Snoring is common in the general population, with up to 25% of women and 45% of men reporting habitual snoring.\(^1,2\) It is the most common symptom of obstructive sleep apnea (OSA), occurring in 70% to 95% of patients.\(^3,4\) However, snoring is a poor predictor of OSA because of the high prevalence of snoring in the general population.\(^5\) Contrary to non-apneic snoring, OSA is closely associated with a number of serious illnesses, including arterial hypertension, cardiovascular disease, stroke, and metabolic syndrome.\(^6,7\)

The sound of snoring in patients with OSA is produced when air flows through the narrowed upper airway which closes and reopens rapidly causing increased turbulence, palatal flutter, and hence loud respiratory sounds.\(^8\) Hence, it is reasonable to assume that more frequent obstructive events are associated with louder snoring. Consequently, it is commonly thought that louder snoring is associated with more severe OSA. However, the relationship between snoring intensity and the severity of OSA has not been systematically investigated; the majority of studies have been limited by small sample size and lack of objective monitoring of snoring intensity.\(^9\)

The primary objective of this study was to assess the correlation between the severity of OSA, as reflected by the apnea-hypopnea index (AHI), and the intensity of snoring which was objectively monitored during sleep. The secondary objectives included the evaluation of the association between snoring intensity and other factors known to affect OSA severity, including body position, sleep stage, gender, body mass index (BMI), age, and neck size.
All patients completed a self-answered questionnaire to determine whether they snored, and to rate the perceived loudness of their snoring from 1 (mild) to 4 (severe). The intensity of snoring was measured objectively during PSG by using a digital sound meter. The maximum decibel level recorded on the sound meter during each 30-sec epoch of the polysomnogram was identified and the mean value of this measurement (mean maximum decibel level) during different sleep states and body positions was used to determine snoring intensity. We used the mean maximum decibel level to classify snoring as mild (40-50 db), moderate (50-60 db), or severe (> 60 db). This classification was based on a validation study (unpublished) in a separate group of patients in which we correlated the sleep laboratory technologist’s subjective assessment of snoring intensity with the recorded decibel level.

**OSA Severity**

The severity of OSA was determined by the $AHI_{TS}$, and was classified as no OSA ($AHI < 5$), mild ($AHI < 5$ to 15), moderate ($AHI > 15$ to 30), severe ($AHI > 30$ to 50), or very severe OSA $AHI > 50$. This arbitrary classification, although consistent with a previously published recommendation,11 was primarily used to aid the presentation of our data over a wide range of $AHI$ values.

**Statistical Analysis**

Descriptive statistics were used to describe patient demographics. Differences in proportions of categorical variables between study groups were assessed by the $\chi^2$ test. Differences in means of continuous variables were assessed by Student $t$ test. Pearson correlation coefficient was used to measure the strength of association between continuous variables. A $p$ value $< 0.05$ was considered significant. All data were analyzed with the use of SPSS version 12 software for Windows (SPSS, Inc., Chicago, IL). Continuous data are reported as mean $\pm$ SD.

**RESULTS**

We performed 3,303 PSGs between October 2003 and September 2005. Of these, 1,330 (41%) were excluded from the study for the following reasons: 981 (30%) were CPAP titration studies; 301 (9%) were follow-up PSGs; 34 (1%) were done to assess the response to an oral appliance; 12 (< 1%) were done to assess the impact of upper airway surgery; and 2 (< 1%) were done in patients < 18 years old. Of the remaining 1,973 diagnostic PSGs, 1,643 (83%) were done to patients who reported habitual snoring; and they form the cohort for this study.

The demographics of patients studied are shown in Table 1. There were more males than females; men were older, heavier, and had larger neck circumferences than women. PSG findings are summarized in Table 2.

The indices of snoring intensity are outlined in Table 3. Men had louder snoring than women (54.1 $\pm$ 6.4 versus 47.4 $\pm$ 4 db, $p < 0.001$); this was consistent for all sleep stages, body positions, and weight. Snoring was louder among those with BMI $> 30$ than those with BMI $< 30$ (54.8 $\pm$ 6.7 versus 49.5 $\pm$ 5.3 db, $p < 0.001$); it was also louder among those with neck circumference $> 40$ cm than those $< 40$ cm (54.9 $\pm$ 6.8 versus 49.5 $\pm$ 5.2 db, $p < 0.001$). Snoring was louder in the supine than the non-supine position (53.4 $\pm$ 6.5 versus 50.9 $\pm$ 6.6 db, $p < 0.01$), and during NREM than REM sleep (52.2 $\pm$ 6.7 versus 50.5 $\pm$ 6.1 db, $p < 0.001$).
Snoring Intensity and Severity of OSA

The mean maximum snoring intensity during sleep in the study group was 52 ± 6.5 dB (mean ± SD). Eighty-seven percent (1435/1643) of these patients had OSA (AHI > 5). The mean maximum snoring intensity in the OSA group was significantly higher than in the non-apneic snorers (52.7 ± 5.5 versus 46.3 ± 5.1 dB, p < 0.01).

Patients were further divided into 5 groups based on AHI (< 5, 5-15, 15-30, 30-50, > 50). These groups comprised 208, 475, 414, 277, and 269 patients respectively. These cutoff points represent thresholds commonly used to diagnose and classify the severity of OSA. A progressive increase in the mean maximum snoring intensity was seen across all 5 groups (46.3 ± 3.6, 48.6 ± 4.4, 51.6 ± 4.8, 54.2 ± 5.2, and 60.5 ± 6.4 dB, respectively. Since the decibel units are expressed on a logarithmic scale, a difference of 14.2 dB between those with an AHI < 5 and those with an AHI > 50 represents an increase in snoring intensity of 1420%. This relationship was further evaluated by the Pearson correlation test which showed a relatively strong association between the severity of OSA, reflected by the total AHI, and snoring intensity, reflected by the mean maximum decibel level (r = 0.66, p < 0.01) (Figure 1). Snoring intensity was also positively correlated with neck circumference (r = 0.46, p < 0.01) and BMI (r = 0.49, p < 0.01). There was no correlation between snoring intensity and age.

<table>
<thead>
<tr>
<th>Severity of OSA (AHI)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snoring intensity (dB)</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

**DISCUSSION**

We observed a significant positive correlation between the severity of the OSA and snoring intensity. Previously published data on this association were based upon self-report or family member report of snoring. The current study is the first to use an objective measurement of snoring intensity in a large group of patients to assess the relationship between OSA and snoring severity.

Several small previous studies recorded and analyzed snoring in an attempt to differentiate non-apneic snorers from patients with OSA. Pastercamp et al. recorded the tracheal sound of 8 known OSA patients while awake, and showed increased intensity in low-frequency, medium-frequency, and high-frequency sounds compared to normal subjects. Fiz et al. compared the sound of snoring in 7 non-apneic snorers and 10 patients with OSA and demonstrated significant differences between the two groups in terms of the quality and spectrum of noise. However, neither study was designed to correlate snoring intensity and OSA. Perez-Padilla further evaluated the quality of snoring and showed that in patients with OSA, one can identify post-apnea snores which have different characteristics from non-apneic snoring. This difference may help differentiate OSA patients from habitual snorers. Finally, Liistro et al. reported that snoring is characterized by high-frequency oscillations of the soft palate, pharyngeal walls, epiglottis, and tongue, and that the pattern of snoring is different in OSA compared to habitual snorers.

The present study extends our current understanding of the relationship between OSA and snoring intensity by demonstrating, in a large cohort of adults referred for PSG, a relatively strong positive association between snoring intensity and the presence of OSA.

Our findings have a number of clinical implications. Firstly, it appears that bed partners of patients with OSA are exposed to considerable environmental noise at night. The average sound intensity of our OSA patients exceeded the limits of nocturnal environmental noise pollution levels recommended by government agencies. Furthermore, in some patients, the peak sound...
intensity was above that considered necessary to avoid hearing loss, and our results support recent studies which showed an association between sleep disordered breathing and the bed partner’s quality of life.\textsuperscript{17,18} Secondly, the study supports the clinical observation that there is an association between snoring intensity and OSA. Although this may add to our current risk stratification for OSA, the wide variability of snoring intensity between subjects precludes this as a reliable solitary measure to diagnose sleep apnea, which continues to require more direct measurements of respiratory physiology such as airflow, respiratory effort, and oxygen saturation.

Potential limitations of this study should be addressed. First, our study was based upon a single PSG in each patient; although the monitoring was objective and used standard and calibrated measurements, it is possible the single studies were not representative of the patient’s sleep. Secondly, the external validity of this study is limited; it is not known if a similar relationship exists between OSA and snoring intensity in the general population. Notwithstanding the strength of the association, we found one should be cautious in predicting the presence of OSA by snoring intensity alone.

### ABBREVIATIONS

AHI, Apnea hypopnea index  
BMI, body mass index  
CPAP, continuous positive airway pressure  
CSA, central sleep apnea  
OSA, obstructive sleep apnea  
PSG, polysomnography

### REFERENCES

18. Sharief I, Silva GE, Goodwin JI, Quan SF. Effect of sleep disordered breathing on the sleep of bed partners in the Sleep Heart Health Study. \textit{Sleep} 2008;31:1449-56.

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Address correspondence to: Nimrod Maimon, M.D., Division of Respirology, St. Michael’s Hospital, 30 Bond St, Suite 6049, Toronto, ON, Canada M5B 1W8; Tel: (416) 793-6331; E-mail: nimrod.maimon@gmail.com.

### DISCLOSURE STATEMENT

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