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The Association between Intelligence Levels, Aggression, and Second-To-Fourth-Digit Ratios in Children with Attention Deficit Hyperactivity Disorder

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ABSTRACT

Background: Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental condition that originates in childhood and negatively affects functioning in several domains. According to recent research, the second-to-fourth digit ratio (2D:4D), representing the length of the index finger (2D) relative to the ring finger (4D), serves as a valid predictor of intrauterine testosterone levels due to its inverse correlation with prenatal testosterone exposure (PTE), remains stable throughout life. **Objective:** To study any possible relationship between 2D:4D, aggression and intelligence levels in children with ADHD. **Patients and Methods:** This was prospective randomized study, which was conducted on 60 children and adolescents diagnosed with ADHD at the Pediatric Neuropsychiatric Outpatient Clinic of Al-Azhar Assiut University Hospital during the period from 1st of June 2021 to 31st of March 2022.

Results: The two groups under study differed statistically significantly in terms of age, sex, smoking exposure, sibling order, family history of chronic illness, and family history of ADHD. The two groups under study differed significantly in terms of Teacher T-DSM-IV-S, CPRS-RS, CTRS-RS, and Parent T-DSM-IV-S. The right and left hands of ADHD cases had lower 2D:4D compared to healthy control ($p<0.001$). **Conclusion:** Compared to healthy controls, children with ADHD who have not received therapy had lower right-hand 2D:4D, which are a measure of PTE. Additionally, a potent inverse association between left-hand 2D:4D and hyperactivity ratings were seen. These findings offer more proof that the pathophysiology of ADHD could be affected by prenatal androgen exposure.

Keywords: ADHD, Second-to-fourth-digit ratios, Children, Intelligence.

INTRODUCTION

ADHD is a developmental disease that manifests as either hyperactivity or inattention without accompanying hyperactivity, as well as inattention and distractibility. Inattentive, impulsive, hyperactive, and mixed are the three main forms of ADHD identified in the Diagnostic and Statistical Manual, Fifth Edition (DSM-5) [(1)]. Inattention, with or without hyperactivity, is a common trend among ADHD patients that disrupts everyday life and a child's development. A child's troubles usually appear in two or more areas, such as their home, workplace, school, and social relationships [(2)]. Males are more likely than females to have ADHD, with the ratio of boys to girls ranging from 2:1 to 10:1 [(3,4)]. The exact etiology of ADHD remains uncertain despite the discovery of several possible biomarkers [(5)]. The findings of gender disparities have caused some researchers to wonder whether the neuroendocrine system contributes to the genesis of ADHD [(6)].

One of the fascinating research topics in this regard is exposure to steroid hormones during pregnancy [(7)]. Unfortunately, detecting prenatal steroid hormones is expensive and requires invasive procedures. The intrauterine amount of testosterone is believed to be indicated by the (2D:4D), and is inversely connected with prenatal testosterone exposure (PTE). Numerous studies have shown that this association holds true during an individual's lifetime [(8,9)]. A lot of investigators used the 2D:4D to assess the association between PTE and neurodevelopmental diseases, which include ADHD since it is a non invasive simple tool. Certain researchers included participants with a clinical diagnosis of ADHD, whereas others employed unselected population samples [(8,9)]. Studies utilizing population samples have revealed a correlation between higher masculine ratios and more symptoms, but some research has only included girls in this association, while other studies have only included boys [(10)]. The 2D:4D among individuals with a clinical diagnosis of ADHD were not extensively studied. One of these studies found that male patients with anxiety problems had higher 2D:4D than male cases with ADHD [(11)]. In related research, it was shown that children with ADHD had a lower 2D:4D than controls; however, the female group did not exhibit this difference [(9)].

Parents and educators claim that the right hand 2D:4D aids in distinguishing between boys with ADHD and controls. Additionally, hyperactivity-impulsivity and inattention are more common in men with more masculine ratios [(12)]. Furthermore, studies show that the 2D:4D of the ADHD and control groups were identical [(13)]. Subjects with a lower, more male-typical, 2D:4D typically had more severe symptoms of ADHD, according to an analysis of the research's findings. These results provide credence to the idea that PTE affects a child's development of ADHD [(8,14)]. The current study's objective was to study any possible association between 2D:4D, aggression and intelligence levels in children with ADHD.

PATIENTS AND METHODS

This study was conducted at the Pediatric Neuropsychiatric Outpatient Clinic of Al-Azhar Assiut University Hospital between October 1, 2021, and April 30, 2022, on 60 ADHD children and adolescents aged 6 to 16, as well as 30 children and adolescents of matched age and sex who appeared to be in good health as a control group.

Inclusion criteria: children and adolescents diagnosed with ADHD between 6-16 years old.

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Exclusion criteria: Being left-handed, having a serious neurological or physical illness (such as epilepsy, cerebral palsy, cardiovascular disease, etc.), or having a serious mental illness (such as schizophrenia, bipolar disorder, or autism) that might affect one's ability to think and move, past use of psychiatric drugs.

Every child participating in this research was exposed to: A detailed history was taken, including; personal history, history of current illness: Onset, course, duration, associated and linked symptoms, family history: About other members of the patient's family affected by any neurological or psychiatric disorders, perinatal history, Natal history, and postnatal history: Any resuscitation required, or any abnormalities discovered, nutritional history, vaccination history.

Diagnostic and symptom assessment: Stanford- Binet Intelligence Scales, Fourth Edition (SB4), to assess the ADHD children, the subjects' parents filled out the Conners' (CPRS-RS) and DSM-IV-Based Child and Adolescent Behavioural Disorders Screening and Rating Scale (T-DSM-IV-S), and to determine the children's aggression severity. Evaluations of weight, height, and digit ratio were also done.

Ethical approval: The Al-Azhar University (Assiut) Faculty of Medicine's Ethics Committee gave its approval to the study. The patients' parents or guardians gave their oral approval. Before the data were collected, the parents were informed of the purpose of the work. All collected data were guaranteed to remain private. Both the service offered and the research methods had no negative effects on the participants. The Helsinki Declaration was followed throughout the course of the study.

Statistical analysis

Version 26.0 of the SPSS was used for data analysis. The mean±SD, range, median, and interquartile range were used to characterize quantitative variables. Numbers and percentages were used to characterize qualitative factors. The Student t test was used to compare parametric quantitative variables between the two groups. X^2-test was utilized to compare the qualitative variables; but when frequencies were less than five, Fisher's exact test was used. The connection between two normally distributed variables was assessed using Pearson correlation coefficient. P values less than 0.05 were regarded as significant.

RESULTS

The two groups under study differed statistically significantly in terms of age, sex, smoking exposure, sibling order, family history of chronic diseases, and family history of attention deficit hyperactivity disorder.

Table (1): Comparison between the ADHD group and control group according to Demographic data.

Demographic data	ADHD Group (n = 60)		Control Group (n = 30)		P
	No.	%	No.	%	
Age (years): Min. – Max.	6.0 – 16.0		6.0 – 16.0		**0.02***
Mean ± SD.	9.7 ± 2.3		12.0 ± 3.0		
Sex: Male	42	70.0	16	53.3	**0.018***
Female	18	30.0	14	46.7	
Order among siblings					**<0.001***
1st	20	33.3	8	26.6	
2nd – 3rd	15	25.0	20	66.7	
≥ 4th	25	41.7	2	6.7	
Smoking Exposure					**0.031***
Yes	33	55.0	10	33.3	
No	27	45.0	20	66.7	
Family History of Chronic Diseases					**0.002***
Yes	20	33.3	2	6.7	
No	40	66.7	28	93.3	
Family History of ADHD					**0.023***
Yes	16	26.7	3	10.0	
No	44	73.3	27	90.0	
Weight Percentile					**0.014***
Mean ± SD.	54.6 ± 29.5		66.1 ± 28.5		
Median (IQR)	53.4 (52.4 – 64.4)		64.1 (62.7 – 73.4)		
Height Percentile					**0.007***
Mean ± SD.	51.6 ± 30.1		64.9 ± 26.7		
Median (IQR)	50.2 (49.4 – 68.7)		62.7 (60.7 – 74.4)		
BMI Percentile					**0.037***
Mean ± SD.	53.8 ± 29.9		64.6 ± 29.9		
Median (IQR)	52.8 (51.4 – 69.4)		63.4 (62.4 – 76.4)		

X^2: Chi Square test, **t:** Student t-test, ***** Significant.

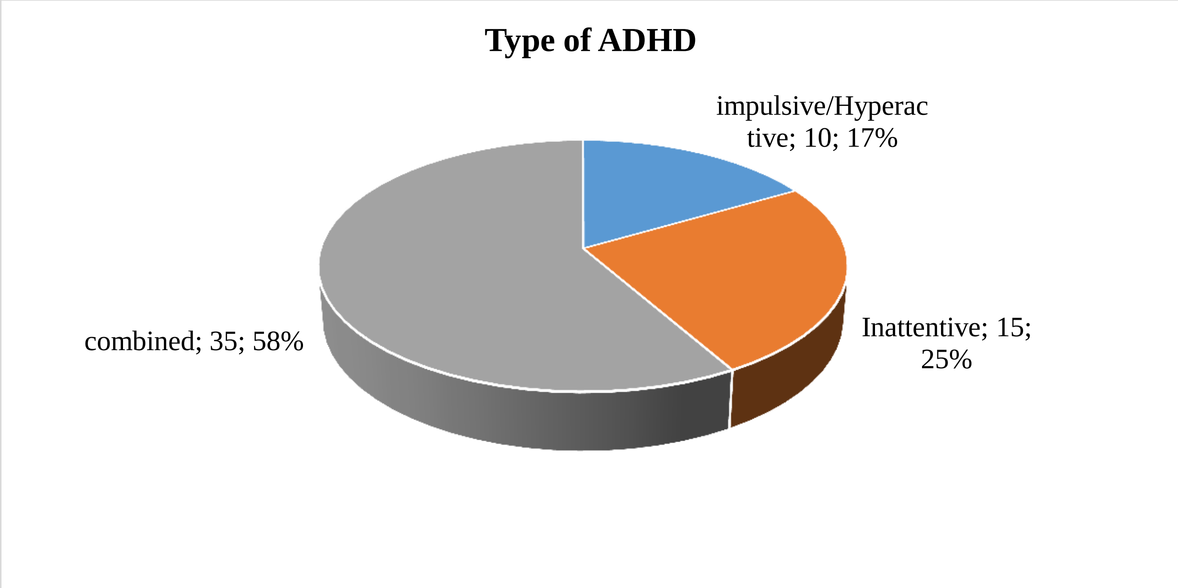

Fig. (1): Distribution of the studied cases according to type of ADHD.

Table (2): Comparison between the ADHD group and control group according to pre-natal, natal and post-natal History.

Items	ADHD Group (n = 60)		Control Group (n = 30)		P
	No.	%	No.	%	
Toxemia of pregnancy					
Yes	35	58.3	6	20.0	**<0.001**
No	25	41.7	24	80.0	
Mode of delivery					
NVD	12	20.0	20	66.7	**<0.001***
CS	48	80.0	10	33.3	
Cyanosis					
Yes	42	70.0	6	20.0	**<0.001***
No	18	30.0	24	80.0	
Lactation					
Breast feeding	20	33.3	25	83.3	**<0.001***
Artificial	40	66.7	5	16.7	
Head trauma					
Yes	33	55.0	13	43.3	0.297
No	27	45.0	17	56.7	
Congenital anomalies					
Yes	39	65.0	8	26.7	**<0.001***
No	21	35.0	22	73.3	
Breastfeeding time Mean ± SD.	13.8 ± 8.2		13.7 ± 7.5		0.935

*: **Significant.**

The two groups under investigation differed statistically significantly according to pre-natal, natal and post-natal history regarding to toxemia of pregnancy, mode of delivery, cyanosis, lactation, head trauma, Apgar score, congenital anomalies, breastfeeding time as demonstrated in (Table 2).

Table (3): Comparison between the ADHD group and control group according to Stanford- Binet Intelligence Scales, Fourth Edition (SB4)

Parameters of intelligence quotient (IQ)	Control N=30	ADHD group N=60	Significance P-value
Vocabulary	62.5 ± 4.5	60.5 ± 6.4	P>0.05
Comprehension	58.5 ± 4.2	56.16 ± 6.9	P>0.05
Verbal Relations test	121 ± 8.7	116 ± 13.3	p>0.05
Abstract Visual Reasoning	90.3 ± 11	45.4 ± 13.5	p<0.01**
Quantitative Reasoning	97.1 ± 9.7	54.2 ± 5.5	p<0.01**
Bead Memory test	46.8 ± 5.6	46.39 ± 7.89	p>0.05
Memory for Sentences	48.1 ± 4.6	40.95 ± 7.62	p<0.05*
Short term Memory	94.9 ± 10.2	87.34 ± 15.51	p<0.05*
Total IQ	92.7 ± 7.9	71.7 ± 9.18	p<0.01**

*: **Significant**

There was highly significant difference between ADHD group and control group regarding Abstract Visual Reasoning, Quantitative Reasoning, Memory for Sentences, Short term Memory and total IQ, as demonstrated in (Table 3).

Table (4): Comparison between the ADHD group and control group according to diagnostic and DSM-4.

Clinical features	ADHD Group (n = 60)	Control Group (n = 30)	P
Parent T-DSM-IV-S			
AD	14.7 ± 5.3	4.2 ± 3.4	0.01*
HA/I	16.2 ± 6.0	3.4 ± 2.7	<0.001*
OD	11 ± 4.9	4.0 ± 3.2	0.01*
CD	3.6 ± 3.7	0.5 ± 1.0	<0.001*
CPRS-RS			
OD	9.5 ± 4.3	4 ± 3.5	0.22
CP-I	11.8 ± 4.2	2.5 ± 2.8	0.01*
HA	9.8 ± 4.4	1.4 ± 1.9	<0.001*
Teacher T-DSM-IV-S			
AD	15.7 ± 5.2	3.4 ± 4	0.12
HA/I	13.5 ± 7.2	1.8 ± 2.9	<0.001*
OD	9.1 ± 5.7	1.3 ± 1.9	<0.001*
CD	3.8 ± 5.1	0.2 ± 0.7	<0.001*
CTRS-RS			
OD	4.6 ± 3.9	1 ± 2.2	0.001*
CP-I	6.9 ± 3.6	1 ± 1.4	<0.001*
HA	10.5 ± 5.7	1 ± 1.4	<0.001*

*: **Significant**

ADHD: attention-deficit/hyperactivity disorder, T-DSM-IV-S: Turgay Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition. AD: attention-deficit, HA/I: hyperactivity-impulsivity, OD: oppositional defiant behaviour, CD: conduct disorder, CTRS-RS: Conners Teacher Rating Scale-Revised Short, CPRSRS: Conners Parent Rating Scale-Revised Short, CP-I: cognitive problems-inattention, HA: hyperactivity.

There was a significant difference between both studied groups as regards Parent Turgay DSM-4-S, CPRS-RS, Conners Teacher T-DSM-IV-S, and CTRS-RS as demonstrated in table 4.

Table (5): Comparison between the ADHD group and control group according to mean 2D:4D.

Mean 2D:4D	ADHD Group (n = 60)	Control Group (n = 30)	P
Right hand (Mean ± SD)	0.85 ± 0.05	0.96 ± 0.1	**<0.001***
Left hand (Mean ± SD)	0.89 ± 0.04	0.98 ± 0.09	**<0.001***

*: **Significant**

There was lower 2D:4D in the right hand and left hand in ADHD compared to the control group as demonstrated in (Table 5).

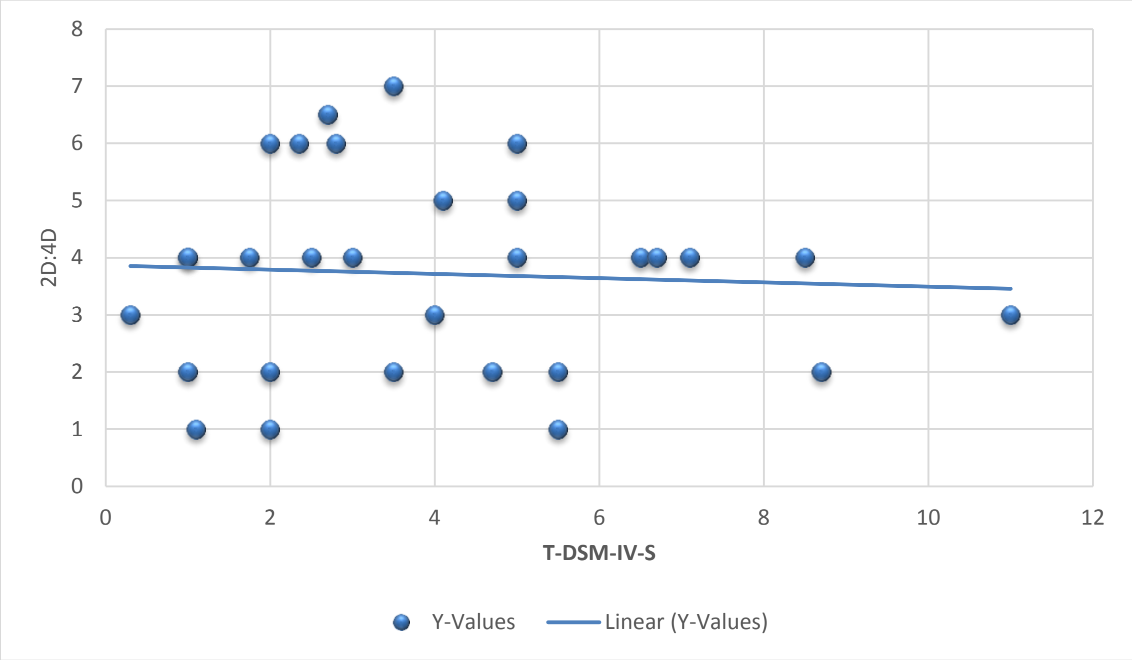

Fig. (2): The correlation between T-DSM-IV-S and 2D: 4D ratio in patient with ADHD group.

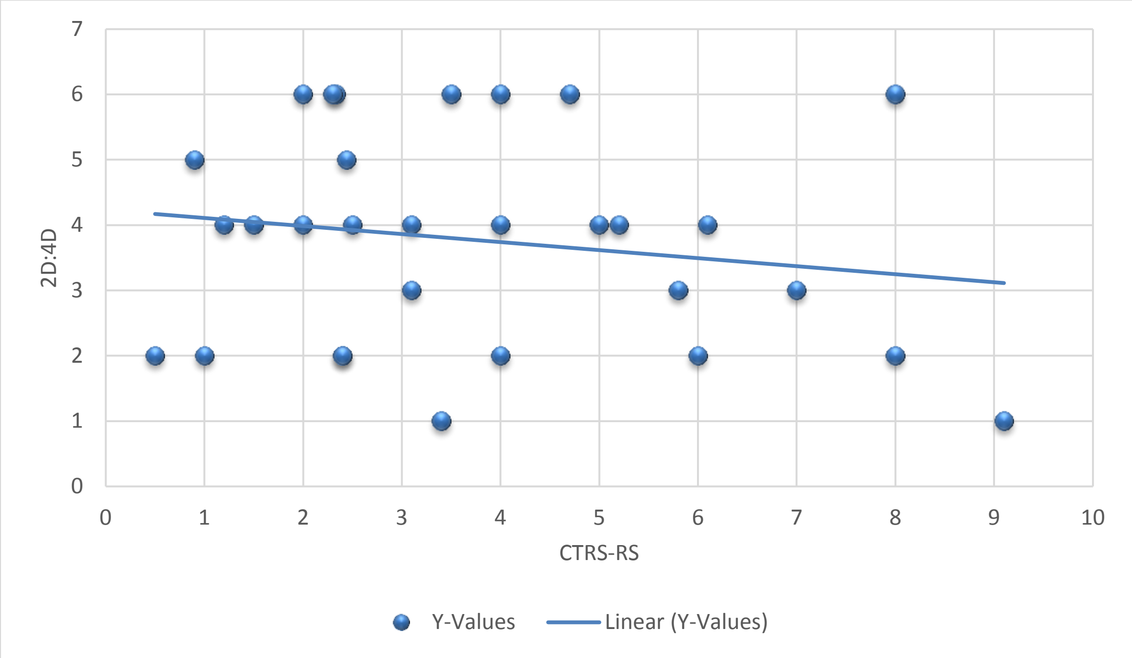

Fig. (3): The correlation between CTRS-RS and 2D: 4D ratio in patient with ADHD group.

This figures shows that there was a significant negative correlation with the hyperactivity scores in the teacher-rated questionnaire (T-DSM-IV-S and CTRS-RS) in boys with ADHD

DISCUSSION

Higher male ratios are consistently associated with more symptoms of ADHD, according to research employing community samples; however, some studies have only included females in this association, while others have only included boys. Studies examining 2D:4D in subjects with a clinical diagnosis of ADHD are scarce. Also, it has been demonstrated that, the 2D:4D of male patients with anxiety disorders were more than those of both anxiety disorders and ADHD. Concurrently, different research discovered that children with ADHD had a lower 2D:4D than controls; however, the female group did not exhibit this difference [(8)].

In terms of age, sex, smoking exposure, birth order, family history of ADHD, and family history of chronic illnesses, the two groups differed statistically significantly, according to the current study. According to **Elsaid *et al.*** [(15)], children with ADHD were 4.95±0.73 years older and 5.46±0.66 years older on average than the control group.

ADHD was more common in men than in women (69.8%), with a man-to-woman ratio of 2.31:1. Additionally, they demonstrated that ADHD is 5.5 times more common in children with first-degree relatives who have chronic illnesses than in children without such conditions, and that ADHD is three times more common in children with first-degree relatives with ADHD [15].

Likewise, **El-Nemr *et al.*** [16] observed that a gender distribution of 2.7:1 and a family history of ADHD were substantial correlation. In agreement, **Banerjee *et al.*** [17] displayed that children are more likely to have ADHD if they had a first-degree relative with a chronic condition.

According to the current study, 30.0% of ADHD patients were females, whereas 70.0% of patients were males. This was in agreement with **Nafi** [18] who discovered a gender difference with 2.9:1 men to women ratio. Additionally, to ascertain ADHD incidence in Egyptian primary school pupils, **Hassaan *et al.*** [19] found that a 3:1 male to female ratio was employed. This is explained by the fact that although boys with ADHD have more "externalizing" manifestations (impulsivity, hitting, and running), girls with ADHD have more "internalizing" manifestations and adverse events (depressive and anxiety manifestations).

Based on the current study's results, up to 25% of the sample had an inattentive type of ADHD (n = 15), 16.7% had an impulsive or hyperactive type (n = 10), and 58.3% had a combined type (n = 35). This came in agreement with **Wolraich *et al.*** [20], who found that between two-thirds and three-quarters of people with ADHD diagnosis will eventually be categorized as having a mixed type. **Hassaan *et al.*** [19] found that 38.0% of ADHD youngsters primarily appeared as ADHD-C type, compared to 28.0% as ADHD-HI type and 34.0% as ADHD-I type. This finding indicated the predominance of ADHD clinical sorts among the patient population.

Additional psychiatric comorbidities were found in nearly 60% of the children in this study (n = 36); these included phonological disorder in 3.3% of cases, obsessive-compulsive disorder in 3.3% of cases, conduct disorder in 10% of cases, anxiety disorder in 1.7% of cases, primary nocturnal enuresis in 21.7% of cases, mixed-type learning disabilities in 25% of cases, adjustment disorder with depressed mood in 6.7% of cases, and oppositional defiant disorder (ODD) in 43.3% of cases. Using the previously supplied data, we see how various comorbidities overlap within the same child.

Our findings concur with those of **Pauli-Pott *et al.*** [21] discovery that conduct disorder and ADHD in school-age children are highly associated. While several studies have looked at the cohabitation of learning deficits and ADHD, few have looked at the incidence of ADHD in a cohort of children with learning challenges. Additionally, **DuPaul *et al.*** [22] discovered that individuals with ADHD have higher impulsive scores on a number of tests. Additionally, **Solanto** [23] discovered that anxiety difficulties are more frequent among persons with ADHD.

EL-Mogy *et al.* [24] displayed that ADHD was positively accompanied by anxiety disorder, psychosomatic condition, conduct problem, learning handicap, and impulsive hyperactivity disorder**. Bishry *et al.*** [25] found that 74 (85.1%) of the students with mental comorbidities also had the propensity for ADHD. The most prevalent conditions were those linked to stress and anxiety. Other diagnoses included conduct and ODD, eating disorders, drug abuse disorders, urinary incontinence, mood disorders, and adjustment disorders.

In the current study, we demonstrated that the two groups under investigation differed statistically significantly in terms of cyanosis, congenital abnormalities, lactation, pregnancy toxicity, and delivery method. According to **EL-Gendy *et al.*** [26] the likelihood of mothers of children with ADHD being older was greater than that of mothers of children without ADHD, as they experience pregnancy-related toxemia, have a Caesarean section (CS), and use artificial feeding.

ADHD may be at risk throughout pregnancy, particularly if there are problems with prenatal toxemia, according to **Sasaluxnanon *et al.*** [27]**.** Regarding advanced mother age or prenatal risks, there was no discernible difference between the cases and controls. In terms of this, **Valdimarsdóttir *et al.*** [28] found that children in Iceland who were suspected of having ADHD had a higher prevalence of CS. This strengthened the connection between the delivery modality (CS) and ADHD. Previous study established the link between artificial feeding and ADHD [29] that discovered a significant increase in bottle feeding among cases as compared to controls. The absence of maternal touch and warmth during breastfeeding may help to explain this.

In this study, we showed that the two groups under investigation differed statistically significantly in terms of height, BMI, and weight percentiles. Likewise, **Bener *et al.*** [30]**,** found that the ADHD and control groups' BMI differed statistically significantly. Additionally, **Işık *et al.*** [8] discovered a significant difference in BMI percentile between healthy controls and children with ADHD.

We conducted a study using the WISC-R and found significant differences in verbal, performance, and overall IQ scores. This was in accordance with **Işık *et al.*** [8], who discovered significant differences in verbal, performance, and total IQ scores according to the WISC-R between ADHD and healthy control groups.

In this study, we demonstrated that the two groups under inquiry differed significantly concerning Parent T-DSM-IV-S, CPRS-RS, CTRS-RS, and Teacher T-DSM-IV-S. **Işık *et al.*** [8] found that the teacher T-DSM-IV-S, CPRS-RS, and CTRS-RS were greater than the controls'. Using Conner's parental rating scale, **Kader *et al.*** [31] found that the ADHD group had greater statistically significant values than the other group.

In this study, we noticed decreased 2D:4D in the right and left hands in ADHD compared to healthy controls ($p < 0.001$).

It has been demonstrated that ADHD has a correlation with reduced 2D:4D, according to the most recent studies on the subject [32]. According to **Martel** [33]**,** more severe symptoms of ADHD were linked to lower 2D:4D. They discovered that higher symptoms of inattentive ADHD were linked to lower finger-length ratios, namely the right 2D:4D. Similarly, past researches displayed that there was a correlation between higher externalizing issues and symptoms of ADHD to more masculine finger-length ratios. More masculinized right 2D:4D was often linked to trait dysregulation, which in turn was linked to greater ADHD symptoms and lower conscientiousness levels. However, **Lemiere *et al.*** [13] discovered that the 2D:4D of ADHD cases and healthy controls were the same.

According to **Hönekopp and Watson** [32]**,** 2D:4D on the right could be a more reliable measure of PTE compared to the 2D:4D on the left. This might help to explain why our study indicated that the 2D:4D of the left and right hands were independently associated with ADHD. Considering all of this, we propose that a low hand 2D:4D is a valid statistical predictor of ADHD in kids and might be a reflection of the amount of testosterone exposure during pregnancy. To learn more about how PTE may affect brain structure and function and maybe predispose kids to ADHD, more study is needed.

Our study found a strong inverse relationship between the hyperactivity scores on the teacher-rated questionnaire and the boys with ADHD. Additionally, we discovered a strong positive connection between IQ and the 2D:4D as well as a significant positive relationship between the two variables. In males with ADHD, there is a substantial negative correlation between PTE as evaluated by 2D:4D and hyperactivity scores on the teacher-rated questionnaire [8]**.**

Several researches studied the correlation between 2D:4D and the intensity of ADHD manifestations [8,10]. Consistent with our investigation's findings, other studies have found a link between hyperactive/impulsive symptoms and 2D:4D. In their investigation of the relationships between troublesome behaviors in childhood and right-handed 2D:4D, **Williams *et al.*** [34] discovered that greater levels of hyperactivity in females, but not in boys, were correlated with lower 2D:4D.

In terms of Caucasian children from Austria and the UK, **Fink *et al.*** [10] evaluated the association between disruptive behavior in youngsters and 2D:4D. In the UK group, behavioral problems and hyperactivity-inattention were associated with lower 2D:4D in boys only. In the Austrian group, lower 2D:4D were associated with more externalizing issues in girls and higher social disorders in boys. In a different research, **Martel *et al.*** [12] showed that lower 2D: 4D ratios were linked to a composite of hyperactive-impulsive and inattentive symptoms in males as judged by parents and teachers.

Furthermore, **Roberts and Martel** [35] revealed a positive association between hyperactive-impulsive symptoms and lower right-hand 2D:4D. Nevertheless, some research revealed no association between 2D:4D and the intensity of ADHD manifestations. In addition, **Lemiere *et al.*** [7] found no statistical relationship between the 2D:4D and any of the behaviour evaluation ratings in the ADHD group or the group as a whole.

Williams *et al.* [34] demonstrated proof of a relationship between IQ and 2D:4D, notwithstanding the intricacy of the observed relationship between the two. There was a positive relationship between verbal intelligence and right-hand 2D:4D, but a negative relationship between right-hand 2D:4D and numerical intelligence.

CONCLUSION

Children with ADHD who did not get therapy had lower right-hand 2D:4D, indicating PTE, than healthy controls. Furthermore, there was a significant negative connection between left-hand 2D:4D and hyperactivity ratings. Our findings suggest the potential that prenatal androgen exposure participates in ADHD development.

RECOMMENDATION

Larger sample numbers, a broad geographic scope, and illness severity rating scales are needed for future studies to completely identify the impact of foetal androgens and the causes of the gender differences in ADHD that are documented. To help parents become better at managing their children's behavior, early detection and parent education programs ought to be put in place.

LIMITATION

However, there were some drawbacks to the current study. First, because of the small number of ADHD patients in our sample, we cannot extend the current results to all ADHD sufferers. Second, we only used 2D:4D as a proxy for foetal testosterone measurements. Fetal testosterone can be measured using more reliable and accurate invasive methods. Finally, we did not compare kids in the same class because we did not measure finger length more than once. The connection between PTE and IQ in individuals with ADHD requires more investigation.

Conflict of interest: None.
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REFERENCES

1. **Ali A (2020):** The effectiveness of neurofeedback as computer based programs for children with attention deficient hyperactivity disorder. Journal of Childhood & Education, 20: 237-268.
2. **Silk T, Malpas C, Beare R *et al.* (2019):** A network analysis approach to ADHD symptoms: More than the sum of its parts. PLoS One, 14(1):e0211053. doi: 10.1371/journal.pone.0211053.
3. **Ramtekkar U, Reiersen A, Todorov A *et al.* (2010):** Sex and age differences in attention-deficit/hyperactivity disorder symptoms and diagnoses: implications for DSM-V and ICD-11. J Am Acad Child Adolesc Psychiatry, 49:217-228.
4. **Willcutt E (2012):** The prevalence of DSM-IV attention deficit/hyperactivity disorder: a meta-analytic review. Neurotherapeutics, 9: 490-499.
5. **Faraone S, Asherson P, Banaschewski T *et al.* (2019):** Attention-deficit/hyperactivity disorder. Nat Rev Dis Prim., 1: 15020. doi: 10.1038/nrdp.2015.20.
6. **Işık Ü, Bilgiç A, Toker A *et al.* (2018):** Serum levels of cortisol, dehydroepiandrosterone, and oxytocin in children with attention-deficit/hyperactivity disorder combined presentation with and without comorbid conduct disorder. Psychiatry Res., 261:212-219.
7. **Barrett E, Mbowe O, Thurston S (2019):** Predictors of steroid hormone concentrations in early pregnancy: results from a multi-center cohort. Matern Child Health J., 23(3): 397–407.
8. **Işık Ü, Kiliç F, Akepe E *et al.* (2020):** The relationship between second-to-forth digit ratios, aggression and intelligence levels in children with attention deficit hyperactivity disorder. Psychiatry Investig., 17(6):596-602.
9. **McFadden D, Westhafer J, Pasanen E *et al.* (2005):** Physiological evidence of hypermasculinization in boys with the inattentive type of attention-deficit/hyperactivity disorder (ADHD). Clinical Neuroscience Research, 5(5-6): 233-245.
10. **Fink B, Manning J, Williams J *et al.* (2007):** The 2nd to 4th digit ratio and developmental psychopathology in school-aged children. Pers Individ Dif., 42: 369-379.
11. **De Bruin E, Verheij F, Wiegman T *et al.* (2006):** Differences in finger length ratio between males with autism, pervasive developmental disorder-not otherwise specified, ADHD, and anxiety disorders. Dev Med Child Neurol., 48:962-965.
12. **Martel M, Gobrogge K, Breedlove S *et al.* (2008):** Masculinized finger-length ratios of boys, but not girls, are associated with attention-deficit/hyperactivity disorder. Behavioral Neuroscience, 122(2): 273-81.
13. **Lemiere J, Boets B, Danckaerts M (2010):** No association between the 2D: 4D fetal testosterone marker and multidimensional attentional abilities in children with ADHD. Developmental Medicine & Child Neurology, 52(9): 202-208.
14. **Demirci E, Öztop D (2015):** The relation between aggression, empathy and 2D:4D in male children and adolescents with attention-deficit and hyperactivity disorder. Yeni Symp., 53:2-8.
15. **Elsaid N, Mahrous O, Al-Bahnasy R *et al.* (2018):** Prevalence of attention deficit hyperactivity disorder among preschool children (3-6 years): Menoufia governorate. The Egyptian Family Medicine Journal, 2(2): 105-119.
16. **El-Nemr F, Badr H, Salem M (2015):** Prevalence of attention deficit hyperactivity disorder in children. Science Journal of Public Health, 3(2): 274-280.
17. **Banerjee T, Middleton F, Faraone S (2007):** Environmental risk factors for attention-deficit hyperactivity disorder. Acta Paediatrica, 96(9): 1269-1274.
18. **Nafi O (2013):** Prevalence of attention-deficient/hyperactivity disorder co-morbidities in children of south Jordan. European Scientific Journal, 9(20): 233-37.
19. **Hassaan F, Abd Elnaby S, El-Fotoh W *et al.* (2020):** Identification of risk factors of attention-deficit hyperactivity disorder in Egyptian children. Menoufia Medical Journal, 33(3): 856. DOI: https://doi.org/10.4103/mmj.mmj_373_18
20. **Wolraich M, Brown L, Brown R *et al.* (2011):** Subcommittee on Attention-Deficit/Hyperactivity Disorder; Steering Committee on Quality Improvement and Management. ADHD: clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. Pediatrics, 128(5): 1007-1022.
21. **Pauli-Pott U, Neidhard J, Heinzel-Gutenbrunner M *et al.* (2014):** On the link between attention deficit/hyperactivity disorder and obesity: do comorbid oppositional defiant and conduct disorder matter? European Child & Adolescent Psychiatry, 23(7): 531-537.
22. **DuPaul G, Stoner G (2014):** ADHD in the schools: Assessment and intervention strategies. Guilford Publications. Second Edition, pp. 252-266. https://eric.ed.gov/?id=ED489448
23. **Solanto M (2002):** Dopamine dysfunction in AD/HD: integrating clinical and basic neuroscience research. Behavioural Brain Research, 130(1-2): 65-71.
24. **El-Mogy M, El-Sayed R, Mohamed M *et al.* (2018):** Prevalence of ADHD symptoms among a sample of Egyptian school age children. The Medical Journal of Cairo University, 86: 1719-1725.
25. **Bishry Z, Ramy H, El-Shahawi H *et al.* (2018):** Screening for ADHD in a sample of Egyptian adolescent school students. Journal of Attention Disorders, 22(1): 58-65.
26. **EL-Gendy S, El-Bitar E, El-Awady M *et al.* (2017):** Attention-deficit/hyperactivity disorder: Prevalence and risk factors in Egyptian primary school children. The Egyptian Journal of Community Medicine, 35(1): 1-16.
27. **Sasaluxnanon C, Kaewpornsawan T (2005):** Risk factor of birth weight below 2,500 grams and attention

deficit hyperactivity disorder in Thai children. Journal-Medical Association of Thailand, 88(11): 1514-18.

28. **Valdimarsdóttir M, Hrafnsdóttir A, Magnússon P *et al.* (2006):** The frequency of some factors in pregnancy and delivery for Icelandic children with ADHD. Laeknabladid, 92(9): 609-614.
29. **El-Tallawy H, Hassan W, El-Behary A *et al.* (2005):** Prevalence of attention deficit hyperactivity disorder among elementary schools children in Assiut City-Egypt. Egyptian Journal of Neurology, Psychiatry and Neurosurgery, 42(2): 517-526.
30. **Berner A, Kamal M, Bener H *et al.* (2014):** Higher prevalence of iron deficiency as strong predictor of attention deficit hyperactivity disorder in children. Annals of Medical and Health Sciences Research, 4(3): 291-297.
31. **Kader A, Mohamed N, El Sayed B *et al.* (2016):** Continuous performance task in attention deficit hyperactivity disorder children. The Egyptian Journal of Neurology, Psychiatry and Neurosurgery, 53(1): 19. DOI:10.4103/1110-1083.176340
32. **Hönekopp J, Watson S (2011):** Meta-analysis of the relationship between digit-ratio 2D: 4D and aggression. Personality and Individual Differences, 51(4): 381-386.
33. **Martel M (2019):** Conscientiousness as a mediator of the association between masculinized finger-length ratios and attention deficit hyperactivity disorder (DEHB): J Child Psychol Psychiatry, 50: 790-798**.**
34. **Williams J, Greenhalgh K, Manning J (2003):** Second to fourth finger ratio and possible precursors of developmental psychopathology in preschool children. Early Hum Dev., 72: 57-65.
35. **Roberts B, Martel M (2013):** Prenatal testosterone and preschool disruptive behavior disorders. Pers Individ Dif., 55:962-966.