Snoring and Nocturnal Oxygen Desaturations in an Italian Middle-aged Male Population*

Epidemiologic Study With an Ambulatory Device

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Recent studies have suggested that portable monitoring may be a valid means of finding respiratory disturbances in epidemiologic research on a large scale. The aim of this cross-sectional study was to evaluate by means of an appropriately validated portable instrument (MESAM 4) the nocturnal oxygen desaturations in a representative sample of adult male population in North Italy. We randomly chose 750 subjects: 399 subjects (53.2 percent) agreed to participate and a complete evaluation of nocturnal recording was possible in 349 subjects (87.5 percent). Seventeen percent of subjects were every-night snorers; a number of oxygen desaturations per hour (ODI) >10 was found in 13.7 percent, and an ODI >20 resulted in 4.8 percent. Age, neck circumference corrected for height, snoring time (measured by MESAM), and self-reported snoring were the variables best explaining ODI in our multivariate approach. This study reports the highest prevalence, using nocturnal oxygen desaturation indices as marker, of sleep-disordered breathing than any reported until now in a general population. (Chest 1994; 105:1759-64)

It has been reported previously that loud continuous snoring may be associated with alveolar hypoventilation and, like obstructive sleep apnea (OSA), increases in pulmonary and systemic arterial pressures. Habitual snoring may be related to OSA and originates from upper airway narrowing during sleep. Several epidemiologic studies on the relation between snoring and different diseases, particularly those of the cardio- and cerebrovascular systems, have suggested that snoring is a risk factor for these diseases. It is increasingly recognized that OSA is an important medical condition, producing severe morbidity and appreciable increased mortality. Therefore, it is helpful to know the prevalence of snoring and OSA in the general population to define a prevention and treatment program for these disorders. Due to the lack of simple and inexpensive sleep-recording techniques, most studies on snoring and OSA are based on questionnaires. A wide variation in the prevalence of habitual snoring has been reported (4 percent to 29 percent in male population). Some studies indicated that the questionnaires tend to underestimate the prevalence of snoring.

Since polysomnography is an expensive and effort-intensive procedure, recent studies have suggested that portable monitoring ambulatory device may be a valid means to find respiratory disturbances in epidemiologic researches on large samples. However, very few of the ambulatory systems currently advertised for use in sleep medicine have been appropriately validated. A digital recording device (MESAM 4) has been developed to monitor oxygen saturation (SaO2), heart rate (HR), snoring, and body position. A validation study that recently compared MESAM 4 results with nocturnal polysomnography showed MESAM 4 provides a valid and highly reproducible index for assessment of sleep-related respiratory disturbances.

The aim of this cross-sectional study was to evaluate (1) the prevalence of snoring and, by means of MESAM 4, the number of nocturnal oxygen desaturations in a representative sample of the adult male population, and (2) the value of self-reported snoring as a screening symptom of sleep-related respiratory disturbances.

METHODS

Subjects

From official records of the town of Abbiategrasso (20 km southwest of Milano; 28,000 inhabitants), we selected male sub-

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objects born and still resident in Abbiategrasso and aged between 40 and 65 years. We obtained a sample of 1,700. From these subjects, 750 were randomly chosen for the study, on the basis of power analysis considerations and refusal estimate. Each subject received a letter of explanation followed by a telephone call.

The study was done between January and April 1992. The subjects were asked to meet the research staff in the hospital of Abbiategrasso. Between 6 pm and 8 pm, they were provided with recording equipment, the MESAM 4. The preparation for the monitoring takes about 3 to 4 min of a technician’s time for each subject, and placing the leads about 5 mins.

Before the placement of the leads, an interview based on a symptom checklist was administered to each subject asking about life habits, medical history, and sleep habits with particular reference to snoring. The following information was requested for analysis in this study: snoring, weight, height, and neck circumference (at the level of the cricothyroid membrane). Snoring was defined on the basis of the answer to the question “Do you snore?” The possible answers were “never,” “sometimes,” “often,” “always.” Afterwards, each subject went to bed at home until the next morning.

Equipment

The MESAM 4 is a four-channel digital recording device for monitoring HR, snoring sounds, SaO2, and body position. The HR is monitored through a single-lead ECG (modified V2) and R-R intervals are measured in milliseconds. Snoring sounds are monitored through an electric subminiature microphone, type MCE 2.000, that is taped above the larynx. The SaO2 is measured with a finger probe. The body position sensor, a flat cylinder 18 mm high with a diameter of 50 mm, is placed on the lower part of the sternum of the subject. A personal computer (IBM compatible) is used for data analysis. Software provided with the equipment is used for the automatic analysis of HR, breathing sounds, and SaO2 drops.15–16

Scoring of the Individual Recording

MESAM 4 calculates and presents separately three different indices: (1) an oxygen desaturation index (ODI), which shows the number of oxygen desaturations > 4% per hour of analyzed time; (2) an HR variation index; and (3) a snoring index called the “intermittent snoring index.” A previous validation study performed on MESAM 415 showed that ODI, among the three indices, was the most reliable index for the assessment of sleep-related respiratory disturbances when compared with nocturnal polysomnography. Thus, in our study, we considered ODI for the scoring. Many authors consider more than ten episodes of oxygen desaturation per hour of sleep to be clinically significant.17,18

The analysis time, which should resemble total sleep time, was estimated by using a subject diary (lights-out and lights-on times; “wake periods” during the night) in conjunction with a visual assessment of the overnight tracing, for evidence of an awake state as suggested by up-position and HR acceleration. The “wake-periods” during the night were not included in the final analysis. Other variables we considered were the following: (1) the “snoring time” (time with the presence of snoring/analysis time × 100); (2) the time with SaO2 < 90 (time with SaO2 < 90/analysis time × 100); and (3) the minimum SaO2 value. All three indices are automatically calculated by the MESAM 4 for each subject. A visual quality control of each recording was performed to exclude possible artifacts in detecting the minimum SaO2 value and the time spent with SaO2 < 90.

Statistical Analysis

Sample descriptive statistics, including possible age distribution differences between random and studied samples, were analyzed by the Student’s t test, ANOVA, or x2, as appropriate. The association between “always snoring” and ODI > 10 was evaluated in terms of odds ratio with 95 percent confidence intervals. The main criterion variable of the study was ODI, as measured by the recording device. Since it was a continuous variable, multiple regression correlation was used to condense the available information into a model with ODI as the criterion variable. A stepwise procedure was performed after forced entry to allow testing of explanatory variables entered the last. The sequence was age (years), body mass index (BMI in kg/m2), neck diameter (cm), predicted normal neck circumference (PPNC = [110*10/neck cm]/0.55*height cm)+310),19 snoring time (percent), and self-reported snoring.

An epidemiologic analysis of self-reported snoring with different thresholds was eventually provided, including snoring frequency, predictive value, sensitivity, and specificity as a screening symptom for subjects with ODI > 10.

RESULTS

Of 750 randomly selected male subjects, 399 agreed to participate (53.2 percent). Refusals were motivated with “being busy with work” (n=167), intercurrent illness (n=33), fear of examination (n=139), and unspecified by 12 subjects.

Table 2—Distribution of ‘Snoring Time’ and Oxygen Desaturations > 4 percent per Hour by Self-Reported Snoring Categories

<table>
<thead>
<tr>
<th>Self-Reported Snoring, %</th>
<th>Snoring Time, %</th>
<th>ODI</th>
<th>Min SaO2</th>
<th>Time With SaO2&lt;90, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Never</td>
<td>11.6</td>
<td>16.0</td>
<td>4.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Sometimes</td>
<td>15.7</td>
<td>16.0</td>
<td>4.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Often</td>
<td>17.3</td>
<td>15.7</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Always</td>
<td>22.5</td>
<td>16.2</td>
<td>10.9</td>
<td>11.8</td>
</tr>
<tr>
<td>ANOVA p</td>
<td>&lt;0.0001</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

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Epidemiologic Study of Snoring and Nocturnal Oxygen Desaturations (Ferini-Strambi et al)
Table 3—Distribution of Oxygen Desaturations >4 percent per Hour

<table>
<thead>
<tr>
<th>ODI</th>
<th>Subjects</th>
<th>Min SaO2 Value</th>
<th>Time With SaO2 &lt;90, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>Mean</td>
</tr>
<tr>
<td>0-5</td>
<td>226</td>
<td>64.8</td>
<td>90.5</td>
</tr>
<tr>
<td>6-10</td>
<td>75</td>
<td>21.5</td>
<td>86.8</td>
</tr>
<tr>
<td>11-20</td>
<td>31</td>
<td>8.9</td>
<td>88.4</td>
</tr>
<tr>
<td>&gt;20</td>
<td>17</td>
<td>4.8</td>
<td>77.7</td>
</tr>
<tr>
<td>ANOVA p</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The age mean and distribution of the subjects studied was not significantly different from that of the initial random group, nor was BMI (Table 1). No statistical differences were found in social class and employment between the two groups.

From the 399 MESAM recordings, a complete evaluation of all the parameters was possible in 349 subjects (87.5 percent), while in another 23 cases (5.8 percent), “snoring time” was calculated but no ODI, because of finger probe displacement of the pulse oximeter during the night. Twenty-seven recordings (6.7 percent) were unusable: microphone displacement in 11 subjects, microphone and finger probe displacement in 16 subjects.

At the interview, the answers of the 399 subjects to the question “Do you snore during sleep?” were: “never” in 19 percent of subjects, “sometimes” in 33 percent, “often” in 31 percent, and “always” in 17 percent. The self-reported snoring categories correspond to significantly different objective measures, i.e., snoring time and ODI (Table 2). Snoring time and ODI linear correlation coefficient was r=0.33 (p<0.001).

Table 3 shows the prevalence of sleep-disordered breathing, according to ODI. Thirteen percent of our sample had an ODI >10, and 4.8 percent had an ODI >20. Minimum value of SaO2 significantly decreased and time with SaO2 significantly increased by increasing ODI.

Table 4 shows the habitual snorers and the subjects with ODI >10 in our population divided into five subgroups based on 5-year intervals of age. Of 399 subjects, 68 were habitual snorers (17.0 percent), and an ODI >10 was found in 48 of 349 subjects (13.7 percent). Occurrence of ODI >10 progressively increased until age 60 years, after which there was a slight decrease. The association between always snoring and ODI >10 resulted statistically significant (OR=3.9), particularly in the 51 to 55-year-old age group (OR=7.2).

The variable best-explaining ODIs in our multivariate approach were age (β=0.13), PPNC (β=0.11), snoring time (β=0.26), and self-reported snoring (β=0.16). Neck diameter and BMI were kept out by this model. It is worth reporting that the PPNC and BMI correlation coefficient was r=0.74 (p<0.001).

Figure 1 illustrates the parameters of self-reported snoring as a screening symptom for desaturation events assessed by MESAM (ODI >10). When “any snoring” (sometimes or often or always) subjects were considered, a population frequency of 81.4 percent was observed, with a predictive value of 15.1 percent, sensitivity of 89.6 percent, and specificity of 19.9 percent. When “often snoring” or “always snoring” subjects were considered, a population frequency of 49.9 percent was observed, with a predictive value of 21.3 percent, sensitivity of 77.1 percent, and specificity of 54.5 percent. When “always snoring” subjects were considered, a population frequency of 17.8 percent was observed, with a predictive value of 30.6 percent, sensitivity of 39.6 percent, and specificity of 85.7 percent.

**Discussion**

Comparisons of the studies on the prevalence of snoring, measured by questionnaire or interview, are
limited by differences in the definition of snoring.\textsuperscript{8} This limitation accounts for wide variations in the prevalence data. Previous studies that attempted to validate their questionnaires in the sleep laboratory found that people are often unaware of their snoring habits and, thus, the prevalence of snoring could be easily underestimated.\textsuperscript{20,21}

In some cases, large questionnaire surveys have been used to select subjects for further polygraphic monitoring in the sleep laboratory to evaluate the prevalence of OSA. Lavie\textsuperscript{22} invited 300 presumably healthy male industrial workers to a polysomnographic recording but only 78 (26 percent) participated. This study showed that the prevalence of OSA in the adult male population was at least 0.89 percent. In a similar study, Gislason et al\textsuperscript{23} found that the prevalence of OSA among men aged 30 to 69 years was at least 1.3 percent. Cirignotta et al\textsuperscript{24} studied, by polysomnography, a random sample of 40 habitual snorers chosen from a group of 1,170 male subjects previously investigated by a mail questionnaire. These authors estimated that the minimal prevalence of sleep apnea among the 30 to 69-year-old men was 2.7 percent considering an apnea + hypopnea index \(>10\) as abnormal.

The small samples evaluated in these studies on the prevalence of OSA are related to polysomnography, an expensive and effort-intensive procedure. For use in epidemiologic studies of general populations, the assessment of snoring and OSA requires the use of tools that are not excessively costly or complex, and that provide reproducible data. Several portable devices are currently commercially available.\textsuperscript{25} Our study was performed by MESAM 4, an ambulatory device that has been appropriately validated by comparison with standard polysomnography.\textsuperscript{15} We studied male subjects aged 40 to 65 years since it is well known that snoring and OSA have a strong male middle-aged predominance.\textsuperscript{26,27} However, it has been reported recently that the prevalence of undiagnosed sleep-disordered breathing is much higher than previously suspected among women.\textsuperscript{28} To have a homogeneous population, we considered the subjects born and living in a small town of northern Italy; 53.2 percent of 750 randomly selected subjects agreed to participate. The studied sample and the target population had the same age and BMI distribution. The prevalence of habitual (every night) snoring found in our study was similar to that reported by Mondini et al\textsuperscript{29} in a male 30 to 59-year-old sample and by Gislason et al\textsuperscript{23} in a male 30 to 69-year-old sample. In our subjects, a decline in habitual snoring was found after the age of 60 years, as previously found.\textsuperscript{21,26} A possible explanation of this, based on the data of an association between snoring and vascular diseases,\textsuperscript{3-5,30} is a precocious mortality in habitual snorers and, so, the decrease in snoring prevalence with increasing age may be result of selection.\textsuperscript{31}

Stradling and Crosby,\textsuperscript{12} in a randomly selected group of middle-aged men, found that the number of nocturnal oxygen desaturations correlated with the history of snoring. Young et al\textsuperscript{25} showed that habitual snorers among middle-aged adults tended to have

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**FIGURE 1.** Snoring as a screening symptom for obstructive sleep apnea assessed by MESAM 4.
a higher prevalence of apnea-hypopnea scores of 15 or higher in comparison to nonsnorers. Previously, Telakivi et al., in a study on 52 middle-aged men, divided into two groups according to the snoring history, found a significantly higher snoring index and ODI in habitual snorers than in nonsnorers. However, our data are the first on a large sample to show a significant link among self-reported snoring, objective snoring time, and number of oxygen desaturations. A possible bias of our study is the detection of snoring by MESAM. In fact, this device does not discriminate the continuous snoring from “snoring,” resulting in a possible overestimation of the total “snoring time.” Only a device that provides a detailed and selective analysis of the single snores can distinguish the two different types of snoring.

For detecting the SaO2, we used a finger probe that has a lower agreement with the direct intra-arterial values than ear probe, especially for values under 85 percent. However, in our sample, we found very few subjects with deep O2 desaturations.

The value of self-reported snoring as a screening symptom of sleep-disordered breathing has been addressed in this study. Seventeen percent of “always snoring” subjects have been found in a sample of middle-aged men, and 13.7 percent had an ODI > 10. We found that higher specificity on snoring reported as “always” indicates this as the threshold to be used in the selection of subjects for further laboratory polysomnography. The higher sensitivity on snoring reported as “often or more” indicates this as another threshold to be used in less expensive and effort-intensive confirmatory evaluations, like ambulatory monitoring.

Our study confirms the data of Davies et al., that showed that the link between obesity and snoring is probably due to increased neck circumference rather than general obesity. In our subjects, the relation between BMI and PPNC was, of course, very strong, but it is possible to have BMI within normal range and have a large neck, and vice versa.

In conclusion, our study showed that the prevalence of nocturnal desaturation events is high among middle-aged men. A further polysomnographic study in our subjects was not possible and this could be considered a bias of our research. Nevertheless, a recent polysomnographic study, on a large sample of middle-aged adults showed a similar prevalence of sleep-disordered breathing we found among men (15 percent of subjects with apnea-hypopnea score > 10). In that study, the estimated prevalence of OSA, considering the sleep-disordered breathing and the daytime hypersonolence, was 4 percent. In our sample, the subjective finding of daytime hypersonolence has not been correlated yet to other parameters, but a similar estimate prevalence of OSA could be supposed.

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