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Original Article

Comparative assessment of cognitive function of asthmatic and non-asthmatic children in Ilorin, Nigeria

Salihu Sheni Mohammed[1], Rasheedat Mobolaji Ibraheem[2], Mohammed Baba Abdulkadir[2], Muhammed Akanbi Nurudeen Adeboye[2], Aishatu Ahmed Gobir[2], Wahab Babatunde Rotimi Johnson[2]

Abstract

Background The presence of asthma in children may negatively impact their cognitive function, possibly due to intermittent hypoxia from repeated acute exacerbations, sleep deprivation, and school absenteeism. However, conflicting reports abound on cognitive performance among children with asthma.

Objective To assess and compare the cognitive function of asthmatic and non-asthmatic children in Ilorin, Nigeria.

Methods This cross-sectional study compared the cognitive performance scores of 66 children with asthma aged 6-17 years, and the corresponding scores of 66 healthy age- and gender-matched children without asthma. Data obtained included sociodemographic, anthropometric, and clinical details. Cognitive function was assessed with the *Raven's Progressive Matrices* (RPM) psychometric test.

Results The male: female ratio was 1.3:1. The median RPM score of 50.0 [interquartile range (IQR) 25.0-75.0] in children with asthma was significantly higher than that of non-asthmatic children [32.5 (IQR 10.0-50.0)]; (P=0.016). A significantly higher proportion of asthmatic subjects (74.2%) were in the high grade RPM score category compared to the non-asthmatic children's concomitant proportion (57.6%). Asthmatic subjects were twice as likely to belong to the high grade RPM score category than their non-asthmatic counterparts (OR=2.12; 95%CI 1.02 to 4.44; P=0.043). There was no significant association between RPM score grade and clinical severity of asthma in the subject population (P=0.554).

Conclusion Children with asthma perform better in cognitive function assessment, using RPM test, compared to their non-asthmatic counterparts in Ilorin, Nigeria. **[Paediatr Indones. 2024;64:97-105; DOI: 10.14238/pi64.2.2024.97-105]**.

Keywords: *asthma; cognitive function; children; Nigeria; Raven's Progressive Matrices*

Cognition refers to the mental process needed to carry out any task, or simply, the ability of the brain to think and reason.[1] Thus, a child's cognitive function can be defined as their problem-solving skills.[1,2] Intelligence quotient (IQ) tests remain the most useful, reliable, and valid clinical/psychometric tool for assessing a child's cognitive function.[2] Indeed, IQ tests constitute a valid index of evaluating how well a child can perform in school.[1]

Bronchial asthma is a chronic disorder characterised by episodic breathlessness, wheezing, cough, and chest tightness.[3] With an estimated 300 million people affected globally, a significant proportion of whom are children and adolescents, bronchial asthma remains a major cause of chronic morbidity in childhood.[4] Regional differences in asthma prevalences exist. Moreover, the last two decades have witnessed an overall increase in the global burden of disease amongst children living both in developed and developing countries.[3,5]

From the Department of Paediatrics, General Hospital[1], Department of Paediatrics & Child Health, University of Ilorin and University of Ilorin Teaching Hospital[2], Ilorin, Kwara State, Nigeria.

Correspondence author: Salihu Sheni Mohammed. Department of Paediatrics, General Hospital, Abdulazeez Attah Road, Ilorin, Kwara state, Nigeria; Email: salihusheni@yahoo.com or salihusheni@gmail.com.

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Using the *International Study of Asthma and Allergies in Childhood* (ISAAC) protocol, a study reported a prevalence of 5.1% among primary school pupils in Ibadan, South-West Nigeria.[6] In contrast, a study in Nnewi, South-Eastern Nigeria, reported a prevalence of 14.3% among adolescents.[7] A recent multicentre survey in Nigeria identified a nationwide prevalence of 3.1 (range 2.88-3.32)% for clinical asthma among children aged 6-17 years.[8]

The presence of asthma in children may negatively impact their cognitive function because of intermittent hypoxia from repeated acute exacerbations, sleep deprivation, and side effects of anti-asthmatic medications.[9-11] Previous studies, though few, have sought to determine the cognitive performance of asthmatic children compared to their healthy peers using standardized test scores, grade point averages, and IQ tests as indices of cognition. However, these studies have yielded inconsistent findings on whether the presence of asthma truly puts a child at risk of poor cognitive performance compared to children without asthma. Some evidence suggested that children with asthma performed just as well as their healthy peers without asthma, using academic performance and IQ tests.[12-17] Other studies have shown that children with asthma are at an increased risk of learning disability, grade failure, and performing lower on standardized tests than otherwise healthy non-asthmatic children.[18,19] Furthermore, some studies have reported that the cognitive function of asthmatic children may be better than that of their healthy peers.[20-22]

Many asthmatic children tend to miss more school days than their non-asthmatic and healthy peers, on account of recurrent acute exacerbations.[15,23,24] However, these missed days have not been shown to affect their academic performance adversely compared to that in otherwise healthy non-asthmatic children.[22] Academic performance is not solely determined by cognitive function; it also depends on features such as persistence, interest in school, and willingness of the pupil/student to study.[25] Hence, for a proper evaluation of the actual or innate intelligence of the target population of children, the need to deploy a measure of cognitive function independent of school attendance was required. A recent study that determined the effects of asthma on 'school function' in Nigerian children with asthma made some observations on attention span, ability to keep up with school work, and asthmatic children's vulnerability to missing school attendance.[24] However, there is an evident lack of reports on the cognitive function of asthmatic children in the West African Sub-region in general, including Nigeria.

As such, we conducted this study to assess and compare the cognitive function of asthmatic children aged 6-17 years at the University of Ilorin Teaching Hospital, with that of apparently healthy, non-asthmatic children in selected primary and secondary schools in the Ilorin metropolis using *Raven's Progressive Matrices* (RPM) test.[26] The RPM test is a widely accepted tool for assessing cognitive function.[27] The test appraises visuo-spatial and deductive reasoning, abstract thinking, as well as general intelligence or "g". One of the merits of RPM is that it can be validly administered to individuals or groups ranging from six-year-olds to the elderly.[28] The RPM was designed with an intrinsic capacity to minimize the influence of culture on performance results, hence, obtainable results are expected to be globally reproducible. This peculiarity underscores its applicability to subjects living in resource-poor settings. It contains non-verbal problems that require abstract reasoning, and the required knowledge is minimally dependent on the cultural background of the test subject. In essence, the RPM is a culture-friendly tool for assessing cognitive functioning.[29]

This study aimed to assess cognitive function of asmathic compared to non-asmathic children using the RPM test.

Methods

This cross-sectional study was conducted at the Paediatric Respiratory Clinic of the University of Ilorin Teaching Hospital (UITH) and four randomly selected schools in Ilorin. The UITH is a 500-beds tertiary health facility located in Ilorin, the capital city of Kwara State in North Central Nigeria. Data collection was done from January to June 2016.

Participants were children with asthma aged 6-17 years in follow-up care at the Paediatric Respiratory Clinic, University of Ilorin Teaching Hospital (UITH). The control group of apparently healthy, non-asthmatic schoolchildren aged 6-17 years were recruited from the four randomly selected schools in Ilorin. The inclusion criteria for the asthmatic group were physician-diagnosed asthma in children who were free of symptoms of exacerbation and in relative good health for at least two weeks prior to recruitment. The inclusion criteria for the non-asthmatic group were apparently healthy, non-asthmatic schoolchildren who had been free from any acute illness for at least two weeks prior to recruitment. Children with neurological disorders (congenital or acquired), visual or hearing impairment, overt malnutrition, sickle cell anemia, diabetes mellitus, or any other chronic illnesses were excluded from the study.

Children with asthma were recruited from the clinic using purposive sampling, in which all the asthmatic children who were available and met the eligibility criteria were consecutively recruited without age or gender stratification; recruitments were made until the desired sample size was attained. A multi-stage stratified random sampling technique was used in the selection of controls from four randomly selected schools (one private primary, one public primary, one private secondary, and one public secondary) in Ilorin.

A semi-structured proforma was administered to obtain sociodemographic information and relevant medical history like pregnancy and birth history to rule out perinatal complications that may have affected cognition. Other medical information collected included developmental history, history of chronic illness, or acute illness in the preceding two weeks. In addition, a detailed history of when and where asthma was first diagnosed, frequency of asthma symptoms, and the timing of the most recent asthma exacerbation were obtained for asthmatic subjects. The socio-economic class of the subjects were determined using the classification of Oyedeji in which the parents' occupation and educational status were graded into five classes I to V in descending order of privilege.[30] The five occupational classes were; class I: senior public servants, professionals, managers, large scale traders, businessmen and contractors; class II: intermediate grade public servants and senior school teachers; class III: junior school teachers, professional drivers, artisans; class IV: petty traders, labourers, messengers; class V: unemployed, full-time housewife, students and subsistence farmers. On the other hand, the educational classes include; class I: university graduates or equivalents; class II: school certificate holders who also had teaching or other professional training; class III: school certificate or grade II teachers certificate holders or equivalents; class IV: modern three and primary six certificate holders; class V: those who could either just read and write or were illiterate.[30] The mean of four classes (two for the father and two for the mother) approximated to the nearest whole number was the socio-economic class assigned to the child. For example, if the mother was a junior school teacher (class III), and the father a senior school teacher (class II) and the educational attainment of the mother was primary six (class IV) and the father was a school certificate holder (class II), the socio-economic class for this child was: $(3+2+4+2)\div 4 = 11\div 4 = 2.75$, the nearest whole number = 3 (which is class III).

All participants had general physical examinations with anthropometry (weight and height), neurological evaluation, and examination of the respiratory, cardiovascular, and alimentary systems. Subject's peak expiratory flow rate (PEFR) and forced expiratory volume in one second (FEV1) were measured using a handy digital peak flow meter (*Piko-1*® digital peak flow meter manufactured by *nSpire Health Inc.* Longmont, CO, USA). The *Piko-1*® digital peak flow meter is a battery-operated device that measures both the PEFR and FEV1 to the nearest 1L/min and 0.01L, respectively. Measurement of PEFR and FEV1 was done after the appropriate demonstration as follows. With the subject in a standing position, a disposable mouthpiece was attached to the *Piko-1*® device. The participant held the device in one hand without covering the vent. The button on the device was then pressed until a short beep confirmed the action. A blow icon was displayed on the liquid crystal display (LCD) screen with a second beep, indicating that the test could begin. The subject then placed the mouthpiece in their mouth, inhaled as fully as they could, and then blew as hard as possible. The test results (PEFR and FEV1) were displayed on the LCD screen as soon as the blowing manoeuvre was completed. Three consecutive satisfactory readings were taken for each subject, and the best of the three readings was recorded as valid PEFR and FEV1 for all subjects. The disposable mouthpiece was changed between subjects to prevent cross-infection.

The clinical severity of asthma was classified using GINA (2006) guidelines based on the frequency of asthma symptoms, and percentage predicted PEFR and FEV1 values. Each subject's asthma severity was categorized into mild intermittent, mild persistent, moderate persistent, or severe persistent, according to the GINA classification.[31]

The cognitive function of study participants was assessed using the RPM test. The RPM test kit contains test booklets, answer sheets, answer keys, and a test manual. The kits used in this study were obtained from the publisher (*Pearson PLC*).

The RPM test consisted of 60 multiple choice questions listed in order of difficulty. For each test item, the subject was asked to identify the missing element that completes a matrix pattern. The test subject figured out the rules governing the patterns, then used those rules to pick the item that best fills the missing pattern. It took an average of 30 minutes to complete the RPM test. Appropriate instructions were given before providing the test booklets and answer sheets to the study participants. Each person taking the test was given two writing pencils, an eraser, a test booklet, and an answer sheet. The test was carried out in a designated room in the clinic (for asthmatic children) and designated classrooms in the schools (for children without asthma) to avoid distractions. Participants had a maximum of 30 minutes to answer the questions without interruption. The answer scripts were marked by one of the investigators using an answer key provided by the publisher. The scores obtained for each child were converted into percentiles, using the percentile-for-age charts in the test manual. Each child's percentile score was recorded as the RPM score. The RPM scores were then classified into five grades as recommended in the test manual, as detailed below: grade 1 (intellectually superior): if a score lied at, or above the 95^{th} percentile for people of the same age group; grade 2 (definitely above average in intellectual capacity): if a score lied at, or above the 75^{th} percentile; grade 3 (intellectually average): if a score lied between the 25^{th} and 75^{th} percentiles; grade 4 (definitely below average in intellectual capacity): if a score lied at or below the 25^{th} percentile; grade 5 (intellectually impaired): if a score lied at or below the 5^{th} percentile for that age group. For the purpose of analysis, the grades were further classified as high (grades 1, 2 and 3) or low (4 and 5).

Data entry and analyses were carried out using *SPSS version 20®* software. Tables were used to report descriptive statistics. Mean values and standard deviations (SD), as well as median and interquartile range (IQR) values, were provided as appropriate. Discrete variables were compared using the Chi-square test or Yate's corrected Chi-square values, for tables containing cells with values less than 5. Mann-Whitney U test or Kruskal-Wallis test were used to compare median (IQR) values, as appropriate. Odds ratio (OR) and 95% confidence intervals (CI) were calculated to test the significance of associated factors. The level of significance was established at a P value of ≤ 0.05.

Ethical approval was granted by the Ethics and Research Committee of the University of Ilorin Teaching Hospital. Also, written permission was obtained from the Kwara State Ministry of Education for the control group. Informed consent was also obtained from respective parents/caregivers of children as applicable, after clearly explaining what the study entailed, and before subject evaluation and recruitment. Assent was also sought from children aged ten years and above.

Results

A total of 132 children, comprising 66 children with asthma and 66 non-asthmatic children, participated in the study. Sociodemographic characteristics of study participants are shown in **Table 1**. There were 74 males and 58 females, with a male: female ratio of 1.3:1. There were no significant differences in the socio-economic status and other sociodemographic parameters between the two groups (**Table 1**). The median duration after diagnosis of asthma in the asthma group was 5.0 (IQR 3.0-7.3) years. A high proportion (44; 66.7%) of cases were diagnosed at UITH, 16 (24.2%) at private hospitals, and six (9.1%) at General Hospital, Ilorin.

Selected anthropometric parameters of study participants were measured and compared between the asthmatic and non-asthmatic children, including weight, height and BMI. The statistical values and levels of significance of the selected parameters compared are detailed in **Table 2**. There were no significant differences between the mean weight, mean height, or mean BMI between the two groups of children (**Table 2**).

Table 1. Sociodemographic characteristics of subjects

Characteristics	Asthmatic (n=66)	Non-asthmatic (n=66)	Total (N=132)	χ^2/χ	P value
Age group, n (%)					
6-9 years	29 (44.0)	29 (44.0)	58 (44.0)		
10-13 years	21 (31.8)	21 (31.8)	42 (31.8)	-	-
14-17 years	16 (24.2)	16 (24.2)	32 (24.2)		
Sex, n (%)					
Male	37 (56.0)	37 (56.0)	74 (56.0)		
Female	29 (44.0)	29 (44.0)	58 (44.0)	-	-
Socio-economic class, n (%)					
I	21 (31.8)	11 (16.7)	32 (24.3)		
II	24 (36.4)	20 (30.3)	44 (33.3)		
III	6 (24.2)	24 (36.4)	40 (30.3)	7.561	0.109
IV	3 (4.6)	8 (12.1)	11(8.3)		
V	2 (3.0)	3 (4.5)	5 (3.8)		
Type of family, n (%)					
Monogamous	57 (86.4)	53 (80.3)	110 (83.3)		
Polygamous	9 (13.6)	13 (19.7)	22 (16.7)	0.873	0.350
Paternal educational status, n (%)					
None	1 (1.5)	4 (6.1)	5 (3.8)		
Primary	3 (4.5)	2 (3.0)	5 (3.8)		
Secondary	10 (15.2)	17 (25.8)	27 (20.4)		
Tertiary	52 (78.8)	43 (65.1)	95 (72.0)	2.807*	0.422
Maternal educational status, n (%)					
None	2 (3.0)	3 (4.5)	5 (3.8)		
Primary	4 (6.1)	6 (9.1)	10 (7.6)		
Secondary	19 (28.8)	22 (33.3)	41(31.0)		
Tertiary	41(62.1)	35 (53.1)	76 (57.6)	0.527*	0.913

χ^2=Chi-square; χ=Yates corrected Chi-square

Table 2. Anthropometric parameters of subjects

Parameters	Asthmatic	Non-asthmatic	T	P value
Mean weight (SD), kg	35.4 (11.7)	33.1 (10.9)	1.143	0.255
Mean height (SD), cm	140.7 (15.4)	137.4 (14.8)	1.257	0.211
Mean BMI (SD), kg/m^2	17.3 (2.8)	17.1 (2.7)	0.500	0.618

T=independent samples T-test

Table 3 shows that the median (IQR) FEV1 value of 1.1 (0.9-1.7) L in asthmatic children was significantly lower than the median (IQR) FEV1 values of 1.4 (0.9-2.0) L in non-asthmatic children (P=0.049). Also, the median (IQR) PEFR of 163.5 (118.0-241.8)L/min in asthmatic children was significantly lower than the corresponding value of 197.0 (138.0-289.0) L/min in non-asthmatic children (P=0.045).

The median (IQR) RPM score of the asthma group was 50.0 (25.0-75.0), which was significantly higher than that of the non-asthmatic group [32.5 (10.0-50.0)]; (P=0.016). As shown in **Table 4**, a higher proportion of asthmatic subjects (74.2%) had high grade RPM score compared to non-asthmatic children (57.6%). Children with asthma were twice as likely to have a high grade RPM score than their non-asthmatic counterparts (OR=2.12; 95%CI 1.02 to 4.44; P=0.043).

As presented in **Table 5**, there was no significant association between RPM score grade and clinical severity of asthma in asthmatic subjects (P=0.554).

Table 3. FEV1 and PEFR of the study participants

Parameters	Asthmatic	Non-asthmatic	U	P value
Median FEV1 (IQR), L	1.1 (0.9-1.7)	1.4 (0.9-2.0)	1745.000	0.049
Median PEFR (IQR), L/min	163.5 (118.0-241.8)	197.0 (138.0-289.0)	1738.000	0.045

IQR=interquartile range; U=Mann-Whitney U test-value; FEV1=forced expiratory volume in one second; PEFR=peak expiratory flow rate

Table 4. Comparison of cognitive function (using RPM score grade) between asthmatic and non-asthmatic children

RPM score grade	Asthmatic	Non-asthmatic	OR (95%CI)	χ^2	P value
High, n (%)	49 (74.2)	38(57.6)	2.124 (1.017 to 4.437)	4.080	0.043
Low, n (%)	17 (25.8)	28(42.4)			

Table 5. Analysis of cognitive function (using RPM score grade) and clinical severity of asthma among asthmatic subjects

RPM score grade	Asthma severity					
	Mild intermittent (n=46)	Mild persistent (n=10)	Moderate persistent (n=4)	Severe persistent (n=6)	χ^2	P value
High, n (%)	32 (69.6)	9	3	5	2.085	0.554
Low, n (%)	14 (30.4)	1	1	1		

Discussion

The finding of higher RPM cognitive test scores in children with asthma compared to non-asthmatic children constitutes the most important highlight of this study. This observation was similar to findings reported in Scotland,[20] Israel,[21] and the USA.[22] The comparable findings between the Israeli study and ours may be partly ascribed to the common deployment of the RPM tool, despite the former study restricting their subject selection to 17-year-old adolescent males.[21] The similar age and gender distribution of the US-based report[22] and the Scottish study,[20] to those of our study underscores the comparability of the studies. However, another study in US used the academic achievement test, a less accurate index of determining children's cognitive ability.[22] Furthermore, Mitchell *et al.*[20] did not explicitly state the test instrument used to assess cognition in their study. In addition, a study inferred that children with asthma had higher cognitive function by identifying a higher incidence of asthma among intellectually gifted US children,[32] which is in agreement with our finding of superior cognition amongst children with asthma.

Asthmatic children's higher cognitive performance in our study may be partly explained by the 'hygiene hypothesis'. This hypothesis suggests that asthmatic children are more likely to grow up in families with higher socioeconomic levels; such families are more likely to have cleaner environments.[33-35] Also, children born into such families are likely to be inherently more intelligent, as intelligence has been shown to be highly heritable.[36] In addition, asthmatic children are more likely to engage in cognitively stimulating or intellectually demanding play, which may not be physically demanding in view of their inherent physical limitations. Earlier reports have shown that asthmatic children engage in lower levels of physical activity compared to their non-asthmatic peers.[37,38] This may, in turn, be explained by the perceived dangers of engaging in physical exercise by asthmatic children.[39] Since cognitively stimulating play has been reported to enhance children's intellectual development,[40] the higher cognitive status recorded among asthmatic children in our study may not be entirely surprising. Furthermore, high cognitive performance levels may be a genetic 'side effect' of asthma, as has been suggested in some other hereditary diseases especially among the reportedly more cognitively endowed Ashkenazi Jews.[41,42] This proposition, however, remains unproven as there are no documented genetic links between asthma and high cognitive function.

In contrast, earlier studies reported no difference in cognitive performance of asthmatic children compared to controls.[12,14-16,22,23,43] It is, however, instructive to note that a previous study which deployed the WISC psychometric tool, found no statistically significant difference between IQ scores of asthmatic (mean score of 109) and non-asthmatic children (mean score of 108).[16] Similarly, in a Nigerian study a higher mean RPM test score of 24.5 (SD 11.2) was recorded in atopic children, regardless of their asthma status, compared to mean score of 23.2 (SD 11.8) in non-atopic children.[44]

Contrary to our findings, two reports from Egypt posited that the cognitive performance of asthmatic children was inferior to their non-asthmatic peers.[18,19] However, these two studies deployed the WISC tool. The WISC tool, with an inherent capacity for testing both verbal and non-verbal components of intelligence, differs from the RPM tool, which tests only the non-verbal element of intelligence. Furthermore, the RPM is matrix-based, and test results may be independent of subjects' literacy status and sociocultural settings. A previous study suggested that some possible reasons for low IQ in asthmatic children were poverty and poor asthma control, with a potential long term effect of intermittent cerebral hypoxia. The majority of their asthmatic subjects belonged to the low socioeconomic class, making poverty a plausible explanation. However, the authors did not subject this observation to statistical analysis.[18] Similarly, a study postulated that low IQ in their asthmatic subjects could be attributed to subsisting poverty and family dysfunction. While poverty and family dysfunction constitute possible factors for asthmatics' reported poor cognitive function, asthma and poor cognition were not shown to be associated.[19] Such putative differences in findings may be ascribed to methodological issues such as differences in methods of cognitive function assessment, sample size limitations, and different geographic locations of the studies.

There was no significant association between cognition, as reflected by RPM scores, and asthma severity in our study. This finding may have been due to the overrepresentation of mild intermittent asthma compared to the relatively few subjects with other clinical severity types. Hence, the validity of the absence of an association between asthma severity and RPM test scores may require a larger sample size to incorporate a more representative sample in terms of disease severity. However, a previous study reported a similar lack of association between cognition and asthma severity in the USA.[22] Similarly, in another US-based report involving only subjects with severe asthma, no significant difference was identified in the cognition of children with severe asthma compared to that of non-asthmatic controls.[14] Furthermore, studies in the US[12] and Iran,[16] did not identify a significant association between the cognitive performance scores in subjects with the moderate forms of the disease compared to scores of those with mild disease.

A limitation of our study was the cross-sectional study design which precludes the establishment of a causal relationship between asthma and high cognitive performance. Also, the underrepresentation of subjects with moderate and severe asthma may have influenced the lack of an association between clinical severity of asthma and cognitive performance.

In conclusion, the cognitive performance of asthmatic children using the RPM test tool is high. Children with asthma have significantly higher RPM test scores compared to that of non-asthmatic controls. This finding may reinforce parental acceptance of and adherence to treatment recommendations as well as enhance self-esteem and confidence in guided self-care in older asthmatic children and adolescents.

Conflict of interest

None declared.

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