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Research Article

Correlations between MRI brain volumetric measurements and IQ scores in Egyptian children

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Abstract

Background: The correlation between IQ scores and brain structures is still unclear. The brain volume may be one of the neurophysiological indicators for assessment of intelligence in children. This study aims to find the correlation between IQ score levels in Egyptian children and the MRI volumetric measurements of brain structures in aberrantly normal conventional MRI. **Methods:** A retrospective study included fifty-one children with normal conventional brain MRI studies were referred from Children and Maternity Hospital, Minya University in the duration from October 2018 to December 2019. Their ages were ranged from 2 to 14 years. Inclusion criteria: child has delayed speech, hyperactivity or learning disabilities in preschool age with aberrantly normal conventional MRI examination, exclusion criteria: Children with an abnormal MRI brain examination or have a contraindication for MRI techniques were excluded from this study. All children presented with delayedspeech or with history of delayed speech as early clinical sign of delayed milestone They suspected to convectional MRI and volumetric MRI examination & IQ test (Stanford-Binet intelligence scales: fifthedition). Volumetric MRI assessed by automated online processing using (VolBrian.com) pipeline. **Result:** 51 subjects were included in this study for an average age of 7.8±3.1year, the average IQ level was 64.69±13.9, with an average total brain volume 1227.96±204.26cm3. Despite positive correlation between IQ scores and brain radiographic measures, only total brain volume (p-value = 0.024), intracranial cavity (p-value = 0.041) and grey matter volume (p-value = 0.009) had a statistically significant correlation with IQ levels. Additionally, males had a significant correlation between IQ scores and total brain volume (p-value = 0.043) as well as grey matter volume (p-value=0.012). **Conclusion:** Total brain volume is directly and significantly correlated with IQ scores in Egyptian children, especially in males. Further studies with more robust design are needed.

Keywords: MRI, CNS, Egyptian children, brain volumetry, IQ.

Introduction

Most of the humans' intelligence is related to factors influencing their cognitive power[1]. Earlier studies have shown that these factors areoccupational, educational, or physiological factors related to brain structures[2]. Concerning the physiological factors, total brain volume is one of the most important structures that can affect the intelligence scores especially in young children [3].

Total brain volume is linked to the total network of neurons[4]. Accordingly, some studies have attributed larger brain volumes to more complex cognitive functions[5]. Primary brain radiographic studies revealed a potential correlation between total brain volume and intelligence scores[6]. Additionally, the correlation between total brain volume and intelligence was even stronger in boys compared to girls[7].

Other structures as cortical thickness is one of these measures evaluated by MRI, it had a moderate correlation with cognitive ability. This is particularly important in the prefrontal area [8,9] Additionally, other reports supported the measurements for neurons networks which handle the transfer of information in the brain can be correlated to cognitive levels[10]. Brain white matter and grey matter also have been examined and shshowno handle a 10% of variation in cognitive ability [11].

There is scarcity of data on the correlation between different brain variables and level of intelligence especially in children population [12]. Furthermore, most of the earlier studies used as a measure for intelligence, while IQ could be a measure of more clinical relevance [13]. Therefore, the goal of this study is to evaluate the correlation between IQ levels and radiographic volumetric measures for different brain structures in children in Egypt.

Materials and Methods

Study design and participants:

A retrospective study included fifty-one children (19 girls and 32 boys) with normal conventional brain MRI studies were referred from Children and Maternity Hospital, Minya University in the duration from October 2018 to December 2019. Their ages were ranged from 2 to 14 years. Inclusion criteria: child has delayed speech, hyperactivity or learning disabilities in preschool age with aberrantly normal conventional MRI examination, exclusion criteria: Children with an abnormal MRI brain examination or have a contraindication for MRI techniques wereexcluded from this study.

All children presented with delayed speech or with history of delayed speech as early clinical sign of delayed milestone They suspected to convectional MRI and volumetric MRI examination & IQ test (Stanford-Binet intelligence scales: fifth edition). Volumetric MRI assessed by automated online processing using (VolBrian.com) pipeline.

Data collection:

A pre-designed excel sheet was used to report the MRI measures of different brain structures. Intelligence was evaluated for all the included children using the Arabic version of Stanford- Binet Intelligence scale 5th edition [14]. The evaluated brain structures that were included: total brain volume, intracranial cavity, cerebrospinal fluid volume (CSF volume), grey matter volume and white matter volume. Brain volume was evaluated using an online automated system Information on the MRI machine used, and the radiographic protocol areshowed in table 1 [15].

Table (1): Details on the MRI machine, protocol and post processing

MRI protocol	MRI machine: Philips, Ingenia 1.5T MR scanner
	Conventional MRI examination: T2WI: T2: FOV: covering whole brain (230mm), voxel: 1x1x1 isotropic, SNR= 1, TE: 245ms, TR: 1500ms, SNR=1. FLAIR: FOV: 230, voxel: 1.16x1.44x5mm, TR: 11000ms, TE:140ms, SNR=1
	Volumetric MRI examination: T1WI 3D: sT1W_3D_TFE, FOV: covering whole brain (230mm), voxel: 1x1x1 mm isotropic, SNR= 1, Echo pulse sequence: Gradient, Flip angle: 30, TE: 3.4ms, TR: 7.3ms.
Post processing:	Conventional assessment: using Philips ISP (intellspace portal v. 9), for primary reporting Volumetric and segmentations reporting: A compressed T1WI dataset in NIFTI was uploaded to online MRI-brain volumetric system at www.volbrain.com (VolBrain version 1.0 for whole brain segmentation) when automatic process is complete a PDF report is created containing volumetric data of the grey matter, white matter, CSF and subcortical grey matters validate NIFTI files using ITK-SNAP Version 3.4.0 software for all cases
	(intellspace portal v. 9), for primary reporting
	Detailed volumetric report in PDF format was exported.

Statistical analysis:
All data were represented in the form of counts.Means and standard deviations were measured for all numerical variables. Also, correlations using linear regression were carried out between numerical variables. Student t-test was used to compared between different brain struc-tures over different gender. Level of signi-ficance was evaluated at p-value<0.05.

Ethical considerations:
Institutional research ethics board approval wasacquired before conducting any study procedure.

Results

Fifty-one children were included in this study. Radiographic imaging findings and general characters of subjects are proved below.

General Characters of subjects:
Out of 51 participants, 32 children were boys, and 19 children were girls. The average age for the whole cohort was 7.8±3.3 years, with aminimum age of 2 and maximum age of 14 years old. The average IQ was 64.69±13.9, withthe lowest IQ of 36 and the highest IQ of 98. The average total brain volume was 1227.96±204.26cm3, the description of all brain radiographic findings and IQ among bothgenders is shown in table 2.

Correlation between IQ scores and other volumetric parameters among the whole cohort:
The values of volumetric parameters of theincluded children were correlated to their IQ scores using linear regression. It has been proved that there is a strong positive correlation between all the volumetric variables and the IQ level. However, only total brain volume, intracranial cavity and grey matter volume had a statistically significant correlation with IQ, with p-values= 0.024, 0.041, and 0.009,respectively, as shown in table 3. Correlation between IQ scores and other radiographic parameters over both genders

The correlation between IQ scores and radiographic parameters was also evaluated and compared over both gender through linear regression:
It has been shown that all the variable had a positive and strong correlation with IQ level. However, only males showed a significant correlation between IQ scores and total brain volume (p-value = 0.043) and grey matter volume (p-value=0.012) as shown in table 4. Also, figure 1 shows the linear regression curvefor the correlation between IQ scores and total brain volume for the whole cohort. group.

Comparison of all variables over both genders:
All variables were compared over both genders using one-way ANOVA test at level of significance p-value < 0.05. The included variables were total brain volume, intracranial activity, CSF volume, Grey matter volume, white matter volume and IQ level. It has been proved that there was non-significant differenceamong both boys and girls as shown in table 5.

Table (2): Characters of subjects based on their gender.

		Count	Mean	SD	Minimum	Maximum
boys	**Age**	32	7.81	3.1	2	13
	IQ	32	64.7	14.6	40	98
	Intracranial cavity	32	1323.2	204.3	993.1	1761.7
	CSF volume	32	104.4	30.7	26.10	161.6
	Grey matter volume	32	811.8	132.4	599.5	1110.2
	White matter volume	32	514.4	642.7	261	4011
	Total brain volume	32	1218.8	194.2	928.8	1656.6
girls	**Age**	19	7.8	3.2	3	14
	IQ	19	64.6	13.1	36	83
	Intracranial cavity	19	1354.2	232.4	937.31	1713.3
	CSF volume	19	111.2	34.4	38.7	178.8
	Grey matter volume	19	808.8	143.1	503.6	1046.6
	White matter volume	19	447.9	91.5	329	652
	Total brain volume	19	1243.4	224.9	832.6	1652.2
Total	**Age**	51	7.8	3.1	2	14
	IQ	51	64.6	13.9	36	98
	Intracranial cavity	51	1334.8	213.4	937.3	1761.7
	CSF volume	51	106.9	31.9	26.1	178.7
	Grey matter volume	51	810.6	135.1	503.5	1110.2
	White matter volume	51	489.7	510.1	261	4011
	Total brain volume	51	1227.9	204.3	832.5	1656.5

Table (3): Correlation between IQ scores and other radiographic parameters among the wholecohort

	r	P-value
Total brain volume	0.900	0.024*
Intracranial cavity	0.918	0.041*
CSF volume	0.989	0.457
Grey matter volume	0.868	0.009*
White matter volume	0.985	0.4

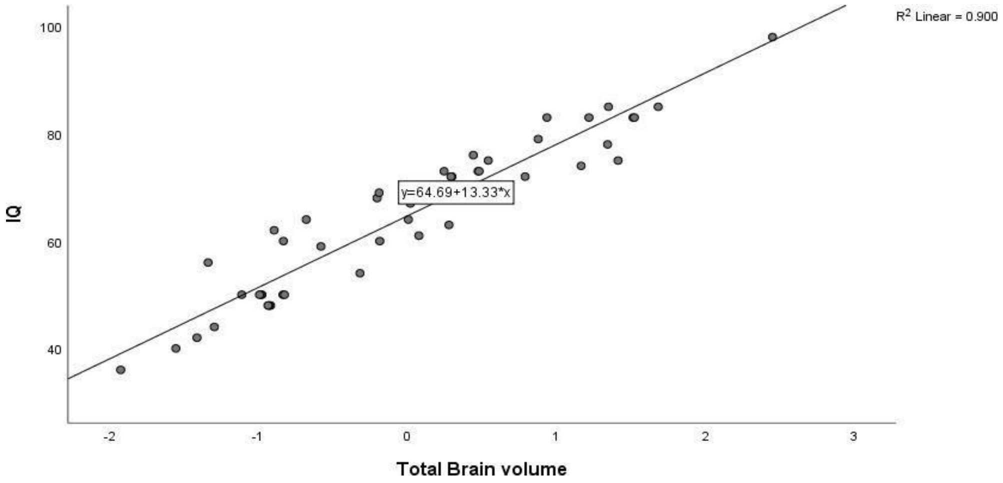


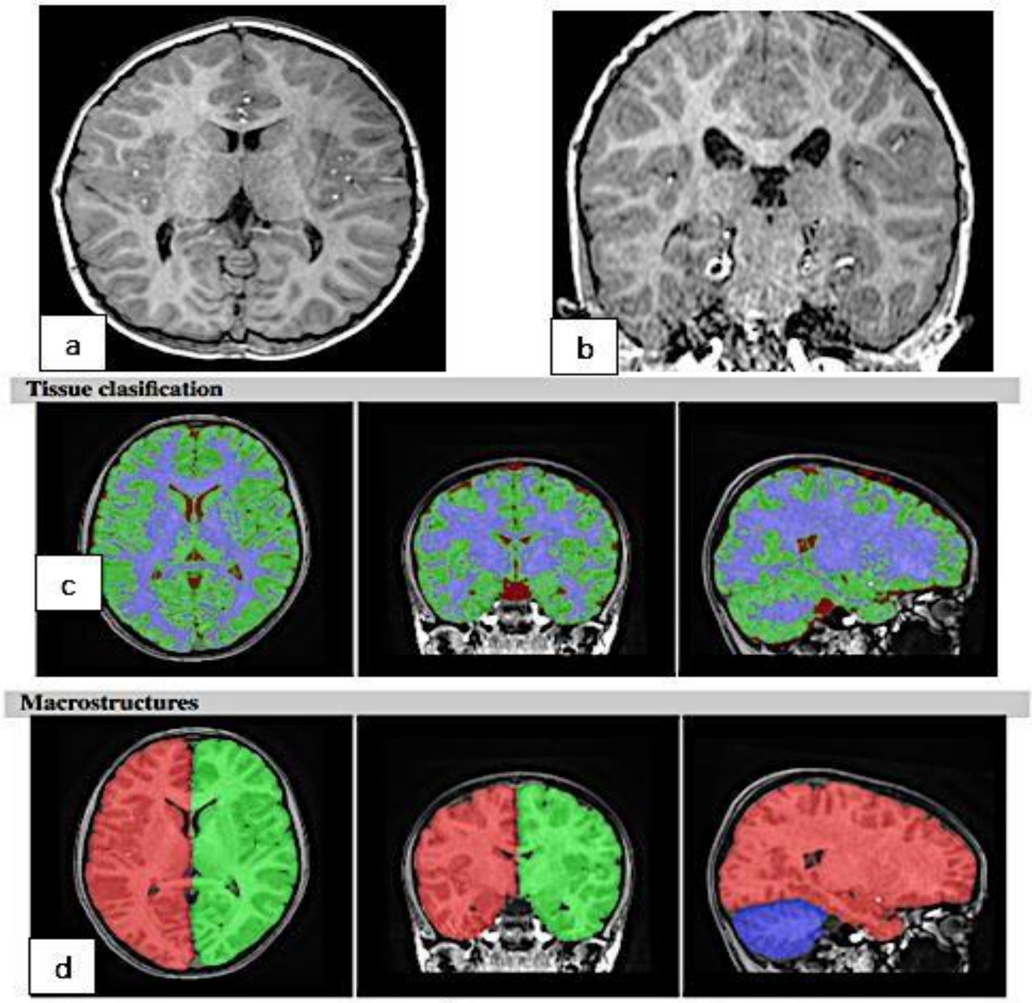
Figure (1): Linear regression between IQ scores and total brain volume in the whole cohort.

Table (4): Correlation between IQ scores and other radiographic parameters over bothgenders

	boys		girls	
	r	P-value	r	P-value
Total brain volume	0.871	0.043*	0.936	0.295
Intracranial cavity	0.891	0.065	0.951	0.364
CSF volume	0.994	0.676	0.975	0.514
Grey matter volume	0.806	0.012*	0.947	0.344
White matter volume	0.973	0.365	0.940	0.313

Table (5): Comparison of all variables over both genders using one-way ANOVA.

	boys		girls		P-value
	Mean	SD	Mean	SD	
Total brain volume	1218.8	194.2	1243.4	224.9	0.694
Intracranial cavity	1323.2	204.3	1354.2	232.4	0.633
CSF volume	104.4	30.7	111.2	34.4	0.486
Grey matter volume	811.8	132.4	808.8	143.0	0.940
White matter volume	514.4	642.8	447.9	91.5	0.569
IQ	64.7	14.6	64.6	13.1	0.983



Tissue type	Volume (cm^3/%)		Image information	
White Matter (WM)	471.14 (27.42%)	[26.68, 40.16]	Orientation	radiological
Grey Matter (GM)	1174.29 (68.34%)	[49.23, 61.67]	Scale factor	0.90
Cerebro Spinal Fluid (CSF)	72.88 (4.24%)	[5.28, 16.98]	SNR	38.72
Brain (WM + GM)	1645.44 (95.76%)	[83.02, 94.72]		
Intracranial Cavity (IC)	1718.32 (100.00%)			

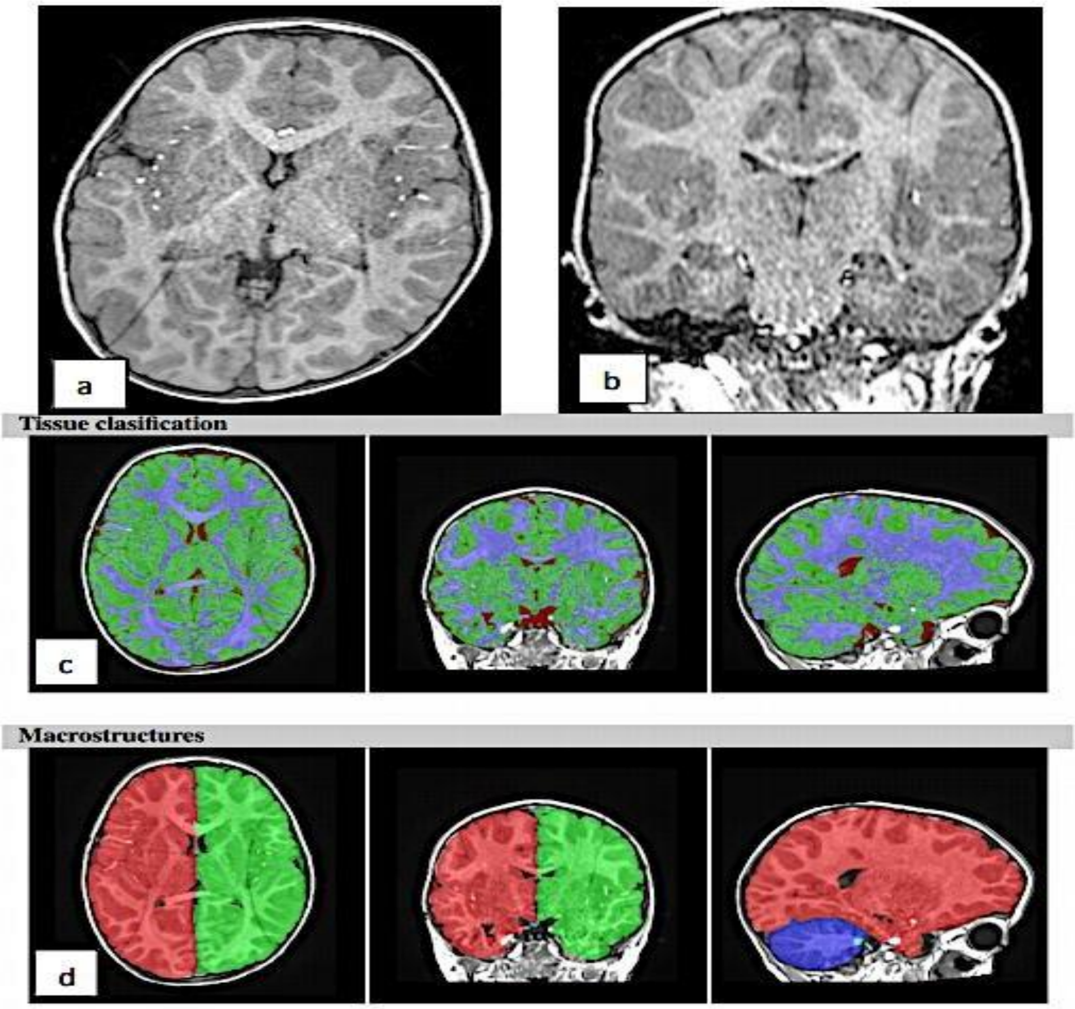
Structure

Cerebrum	Total (cm^3/%)	Right (cm^3/%)	Left (cm^3/%)	Asym.(%)
	1445.85 (84.14%)	723.87 (42.13%)	721.98 (42.02%)	0.2619
	[71.61, 82.74]	[35.60, 41.33]	[35.96, 41.45]	[-2.49, 1.25]

GM	WM	GM	WM	GM	WM
1000.04	445.81	498.81	225.06	501.23	220.75
(58.20%)	(25.94%)	(29.03%)	(13.10%)	(29.17%)	(12.85%)
[41.86, 52.34]	[24.13, 36.01]	[20.83, 26.10]	[11.96, 18.04]	[21.01, 26.26]	[12.14, 17.99]

e

Case1: 7 years boy
a & b: axial and coronal 3D T1WI shows no significant structure abnormalityc & d: tissue classification & macrostructures using Vol Brain software
e: analysis report shows increased volume of the **grey matter** as well as whole brain volume & reduced CSF volume regarding patient age
*Values between brackets show expected limits (95%) of normalized volume in function of sex and age for each measure for reference purpose.
*Green and red values indicate that the volume is above or under the expected volume limits respectively.



Tissue type	Volume (cm^3/%)		Image information	
White Matter (WM)	651.67 (38.04%)	[22.15, 37.80]	Orientation	radiological
Grey Matter (GM)	1000.55 (58.40%)	[53.10, 65.87]	Scale factor	0.93
Cerebro Spinal Fluid (CSF)	61.08 (3.56%)	[5.43, 15.65]	SNR	48.62
Brain (WM + GM)	1652.21 (96.44%)	[84.35, 94.57]		
Intracranial Cavity (IC)	1713.29 (100.00%)			

Structure

Cerebrum	Total (cm^3/%)		Right (cm^3/%)		Left (cm^3/%)		Asym.(%)
	1466.70 (85.61%) [73.45, 83.03]		733.79 (42.83%) [36.72, 41.57]		732.91 (42.78%) [36.67, 41.52]		0.1209 [-1.86, 2.24]
	GM	WM	GM	WM	GM	WM	
e	888.75 (51.87%) [45.63, 56.53]	577.95 (33.73%) [20.35, 33.97]	443.92 (25.91%) [22.85, 28.32]	289.87 (16.92%) [10.12, 17.01]	444.83 (25.96%) [22.76, 28.24]	288.08 (16.81%) [10.21, 16.98]	

Case 2: 8 years girl
a & b: axial and coronal 3D T1WI shows no significant structure abnormalityc & d: tissue classification & m acrostructures using VolBrain software
e: analysis report shows increased volume of the **white matter** as well as whole brain volume & reduced CSF volume regarding patient age
*Values between brackets show expected limits (95%) of normalized volume in function of sex and age for each measure for reference purpose.
*Green and red values indicate that the volume is above or under the expected volume limits respectively.

Discussion

IQ level is a commonly used estimation for thelevel of intelligence in humans. There are multiple physiological, genetic, and environmental factors that has been found to influence the IQ scores especially in the early years of life [16]. Additionally, factors related tobrain structures have been related to the IQ scores[17]. However, it is important to understand the differences between both genders in terms of their brain structures and how this can then affect the IQ level [18].

There was a positive, strong correlation between IQ scores and brain MRI volumetric measures, though, only total brain volume (p-value = 0.024), intracranial cavity (p-value = 0.041) and grey matter volume (p-value =0.009) had a statistically significant correlation with IQ scores. Moreover, males had a significant correlation between IQ scores and total brain volume (p-value = 0.043), as well as grey matter volume (p-value =0.012).

The correlation between IQ scores and different brain structures have been evaluated in differentclinical settings. Gignac et al.,[19] have carried out a meta-analysis on the correlation between total brain volume and IQ in adults. Gignac et al.,[19] proved that there was a weak correlation between IQ scores and brain volume (r = 0.2). However, Gignac et al.,[19] did not proved any correlations in children.

On the contrary, the present study evaluated thecorrelation between IQ scores and total brain volume in pediatrics, in addition to other brain structures volumetric measures. It has been revealed that there is a strong, positive, and significant correlation between IQ scores and total brain volume (p-value = 0.024). Additionally, boys showed a significant correlation between IQ scores and total brain volume in comparison to girls.

In support of our findings, Pietschnig et al.,[20] reviewed the correlation between IQ scores andwhole brain size in different age groups and among both genders. Pietschnig et al.,[20] showeda significant and positive correlation between IQ scores and brain volume. However, there was non-significant difference among both boys and girls. Additionally, there was non-significant difference among different age groups (children versus adults).

Although the present study showed a significant correlation between IQ scores and total brain volume, there was non-significant differenceamong both boys and girls in terms of their IQ scores or their total brain volume.

Furthermore, Ritchie et al.,[21] included 672 participants to explore the correlation between brain size and general intelligence. Ritchie et al.,[21] also examined cortical thickness, white matter structure, iron deposits, white matter hyper-intensity load, and micro-bleeds. Ritchie et al.,[21] showed that the brain volume was themost significant variable to correlate with general intelligence level.

Similarly, the present study showed a significant correlation between total brain volume and IQ scores in the whole cohort which was also maintained among boys. Additionally, grey matter volumes also significantly correlated to IQ scores in boys (p-value =0.009).

The present study had some limitations; the study was only single centered, which could affect the external validation of the outcomes. Moreover, the sample size was small torepresent the pediatric population in Egypt. This is the first study to evaluate the correlationbetween IQ scores and brain structures radiographic measures in Egyptian children.

Conclusion

There is a significant direct correlation betweentotal brain volume measure and IQ scores, particularly in boys. Other potential brain structures that could have an influence on IQ scores are intracranial cavity measure and greymatter volume.

However, larger studies with more robust design (multi-center) to confirm the findings of this study. Also, brain radiographic measures should be compared with other environmental and demo-graphic variables that could affect the IQ scores in children.

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