken for calculating reaction time.

Statistical analysis

The data were expressed as Mean± SD, appropriate statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 20. We compared the neuro cognitive test parameters, visual and auditory reaction time between the two groups using unpaired t test. For all the variables the statistical significance was set at p value <0.05.

RESULTS

Thirty adolescent chess players with the mean age group of 14.07±0.52 years with BMI of 20.74± 1.56 kg/m^2 and non-chess players with the mean age of 13.83±0.65 years and BMI 19.75±2.76 kg/m^2 were recruited for the study (Table 1). When their neuro cognitive test scores were compared, the chess player group showed a significant improvement in the tested parameters compared to non-chess players (Table 2). The p value of trail making test A (TTA) is 0.002, for trail making

Table 1. Comparison of baseline characteristics of Chess and non-Chess players

S.No.	Parameter	Chess player(n=30) (Mean ± SD)	Non chess player(n=30) (Mean ± SD)	p value
1.	Age(years)	14.07 ± 0.52	13.83 ± 0.65	0.130
2.	Height(cm)	141.47 ± 4.89	140.7 ± 5.82	0.582
3.	Weight(kg)	41.43 ± 2.40	39.1 ± 6.44	0.068
4.	BMI(kg/m²)	20.74 ± 1.56	19.75 ± 2.76	0.093

Table 2. Comparison of neurocognitive test parameters in Chess and non-Chess players

S.No.	Parameter	Chess player(n=30) (Mean ± SD)	Non chess player(n=30) (Mean ± SD)	p value
1.	TTA (seconds)	34.00 ± 3.52	39.5 ± 8.82	0.002
2.	TTB (seconds)	50.17 ± 9.44	63.56 ± 13.38	<.0001
3.	LCT (seconds)	52.2 ± 7.24	62.06 ± 3.86	<.0001
4.	LCT (Omission)	1.56 ± 1.56	1.53 ± 1.38	0.931
5.	LCT (Commission)	0.06 ± 0.25	0.13 ± 0.57	0.562

p<.05 was considered to be statistically significant; TTA- Trail making test A, TTB- Trail making test B, LCT- Two target Letter Cancellation test

Table 3. Comparison of visual and auditory reaction time in Chess and non-Chess players

S.No.	Parameter	Chess Player(n=30) (Mean ± SD)	Non chess player(n=30) (Mean ± SD)	p value
1.	VRT (msec)	221.16 ± 22.31	248.80 ± 36.87	<0.001
2.	ART(msec)	187.73 ± 13.39	192.80 ± 22.46	0.293

p<0.05 was considered to be statistically significant: VRT- Visual reaction time, ART- Auditory reaction time

test B (TTB) p <0.0001 and for two target letter cancellation test LCT p <0.0001. We also observed improvement in visual reaction time in chess players compared to non-chess players p<0.001 & no statistically significant difference observed in auditory reaction time (ART) between chess and non-chess player groups (p=0.293).

DISCUSSION

The objective of the study was to assess and compare the neurocognitive test performance, visual and auditory reaction time in adolescent chess and non-chess players. Our results demonstrated that there was a significant improvement in all the measured paper and pencil neuro cognitive test parameters in the chess group compared to non- chess group except in the omission and commission of LCT scores where there was no significant difference observed. The various cognitive functions that are assessed by the neurocognitive tests like LCT, TTA & TTB include attention, executive functions, visuo-spatial perception, motivation, working memory and decision making. It is seen from our study that the neurocognitive domains are statistically significant in the chess players compared to the non-chess players. The mechanism behind this has been proposed by Sridharan *et al* in his study, which states that central executive network (CEN), which includes the dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex (PPC) is getting activated and is responsible for working memory, attention control, judgement and decision making in the context of goal-directed behaviour and in chess players during playing increased activity is found in these areas, thus indicating a better cognitive function (Sridharan *et al.,* 2008), this study supports our finding. But on the contrary in a fMRI study of Atherton *et al*. he had showed the paucity of activation in the frontal lobes in expert chess players during playing indicating poor executive functions compared to novice players (Atherton *et al.,* 2003; Nejati and Nejati, 2012).

OgnjenAmidzic *et al.* (2001) found that highly skilled chess grandmasters had more bursts of gamma-band activity in the frontal and parietal cortices compared to amateur players and this has been further reinforced by Banich *et al.* (2009) who found that chess players has increased activity in the prefrontal areas, especially the dorsolateral prefrontal areas that is involved in executive functions (EF), this corroborates with our study. EF includes cognitive processing involved in goal-directed behaviour and the control of complex cognition. But this was against the views of Nichelli *et al.,* (1994) who showed in one of his studies a decreased frontal lobe activity in chess players and hence decreased cognition. Connors *et al.,* (2011) in his study showed that chess grand masters have better decision making ability than experts and experts in turn have better decision making ability than intermediaries and novice, implying regular practising of chess improves the cognitive function of the players. Reaction time is a measure of the response to a stimulus.In our study we measured recognition reaction time for visual & auditory stimuli.We observed improvement in visual reaction time in chess players compared to non-chess players, it could be due to expertise in visual stimulus domain, enhanced perceptual capabilities and improved perception processing leading to improvement in visual reaction time. We speculate that chess players are exposed to visual stimulus domain, which improves visual attention, processing speed compared non -chess players.Our findings corroborate with previous study done by Maunsell *et al.* (2002) which states that directing attention to a particular location in the visual field improves detection and discrimination, and shortens reaction times in that location relative to others and Yagi *et al.* (1999) had showed that RT to visual stimuli is faster than auditory stimuli. Atherton *et al*, in his fMRI study observed that chess players showed increased occipital lobe activity, which represent better visual processing function and improvement in VRT.

Scholastic advantages of Chess (William, 2014)

Introducing chess to school aged students has a very good impact in improving their cognitive skills particularly the attention span, calculation, remembering ability and decision making. Kazemi *et al.* in 2012 examined the cognitive effects of chess play and proposed that playing chess improves significantly the mathematical abilities and the metacognitive capacities of school-aged students.

Conclusion

In this study we have recorded the commonly used paper & pencil neurocognitive tests, visual and auditory reaction time to asses certain cognitive domain in adolescent chess & non-chess players aged between 12 and 17 years. Our study showed a significant improvement in the tested cognitive parameters like attention, executive function, working memory, visual scanning, psychomotor speed, shift strategy & visual reaction time in chess players compared to non-chess players. Therefore we suggest that students can be encouraged to play chess for improving their cognitive capacity.

Limitation

Further studies can be done with larger sample size, performing objective tests of cognition and including more neuropsychological test batteries. Future studies may be extended to compare the subjects who are exclusively playing chess with those who are involved in other sports or physical activities, the data regarding the involvement of the subjects in other sports activities is lacking in this study.

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