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 volumetry 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 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. 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 Early studies have shown that these factors are occupational, 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

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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 shown to 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 were excluded 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 (VolBrain.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 are shown in table 1 [15].

| MRI protocol | 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 structures over different gender. Level of significance was evaluated at p-value < 0.05.

Ethical considerations:
Institutional research ethics board approval was acquired 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 a minimum age of 2 and maximum age of 14 years old. The average IQ was 64.69±13.9, with the 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 both genders is shown in table 2.

Correlation between IQ scores and other volumetric parameters among the whole cohort:
The values of volumetric parameters of the included 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 curve for 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 difference among both boys and girls as shown in table 5.
Table (2): Characters of subjects based on their gender.

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

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

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total brain volume</td>
<td>0.900</td>
<td>0.024*</td>
</tr>
<tr>
<td>Intracranial cavity</td>
<td>0.918</td>
<td>0.041*</td>
</tr>
<tr>
<td>CSF volume</td>
<td>0.989</td>
<td>0.457</td>
</tr>
<tr>
<td>Grey matter volume</td>
<td>0.868</td>
<td>0.009*</td>
</tr>
<tr>
<td>White matter volume</td>
<td>0.985</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Amin et al.,

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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 both genders

<table>
<thead>
<tr>
<th></th>
<th>boys</th>
<th>girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>P-value</td>
</tr>
<tr>
<td>Total brain volume</td>
<td>0.871</td>
<td>0.043*</td>
</tr>
<tr>
<td>Intracranial cavity</td>
<td>0.891</td>
<td>0.065</td>
</tr>
<tr>
<td>CSF volume</td>
<td>0.994</td>
<td>0.676</td>
</tr>
<tr>
<td>Grey matter volume</td>
<td>0.806</td>
<td>0.012*</td>
</tr>
<tr>
<td>White matter volume</td>
<td>0.973</td>
<td>0.365</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>boys</th>
<th></th>
<th>girls</th>
<th></th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Total brain volume</td>
<td>1218.8</td>
<td>194.2</td>
<td>1243.4</td>
<td>224.9</td>
<td>0.694</td>
</tr>
<tr>
<td>Intracranial cavity</td>
<td>1323.2</td>
<td>204.3</td>
<td>1354.2</td>
<td>232.4</td>
<td>0.633</td>
</tr>
<tr>
<td>CSF volume</td>
<td>104.4</td>
<td>30.7</td>
<td>111.2</td>
<td>34.4</td>
<td>0.486</td>
</tr>
<tr>
<td>Grey matter volume</td>
<td>811.8</td>
<td>132.4</td>
<td>808.8</td>
<td>143.0</td>
<td>0.940</td>
</tr>
<tr>
<td>White matter volume</td>
<td>514.4</td>
<td>642.8</td>
<td>447.9</td>
<td>91.5</td>
<td>0.569</td>
</tr>
<tr>
<td>IQ</td>
<td>64.7</td>
<td>14.6</td>
<td>64.6</td>
<td>13.1</td>
<td>0.983</td>
</tr>
</tbody>
</table>
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Case 1: 7 years boy
a & b: axial and coronal 3D T1WI shows no significant structure abnormality
c & 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.
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Case 2: 8 years girl
a & b: axial and coronal 3D T1WI shows no significant structure abnormality
c & d: tissue classification & macrostructures 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 the level 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. Additionally, factors related to brain structures have been related to the IQ scores. 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.

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

On the contrary, the present study evaluated the correlation 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. reviewed the correlation between IQ scores and whole brain size in different age groups and among both genders. Pietschnig et al. showed a significant and positive correlation between IQ scores and brain volume. However, there was no significant difference among both boys and girls. Additionally, there was no 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 no significant difference among both boys and girls in terms of their IQ scores or their total brain volume.

Furthermore, Ritchie et al. included 672 participants to explore the correlation between brain size and general intelligence. Ritchie et al. also examined cortical thickness, white matter structure, iron deposits, white matter hyper-intensity load, and micro-bleeds. Ritchie et al. showed that the brain volume was the most 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 to represent the pediatric population in Egypt. This is the first study to evaluate the correlation between IQ scores and brain structures radiographic measures in Egyptian children.

Conclusion

There is a significant direct correlation between total 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 grey matter 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.

References


