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Validation of a new snoring detection device based on a hysteresis extraction algorithm

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ABSTRACT

Objective: This paper aims to introduce and validate our newly developed snoring detection device to automatically identify the incidence and amplitude of snores using the hysteresis extraction method.

Methods: Thirty patients (16 males and 14 females) with a history of snoring were included in this study. Each patient underwent a conventional polysomnography (PSG). Natural overnight snoring was recorded from each subject using our original snore detection device and an integrated circuit (IC) recorder while the patient slept during PSG. A new algorithm based on hysteresis extraction was used to detect snores and qualify the level of each event at 30-s intervals (one epoch). The automated and subjective assessment concordance was evaluated by comparing a total of 27,295 epochs, and sensitivity, specificity, and accuracy were calculated.

Results: Study population analysis revealed a mean rate of snore time against the total sleep time of $14.1 \pm 7.9\%$. Further, validation of the automatic snore detection revealed the following: sensitivity, 71.2%; specificity, 93.1%; positive predictive value, 77.7%; negative predictive value, 94.6%; and accuracy, 90.7%.

Conclusions: This study revealed the efficacy of our newly developed snoring detection device and indicated that it may serve as a useful method in further snoring analysis via objective medical assessment. However, the sample size of 30 subjects was relatively small; therefore, further research is needed to evaluate this device.

1. Introduction

Snoring is defined as noisy breathing during sleep that is produced by the vibration of soft tissues in the upper airway. According to a review of 16 studies, the prevalence of snoring is 5%–86% (mean, 32%) in males and 2%–57% (mean, 21%) in females [1]. Young et al. reported that 78.4% of patients with sleep-disordered breathing (SDB) had an apnea hypopnea index (AHI) >5, and 95.2% of those with an AHI >15 habitually snored [2].

Snoring creates noise that is disturbing to spouses/partners or roommates because it disturbs others' sleep and may induce secondary sleep disorders in all individuals [3,4]. Heavy snoring has been shown to cause conflicts amongst married couples and may even result in divorce. Therefore, if snoring is disruptive, those afflicted are often eager to seek therapy; however, there are currently no specific drugs available to cure

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snoring, although nasal continuous positive airway pressure therapy is indicated for severe obstructive sleep apnea (OSA)-related snoring, and both mandibular advancement devices (MADs) and palatal surgery are indicated for simple cases of snoring and mild OSA-related snoring. MADs are designed to increase the dimensions of the oropharyngeal and hypopharyngeal openings to improve the symptoms of simple snoring and mild OSA. Patients have reported high satisfaction rates with long-term therapy with MADs, and palatal surgery is effective for ameliorating snoring that is caused by the fluttering of the soft palate [5]. However, the therapeutic efficacy of these treatments against the snoring has mostly been evaluated on the basis of questionnaires from patient's spouses/partners or roommates. Snoring can be scored manually with PSG like Alice5, however, it is not easily available only for the evaluation of snoring. Sleep apnea surgeons, oral surgeons, and otorhinolaryngologists require the establishment of an objective medical snoring assessment to show the differences of snoring characteristics before and after the antisnoring therapies such as MADs and palatal surgery.

Therefore, we aimed to introduce and validate a new detection method developed by our lab to automatically identify snoring sounds and calculate the snore amplitude using a hysteresis extraction method.

2. Materials and methods

2.1. Description of the study population

The study cohort comprised 30 patients [mean age = 53.8 - years, range = 21–84 years; 16 males: mean body mass index (BMI) = 26.2 kg/m^2; 14 females: mean BMI = 24.5 kg/m^2] who complained of snoring. Patients receiving antianxiety or antipsychotic drugs were excluded from the study. Each patient underwent conventional PSG to record natural overnight snoring while sleeping alone at night in a standard hospital bed in the sleep laboratory of Yamaguchi University Hospital between August 2011 and March 2012.

The study protocol was approved by the institutional review board of Yamaguchi University Hospital (Permit no. H22-155), and written informed consent was obtained from all study participants. This study was conducted in accordance to the Declaration of Helsinki.

2.2. Polysomnography

Conventional PSG was performed using the Alice 5 Diagnostic Sleep System (Philips Respironics, Inc., Murrysville, PA, USA). PSG acquisition and evaluation were performed on the basis of the Rechtschaffen and Kales sleep scoring system, the American Sleep Disorders Association instruction guide, and the American Academy of Sleep Medicine Manual for the Scoring of Sleep and Associated Events 2007 [6–8].

2.3. Snore recording

The snore detection device utilized the noncontact biomotion data logger named Sleep Design® (Omron Healthcare Co., Ltd., Kyoto, Japan), which incorporated a microphone to record the snores and an originally developed algorithm to evaluate the snores. Briefly, the examiner placed the device 0.5 m from the patient's chest, 0.25 m above the height of the mattress, and faced it toward the patient's torso (Fig. 1). Snoring sounds were recorded during the entire sleep period at a sampling rate of 4000 Hz using the pulse code modulation (PCM) format, and the level of each event was qualified every 30 s (set as one epoch) using a specific investigatory algorithm and stored on a secure digital memory card.

An integrated circuit (IC) recorder (Voice Trek V-85; Olympus Corp., Tokyo, Japan) was set in the same location as the snore detection device, and snoring sounds were recorded at a sampling rate of 44,100 Hz in the PCM format. The recorded snores were used as a reference for the comparative analysis of snoring sounds to validate the accuracy of the snoring evaluation device. Both the recorded snores were later objectively validated by three examiners.

2.4. Hysteresis extraction algorithm

A new algorithm based on hysteresis extraction was developed to detect the snores and qualify the level of each event. Hysteresis extraction is frequently used to control noise reduction, and its primary merit is the small computational quantity. To analyze snoring sounds, the sound intervals wherein the amplitude exceeded the threshold volume were

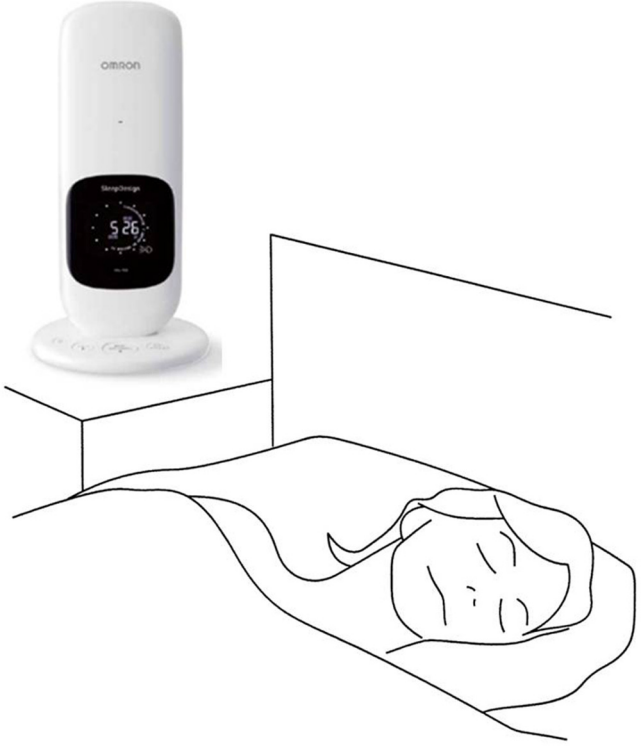

Fig. 1. The original snore detection device was equipped with a microphone to record the snores and an algorithm to evaluate snoring apart from outside noises.
The device was set with approximate dimensions and placed relative to the bed and the snorer.

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