INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) was first described by Dr. Heinrich Hoffman in 1845, yet it was not until 1902 that Sir George F. Still described a group of impulsive children with significant behavioral problems related to genetic dysfunction. Since then many scientific studies have elucidated the nature of this disorder, associated genetic and neurochemical findings, and modes of diagnosis and treatment. As defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM IV), to meet criteria for the diagnosis of ADHD, a child has to have at least six out of nine symptoms in either inattention or hyperactivity/impulsivity domains, have an age of onset before 7 years, manifest these symptoms in at least two separate settings, and have impairment from the symptoms in various domains of functioning. The duration needs to be at least 6 months and the symptoms cannot be accounted for by another medical or psychiatric condition.

It is estimated that between 3% and 5% of children have ADHD. Boys are more frequently affected than girls in both clinical and community settings. The principal characteristics of this disorder are inattention, hyperactivity, and impulsivity. The symptoms may emerge depending on the demands of the situation imposed on the child. Most children with ADHD have the subtype, which combines inattention with hyperactivity/impulsivity symptoms. ADHD is often comorbid with other psychiatric conditions during childhood including learning disorders, oppositional and conduct disorder, anxiety, and depressive and tic disorders. Adolescents with ADHD are at higher risk for substance use and abuse. Most children with ADHD continue to have symptoms and impairment from ADHD in their adulthood. Untreated, it often leads to academic underachievement and school failure, poor self-esteem, peer problems, greater risk of accidents, and injuries in childhood and adolescence as well as problems related to work performance and inter-personal relationships in adulthood.

One of the symptoms of children with hyperactivity/impulsivity is talkativeness. Hyperactive children are constantly in motion, playing, squirming, and roaming around the room. As part of their internal restlessness, we see them talking incessantly and due to their frequent tantrums and impulsive behavior they may scream, yell, and shout often. There are few reports in the literature addressing speech and language disorders in children with ADHD but none has evaluated their voice. In a study looking at the performance of ADHD children on semantic category fluency versus initial letter fluency tasks, the results indicated that children with ADHD symptoms show a delay in the development of automating skills for processing abstract verbal information.

Risk factors for childhood dysphonia have included hearing problems, upper respiratory tract infections, large families, and a noisy home. Excessive high vocal demand, competing for speaking time, a high ambient noise-level speaking environment, excessive coughing, and throat clearing were all possible explanations for the prevalence of dysphonia in children. ADHD was never considered a potential risk factor for childhood dysphonia.

We intend in this study to evaluate vocal characteristics of patients with ADHD in comparison to a normal group of children.

SUBJECTS

A total of 38 children aged 5–12 years (prepubertal) were recruited for this study. Nineteen children with ADHD, 17 males and two females, and 19 controls matched according to age and gender participated. The study was approved by the Institution Review Board at the American University of Beirut. Parental consent and child assent for the study were obtained. ADHD was diagnosed by one of the coauthors (J.F.), a board-certified child and adolescent psychiatrist with 18 years of clinical experience in child and adolescent psychiatry. The diagnosis was made according to DSM IV criteria by seeking clinical information from multiple informants including parents, child, and...
teachers. Measurement tools included standardized rating scales such as the DuPaul Teachers and Parents rating scales and computerized standardized measures of inattention and impulsivity such as the Test of Variables of Attention or the Continuous Performance Test. Consecutive children who presented for evaluation to an outpatient child psychiatry clinic were screened for inclusion in this study. Only children with the combined inattention and hyperactivity/impulsivity subtype were included to maintain homogeneity of the sample. Children with pervasive developmental disorders (eg, Autism), mental retardation, Tourette’s and other tic disorders, speech and language disorders, neurologic disorders, and any condition involving vocal stereotypes or tics were excluded. Children with recent history of upper respiratory tract infection and/or upper airway manipulation were also not included.

Children in the control group were consecutively recruited over the same time period as the children with ADHD and were matched for gender and age.

METHOD

All children underwent both perceptual evaluation of their voice, followed by an acoustic analysis. The perceptual analysis included the following parameters: hoarseness, breathiness, strain, and loudness. Hoarseness was defined as an atypical voice characterized by roughness, breathiness as an atypical voice characterized by an air leak during phonation, and strain as a choky or strangulated voice. The severity of the perceptual evaluation was graded on a scale of 0–3 using a four-point scale where a score of 0 was indicative that this characteristic was not present and a score of 3 indicated that this characteristic was present in a severe form. A score of 1 would indicate a mild form and a score of 2 would indicate a moderate form. This applied for hoarseness, breathiness, and strain. For loudness, a score of 0 would indicate normal and a score of 3 would indicate severely elevated or high. The acoustic analysis included the voice quality assessment module and the pitch energy display module of the VP 3300 software program (Kay Elemetric, Lincoln Park, NJ, USA). The following parameters were recorded: Fundamental frequency, Shimmer, Relative average perturbation (RAP), Noise-to-Harmony ratio (NHR), Voice Turbulence Index (VTI), and Habitual pitch.

The analysis involved the child speaking in a quiet room into a microphone that was positioned on the desk and 10 cm away from his mouth. The counting task along with the interview was used for the perceptual evaluation, whereas the sustained vowels were used for the acoustic analysis. The child was asked to sustain the vowel /a/ using his modal register and loudness (comfortable pitch and loudness) for 2 seconds. The test was repeated three times, and then the child was asked to count to 10 again in a comfortable loudness and pitch.

STATISTICS

Frequencies and means were calculated for categorical and continuous variables, as appropriate. Cases and controls were compared with respect to perceptual evaluation of voice as well as acoustic analysis using nonparametric tests. The chi-square test was used for comparison of cases and controls with respect to self-perceived evaluations of voice and the Mann-Whitney U test for age and the continuous variables of the acoustic analysis. All analysis was conducted using SPSS (SPSS, Chicago, IL, USA) and a P value <0.05 was considered significant.

RESULTS

With respect to the perceptual evaluation, children with ADHD were perceived to have more hoarseness, breathiness, and strain in their voice. They also had a louder voice compared to controls. The differences between the two groups were significant as seen in the P values in Table 1. Close to 50% of children with ADHD had moderate to severe hoarseness compared to none in the control group. Likewise only 10% of the control had moderate to severe breathiness versus 50% in the ADHD group. With respect to loudness, 31.6% were perceived to have moderate to severe loud voice compared to none of the controls.

With respect to the acoustic analysis, only the Fundamental frequency was found to be statistically lower in the ADHD group compared to the control group (P = 0.034). This was commensurate with a drop in the habitual pitch along the same direction. Also, the RAP and NHR were noticed to be slightly higher in the ADHD group compared to controls; however, the differences were not statistically significant as seen in Table 2.

DISCUSSION

Vocal disturbances in children are surprisingly common. Most authors agree that anywhere from 1% to 23% of children have a voice disorder at any point in time and that 6–9% is the best estimate of prevalence. Disturbances in the vibratory characteristic of the vocal folds or in the function of the laryngeal muscles may be the cause of dysphonia. Early identification of pediatric voice disorders is advisable because these disorders may progress to lifelong communicative impairments if left untreated. A child who presents with hoarseness demands a rapid and thorough assessment. It is critical that an informed differential diagnosis be made to determine whether a voice disorder can be overlooked as laryngitis, when in fact the problem may be organic or functional in origin.

The perceptual evaluation of voice is of obvious importance in the initial evaluation and as a tool that can be used to follow a child’s development after surgical, medical, and behavioral interventions. According to Ramig and Verdolini, voice disorders are “generally characterized by an abnormal pitch, loudness, and/or voice quality resulting from a disordered laryngeal, respiratory, and/or vocal tract functioning.” For this reason, the voice is more often evaluated according to the quality of resonance, pitch level, rate, and loudness. The range of dysphonia or change in voice quality may vary from mild hoarseness to complete aphonia. In our perceptual evaluation, we have included hoarseness, breathiness, strain, and loudness to cover vocal characteristics.

After precluding organic causes, hyperfunctional dysphonia is often incriminated in most cases of pediatric dysphonia, especially when related to voice abuse/misuse, or when
a psychosomatic etiology is suspected. Andrews, Glaze, and Peppard in 1996 reported that hyperfunction is the most likely disorder seen in children and Peppard used the term functional disorders.23–25 Hyperfunctional dysphonia is a type of functional voice disorder that cannot be explained on the basis of a structural or neurological lesion. It is characterized by excessive muscular contraction within the vocal tract. External features include visible and palpable muscular tension around the larynx whereas endoscopically, we expect to observe various muscle tension patterns, both in the anteroposterior and the mediolateral dimensions.26–28 These immediate effects of laryngeal hyperfunction may lead with time to chronic irritation of the vocal folds with consequent edema, development of nodules, polyps, and ulcers. Early diagnosis and proper intervention by altering the hyperfunctional vocal behavior may reverse these effects and prevent their occurrence.29

It is not uncommon to hear the outcome of laryngeal hyperfunction in a school-aged child as a loud voice with prominence of the extrinsic laryngeal muscles and tension in the neck as the child speaks.30 This vocal behavior may be the early symptom of neurologic or psychiatric disorders, leading to emotional, social, and behavioral problems. Children with ADHD may abuse their voice more often than others. There are no studies in the literature that have evaluated the vocal characteristics in children with ADHD. In our investigation, it became apparent that there were significant changes in the vocal perceptual evaluation of ADHD patients compared to controls. They seem to have a louder voice, more straining, hoarseness, and breathiness while speaking, most likely reflecting a hyperfunctional vocal behavior that may with time lead to phonotrauma. Aggression, screaming, hyperactivity, and loud talking are all factors that have been incriminated in the development of vocal fold nodule despite the lack of a clear cause-effect relationship.31 In a retrospective review of 646 patients seen in a tertiary care pediatric hospital’s voice center, 40% had vocal fold nodules and three fourth had hyperfunction. Hyperfunction of the larynx correlated with the size of vocal nodules and perceptual analysis revealed positive correlation of the severity of hoarseness, breathiness, straining, and aphonia with the size of vocal nodules.32 All this leads us to say that the possible presence of hyperfunctional vocal behavior in children with ADHD as reflected by the increased strain and loudness in their voice, may result in the formation of vocal fold nodules, if not treated.

The straining voice perceived in children with ADHD may be related to the overall hyperactivity of the child. One of the core deficits in ADHD is deficient inhibitory control of ongoing motor response, which may be related to underactivity in the brain prefrontal cortex.33,34 It is thus plausible that the same mechanism involving disinhibition of motor control in the neck, back, abdomen, and limbs may also involve the vocal folds.

Hoarseness and breathiness are often attributed either to a change in the vibratory characteristics of the vocal folds or to incomplete closure during vibration of the vocal folds. In children with ADHD, the prevalence of severe hoarseness and breathiness may be secondary to swelling or nodular formation that was not investigated endoscopically.

Further understanding why children with ADHD have a loud voice will entail laryngeal aerodynamic analysis, as the major determinants of loudness are subglottic pressure and glottal resistance. We believe this will be the subject of a future study.

In a study done to characterize pediatric normative database and to compare the normative data with the vocal profiles of patients with vocal fold nodules, results indicated that the vocal profile of children is uniform across all girls and prepubescent boys and that patients with vocal fold nodules demonstrated a consistent acoustic profile characterized by an elevation in frequency perturbation measurements.35 We know that changes in the mechanical properties of the vocal folds in the presence of a lesion or altered mucous viscosity are usually manifested by an alteration in the acoustic parameters and mainly as an

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD</th>
<th>Controls</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>9.84 ± 1.98</td>
<td>8.79 ± 2.82</td>
<td>0.107</td>
</tr>
<tr>
<td>Habitual pitch</td>
<td>239.18 ± 32.59</td>
<td>249.81 ± 32.64</td>
<td>0.166</td>
</tr>
<tr>
<td>FO</td>
<td>238.08 ± 34.83</td>
<td>251.59 ± 29.77</td>
<td>0.034</td>
</tr>
<tr>
<td>RAP</td>
<td>1.16 ± 0.62</td>
<td>0.92 ± 0.61</td>
<td>0.194</td>
</tr>
<tr>
<td>Shimmer</td>
<td>3.63 ± 1.17</td>
<td>3.97 ± 1.65</td>
<td>0.704</td>
</tr>
<tr>
<td>NHR</td>
<td>0.16 ± 0.19</td>
<td>0.11 ± 0.03</td>
<td>0.651</td>
</tr>
<tr>
<td>VTI</td>
<td>0.03 ± 0.01</td>
<td>0.04 ± 0.01</td>
<td>0.156</td>
</tr>
</tbody>
</table>

FO = fundamental frequency
increase in the perturbation parameters. In our study, there was an increase in the RAP and NHR; however, this increase was not significant. Despite the fact that the perceived increase in loudness and straining indicates and/or makes one anticipate an increase in the Fundamental frequency, our findings indicate the opposite. This may be explained on the possible increase in mass in the vocal fold secondary to either mucosal swelling or hypertrophy of the vocalis muscle. Unfortunately, we do not have laryngeal endoscopic data to either substantiate or refute this hypothesis.

Children with voice disorders do respond to treatment, with vocal hyperfunction being the predominant disorder. The therapy can be divided into five groups: counseling, voice reeducation, drug treatment, psychotherapy, and surgery. The efficacy of voice therapy on functional dysphonia was assessed in 16 subjects and the results showed that close to 60% either improved or healed, thus indicating that voice therapy could improve functional dysphonia. Prerequisites are motivation and having a psychological background on the child before therapy. Proper diagnosis of functional disorders in hyperactive children at an early stage is important. We know that multiple domains of quality of life may be impaired in children with ADHD including their communication skills and vocal performance. The treatment of ADHD includes both medication and behavioral/psychoeducational therapy.

The findings and conclusion of our study highlight possible vocal hyperfunction in the affected children and hence invite the introduction of behavioral changes and voice therapy as modes of treatment if these findings are substantiated by future studies. The speech-language pathologist and vocal therapist may play a role in the treatment of children with ADHD by adding special expertise to the multimodal management plan for caring to these children.

Our study has two main limitations: first is the small number of cases, and second is not having done laryngeal fiberoptic endoscopy in children with ADHD to further substantiate the presence of the intrinsic muscle tension in these patients and to rule out the presence of benign laryngeal lesions. Nevertheless, this study is the first to draw attention to the phonotmatic behavior of children with ADHD and the possible role of voice therapy in addressing this issue.

CONCLUSION

Children with ADHD have more hoarseness, breathiness, strain, and loudness than normal children. Early evaluation of these vocal characteristics and proper diagnosis of vocal symptoms in this group of children may be important for the prevention of hyperfunctional voice disorders.

REFERENCES


