Reduced language abilities in adolescents who snore

Georgia Andreou *, Paraskevi Agapitou

Department of Special Education, University of Thessaly, Greece

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Abstract

Polysomnographic assessment of 20 adolescents who were referred to hospital for loud and frequent snoring showed they suffered from obstructive sleep apnea syndrome (OSAS). Their apneas and desaturation rates (SaO2) were abnormal in comparison with the non-snoring adolescents, who served as their controls. The snoring group obtained lower scores on phonemic and semantic tests and had lower marks in the Greek language subject at school than the non-snoring group. These findings could be explained by the fact that OSAS causes certain physiological disturbances which may lead to dysfunction of the prefrontal cortex which plays an active role in language and verbal skills.

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1. Introduction

Obstructive sleep apnea syndrome (OSAS) is defined as the presence of continued chest and abdominal motion in the absence of airflow during sleep. OSAS affects up to 2.5% of children and adolescents with snoring its primary symptom, affecting up to 27% of this group of people (O’Brien & Gozal, 2002). Although snoring is not normal and indicates the presence of heightened upper airway resistance, many snoring children have primary snoring, i.e. habitual snoring without alterations in sleep architecture, alveolar ventilation and oxygenation. Polysomnographic assessment, as shown in previous studies (Andreou, Galanopoulou, Gourgoulianis, Karapetras, & Molyvdas, 2002; Gozal & Pope, 2001; Kennedy et al., 2004), is required for the definitive diagnosis of OSAS because clinical history and physical examination are insufficient to confirm accurately its presence or severity. A recent review of the studies (Marcus, 2001) on the pathophysiology of OSAS in children has stated that these children have increased upper airway collapsibility and enlarged tonsils and adenoids play a major role.

Although the neurocognitive implications of OSAS in children have been recognized for over a century (Hill, 1889), it is only in the last decade that a more systematic exploration of this problem has been undertaken. Schooling problems have been repeatedly reported in case-series of children with OSAS, and in fact, may underlie more extensive behavioral disturbances such as restlessness, aggressive behaviour, excessive daytime sleepiness and poor neurocognitive performances (Gozal & Pope, 2001; Leach, Olson, Hermann, & Manning, 1992).

More specifically, it has been shown (Urschitz et al., 2003) that children who snored habitually had at least twice the risk of performing poorly at school, with this association becoming stronger with increasing snoring frequency. In
addition, children with desaturation events were at higher risk of doing poorly at school subjects when compared with children without. In general, children with OSAS show reduced attentional capacity (Blunden, Lushington, Kennedy, Martin, & Dawson, 2000; Owens-Stively et al., 1997), impaired learning and school performance (Gozal, 1998), while at the more severe end of the spectrum, reduced memory (Rhodes et al., 1995) and reduced intelligence were found (Lewin, England, & Rosen, 1999). Concerning intelligence scores, verbal IQ was found particularly low in snoring children compared to non-snoring ones (Kennedy et al., 2004).

The impairment of neurocognitive domains in children with OSAS is also supported by reports of its improvement if OSAS is reversed. This includes evidence from both parental report (Brouillette, Fernback, & Hunt, 1982) and standardized testing (Goldstein, Post, Rosenfeld, & Campbell, 2000) that adenotonsillectomy in children with OSAS reduces symptomatology and is accompanied by a significant improvement in cognitive function and learning (Goldstein et al., 2000). However, it has been shown (Gozal & Pope, 2001) that residual deficits in learning performance may still be detected several years after snoring has resolved. This could be explained by the fact that long-term decreases in learning performance could represent a residual and irreversible neurocognitive deficit in children who experienced OSAS during a critical age associated with brain development.

The mechanism explaining neurocognitive deficits in children with OSAS is unclear. Three potential pathways, namely intermittent hypoxia, repeated arousal and periodic or continuous alveolar hypoventilation resulting in hypercarbia are suggested (O’Brien & Gozal, 2002). These physiological disturbances are thought to cause prefrontal cortical dysfunction leading to impaired cognitive execution (O’Brien & Gozal, 2002). Beebe and Gozal (2002) proposed that the cognitive deficits seen in children with OSAS are secondary to prefrontal cortex dysfunction caused by sleep disruption, hypoxemia and hypercarbia. The prefrontal cortex is well known to play an important role in executive functioning including cognitive flexibility, reasoning and memory. Unlike the majority of other regions of the brain, this region shows decreased activity during all sleep stages and appears to functionally disconnect from other brain regions during sleep, allowing it to recalibrate. It has been suggested (Beebe & Gozal, 2002) that the physiological sequelae of OSAS alter the metabolism and neurochemistry of this vulnerable region (Gozal & Pope, 2001) and because of its relatively late maturity compared to other brain regions, it may be more susceptible to the disruptive physiological effects of hypoxemia, hypercarbia and sleep fragmentation, especially if prolonged.

Damage to prefrontal cortex has been associated with impaired verbal fluency and retrieval, which causes changes in the speed and ease of verbal production. Impaired verbal retrieval shows up as finding problems and defective performance on fluency tests (Janowski, Shimamura, & Squire, 1989; Lezak, 1995). When fluency is tested during PET scanning, activation of prefrontal regions has been shown (Parks, Loewenstein, & Dondrill, 1988).

In addition, damage to prefrontal cortex causes information processing deficit. This kind of deficit is accompanied by a tendency for a dissociation between language behaviours and ongoing activity so that people who exhibit such a deficit are less apt to use verbal cues to direct, guide or organize their ongoing behaviour with resultant perseveration, fragmentation or premature termination of a response. Thus, planning and problem solving which require intact sequencing and organizing abilities are impaired in people with damage to prefrontal cortex (Shallice, 1988; Vilkkie, 1988).

On the basis of the above findings, the present study was conducted in order to examine further the hypothesis that OSAS during childhood may have long-term decreases in verbal fluency and language school performance.

2. Method

Forty adolescents from Thessaly and the wider area of central Greece participated in this study. Their mean age was 18.41 ± 0.37. Twenty, 12 boys and 8 girls, were adolescents who were referred to the hospital for excessive snoring. Twenty nonsnoring controls were also recruited who were matched for sex, age and educational level. They were from the same street of residence as the snoring adolescents or were friends of theirs. The latter selection criteria were used in order to ensure the same socioeconomic status between the two groups as they have previously been used in other studies for the same reason (Gozal & Pope, 2001; Kennedy et al., 2004). A cover letter explaining the study and an informed consent form were sent home to the controls and their parents requesting the participation of the adolescents in the study. Each parent or adolescent who responded was contacted by telephone, provided more detailed information and offered an appointment. Both parent and adolescent were informed of the voluntary nature of the study and that consent could be withdrawn at any time if so desired. There was no monetary gratuity offered for participation.
Both snoring adolescents and controls filled in a detailed questionnaire with the help of their parents concerning their medical history. None of the individuals had congenital heart disease or asthma and although enlarged tonsils or adenoids were detected, none of them had undergone tonsillectomy or adenoidectomy up to the time of the experiment. They were also asked to report the mark they had obtained on the Greek language subject at school the previous year. The highest possible mark students in Greek high schools can take is 20.

Overnight polysomnographic studies were performed for all individuals. For this purpose, a portable breathing heart function JAGER machine was used, which was put on half an hour before the individual’s night sleep. All of them slept spontaneously without sedation.

The following parameters were measured: airflow by thermistor, snoring by microphone on neck, arterial oxygen saturation (SaO₂) by pulse oxymetry and heart rate by electrocardiogram. Polysomnograms were defined as abnormal if they demonstrated one or more of the following: more than ten episodes of apneas per hour of sleep, SaO₂ <95% per event, and heart rate >60 pulses per minute. The recordings were scored through automated programmes.

In addition, all individuals were given the Greek version (Kosmidis, Vlachou, Panagiotaki, & Kiosseoglou, 2004) of two standardized verbal fluency tests, a semantic and a phonemic one. On the semantic test, we asked individuals to generate as many different words as possible belonging to each of the following three semantic categories: animals, fruit and objects. On the phonemic test, we asked individuals to generate as many different words as possible beginning with each of the following Greek letters: X (Chi), Σ (Sigma) and A (Alpha). The letters were selected based on the ratio of words in the Greek language starting with these letters relative to the total number of words in a Greek dictionary, which corresponds to the ratio of words in the English language beginning with the letters F, A and S relative to the total number of words in an English dictionary. We instructed individuals to begin generating items verbally as soon as the researcher announced the category or letter, and to avoid repetitions, variations of the same word and proper nouns (on the phonemic test). Examiners allowed 60 s for each trial.

For the statistical evaluation of the data paired samples t-tests were performed on the scores of the phonemic and semantic tests, on the marks obtained by the two groups on the Greek language subject and on the parameters of the polysomnographic study in order to detect possible statistically significant differences between snoring adolescents and non-snoring controls. Furthermore, regression analysis was performed to find out if the parameters of the polysomnograms were interrelated and if they were related with the scores obtained for semantic and phonemic tests as well as the marks obtained by the individuals on the Greek language subject at school. The SPSS statistical programme was used to analyse the data.

3. Results

The results of the polysomnographic studies showed that all 20 adolescents who were referred to hospital for excessive snoring suffered from OSAS and had more than 10 apneas per hour and desaturation rates (SaO₂) <95%, which were abnormal. Paired samples t-tests performed on these two parameters revealed statistically significant differences (p < .05) between snoring and non-snoring adolescents: Apnea: snoring group: 15.48, non-snoring group: 3.15, t = 6.905, p = .000, SaO₂: snoring group: 78.00, non-snoring group: 41.00, t = 22.365, p = .000. Both groups

| Table 1
<p>| Mean scores of polysomnographic parameters, phonemic and semantic tests and marks on the Greek language subject in snoring and non-snoring groups |</p>
<table>
<thead>
<tr>
<th>Snoring group</th>
<th>Non-snoring group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apneas(^a)</td>
<td>15.48</td>
</tr>
<tr>
<td>SaO₂(^b)</td>
<td>78.00</td>
</tr>
<tr>
<td>Heart rate</td>
<td>59.41</td>
</tr>
<tr>
<td>Phonemic test</td>
<td>20.45</td>
</tr>
<tr>
<td>Semantic test</td>
<td>28.60</td>
</tr>
<tr>
<td>Greek lang. marks(^c)</td>
<td>13.25</td>
</tr>
</tbody>
</table>

\(^a\) More than 10 episodes per hour of sleep.

\(^b\) Desaturation rates <95% per event.

\(^c\) Greek language marks out of 20.
had normal heart rates, <60 pulses per minute, and there was not a statistically significant difference between them.

Paired samples $t$-tests performed on the scores obtained by the two groups on the semantic and the phonemic tests as well as their marks on the Greek language subject at school revealed the following statistically significant differences: Semantic test: snoring group: 28.60, non-snoring group: 54.45, $t = -7.816$, $p = .000$. Phonemic test: snoring group: 20.45, non-snoring group: 37.30, $t = -12.723$, $p = .000$. Marks: snoring group: 13.25, non-snoring group: 18.60, $t = -12.596$, $p = .000$. Mean scores of the two groups for the polysomnographic parameters, the phonemic and semantic tests as well as their marks on the Greek language subject are presented in Table 1.

Regression analysis performed on the parameters of the polysomnographic studies revealed the following statistically significant relations between them: $\text{SaO}_2$ interrelated with snoring $R = .701$, $p = .000$ and apnea interrelated with snoring $R = .568$, $p = .000$.

Regression analysis of the data revealed the following statistically significant relations between the parameters of the polysomnographic studies and the semantic and phonemic tests and the marks on the Greek language subject: apnea related with: semantic test, $R = .812$, $p = .000$, phonemic test, $R = .671$, $p = .000$, marks, $R = .684$, $p = .000$, $\text{SaO}_2$ related with: semantic test, $R = .598$, $p = .000$, phonemic test, $R = .778$, $p = .000$, marks, $R = .791$, $p = .000$ and snoring related with: Semantic test, $R = .412$, $p = .000$, phonemic test, $R = .854$, $p = .04$, marks, $R = .778$, $p = .000$.

4. Discussion

In this study we found that compared to non-snoring controls, snoring adolescents showed reduced language and verbal abilities which were associated with disruption of sleep by apneas and desaturation events.

Excessive snoring indicates the presence of higher upper airway resistance and is associated with OSAS as shown in our study by polysomnographic assessment, which is a definitive diagnosis of OSAS. This is also proved by the strong interrelation of snoring with the other two parameters of OSAS, apneas and $\text{SaO}_2$, in our study.

Our findings are in line with previous findings (Kennedy et al., 2004; Leach et al., 1992) which proved that individuals who snore exhibit reduced neurocognitive performance and run the risk of performing poorly at school and displaying verbal deficits. It has been claimed that (Urschitz et al., 2003) that this association becomes stronger with increasing snoring frequency which is the case in our study, since the parents of the snoring group reported that their children snored for over four years and their snoring became louder and more frequent every year. In addition, desaturation events have also been associated with poor school performance (Urschitz et al., 2003) which is also proved by our study since the snoring group which also presents abnormal desaturation rates, obtained statistically significant lower marks on the Greek language subject at school and lower scores in both the verbal tests than the non-snoring group. It seems that OSAS experienced during critical ages such as childhood and adolescence, which are associated with brain growth and development, can cause long-term decreases in learning performance.

As mentioned elsewhere by researchers (Beebe & Gozal, 2002; O’Brien & Gozal, 2002) who tried to explain the mechanism by which neurocognitive deficits and poor academic performance are presented in individuals with OSAS, OSAS is associated with a number of physiological disturbances, namely sleep disruption, hypoxemia and hypercarbia which cause prefrontal cortical dysfunction. Since this brain region matures relatively later than other brain regions, it is more vulnerable to the disruptive physiological effects of hypoxemia, hypercarbia and sleep fragmentation, especially if prolonged as was the case with snoring adolescents in our study. The association between the physiological disturbances and language and verbal deficits may be explained by the cumulative effect of the chronicity of sleep architecture disruption over many years and the simultaneous rapid development of the child’s neuronal synaptic network.

Impaired verbal fluency and retrieval have often been associated with prefrontal cortex dysfunction (Desmond & Fiez 1998; Janowski et al., 1989; Lezak, 1995) which manifests in defective performance in fluency tests. Our study lends support to these findings and extends the role of prefrontal cortex in cognitive function and especially its prominent role in verbal production. Moreover, as was previously found (Shallice, 1988; Vilkkie, 1988), prefrontal cortex dysfunction causes information processing deficit which is accompanied by a tendency for a dissociation between language behaviours and ongoing activity. This is probably the reason that the snoring group in our study had low marks in the Greek language subject at school because obviously they were less apt than the non-snoring group to use verbal cues to direct, guide or organize their ongoing language behaviour, skills needed for both oral and written language production.
In conclusion, our findings substantiate the potential for adverse and sustained language and verbal deficits being associated with loud and frequent snoring, which is an indicator of OSAS, particularly when the latter is prolonged and occurs during critical ages of brain growth and development. However, further research is needed in order to elucidate whether the adverse effects of OSAS on the learning process persist and how long after the elimination of causing factors such as enlarged tonsils or adenoids. The findings of this study justify implementation of future research in the field in order to examine further whether early recognition of the problem of snoring and early intervention reduce or abolish its adverse outcome on learning and academic achievement.

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References


