Neuroanatomical Differences Between Girls and Boys with Attention-Deficit Hyperactivity Disorder: A Critical Review and Implications for Treatment
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Abstract
Attention-deficit/hyperactivity disorder (ADHD) is a childhood neurodevelopmental disorder characterized by developmentally inappropriate levels of inattention, hyperactivity, and impulsivity (Diagnostic and Statistical Manual of Mental Disorders; 5th ed., American Psychiatric Association, 2013). About 5% of school age children are diagnosed with this disorder and about 85% will have symptoms that persist beyond adolescence (Fridman & Rapport, 2015). Although girls with ADHD exhibit different symptoms relative to boys with ADHD, there is a lack of research on sex differences in ADHD-related neuroanatomical structures. There is evidence, however, that girls with ADHD have a 10% decrease in total cerebral gray matter volume compared to boys (Mahone & Wodka, 2008), and girls with ADHD have significantly lower cortical thickness compared to boys (Rodriguez et al., 2002). Therefore, there is a need to continue research on sex differences in ADHD-related neuroanatomical structures.

Neuroanatomical Differences in Girls with ADHD
- Difficulty for parents and teachers to recognize girls with ADHD because their symptoms are similar to those of typically developing boys of the same age
- White girls with ADHD have fewer symptoms than boys with ADHD as children, during puberty, the increase of dopamine receptors caused by the increase in estrogen may lead to an increase in symptoms in adolescence (Mahone & Wodka, 2008)
- See Table 1 for 3 distinctions in neuroanatomical differences in ADHD

ADHD in Girls vs. Boys
- Girls have a 10% less total cerebral gray matter volume compared to boys (Mahone & Wodka, 2008)
- Boys have a 10% less total cerebral gray matter 3.5 years earlier than boys (Mahone & Wodka, 2008)
- Boys have significantly lower cortical thickness in brain regions, where they make higher activation (van Swagemakers et al., 2011).

Figure 2: Gray matter maturation between ages five and twenty

Table 1: Neuroanatomical Differences in Girls with ADHD

<table>
<thead>
<tr>
<th>Function of Brain Region</th>
<th>Girls with ADHD</th>
<th>Boys with ADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefrontal Cortex</td>
<td>Smaller surface area</td>
<td>Smaller surface area</td>
</tr>
<tr>
<td>Functional Connectivity</td>
<td>Larger volume</td>
<td>Larger volume</td>
</tr>
<tr>
<td>Motor Function</td>
<td>Smaller volume</td>
<td>Smaller volume</td>
</tr>
</tbody>
</table>

Parent and Teacher Evaluations
- Parent and Teacher ratings commonly used for ADHD diagnosis
- Rating scales that are symptom-focused may be more helpful for understanding clinical differences between boys and girls with ADHD to improve diagnostic accuracy

Implications for Treatment
- Gender differences have been reported regarding the different ADHD subtypes (ADHD vs. ADHD-I; Gerber, 2002)
- Future research needs to consider the evaluation of gender differences in the DSM (Gerber, 2002)
- Gender differences would be expected to be smaller between the genders; assessment of these comorbid disorders is necessary (Gerber, 2002)

Summary and Conclusion
- The lack of research on girls with ADHD is pronounced. It is necessary to continue to research girls with ADHD because the symptoms, severity, and sex differences are different than in boys. Specifically, anatomoinal, functional, cognitive, and behavioral research is needed to elucidate on neuroanatomical differences between boys and girls (Dirlikov et al., 2015). Neuroanatomical research has found multiple critiques to sex differences in ADHD. Therefore, a lack of research on girls with ADHD is pronounced.

References

Figure 1: Age of attaining peak cortical thickness in children with ADHD compared to typically developing children

Methods
- We used Google Scholar and PsychINFO to find relevant articles. We used the search terms: ‘ADHD’, ‘neuroanatomical’, and ‘girls’.
- To refine the search, we specified the date range as 1997-2015.
- We found 59 articles directly applicable to our research. Fourteen articles were later excluded because upon further review, they did not contain information pertinent to our focus. After exclusions, 45 articles were included in this review. The articles included lacked information on girls with ADHD, did not evaluate parent and teacher ratings, or did not include statements about psychostimulant medications.

Figure 2: Age of attaining peak cortical thickness in children with ADHD compared to typically developing children

Table 2: Gender Differences in Symptoms, Diagnosis, and Outcomes

<table>
<thead>
<tr>
<th>Boys with ADHD</th>
<th>Girls with ADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalent symptoms</td>
<td>Higher instances of depressive and anxiety symptoms (Gershon, 2002)</td>
</tr>
<tr>
<td>Less attentional symptoms</td>
<td>Fewer inattentive symptoms (Mahone &amp; Wodka, 2008)</td>
</tr>
<tr>
<td>More motor symptoms</td>
<td>Less effortful response inhibition (Mahone &amp; Wodka, 2008)</td>
</tr>
<tr>
<td>Less aggressive behavior</td>
<td>More inattentive symptoms (Gaub &amp; Carlson, 1997)</td>
</tr>
</tbody>
</table>

Implications for Research
- Lack of information has serious implications because there are various long-term effects of ADHD, such as social, academic, and emotional difficulties (Mahone & Feinman, 1991).
- Necessary to study boys and girls at their average onset of peak ADHD symptomatology to ensure proper diagnosis and treatment