ORIGINAL ARTICLE

Childhood Obesity and Sleep-related Breathing Disorders

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KEYWORDS

Sleep-related breathing disorders in children; Childhood obesity; Sleep apnea syndrome in children

Abstract

Introduction: The increasing prevalence of childhood obesity leads to an increase risk of sleep-disordered breathing and may exacerbate their comorbidities.

Purpose: To assess the rate of obesity in children with sleep-disordered breathing and to study the possible clinical and epidemiological differences between children with and without overweight in a private hospital in the Mediterranean area.

Materials and methods: We prospectively studied 340 children between 2 and 10 years. There were 170 children with sleep-disordered breathing (study group) and 170 healthy children (control group). In the problem group, the apnea-hypopnea index was around 7.61±6.3.

Results: The comparison of the percentage of cases with a BMI percentile ≥85 (overweight) between problem and control groups (44: 25.9% vs 34%; 20%) or with a BMI ≥95 (obesity) (30: 17.6% vs 20%; 11.8%) showed no statistically significant differences. In addition, the comparison of clinical and epidemiological variables in the problem group, cases with (44/170: 25.9%) and without (126/170: 74.1%) overweight, did not show significant differences in any of the parameters analysed.

Conclusion: In the population studied, it does not appear that the group of children with sleep breathing disorders presents higher rates of obesity, nor does obesity influence its presentation clinically. These results had probably been influenced by the characteristics of the studied population and therefore should not be an obstacle for being attentive to the possible association of respiratory disease to obesity and its negative consequences.

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Palabras clave
Trastornos respiratorios del sueño infantil; Obesidad infantil; Síndrome de apnea obstructiva del sueño infantil

Obesidad infantil y trastornos respiratorios del sueño

Resumen
Introducción: La creciente prevalencia de obesidad infantil genera un incremento del riesgo de desarrollar trastornos respiratorios del sueño y puede agravar sus comorbilidades.
Objetivo: Estudio prospectivo para evaluar la tasa de obesidad en niños con trastornos respiratorios del sueño y estudiar las eventuales diferencias clínicas y epidemiológicas entre los niños con y sin exceso de peso en un hospital privado del área mediterránea.
Método: Se estudian 170 niños entre dos y 10 años con trastorno respiratorio del sueño y un grupo control de 170 niños sanos. En el grupo problema el índice de apnea-hipoapnea medio es de 7,61 ± 6,3.
Resultados: La comparación del porcentaje de casos de percentil del índice de masa corporal (IMC) ≥ 85 (sobrepeso) entre ambos grupos problema y control (44: 25,9% vs 34: 20%) o los de IMC ≥ 95 (obesidad) (30: 17,6% vs 20: 11,8%) no muestra diferencias estadísticamente significativas. La comparación de las variables clínicas y epidemiológicas en el grupo problema entre los casos con sobrepeso (44/170: 25,9%) y sin sobrepeso (126/170: 74,1%) tampoco muestra diferencias en ninguno de los parámetros analizados.
Conclusión: En el ámbito del estudio no se observa que los niños con trastornos respiratorios del sueño presenten mayor tasa de obesidad ni que ésta condicione clínicamente la forma de presentación. Es probable que el tipo de población de este estudio condicione estos resultados y por tanto no debe ser óbice para no estar atentos a la posible asociación de la afección respiratoria y obesidad por sus consecuencias negativas.
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Introduction

The prevalence and severity of childhood obesity have become a veritable epidemic problem in the past 30 years. The figures observed in the Western world stand at a quarter of the childhood population.\(^2\)\(^{4}\)\(^\text{-}^{14}\) Moreover, this trend seems to be increasing.\(^2\)\(^{5}\)\(^\text{-}^{6}\)

Between 1980 and 2000, the prevalence of overweight children in the United States has doubled in the population between 6 and 11 years of age and tripled among those between 12 and 17 years of age.\(^2\)\(^{4}\) In Spain, the study “enKid”, conducted with data from the years 1998 to 2000, contained a sample of children and youths between 2 and 24 years, with a total of 3500 individuals. This study showed that the prevalence of childhood and adolescent obesity in Spain was 13.9% and that of overweight was 12.4%. The sum of both concepts represented 26.3% of the population.\(^7\)

The increased prevalence and severity of obesity results in a corresponding increase in the prevalence of diseases, particularly those affecting the metabolic and cardiovascular systems.\(^2\)\(^{5}\) These diseases include sleep-disordered breathing (SDB), whose severity appears to be proportional to the degree of obesity.\(^1\)\(^{4}\)\(^{6}\)\(^{8}\)\(^{10}\)

The first descriptions of the disease reported that the typical syndrome in children differed markedly from that of adults, especially in relation to gender, clinical manifestations, polysomnographic findings and therapeutic approach.\(^11\) However, the growing epidemic of childhood obesity has led to the emergence of a phenotypic variant of obstructive sleep apnoea syndrome (OSAS) in children which closely resembles that of adults with this disease.\(^12\)

If children with SDB, especially in its obstructive sleep apnoea–hypopnoea syndrome (OSAHS) form, are not treated or are treated too late they may develop high morbidity.\(^2\) Both alterations, OSAHS and obesity, may become amplified and synergistically increase the magnitude of their respective adverse consequences when associated in the same individual.\(^2\)\(^{5}\)

This association may lead to increased comorbidities such as metabolic and cardiovascular disorders\(^2\)\(^{6}\)\(^{13}\)\(^{14}\) or even neurocognitive and behavioural disorders.\(^2\)\(^{15}\)\(^{16}\) The risk of persistence of OSAHS in obese children after correct treatment\(^2\)\(^{17}\)\(^{20}\) or that of complications in the immediate postoperative period when treatment is surgical\(^21\)\(^{22}\) have also been widely reported.

This work presents a prospective study with 2 main objectives: the first is to assess the rate of obesity in a population of children with SDB candidates for adenotonsillar surgery compared with a control group of healthy children, and the second is to analyse the potential clinical and epidemiological differences among children with SDB with and without overweight.

Methods

Problem Group

The problem group included 170 consecutive patients, aged between 2 and 10 years, attending the Otolaryngology consultation due to clinical suspicion of SDB. This group was part of the population of patients enrolled in 2 prospective studies on the negative consequences of SDB and the effectiveness of adenotonsillar surgery. Both studies were approved by the Clinical Trials Committee of the hospital.

All cases underwent clinical and polysomnographic diagnosis, as well as a routine physical examination included
in the protocol for childhood SDB at our centre. The children, whose legal guardians agreed to their inclusion in the mentioned studies, completed a questionnaire with the aid of their parents which included questions on sleep, breathing problems and behavioural and neurocognitive disorders. These questionnaires were completed at the time of first consultation and, in case they underwent surgery, 12 months after it. Parents were guaranteed the confidentiality of their responses in writing.23

In addition, we also performed a complete ENT examination, including flexible endoscopy of the upper airway in most cases. The assessment of tonsillar hypertrophy was carried out using the Friedman classification, which grades tonsillar obstruction between 1 and 4.24 All cases were also subject to neurocognitive evaluation25 and dentofacial examination.26

Polysomnography was performed through a registration of 8 h, with mothers being allowed to stay in a bed next to their children. Registration took place under the usual sleeping conditions of each child, having dined at regular hours and with no medication to induce sleep. We studied brain activity using surface electrodes located on both rolandic areas in monopolar derivation. Electromyographic activity was obtained by applying contact electrodes in the submental region.

Eye movements were examined through 2 electrodes placed at the superior angle of the left eye and at the inferior angle of the right eye. Respiratory graphs were obtained through nasal and oral thermal resistance, as well as thoracic and abdominal mercury bands. We recorded oxygen saturation throughout the night by pulse oximetry. The exploration was complemented with the registration of body movements by applying 2 electrodes in the tibialis anterior muscle. Registration was performed at a speed of 30s per page. In order to assess the study we followed the criteria contained in the Manual of standardised terminology, techniques and scoring system for sleep stages in human subjects by Rechtschaffen and Kales.

Control Group

The control group collected a total of 170 patients obtained from the outpatient Paediatric Department of our hospital. These children were attended for a routine control. We attempted to adjust both age and gender distributions to make them equivalent to the problem group. We excluded from this group those children with known ENT, endocrine and respiratory diseases.

The basic epidemiological characteristics of both groups are shown in Table 1, which demonstrates that both groups were comparable in terms of age and gender.

### Table 1 Homogeneity of Problem and Control Groups.

<table>
<thead>
<tr>
<th></th>
<th>Problem (n=170)</th>
<th>Control (n=170)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age months</td>
<td>57.98±21.5</td>
<td>61.35±22.46</td>
<td>NS</td>
</tr>
<tr>
<td>Age years</td>
<td>4.8±1.79</td>
<td>5.1±1.87</td>
<td></td>
</tr>
<tr>
<td>Cases 2–5 years</td>
<td>108 (63.5%)</td>
<td>98 (57.6%)</td>
<td>NS</td>
</tr>
<tr>
<td>Cases 5–10 years</td>
<td>62 (36.5%)</td>
<td>72 (42.4%)</td>
<td></td>
</tr>
<tr>
<td>Male gender</td>
<td>109 (64.1%)</td>
<td>105 (61.8%)</td>
<td>NS</td>
</tr>
<tr>
<td>Female gender</td>
<td>61 (35.9%)</td>
<td>65 (38.2%)</td>
<td></td>
</tr>
</tbody>
</table>

NS: not significant.

Obesity Criteria

Anthropometric variables, weight and height, were measured coinciding with the date of polysomnography in the problem group, with children not wearing clothes nor shoes. Children in the control group were also weighed and measured under the same conditions. We also noted the dates of measurement and birth. These values were subsequently introduced into the Seinaptracker program for auxological calculations. Thus, from data on age, gender, weight and height it was possible to calculate body mass index (BMI). In turn, this data provided BMI Z-scores and percentiles when compared with normal population standards (Andrea Prader Centre, Zaragoza 2002, normally maturing patients). Following commonly accepted criteria, obesity was defined from a percentile of 95 or +2 SD and overweight from a percentile of 85.27

Statistical Study

We present a study of 2 comparative analyses. The first compared the variables weight and BMI, as well as their percentiles and Z deviations, between the control group and the problem group (comparable in terms of age and gender). This comparison included both their expression as quantitative variables and as qualitative variables after transforming them by using cut-off points identified in the literature in order to establish groups. The second analysis divided the problem group into 2, depending on whether children were overweight or not. A subset of children with normal weight was then randomly selected, which was comparable in terms of age, gender and sample size with the group of overweight children, and a comparative study of clinical and epidemiological factors was then performed between these groups.

Both analyses presented descriptive results, mean and standard deviation or frequency and percentage by type of variable. In addition, comparison of qualitative variables was performed through an $\chi^2$ test, while the Student t-test or Mann–Whitney U test were used for quantitative variables, depending on whether they were distributed or not as a normal condition, which was verified using the Kolmogorov–Smirnov test. All tests were performed with a value of $P<.05$. 
Results

Comparison of Weight Data Between the Problem and Control Groups

The control and problem groups were compared using different parameters, indicating overweight and normal weight. These data are shown in Table 2. The most widely accepted values in the literature as indicators of obesity or overweight did not show statistically significant differences between both groups: 25.9% of children in the problem group had a percentile greater than or equal to 85 (overweight) and 17.6% greater than or equal to 95 (obesity). In the control group the figures were 20% (overweight) and 11.8% (obesity), respectively.

Clinical Data of the Problem Group

The clinical data obtained based on questionnaires and exploration is shown in Table 3. The entire group of patients in the problem group referred snoring and over 80% had a value over 6 in the visual analogue scale ranging between 0 and 10. The presence of apnoeas observed by parents, occasionally or daily, was reported by 87.1% of parents surveyed. Referred to the 4 degrees in the Friedman scale, tonsillar hypertrophy was above 2 in 70% of children in the group. The mean apnoea-hypopnoea index (AHI) among the 170 patients in the group was 7.61±6.03, and in 87.64% of cases, the AHI was greater than or equal to 3.

Problem Group Data Comparing Between Cases With Normal and Excessive Weight

We compared the variables between the groups with and without overweight in order to evaluate the influence of excess weight on the clinical and epidemiological characteristics of children with SDB. As baseline, we took cases with a BMI percentile less than 85 (126/170: 74.1%) and cases with that percentile equal to 85 (44/170: 25.9%). The results obtained are shown in Table 4. Comparing these results we noted that none of the parameters analysed showed a statistically significant difference. In addition to the parameters mentioned in Table 4, we analysed other clinical variables obtained from the questionnaires (nasal obstruction, nocturnal enuresis, agitated sleep, profuse night sweats, leg pain, teeth grinding, sleepwalking, night terrors, aggressiveness, hyperactivity, speech delay, poor school performance and impaired memory and attention). None of these analyses showed statistically significant differences when comparing children with and without excess weight.

We conducted other statistical comparisons so as to avoid potential bias resulting from differences in age groups and population sizes between cases with and without excess weight. We randomly collected a homogeneous group of patients with normal weight which was equivalent to the overweight group and carried out the same comparisons. These comparisons were made for patients overall and separately by age groups from 2 to 5 years and from 5 to 10 years. The same was done with the BMI percentile greater than or equal to 95. None of these comparisons resulted statistically significant. In other words, the clinical and epidemiological variables compared between patients with obesity and overweight, both overall and by age groups, showed no differences in our problem group.

Discussion

SDB, specifically in its OSAHS form, has become more common due to rising childhood obesity in the Western world. Several pathophysiological mechanisms are thought to contribute to the association of obesity and OSAHS. Obesity would contribute through an increase in airway closure critical pressure and fatty infiltration of upper airway structures would favour their tendency to collapse. Obesity would also affect ventilation and favour the appearance of anomalies in the ventilation response.

Overweight in children does not only include the risk of suffering SDB, but also increases the chances of suffering

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Weight Data Comparing Between Problem and Control Groups.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Problem group</strong></td>
</tr>
<tr>
<td>Percentile weight≥90</td>
<td>45 (26.5%)</td>
</tr>
<tr>
<td>ZS weight≥+2</td>
<td>17 (10%)</td>
</tr>
<tr>
<td>Percentile BMI≥85</td>
<td>44 (25.9%)</td>
</tr>
<tr>
<td>ZS BMI≥+2</td>
<td>22 (12.9%)</td>
</tr>
<tr>
<td>Percentile BMI≥95</td>
<td>30 (17.6%)</td>
</tr>
</tbody>
</table>

BMI: body mass index; ZS: Z-score.
* Statistically significant difference (P<.05).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Clinical Data of the Problem Group: 170 Children With SDB Syndrome Candidates for Adenotonsillar Surgery.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td><strong>Number and percentage</strong></td>
</tr>
<tr>
<td>Snoring level, VAS</td>
<td>6.95±1.74</td>
</tr>
<tr>
<td>Apnoeas observed always</td>
<td>72 (42.4%)</td>
</tr>
<tr>
<td>Apnoeas observed occasionally</td>
<td>76 (44.7%)</td>
</tr>
<tr>
<td>Nasal obstruction</td>
<td>151 (92.6%)</td>
</tr>
<tr>
<td>Daytime sleepiness</td>
<td>37 (22.7%)</td>
</tr>
<tr>
<td>Hyperactivity</td>
<td>77 (47.2%)</td>
</tr>
<tr>
<td>Attention deficit</td>
<td>71 (43.6%)</td>
</tr>
<tr>
<td>Friedman tonsillar degreea</td>
<td>2.94±0.72</td>
</tr>
<tr>
<td>Mean AHI and extremes</td>
<td>7.61±6.03 (0.17–39.6)</td>
</tr>
</tbody>
</table>

AHI: apnoea–hypopnoea index; SDB: sleep disordered breathing; VAS: visual analogue scale between 1 and 10.

a Friedman classification of tonsillar hypertrophy degrees between 1 and 4.
negative consequences from this disease.\textsuperscript{2,8,32-34} The association of both processes, obesity and SDB, may involve an amplification of comorbidities,\textsuperscript{1,5,35} as well as an obvious risk that they are maintained throughout adult age.\textsuperscript{3}

Current published trends show, in an increasingly conclusive manner, an increased risk of SDB among children with excess weight.\textsuperscript{36-39} Studies based on objective data indicate that 47\% of obese children suffer symptoms of moderate or severe OSAHS and 39\% suffer mild symptoms.\textsuperscript{15,40} Studies by the group of Louisville, including a large number of patients, also found that the percentage of overweight children among cases referred for evaluation due to suspicion of SDB was 45\%-55\%.\textsuperscript{2}

It could be argued that such high figures overestimate the problem. Many of these studies are biased, since they have been conducted on populations of children referred for the presence of OSAS. Other have been conducted on relatively small samples.\textsuperscript{2,6} However, this interrelation was also demonstrated when the prevalence of SDB was examined in the general population.\textsuperscript{9,41-43}

The work by Marcus showed that 46\% of obese children and adolescents presented evidence of polysomnographic alteration. Furthermore, in 27\% this alteration was moderate to severe.\textsuperscript{9} In addition, the same author found a positive correlation between obesity and AHI, and an inverse relationship between obesity and oxygen saturation.\textsuperscript{9} In another study, Wing used polysomnography to compare 46 obese and 44 non-obese children. The conclusion of this study was that the percentage of OSASH stood at about 33\% in obese cases compared to 3%-4\% in non-obese children.\textsuperscript{41}

In our series, the figures obtained by comparing the 170 cases in the problem group with the 170 controls only obtained statistically significant differences in relation to the weight percentile. We obtained no differences when we evaluated the most universally accepted parameters defining overweight (BMI percentile above or equal to 85) and obesity (BMI percentile above 95). Therefore, among the population and scope of work of this study, children with SDB symptoms did not present a significantly higher rate of overweight cases, compared with a control population of healthy children.

It is likely that some confounding factors have had an influence on our data. The prevalence rate may be different for a number of reasons, including different ethnicities, different diagnostic criteria for OSAHS and obesity and, above all, the different age ranges analysed.\textsuperscript{6,44} Our study population represented a group of high socioeconomic status, due to the characteristics of patients attending a private hospital in the metropolitan area of a city like Barcelona. In addition, our centre is located in an area where the Mediterranean diet is very common and this may generate lower rates of overweight among our population.

Lastly, a third possible confounding factor is related to the age of the population. In the present study, the mean age of the problem group was 4.8 years and 63.5\% of children were in the age range between 2 and 5 years. These figures are clearly lower than the vast majority of referenced publications.

Several studies have shown that the association between obesity and OSAHS is clearly higher among older children. In a recent work, Kohler noted that the risk of OSAS in children under 12 years was 3.5 times for each BMI standard deviation, whereas this detail was not observed in younger children.\textsuperscript{44} In our study, cases with a BMI percentile greater than or equal to 85 among the group of children with SDB aged between 2 and 5 years were 20.4\%, and 35.3\% between those aged 5 to 10 years. This difference was statistically significant (P=.030).

The reason for this high prevalence of OSAHS among overweight children could be related to a different underlying phenotype which makes it different from OSAHS in non-obese children and/or an increased effect in known causal factors resulting from the obesity phenotype.\textsuperscript{6} That is, the typical presentation in children with OSAHS with normal weight or overweight and with adenotonsillar hypertrophy, is being increasingly replaced by patients with OSAHS and overweight.\textsuperscript{2}

In a recent review, Arens established a clear definition of the different phenotypes of OSAHS in children. According to this author, there are at least 4 different phenotypes.\textsuperscript{6} The first phenotype would be associated with adenotonsillar hypertrophy and increased collapsibility of the upper airways. This would affect about 2\% of normal children between the ages of 2 and 8 years and could lead to significant neurocognitive deficits and cardiovascular dysfunction if not treated.\textsuperscript{4}

The second phenotype would be associated with craniofacial malformations and certain syndromes such as Down syndrome and Pierre-Robin syndrome. The third phenotype would be associated with primary neuromuscular disorders, such as Duchenne muscular dystrophy or spinal muscle atrophy.\textsuperscript{6}

The fourth phenotype would be associated with obesity. The prevalence of OSAHS among obese children seems to be higher than that of any other phenotype and could increase the risk by more than 4 times.\textsuperscript{6,12} This phenotype, which

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### Table 4 Data Compared Among the Problem Group Between Cases with Normal and Excessive Weight.

<table>
<thead>
<tr>
<th></th>
<th>Percentile BMI ≤85 (n = 126)</th>
<th>Percentile BMI ≥85 (n = 44)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age months</td>
<td>56.96±21.91</td>
<td>60.40±20.12</td>
<td>NS</td>
</tr>
<tr>
<td>Gender, male</td>
<td>82 (65.1%)</td>
<td>27 (61.4%)</td>
<td>NS</td>
</tr>
<tr>
<td>Apnoeas observed</td>
<td>112 (88.9%)</td>
<td>36 (81.8%)</td>
<td>NS</td>
</tr>
<tr>
<td>Snoring level, VAS</td>
<td>6.99±1.81</td>
<td>6.83±1.53</td>
<td>NS</td>
</tr>
<tr>
<td>Excessive daytime sleepiness</td>
<td>27 (22.3%)</td>
<td>10 (23.8%)</td>
<td>NS</td>
</tr>
<tr>
<td>Friedman degree</td>
<td>2.93±0.73</td>
<td>2.95±0.70</td>
<td>NS</td>
</tr>
<tr>
<td>AHI</td>
<td>7.77±6.04</td>
<td>7.16±6.06</td>
<td>NS</td>
</tr>
</tbody>
</table>

AHI: apnoea–hypopnoea index; BMI: body mass index; NS: not significant; VAS: visual analogue scale between 1 and 10.
increases in parallel with childhood obesity, would include a type of patient with clinical characteristics more similar to those of adults with OSAHS. Among them, a greater presence of excessive daytime sleepiness, higher rates of pathophysiologica factors and metabolic and cardiovascular morbidity and a response to surgical treatment similar to that of adults.12

The present study failed to demonstrate that the population of overweight children in the group of children with SDB was substantially different, in these clinical or epidemiological aspects, to the population of children with SDB and without excess weight. None of the parameters evaluated: epidemiological such as age or gender, clinical such as observed apnoeas, level of snoring or excessive daytime sleepiness, anatomical as assessed through the Friedman tonsillar grading scale and, finally, OSAHs severity as assessed by the AHI, were statistically significant when comparing the group of overweight or obese children and the group of children with normal weight.

Conclusions

According to data obtained in this study population, at present and within our work environment, we could not support the idea of differentiating a specific phenotype for children with SDB and obesity, separating them from children with SDB without obesity.

It is highly probable that the confounding factors in this study, namely children from a high sociocultural environment and with lower ages than those in other studies, clearly conditioned our results. Therefore, our findings should not be considered as an obstacle for paying special heed to the presence of both inflammatory conditions, obesity and OSAHs, associated in children. Their combination has been proved highly detrimental regarding the increase and severity of the negative consequences of childhood OSAHS when untreated or treated belatedly.

Conflict of Interests

The authors have no conflicts of interest to declare.

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