Original Article

JOMP Journal of Oral Medicine and Pain

pISSN 2288-9272 eISSN 2383-8493
J Oral Med Pain 2017;42(1):1-7
https://doi.org/10.14476/jomp.2017.42.1.1

# Clinical Characteristics and Polysomnographic Features of Patients Visited a Snoring and Sleep Apnea Clinic of Dental Hospital in Korea

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**Received** February 10, 2017
**Revised** March 16, 2017
**Accepted** March 17, 2017

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**Purpose:** The aims of this study were to evaluate the clinical characteristics and polysomnographic results of patients visited the Seoul National University Dental Hospital (SNUDH) and to suggest guidelines for the management of sleep disordered-breathing patients in a dental clinic.

**Methods:** Five hundred sixty-two patients who visited the Snoring and Sleep Apnea Clinic of SNUDH were evaluated for clinical characteristics including associated comorbidities, age, gender, body mass index (BMI), neck circumference, and daytime sleepiness and among them 217 patients were performed nocturnal polysomnography for evaluating respiratory disturbance index, apnea-hypopnea index (AHI), oxygen saturation levels, and sleep stages. The associations among clinical characteristics, sleep parameters, and positional and rapid eye movement (REM) dependencies of the patients were analyzed.

**Results:** The most common co-morbidities of the patients were cardiovascular (30.2%), endocrine (10.8%), and respiratory diseases (7.9%). Age ($\beta$=0.394), total AHI ($\beta$=0.223), and lowest $O_2$ saturation levels ($\beta$=0.205) were significantly associated with the number of co-morbidities in patients with obstructive sleep apnea (OSA). Mean $O_2$ saturation was not significantly associated with number of co-morbidities. Non-positional OSA patients had higher BMI, longer neck circumferences, more severe AHI values, and lower mean and lowest $O_2$ saturation levels compared to positional OSA patients. Not-REM-related patients were older and had more severe AHI values compared to REM-related patients. Not-REM-related patients have longer duration of stage I sleep and shorter stage II, III, and REM sleep than REM-related patients. There were no significant differences in each sleep stage between positional and non-positional patients. Neck circumference, positional dependency, REM dependency, and percentage of supine position were significantly associated with severity of OSA.

**Conclusions:** Age, total AHI, and lowest $O_2$ saturation level were significantly associated with the number of co-morbidities in patients with OSA. Neck circumference, positional dependency, REM dependency, and percentage of supine position were significantly associated with severity of OSA.

**Key Words:** Obstructive sleep apnea; Polysomnography; REM sleep; Sleep position; Snoring

## INTRODUCTION

Obstructive sleep apnea (OSA) is defined as a cessation of breathing by repetitive complete or partial the collapse of upper airway during sleep resulting in sleep fragmentation and oxygen desaturation. Signs and symptoms of OSA include excessive daytime sleepiness, insomnia, nocturia, morning headache, and intermittent hypoxemia. Risk factors for developing OSA include aging, obesity, male gender, menopause, family history, nasal obstruction, alcohol consumption, and craniofacial abnormalities.[1]

The prevalence of OSA is higher in the elderly and male gender. In a recent Korean study, the prevalence of OSA (apnea-hypopnea index [AHI]>5) was reported to be 27.1% in men and 16.8% in women.[2] Despite of its high prevalence, recognition of this disease remains low and many recent studies suggested that untreated patients with OSA have high risk of death from all causes, especially cardiovascular co-morbidities. There are many evidences that OSA causes cardiovascular complications including hypertension, myocardial infarction, stroke and treatment of OSA can improve cardiovascular morbidity and mortality.[3-7]

Various surgical and non-surgical modalities have been suggested for treating snoring and sleep apnea. For non-surgical modalities, general and behavioral therapy, such as weight loss, smoking cessation, avoidance of alcohol, and changing position during sleep can be a possible treatment. People with moderate to severe apnea are recommended continuous positive airway pressure (CPAP) or oral appliances. While CPAP therapy is the most effective treatment option for most patients with OSA, its discomfort causes less tolerance and compliance. Therefore, clinical needs for oral appliance have increased and the role of dentists has become more important in the management of OSA. There are many surgical modalities for treating OSA such as uvulopalatopharyngoplasty, orthognathic surgery, and tracheostomy. The type of surgery should be selected according to the individual's anatomy, health status, age, and severity of sleep apnea.

Even though the upper airway space is not significantly different, the severity of OSA can differ according to the patient's sleep position or duration of rapid eye movement (REM) sleep. Cartwright suggested positional patients were defined as those whose AHI is at least twice as high while sleeping in supine position as in non-supine position.[8] Haba-Rubio et al.[9] suggested REM-related patients were defined as those whose AHI during REM sleep is more than twice than that during non-REM (NREM) sleep.

The aims of this study were to evaluate clinical characteristics and polysomnography data of patients with OSA who visited the Seoul National University Dental Hospital (SNUDH) to evaluate the differences in clinical and polysomnography parameters according to positional or REM dependencies, and to analyze risk factors on severity of OSA.

## MATERIALS AND METHODS

### 1. Subjects

A total of 562 patients who visited the Snoring and Sleep Apnea Clinic from January 2007 through August 2014 for the treatment of snoring and sleep apnea were evaluated. Among them 217 patients were examined by grade I polysomnography, and 163 patients were analyzed after exclusion of the patients who showed AHI score less than 5.

The patients examined by polysomnography were classified into positional (supine AHI ≥2×lateral AHI) and non-positional (supine AHI <2×lateral AHI) OSA patients according to the positional dependency,[8] and REM-related (REM AHI ≥2×non-REM AHI) and not-REM-related (REM AHI <2×non-REM AHI) OSA patients according to the REM dependency.[9] From the 163 subjects, 43 patients were categorized as non-positional OSA and 120 patients as positional OSA, and 105 patients were categorized as not-REM-related OSA and 58 patients as REM-related OSA. Demographic and co-morbidity data of the patients including age, gender, body mass index (BMI), neck circumference, and daytime sleepiness were obtained. The daytime sleepiness was evaluated using Epworth Sleepiness Scale (ESS).

This study was approved by the institutional review board of SNUDH (CRI 14037).

### 2. Polysomnography

Among the patients, 163 patients were performed level 1 polysomnography including electroencephalography (EEG), electrooculography (EOG), chin electromyography (EMG), leg EMG, electrocardiogram (ECG), airflow recorded with nasal thermistor and cannula, pulse oximetry, and body position by Alice 5 (Respironics, Pittsburgh, PA, USA).

Apnea was scored when 1) there is a drop in the peak signal excursion by ≥90% of pre-event baseline using an oronasal thermal sensor. 2) The duration of the ≥90% drop in sensor signal is ≥10 seconds. The duration of the event is from the nadir in flow preceding the first breath that is clearly reduced to the start of the first breath that approximates baseline breathing.

Hypopneas were initially scored when 1) the peak signal excursions drop by ≥30% of pre-event baseline using nasal pressure, 2) the duration of the ≥30% drop in signal excursions is ≥10 seconds, and 3) there is ≥3% oxygen desaturation from pre-event baseline or the event is associated with an arousal.[10] The AHI was defined as the total number of apnea and hypopnea events per hour of sleep. The severity of sleep apnea was classified into mild (AHI 5-14), moderate (AHI 15-30), and severe (more than 30).

The respiratory disturbance index (RDI) was calculated as the number of apnea plus hypopnea plus respiratory effort related arousal.

### 3. Statistical Analysis

Baseline demographics (age, BMI, and neck circumference), total AHI, mean and lowest $O_2$ saturation levels, and differences between positional and REM dependency were analyzed by independent t-test and Mann-Whitney test. Associations between AHI value and risk factors including gender, age, neck circumference, percentage time in supine position, and positional and REM dependencies were estimated using multiple linear regression analysis. Because AHI value showed non-parametric distribution, the AHI value was log-transformed and then used for multiple linear regression analyses.

## RESULTS

### 1. Clinical and Polysomnographic Characteristics of the Patients

The patients were consisted of 437 men (77.8%) and 125 women (22.2%), and age ranged from 2 to 88 years (mean age 48.9±15.4 years). The most common co-morbidities of patients were cardiovascular (hypertension, stroke, and heart disease, 30.2%), endocrine (10.8%), respiratory (7.9%), gastrointestinal (7.7%), and neuromuscular (5.3%) diseases.

Table 1 shows the general characteristics and polysomnographic features. There were 135 men (82.8%) and 28 women (17.2%), age ranged from 11 to 82 years (mean age 44.7±13.2 years). According to their AHI, the percentages of the patients were for mild, moderate, and severe OSA were 42.3%, 21.5%, and 36.2%, respectively.

### 2. Impacts of Sleep Parameters on Number of Co-morbidities

Table 2 shows the results of multiple linear regression analyses of the risk factors on the number of co-morbidities of the patients. Age ($\beta$=0.394), total AHI ($\beta$=0.223), and lowest $O_2$ saturation ($\beta$=0.205) were significantly associated with number of co-morbidities in patients with OSA. However, mean $O_2$ saturation was not significantly associated with number of co-morbidities after adjusting for the confounding factors in patients with OSA.

**Table 1.** Demographic features and polysomnographic results

| Characteristic | Mean±standard deviation | Range |
|---|---|---|
| Age (y) | 44.7±13.2 | 11-82 |
| BMI (kg/m$^2$) | 25.3±3.3 | 17.7-35.1 |
| Neck circumference (cm) | 37.8±3.7 | 27.0-44.5 |
| ESS score | 8.2±4.5 | 0-24 |
| Total AHI | 28.4±23.5 | 5.1-117.2 |
| Supine AHI | 35.1±26.2 | 0-117.4 |
| Lateral AHI | 12.8±22.2 | 0-109.2 |
| Total RDI | 35.3±21.9 | 6.6-118.3 |
| Percentage $SPO_2$ <90 (%) | 4.2±8.1 | 0-42.4 |
| Lowest $O_2$ saturation (%) | 81.7±8.9 | 38-95 |
| Mean $O_2$ saturation (%) | 95.4±1.9 | 89-99 |
| Sleep stage I (%) | 28.5±15.6 | 2.5-89.9 |
| Sleep stage II (%) | 48.9±14.0 | 10.1-73.4 |
| Sleep stage III (%) | 2.5±7.8 | 0-72.6 |
| REM sleep (%) | 16.0±7.3 | 0-35.2 |

BMI, body mass index; ESS, Epworth Sleepiness Scale; AHI, apnea-hypopnea index; RDI, respiratory disturbance index; REM, rapid eye movement.

**Table 2.** Multivariate linear regression analysis of the risk factors on the number of co-morbidities

| Risk factor | Coefficient | β-value | p-value | Adjusted $R^2$ |
|---|---|---|---|---|
| A | | | | 0.458 |
| Age | 0.030 | 0.394 | <0.001 | |
| BMI | 0.025 | 0.080 | 0.320 | |
| Total AHI | 0.009 | 0.223 | 0.022 | |
| Lowest $O_2$ saturation | 0.023 | 0.205 | 0.027 | |
| Total sleep time | 0.002 | 0.132 | 0.088 | |
| B | | | | 0.450 |
| Age | 0.030 | 0.395 | <0.001 | |
| BMI | 0.031 | 0.097 | 0.266 | |
| Total AHI | 0.008 | 0.194 | 0.045 | |
| Mean $O_2$ saturation | 0.097 | 0.179 | 0.072 | |
| Total sleep time | 0.002 | 0.134 | 0.090 | |

A, lowest $O_2$ saturation was included for the risk factor; B, mean $O_2$ saturation was included for the risk factor.
BMI, body mass index; AHI, apnea-hypopnea index.

**Table 3.** Comparison of polysomnographic results according to positional dependency

| Characteristic | Positional (n=120) | Non-positional (n=43) | p-value |
|---|---|---|---|
| Age (y) | 45.3±14.2 | 43.2±10.4 | 0.302[a] |
| BMI (kg/m$^2$) | 24.9±3.1 | 26.5±3.4 | 0.006[a] |
| Neck circumference (cm) | 37.3±3.9 | 39.2±2.8 | 0.020[b] |
| ESS score | 8.6±4.6 | 7.0±4.0 | 0.038[b] |
| Total AHI | 25.2±20.6 | 37.4±28.8 | 0.030[b] |
| Lowest $O_2$ saturation (%) | 82.5±8.8 | 79.4±8.9 | 0.010[b] |
| Mean $O_2$ saturation (%) | 95.7±1.7 | 94.4±2.0 | <0.001[b] |
| Sleep stage I (%) | 28.1±13.8 | 29.7±20.1 | 0.520[b] |
| Sleep stage II (%) | 49.3±13.0 | 47.9±16.8 | 0.888[b] |
| Sleep stage III (%) | 2.8±8.8 | 1.5±3.6 | 0.649[b] |
| REM sleep (%) | 16.3±7.0 | 15.3±8.3 | 0.436[a] |

BMI, body mass index; ESS, Epworth Sleepiness Scale; AHI, apnea-hypopnea index; REM, rapid eye movement.
Values are presented as mean±standard deviation.
[a]p-value was obtained from independent t-test. [b]p-value was obtained from Mann-Whitney test.

### 3. Comparison of Patients according to the Positional and REM Dependencies

Descriptive data between positional and non-positional OSA groups are shown in Table 3. One hundred twenty patients (73.6%) were positional and 43 patients were non-positional OSA. There were significant differences in BMI, neck circumference, and ESS score between positional and non-positional OSA groups. Non-positional OSA patients had more severe AHI values, and lower mean and lowest $O_2$ saturation levels than positional OSA patients. There was no significant difference in each sleep stage between positional and non-positional patients.

Table 4 shows the descriptive data of REM dependencies. One hundred five patients (64.4%) were classified as not-REM-related and 58 patients were classified as REM-related OSA. Not-REM-related patients were significantly older and had more severe AHI values than REM-related patients. Not-REM-related patients have significantly longer duration of stage I sleep and shorter stage II, III, and REM sleep than REM-related group.

### 4. Impacts of Risk Factors on Severity of OSA

Table 5 shows multiple linear regression analysis for the impacts of risk factors on severity of OSA. Neck circumference was the most significant associated factor on severity of OSA (β=0.405). Positional dependency (β=0.190), REM dependency (β=0.271), and percentage of supine position (β=0.200) were also significantly associated with severity of OSA.

**Table 4.** Comparison of polysomnographic results according to REM dependency

| Characteristic | Not-REM-related (n=105) | REM-related (n=58) | p-value |
|---|---|---|---|
| Age (y) | 47.2±13.2 | 40.2±12.4 | 0.001[a] |
| BMI (kg/m$^2$) | 25.3±3.2 | 25.5±3.5 | 0.760[a] |
| Neck circumference (cm) | 38.2±3.6 | 37.1±4.0 | 0.230[b] |
| ESS score | 8.1±4.7 | 8.4±4.2 | 0.540[b] |
| Total AHI | 34.0±25.6 | 37.4±28.8 | <0.001[b] |
| Lowest $O_2$ saturation (%) | 80.6±9.7 | 83.6±7.1 | 0.066[b] |
| Mean $O_2$ saturation (%) | 95.1±2.0 | 95.8±1.6 | 0.079[b] |
| Sleep stage I (%) | 34.0±16.0 | 18.5±8.6 | <0.001[b] |
| Sleep stage II (%) | 45.2±14.2 | 55.7±11.1 | <0.001[b] |
| Sleep stage III (%) | 1.6±5.9 | 4.0±10.3 | 0.001[b] |
| REM sleep (%) | 14.8±7.6 | 18.4±6.2 | 0.002[a] |

REM, rapid eye movement; BMI, body mass index; ESS, Epworth Sleepiness Scale; AHI, apnea-hypopnea index.
Values are presented as mean±standard deviation.
[a]p-value was obtained from independent t-test. [b]p-value was obtained from Mann-Whitney test.

**Table 5.** Multivariate linear regression analysis of the risk factors on AHI

| Risk factor | Coefficient | β-value | p-value |
|---|---|---|---|
| Age | 0.009 | 0.160 | 0.055 |
| Gender (male) | 0.345 | 0.172 | 0.069 |
| Neck circumference | 0.088 | 0.405 | <0.001 |
| Non-positional OSA | 0.350 | 0.190 | 0.025 |
| Not-REM-related OSA | 0.480 | 0.271 | 0.002 |
| Percentage of supine position | 0.006 | 0.200 | 0.016 |
| REM sleep | −0.017 | −0.149 | 0.062 |

AHI, apnea-hypopnea index; OSA, obstructive sleep apnea; REM, rapid eye movement.
Adjusted $R^2$=0.583.

## DISCUSSION

OSA is involved with several co-morbidities including cardiovascular,[4-7] metabolic,[11] and neurocognitive diseases.[12] Above all, hypertension is most strongly associated with OSA and OSA is considered as an independent predictor or major cause of hypertension.[4,13,14] In our study, comorbid diseases accounted for 40.5% of the total patients and the most common co-morbidities were cardiovascular diseases (30.2%), endocrine (10.8%), respiratory (7.9%), gastrointestinal (7.7%), and neuromuscular (5.3%) diseases. Hypertension was the most common single disease with 26.3%. These results were generally agreed with prior studies.[15-17]

Pathophysiology of upper airway obstruction is multifactorial and complex, leading to a chronic recurrent state of intermittent hypoxemia and re-oxygenation during sleep, maintaining a state of oxidative stress, which seems to be the key to development of a number of high systematic complications.[18] Our study showed that lowest $O_2$ saturation levels (β=0.205) were significantly associated with number of co-morbidities in patients with OSA while mean $O_2$ saturation was not associated with the number of comorbidities in patients with OSA. Recently Min et al.[19] also reported the lowest $O_2$ saturation level during sleep was the only significant associated factor (odds ratio=0.9) influencing the presence of hypertension whereas mean $O_2$ saturation did not show any significant associations.

In our study, non-positional OSA patients showed significantly higher BMI, longer neck circumferences, more severe AHI values, and lower mean and lowest $O_2$ saturation levels than positional OSA patients. Oksenberg et al.[20] reported positional patients were on thinner, younger, and less severe breathing abnormalities and preserve better sleep quality than non-positional patients. There is a complex relationship between sleep apnea and BMI, age, and positional dependency, so simple comparison may not be acceptable. Chung et al.[21] reported patients with non-positional OSA had more severe overall AHI values, and showed lower mean $O_2$ saturation, and higher percentage snoring time compared with the age-, gender-, and BMI-matched positional OSA patients.

The overall prevalence of REM-related OSA was similar with previous studies. O'Connor et al.[22] reported an overall

REM-related OSA prevalence of 33.5% of patients, Haba-Rubio et al.[9] reported that REM-related OSA accounted for 36.4% of 415 patients with OSA. We didn't divide patients by gender, but previous studies reported that REM-related OSA accounts for a sizable portion of OSA, while demonstrating a female predominance REM-related OSA was also more prevalent in younger subjects within their respective gender category. REM-related OSA patients were younger and had a disorder significantly less severe than patients with not-REM-related OSA as previously reported by others.[23-25]

AHI is the widely used to represent the severity of OSA. Several risk factors have been identified including aging, obesity, male gender, menopause, family history, nasal obstruction, alcohol consumption, and craniofacial abnormalities. Obesity is a well-known risk factor suggested as BMI, neck circumferences, and waist-to-hip ratio.[26] In our study, BMI and neck circumference were used to analyze the risk on co-morbidities and AHI. Although there was a delicate difference in coefficients, when we put the neck circumference instead of BMI into our regression analysis, we did not find any significant difference. Superiority between BMI and neck circumference is controversial. Correlation between neck circumference and AHI/RDI was significant but less when compared to BMI by Pływaczewski et al.[27] On the other hand, Davidson and Patel[28] show waist and neck circumference are better markers for OSA than BMI. A similar finding was also suggested by earlier analysis of the Wisconsin Sleep Cohort Study where including the waist/hip ratio and neck girth in the model and not BMI resulted in the risk of developing OSA.[29] This is explained by the difference in average BMI according to population and ethnicity.

Positional dependency of OSA can be a characteristic of the natural development of the OSA entity.[20] A previous study reported that positional OSA may convert into non-positional OSA as the severity increases, and supine position worsens and facilitates the breathing abnormalities during REM sleep.[23]

It is well known that each ethnicity has different clinical and craniofacial characteristics. So it is natural that several studies reported different prevalence and severity of OSA. Li et al.[30] compared Far-East Asian and white men and reported that although the Asian patients were less obese and had fewer abnormalities in airway measurements, the severity of their OSA syndrome was similar to that of the white patients. Obesity appears to be a less important risk factor in the Asian patients and Asians have more severe OSA than whites when matched for age, sex, and BMI.[30] In our study, prevalence of OSA with positional dependency was 73.6%. Mo et al.[31] reported 74.7% in Asians, Oksenberg et al.[20] reported 55.9% in Israel, and Chung et al.[21] reported 63.9% in United States.

In conclusion, there were various co-morbidities and the most common medical comorbidity among the patients was cardiovascular diseases. Age, total AHI, and lowest $O_2$ saturation level were significantly associated with the number of co-morbidities in patients with OSA. Non-positional and not-REM-related OSA patients had significantly more severe polysomnographic results. Neck circumference, positional dependency, REM dependency, and percentage of supine position were significantly associated with severity of OSA.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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