RESEARCH PAPER

Children's Color Trail Test for Objective Assessment of Attention in Children with Attention Deficit Hyperactivity Disorder: A Diagnostic Accuracy Study

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Objective: To compare the Children's Color Trail Test scores in children with and without Attention Deficit Hyperactivity Disorder to assess its diagnostic performance in assessing attention-deficit. **Methods**: 50 children with Attention Deficit Hyperactivity Disorder (diagnosed as per Diagnostic and Statistical Manual, 5th edition) and 50 age- and sex-matched children underwent Test 1 and Test 2 of the Children's Color Trail Test. A Receiver Operating Characteristics curve was constructed for the diagnostic accuracy of Children's Color Trail Test in Attention Deficit Hyperactivity Disorder. **Results**: The Receiver Operating Characteristics curve showed a score ≤32 for Children's Color Trail Test 1 [AUC: 0.8 (0.71 to 0.87); *P*<0.001] and score ≤40 for Children's Color Trail Test 2 [AUC: 0.85 (0.77 to 0.92); *P*<0.001] as the best cut-off for diagnosing Attention Deficit Hyperactivity Disorder. **Conclusion**: Children's Color Trail Test is a promising tool for diagnosing attention deficit, and could be used in settings where parent or teacher reports are not available.

Keywords: *Attention deficit disorders, Diagnosis, Neurodevelopmental disorders.*

The diagnosis of Attention deficit hyperactivity disorder (ADHD) is typically based on the reports of the caregivers, family members and teachers. The criteria laid down in the Diagnostic and Statistical Manual for Mental Disorders, 5th edition (DSM-5) is considered the gold standard for its diagnosis [1]. In clinical settings, interview schedules like Conner's Parent Rating Scale (CPRS) and Conner's Teacher Rating Scales (CTRS) [2] are often used to elicit the symptomology, as they provide an objective score, which can be used for assessing response to therapy [3,4]. Although widely accepted, the assessment based on caregivers/teachers report has many shortcomings. At times, the information may be inaccurate. The diagnosis becomes difficult when caregivers and/or teachers are not available, or if their reports are contradictory to each other. There is a need for instruments that can directly assess attention and/ or level of hyperactivity in a child.

Few computer-based tests, commonly referred to as Continuous performance tests (CPTs) have been developed to objectively assess the attention level of a child; however, their cost is prohibitive [5]. Children's Color Trail Test (CCTT) is a simple neuropsychological test that consists of circled numbers 1-15 placed randomly on a paper, which have to be sequenced by a performer [6]. It objectively assesses executive functions of the brain including visual attention, psychomotor speed, sequencing and cognitive flexibility [7]. Although, it was initially developed for use in patients with Human immuno-deficiency virus (HIV) and traumatic brain injury, previous studies have shown that it can differentiate children with attention deficits, and may be helpful in monitoring their course [8]. This study intended to assess the diagnostic performance of CCTT in assessing attention deficit in children with ADHD, and also study the correlation of CCTT with Conner's rating scales.

Methods

Following approval from the Institutional Ethics Committee, this study was carried out from June, 2014 to May, 2016 in the pediatric outpatient department (OPD) and Child development center of Maulana Azad Medical College, New Delhi. A sample of convenience of 100 children aged 8-15 years (50 with ADHD and 50 without ADHD) were enrolled after obtaining informed consent from one of the parents, and assent from the participants.

Consecutive children presenting with features suggestive of ADHD (*e.g.*, lack of concentration in the classroom, poor school performance, lack of interest in studies, motor hyperactivity, forgetfulness, poor listening responses) were assessed for inclusion. ADHD was

diagnosed by a developmental pediatrician using the DSM-V criteria, after interviewing the child and the parents. CPRS and CTRS were administered, and scores on various sub-scales (inattention, hyperactivity, learning problems, executive-functioning, aggression and peer-relationship) were obtained [2]. IQ assessment was done using the Binet Kamat Test [9]. Age- and sex-matched controls were enrolled from the pediatric OPD. Children with Intelligence Quotient (IQ) <70, neurological disorders likely to affect upper limb motor performance or compliance with directions for the test, and those who had received any treatment for behavioral problems/ADHD were excluded.

Children's Color Trails Test (CCTT) was administered to all the subjects by a blinded clinical psychologist. This test has two parts – Part 1 (CCTT1) is a page with circled numbers 1-15 placed randomly on a paper (even numbers printed in yellow circles and odd in pink circles). The child has to rapidly connect numbers in sequence using a pencil. In part 2 (CCTT2) of the test, numbers from 2–15 are presented twice, as both pink and yellow circles. The child has to rapidly connect the numbered circles in sequence, alternating between pink and yellow circles. CCTT takes 15-20 minutes for administration. The examiner records the time taken to complete each trail and errors committed, to arrive at the score of each part [6].

Statistical analysis: SPSS version 20.0 was used. Receiver Operating Characteristics (ROC) analysis was done and Area under curve (AUC) determined as the measure of diagnostic performance of the test. The best cut-offs on CCTT 1 and CCTT 2 for diagnosis of ADHD was ascertained and the sensitivity, specificity, positive predictive value and negative predictive values were reported. Correlation between CCTT scores and CPRS and CTRS subscale scores was evaluated using correlation coefficient (r).

RESULTS

The study population consisted of 100 boys (50 in each group), with median (IQR) age of 9 (8,12) years. The parental educational status and other socio-demographic variables in both groups are shown in ***Web Table* I**. Of the 50 children with ADHD, 39 had combined, 10 had predominantly inattentive, and one had predominantly hyperactive type of ADHD.

Controls had significantly higher mean scores on CCTT 1 [41.7 (7.84) *vs* 29.5 (10.74), *P*<0.001] and CCTT2 scores [45.1 (10.17) *vs* 29.5 (9.99), *P*<0.001] as compared to children with ADHD. The ROC analysis showed that CCTT1 has an AUC of 0.8 (95% CI, 0.71 to 0.87) and CCTT2 has an AUC of 0.85 (95% CI, 0.77 to 0.92, *P*<0.001) for diagnosing ADHD. A score ≤32 for CCCT1 and ≤40 for CCTT2 were the best cut-off values for diagnosis (***Fig.* 1**). The sensitivity (95% CI) and specificity (95% CI) for a DSM-5 ADHD diagnosis was 74 (59.7-85.4) and 74 (59.7-85.4) for a CCTT-I score ≤32, and 84 (70.9-92.8) and 72 (57.5-83.8) for a CCTT-2 score ≤40.

***Table* I** shows the correlation of the two CCTT tests with CPRS and CTRS scores. All Connors scores correlated negatively with CCTT-1 and CCTT-2 scores, with correlation-coefficients (*r)* in the range of –0.44 to –0.59 (*P*<0.001), except for Parent-learning problems subscale, which had *r*= –0.38 with CCTT-1. CCTT-1 and CCTT-2 correlated significantly with each other (*r*=0.637, *P*<0.001).

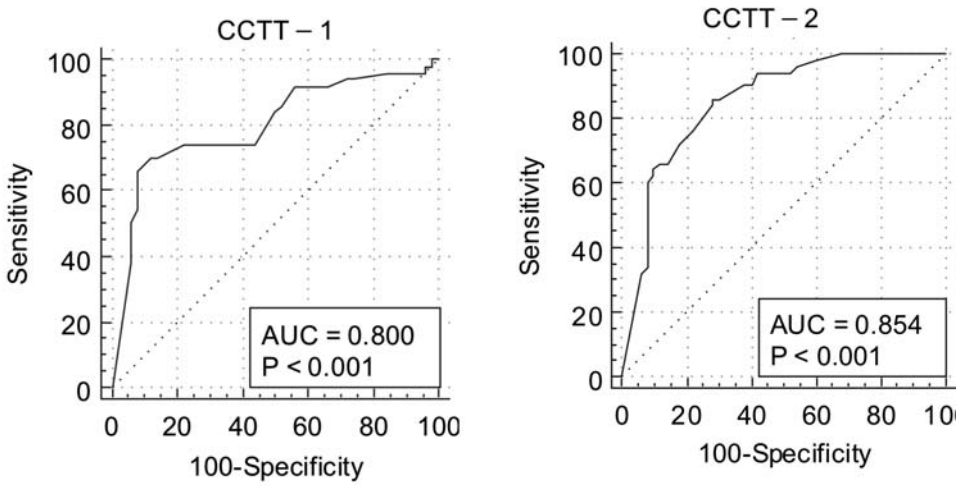

FIG. 1 *ROC curves for diagnostic performance of (a) CCTT1 and (b) CCTT2 against DSM-5 diagnosis of ADHD.*

WHAT THIS STUDY ADDS?

- Children's Color Trail Test is a promising tool in the diagnostic armamentarium for attention deficit, especially in settings where reliable reports from parents or teachers are not feasible.

TABLE I CORRELATION OF CHILDREN COLOR TRAILS TEST SCORES WITH CONNERS RATING SCALE SCORES IN CHILDREN WITH ATTENTION-DEFICIT HYPERACTIVITY DISORDER (*N*=50)

Subscale scores (CRS)	*Correlation coefficient**	
	CCTT1	*CCTT2*
Parent Scale		
Inattention	-.498	-.524
Hyperactivity	-.556	-.596
Learning problems	-.383	-.579
Executive functioning	-.535	-.534
Aggression	-.448	-.487
Peer relationship	-.458	-.581
Teacher Scale		
Inattention	-.537	-.476
Hyperactivity	-.540	-.578
Learning/ Executive functioning	-.531	-.513
Aggression	-.477	-.478
Peer Relationship	-.517	-.513

*CRS, Connors Rating Scale; CCTT, Children's Color Trail Test I and II; *All P<0.001 for correlation between Conners subscale scores and the CCTT scores.*

DISCUSSION

In this study, CCTT showed good performance against DSM-5 criteria for diagnosing ADHD, with a sensitivity and specificity of >72%, at cut-off score of ≤32 and ≤40 for CCTT I and CCTT II, respectively. CCTT also showed significant correlation with various sub-scale scores of Connor's parent and teacher rating scales. As CCTT is a broad screener for executive functions, it correlated well with learning problems and executive functioning sub-scales, in addition to the inattention subscale. The correlation with hyperactivity and aggression sub-scale can be explained by the fact that in most children with ADHD these behaviors often co-exist with inattention.

There are few studies on CCTT in children with attention problems. William, *et al*. [7] compared the time taken to complete the test in children with mild neurological disorders, learning disability, ADHD and controls. Children with ADHD took maximum time to complete the test followed by those with mild neurological disorder [7]. A Korean study [10] also demonstrated that CCTT scores differ significantly between ADHD group receiving medications, ADHD-drug free group and normal children. This study also showed good test-retest reliability of CCTT. Seo, *et al*. [11] showed that CCTT has good correlation with Comprehensive attention test (CAT) in children with ADHD. A few studies have used CCTT as a tool to evaluate improvement in children with ADHD, with a demonstrable change after intervention [12,13].

Studies have attempted to derive normative values of CCTT in different populations. It has been noted that CCTT scores is influenced by socio-demographic variables like age, sex, socio-economic status and ethnicity [14-16].

The major limitations of this study are the small sample size and convenience sampling. Children with predominantly hyperactive type were under-represented in this study, making it impossible to compare the performance amongst different sub-types of ADHD. Further, it would have been ideal to test the tool in a community sample or undiagnosed children with behavioral issues.

The good diagnostic accuracy of the CCTT in this study suggests that its role in evaluation of children with ADHD needs to be further explored. If substantiated, it can prove to be a useful tool in the management of ADHD. Further studies may also explore its use to assess response to intervention (drugs and/or behavioral therapy). Studies with larger number of children in each age-group would be helpful in providing age-specific norms for Indian children.

Contributors: MJ,RJ,DM,SS: study planning; SS,HM,NV; participant assessment and evaluation; HM,DM,RJ,MJ: statistical analysis; HM,DM: manuscript writing. All authors made important intellectual contribution to study planning, data analysis, and manuscript writing. All authors approved the final manuscript.
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WEB TABLE I SOCIODEMOGRAPHIC CHARACTERISTICS OF CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND CONTROLS (*N*=100)

Characteristic	*ADHD Group, n (%)*	*Control Group, n (%)*
Maternal education		
Illiterate	1 (2)	2 (4)
Primary	2 (4)	2 (4)
Senior secondary	20 (40)	27 (54)
Higher education	27 (54)	19 (38)
Paternal education		
Illiterate	1 (2)	0 (0)
Primary	1 (2)	4 (8)
Senior secondary	14 (28)	28 (56)
Higher education	34 (68)	18 (36)
Child's school Grade		
3rd	15 (30)	15 (30)
4th	13 (26)	13 (26)
5th	7 (14)	7 (14)
6th	1 (2)	1 (2)
7th	7 (14)	7 (14)
8th	3 (6)	3 (6)
9th	1 (2)	1 (2)
Age, y		
8	16 (32)	15 (30)
9	13 (26)	14 (28)
10	6 (12)	6 (12)
11	2 (4)	2 (4)
12	5 (10)	5 (10)
13	4 (8)	4 (8)
14	3 (6)	3 (6)
15	1 (2)	1 (2)

50 children in each group; ADHD: Attention Deficit Hyperactivity Disorder.