Associations among Chronic Obstructive Pulmonary Disease and Sleep-Disordered Breathing in an Urban Male Working Population in Japan


Departments of Respiratory Medicine and Respiratory Care and Sleep Control Medicine, and Horizontal Medical Research Organization, Graduate School of Medicine, Kyoto University, Department of Epidemiology and Healthcare Research, Graduate School of Medicine and Public Health, and Environmental Health Nursing, Graduate School of Medicine, Human Health Sciences, Kyoto University, Department of Respiratory Medicine, National Hospital Organization Minami Kyoto Hospital, and Department of Respiratory Medicine, Kyoto City Hospital, Kyoto, Department of Prevalence Medicine and Epidemiologic Informatics, Research and Development Initiative Center, National Cerebral and Cardiovascular Center, Osaka, Department of Respiratory Medicine, Otsu Red Cross Hospital, and Department of Psychiatry, Shiga University of Medical Science, Otsu, Department of Human Nursing, Faculty of Human Health, Sonoda Women’s University, Amagasaki, and Department of Sleep Control Medicine, Graduate School of Medicine, Ehime University, Matsuyama, Japan

Key Words
Chronic obstructive pulmonary disease · Sleep apnea · Overlap syndrome · Actigraph · Portable monitoring

Abstract
Background: There are few reports about sleep disturbances in patients with chronic obstructive pulmonary disease (COPD) in Asian countries. Objectives: To investigate the associations between sleep-disordered breathing (SDB) with hypoxemia and sleep quality, including sleep duration, in patients with COPD, we measured SDB and sleep quality including the objective sleep duration determined by an actigraph and portable monitoring. Methods: A cross-sectional epidemiological health survey of 303 male employees (means ± SD: age 43.9 ± 8.2 years; BMI 24.0 ± 3.1) was conducted. Sleep quality was measured using the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI). A respiratory disturbance index (RDI) ≥5 indicated SDB. Results: Nineteen subjects (6.3%) had COPD. Among these, 11 (3.6%) had COPD with SDB (overlap syndrome). Sleep duration, ESS, and PSQI scores were not significantly different between COPD patients and normal control subjects. However, COPD patients had significantly longer sleep latency (p = 0.019), a lower sleep efficiency (p = 0.017), and a higher sleep fragmentation index (p = 0.041) and average
activity ($p = 0.0097$) during sleep than control subjects. They also had a significantly higher RDI and more severe desaturation during sleep than control subjects ($p < 0.01$). The differences remained after adjustment for age and BMI but disappeared following adjustment for RDI. **Conclusions:** COPD patients with even mild-to-moderate airflow limitations had nocturnal desaturation and RDI-related impaired sleep quality without significant symptoms.

**Introduction**

Chronic obstructive pulmonary disease (COPD) is a common condition caused mainly by smoking, and it has become a burden worldwide [1]. The prevalence of COPD in Japan is 8.6%, which is comparable to that in other countries [2]. The literature reporting on sleep quality in patients with COPD dates back to 1985 when Flenley [3] coined the term 'overlap syndrome' to apply to patients with both COPD and obstructive sleep apnea and to 1987 when Klink and Quan [4] examined sleep quality in 2,187 subjects. Since then, multiple reports have confirmed the presence of increasing sleep complaints with increasing severity of COPD [5]. In the Sleep Health Heart Study (SHHS), co-occurrence of COPD and obstructive sleep apnea in the same individual appeared to have implications for sleep quality and nocturnal oxygenation [6]. In addition, a recent report showed that patients with overlap syndrome had a higher risk of exacerbation and higher mortality than COPD-only patients [7]. However, additional data may prove clinically useful because nighttime symptoms and sleep disturbances in COPD are generally not considered in the clinical management of patients with COPD [8]. The prevalence of overlap syndrome was shown to be 3–4% for males in the USA and Europe [9, 10]. Recently, Shina et al. [11] showed the possibility of cardiovascular sequelae in patients with overlap syndrome in Japan. However, there has been no population-based study of overlap syndrome in Asian regions.

In the SHHS, sleep in COPD patients was investigated mainly by polysomnography (PSG) at home and the measurement of daytime somnolence using the Epworth Sleepiness Scale (ESS) [6]. In the majority of other studies, objective sleep assessment in COPD patients was evaluated by laboratory-based PSG [12]. Although PSG is the gold standard method for sleep studies, it is expensive and it is a complex procedure performed by trained technologists. Actigraphy is much less expensive and allows prolonged objective monitoring of the sleep-wake cycle. An actigraph is a small wrist-worn device that contains an accelerometer to monitor physical activity. According to the physical activity, the sleep/wake state is identified, and sleep parameters such as sleep duration and sleep efficiency are calculated. Although the actigraph may be a useful device for sleep assessment in the home environment, only one report has shown objectively determined sleep disturbances in patients with COPD using actigraphy [12]. That study did not investigate sleep-disordered breathing (SDB), which has a significant effect on sleep disturbance and mortality in COPD patients.

We hypothesized that SDB with hypoxemia in patients with COPD has a significant association with sleep quality, including sleep duration. To test this hypothesis, we measured SDB using a portable monitor and sleep quality, including the objective sleep duration, using an actigraph.
The average value of respiratory disturbance index (RDI), which is the number of apneic and hypopneic events per hour of sleep, was calculated via the summation of two percentages: (1) the percentage of the sleep period spent moving (an epoch with >2 activity counts is considered moving) and (2) the percentage of immobile phases (consecutive epochs with no movement) that are only ≤1 min long [17]. The average activity, which is a specific score from the actigraph indicating physical activity, was defined by the average per minute of activity counts during the sleep period [18]. These sleep parameters were analyzed with Actiware-Sleep version 3.4 (Mini Mitter).

Portable monitor records were visually inspected and scored. There were 4 respiratory doctors who specialize in analyzing and scoring sleep studies, and at least 2 of the 4 doctors scored the data (details were shown previously [14]). The respiratory disturbance index (RDI), which is the number of apneic and hypopneic epi-
Severity of airflow limitation, n  
FEV1/FVC, % 80.2  
FEV1, % predicted 85.7  
FEV1, l 3.20  
FVC, % predicted 92.3  

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[14]  
and the portable monitor for the same night as mentioned above  
ration, was calculated from data obtained from both the actigraph  
sodes per hour of the analyzed time length based on the sleep du-  
ration, was calculated from data obtained from both the actigraph  
and the portable monitor for the same night as mentioned above  
[14]. Apnea (cessation of breathing for ≥10 s) and hypopnea  
(>50% reduction in the amplitude of nasal pressure or respiratory  
effort associated with a more than 3% reduction in oxyhemoglobin  
saturation ≥10 s) were scored blindly. Subjects with an RDI  
≥5 plus ESS >1052 (17.2) 2 (0.66) 6 (2.0)  

Assessment of Subjective Sleep-Related Symptoms  
The modified Japanese version of the ESS was used to assess  
subjective sleepiness [19, 20] and the PSQI was used to assess sub-  
jective sleep quality and sleep disturbances over a 1-month time  
period [21, 22]. Subjects also filled out a sleep diary during the sur-  
ey period.

Table 1. Characteristics of the subjects  

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>All subjects</th>
<th>Overlap syndrome</th>
<th>SDB</th>
<th>COPD</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects, n (%)</td>
<td>303 (100)</td>
<td>11 (3.6)</td>
<td>181 (59.7)</td>
<td>19 (6.3)</td>
<td>114 (37.6)</td>
</tr>
<tr>
<td>Age, years</td>
<td>43.9±8.2</td>
<td>50.2±4.7*</td>
<td>45.9±7.7*</td>
<td>48.5±7.4*</td>
<td>40.7±7.9</td>
</tr>
<tr>
<td>BMI</td>
<td>24.0±3.1</td>
<td>22.3±2.3</td>
<td>24.7±3.2*</td>
<td>22.4±2.9</td>
<td>23.1±2.7</td>
</tr>
<tr>
<td>Waist circumstance, cm</td>
<td>83.9±8.4</td>
<td>82.7±5.4</td>
<td>85.9±8.2*</td>
<td>82.1±8.2</td>
<td>81.0±7.5</td>
</tr>
<tr>
<td>Current/ex-/never smoker, n</td>
<td>167/76/56</td>
<td>9/1/1</td>
<td>93/55/31</td>
<td>16/2/1</td>
<td>67/20/25</td>
</tr>
</tbody>
</table>

RDI ≥5 plus ESS >1052 (17.2) 2 (0.66) 6 (2.0)  

SDB, n (%)  
RDI ≥5  
RDI ≥5 plus ESS >10  

Values are presented as means ± SD unless otherwise indicated. The analysis included 4 subjects with missing smoking information.  
* p < 0.05 vs. control subjects.

Table 2. Comparison of the prevalence of COPD, SDB, and overlap syndrome as defined by FEV1/FVC <70% or the <5th percentile and RDI ≥5 with or without ESS >10  

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total, n (%)</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1/FVC &lt;70%</td>
<td>19 (6.2)</td>
<td>40 (13.2)</td>
</tr>
<tr>
<td>FEV1/FVC &lt;5th percentile</td>
<td>8.4 81.0</td>
<td>8.2 81.0</td>
</tr>
</tbody>
</table>

SDB, n (%)  
RDI ≥5  
RDI ≥5 plus ESS >10  

Spirometry  
Spirometric testing to determine the forced vital capacity (FVC) and the forced expiratory volume in one second (FEV1) was performed using a spirometer (Chestgraph HI-101; CHEST, Tokyo, Japan). Results were expressed as percentages of the predicted values, which were based on recommendations of the Japanese Respiratory Society (JRS) [23]. We used criteria for the diagnosis of COPD based on airflow limitation (FEV1/FVC <70%); however, a bronchial reversibility test could not be performed on our study subjects. Three subjects who had airflow limitation had a history of asthma and were excluded from the diagnosis of COPD. Classification of the severity of airflow limitations was as follows: stage 1: FEV1/FVC <70%, FEV1 ≥80% predicted; stage 2: FEV1/FVC <70%, 50% ≤ FEV1 < 80% predicted; stage 3: FEV1/FVC <70%, 30% ≤ FEV1 < 50% predicted, and stage 4: FEV1/FVC <70%, FEV1 <30% predicted.

In addition, we assessed the data using the FEV1/FVC <5th percentile (lower limit of normal; LLN) as the definition of COPD. The equations for the LLN of FEV1/FVC were based on recommendations of the JRS [23]. The LNN of FEV1/FVC for males was: 0.028 × height (cm) – 0.19 × age + 89.313 – 2 × 6.147. Five subjects who had a lower FEV1/FVC than the LLN of FEV1/FVC had a history of asthma and were excluded from the diagnosis of COPD using the LLN.

Statistical Analysis  
It has been reported that the prevalence of sleep disturbances and COPD patients is approximately 33% [24] and 9% [2], respectively, among adults in the general population and that the rate of sleep disturbances among COPD patients is approximately 61% [8]. Based on these data, the sample size was set to achieve 80% power at a 5% significance level, and it was determined that there should be a sample size of 306 subjects in total.
Statistical analyses were performed using JMP version 9.0.0 statistical software (SAS Institute Inc., Cary, N.C., USA). p < 0.05 was considered statistically significant. Results are expressed as means ± SD. The statistical significance of differences between COPD (or overlap syndrome) patients and others was determined via non-parametric analysis using the Mann-Whitney U test because of the small number of COPD and overlap syndrome patients. The statistical significance of differences between SDB patients and control subjects was determined using an unpaired t test. We used analysis of covariance (ANCOVA) to adjust for age, BMI, and RDI. χ² and Fisher’s exact tests were used to calculate differences in categorized data.

Results

Characteristics of the Subjects
The characteristics of the 303 subjects are presented in table 1. Nineteen subjects (6.3%) had COPD. Among these, 11 subjects (3.6%) had COPD with SDB (overlap syndrome). Of the 303 subjects, 114 (37.6%) had neither COPD nor SDB (control subjects). The severity of airflow limitation in the COPD patients was either stage 1 or stage 2. COPD patients defined by FEV₁/FVC < LLN instead of FEV₁/FVC < 70% included 40 subjects (13.2%). Fifty-two subjects (17.2%) had RDI ≥5 and ESS >10 (table 2).

Sleep Assessment in COPD Patients
As shown in table 3 and figure 3, the COPD patients had worse sleep parameters than the control subjects. The COPD patients had significantly longer sleep latency (p = 0.019), a lower sleep efficiency (p = 0.017), a higher sleep fragmentation index (p = 0.041), and a higher average activity (p = 0.0097) than the control subjects. FEV₁% predicted correlated significantly with sleep latency (r = –0.11; p = 0.0461), sleep efficiency (r = 0.18; p = 0.0015), and average activity (r = –0.13; p = 0.0209). However, sleep duration, ESS, and component and global scores on the PSQI were not significantly different between COPD patients and control subjects. The prevalence of somnolent subjects (ESS >10) and poor sleepers (PSQI global score ≥6) was not significantly different between COPD patients and control subjects (p = 0.56 and p = 0.99 by Fisher’s exact test). The significant difference in RDI, mean SpO₂, lowest SpO₂, total sleep time with SpO₂ <90%, sleep efficiency, and sleep fragmentation index disappeared (table 3; fig. 3). There was no significant difference in the CV of

Table 3. Sleep assessment by type 3 monitor, ESS, and PSQI

<table>
<thead>
<tr>
<th></th>
<th>All subjects (n = 303)</th>
<th>Overlap syndrome (n = 11)</th>
<th>SDB (n = 181)</th>
<th>COPD (n = 19)</th>
<th>Control (n = 114)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 3 monitoring</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>RDI, /h</td>
<td>10.6 ±11.4</td>
<td>14.2 ±8.6†</td>
<td>16.1 ±11.9†</td>
<td>9.40 ±8.7†</td>
<td>2.44 ±1.4</td>
</tr>
<tr>
<td>Mean SpO₂, %</td>
<td>95.9 ±1.8</td>
<td>95.9 ±1.3*</td>
<td>95.4 ±1.7†</td>
<td>95.5 ±2.1†</td>
<td>96.7 ±1.6</td>
</tr>
<tr>
<td>Lowest SpO₂, %</td>
<td>84.2 ±7.2</td>
<td>80.6 ±11.2‡</td>
<td>81.2 ±7.3†</td>
<td>82.4 ±9.6†</td>
<td>88.8 ±4.0</td>
</tr>
<tr>
<td>Total sleep time with SpO₂ &lt;90%, %</td>
<td>2.3 ±6.4</td>
<td>1.42 ±2.4*</td>
<td>3.20 ±6.8**</td>
<td>4.15 ±13.4‡</td>
<td>0.50 ±2.1</td>
</tr>
<tr>
<td>PSQI component score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1: sleep quality</td>
<td>2.12 ±0.64</td>
<td>2.18 ±0.75</td>
<td>2.18 ±0.64*</td>
<td>2.02 ±0.67</td>
<td>2.02 ±0.64</td>
</tr>
<tr>
<td>C2: sleep latency</td>
<td>0.32 ±0.54</td>
<td>0.10 ±0.32</td>
<td>0.29 ±0.52</td>
<td>0.44 ±0.62</td>
<td>0.35 ±0.57</td>
</tr>
<tr>
<td>C3: sleep duration</td>
<td>1.47 ±0.68</td>
<td>1.73 ±0.47*</td>
<td>1.49 ±0.68</td>
<td>1.53 ±0.51</td>
<td>1.42 ±0.67</td>
</tr>
<tr>
<td>C4: sleep efficiency</td>
<td>0.072 ±0.33</td>
<td>0.18 ±0.40</td>
<td>0.072 ±0.33</td>
<td>0.11 ±0.32</td>
<td>0.071 ±0.32</td>
</tr>
<tr>
<td>C5: sleep disturbance</td>
<td>0.61 ±0.50</td>
<td>0.70 ±0.48</td>
<td>0.62 ±0.51</td>
<td>0.72 ±0.46</td>
<td>0.59 ±0.49</td>
</tr>
<tr>
<td>C6: hypnotic medication use</td>
<td>1.03 ±0.23</td>
<td>1.00 ±0.0</td>
<td>1.03 ±0.23</td>
<td>1.00 ±0.0</td>
<td>1.04 ±0.23</td>
</tr>
<tr>
<td>C7: daytime dysfunction</td>
<td>0.77 ±0.74</td>
<td>0.82 ±0.60</td>
<td>0.77 ±0.73</td>
<td>0.68 ±0.58</td>
<td>0.78 ±0.75</td>
</tr>
<tr>
<td>PSQI global score</td>
<td>4.41 ±1.9</td>
<td>4.70 ±1.8</td>
<td>4.48 ±1.8</td>
<td>4.44 ±1.6</td>
<td>4.29 ±2.1</td>
</tr>
<tr>
<td>≥6*, n (%)</td>
<td>73 (24)</td>
<td>4 (36)</td>
<td>45 (26)</td>
<td>5 (28)</td>
<td>28 (26)</td>
</tr>
<tr>
<td>ESS score</td>
<td>8.19 ±4.3</td>
<td>9.22 ±1.7</td>
<td>8.28 ±4.4</td>
<td>8.09 ±2.7</td>
<td>8.04 ±4.1</td>
</tr>
<tr>
<td>&gt;10*, n (%)</td>
<td>80 (26)</td>
<td>2 (18)</td>
<td>52 (29)</td>
<td>3 (16)</td>
<td>28 (25)</td>
</tr>
</tbody>
</table>

Values are presented as means ± SD unless otherwise stated. * p < 0.05 vs. control subjects. † p < 0.05 vs. control subjects after adjustment for age and BMI. ‡ p < 0.05 vs. control subjects adjusted for RDI. χ² (SDB patients) and Fisher’s exact (overlap syndrome and COPD patients) tests were used to compare prevalences with the control subject group.
sleep parameters between COPD patients and control subjects after adjustment for age and BMI or for RDI.

Assessment of Patients with Overlap Syndrome

The overlap syndrome patients had worse sleep parameters than the control subjects. However, after adjustment for RDI, the significant differences disappeared (table 3; fig. 3). The FVC and FEV₁ % predicted of overlap syndrome patients were significantly higher than those of COPD-only patients (4.39 ± 0.42 vs. 4.03 ± 1.1 liters, p = 0.035, and 81.0 ± 5.5 vs. 69.6 ± 10.7%, p = 0.0093, respectively). There were no significant differences between

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**Fig. 3.** Comparison of sleep assessment between COPD patients, SDB patients, and overlap syndrome patients and control subjects. *p < 0.05 vs. control subjects. †p < 0.05 vs. control subjects after adjustment for age and BMI. ‡p < 0.05 vs. control subjects adjusted for RDI.
overlap syndrome and COPD-only patients in sleep parameters other than RDI (14.2 ± 8.6 vs. 2.8 ± 1.5/h; \( p = 0.0003 \)). There were no significant differences between overlap syndrome and SDB-only patients in terms of sleep parameters. In the comparison with COPD only and SDB only, there were significant differences in terms of the average activity and RDI (18.5 ± 7.1 vs. 14.0 ± 8.2 counts/min, \( p = 0.044 \), and 2.81 ± 1.5 vs. 16.2 ± 12.1/h, \( p < 0.0001 \), respectively).

Data Using the LLN of FEV\(_1\)/FVC for Sleep Parameters

The sleep parameters for COPD patients diagnosed with LLN of FEV\(_1\)/FVC criteria were similar to those using fixed FEV\(_1\)/FVC <70% criteria, except for sleep efficiency. The mean and CV of sleep efficiency (79.5 ± 5.4 vs. 83.1 ± 6.3%, \( p = 0.0011 \), and 11.0 ± 6.1 vs. 7.81 ± 4.5%, \( p = 0.0019 \), respectively) in COPD patients with LLN criteria were significantly lower and higher, respectively, than those in control subjects. The significance remained after adjustment for age and BMI or for RDI.

Discussion

This is a cross-sectional study of an urban male working population in Japan that assessed the sleep quality and SDB of COPD patients and, to our knowledge, it is the first such study using actigraphy and portable monitoring in the home environment. The main findings are as follows: (1) COPD patients had impaired sleep quality and nocturnal oxygen saturation even with mild-to-moderate airflow limitations and few sleep-related symptoms; (2) the significant impairment of sleep quality in COPD patients disappeared after adjustment for RDI, and (3) the prevalence of overlap syndrome in urban middle-aged male employees in Japan was 3.6% (11 of 303 subjects).

Sleep Assessment in COPD Patients

Patients with COPD commonly experience poor sleep efficiency, increased sleep latency, a decreased total sleep time, increased waking after sleep onset, and decreased stage N3 and stage R sleep [25]. These sleep disturbances may be related to multiple causes including demographic factors such as age and the presence of obesity, disease-specific symptoms including wheezing and cough, and sleep disorders such as obstructive sleep apnea [8]. In our study, COPD patients had a lower sleep efficiency and higher sleep fragmentation than control subjects. This significance remained after adjustment for age and BMI but disappeared after adjustment for RDI. The SHHS is the largest population study evaluating sleep in COPD patients. Sleep and sleep-related symptoms were evaluated via PSG, ESS, SF-36, and a sleep habit questionnaire. In the SHHS, in the absence of SDB, there were no differences in ESS, sleep latency, or sleep efficiency between subjects with and without airflow limitations [6]. These results suggest that the poor sleep quality in COPD patients was largely related to SDB.

In the SHHS, objective assessment by PSG was performed, and subjective assessment by PSQI was not performed. In the present study, although the number of subjects was smaller than in the SHHS, we used both actigraphy and a sleep diary under usual circumstances for a week, and both the ESS and the PSQI. As our subjects were younger than those in the SHHS, who were in late middle age or elderly, we could evaluate younger (though middle-aged) patients with COPD, a condition that might cause several medical problems with increasing age and its progression.

It has been reported that nighttime symptoms, a forgotten dimension of COPD, are important in the management of COPD patients [8]. Previously, an association between objective measures of sleep quality derived from PSG and subjective complaints of difficulty initiating and maintaining sleep was described in patients with severe COPD [26]. However, several investigators have reported discrepancies between subjective data and surrogate markers of sleep and sleep disturbances [27]. In this study, it was confirmed that the objective sleep quality (sleep latency, efficiency, fragmentation, and average activity) was disturbed while the patients could not perceive such disturbances with the ESS or PSQI. Therefore, attention should be paid to sleep disturbances in COPD patients regardless of mild airflow limitations or the presence of few sleep-related symptoms.

In this study, we did not use a bronchodilator before spirometric testing. Moreover, we added data using the FEV\(_1\)/FVC <5th percentile (LLN) criterion because it is one way to minimize potential misclassification [28]. The prevalence of COPD increased from 6.2 to 13.2% using LLN criteria. The sleep parameters by actigraphy were similar in COPD patients using the fixed criteria of FEV\(_1\)/FVC <70% and in those with LLN criteria, except for the mean and CV of sleep efficiency, which was impaired independently of the RDI in those with the LLN criteria. However, the reason and pathological mechanism for the discrepancy between the two criteria are unknown. Studies following a bronchial reversibility test would provide further information.
In this study, the mean ESS (8.0 ± 4.1) and PSQI (4.3 ± 2.1) scores were quite high even in the controls. Among these company employees, the mean sleep duration of the controls was only 6.1 h, which is shorter than in the general population in Japan [29]. It has been reported that the mean commute time in this urban region is almost 90 min daily [30]. The short sleep duration in the controls might have induced these high ESS and PSQI scores.

Overlap Syndrome in Japan

In our population, which was predominantly males in their 40s, the prevalence of COPD was 6.3%. In the Nippon COPD Epidemiology (NICE) study in Japan, which included males and females, the prevalence of COPD in persons in their 40s was 3.5% [2]. The prevalence of COPD in males was about 3 times that in females (16.4 vs. 5.0%) in the NICE study; therefore, using NICE study data, the prevalence of COPD in males in their 40s could be estimated to be almost 5.3%. Thus, our prevalence of COPD could be considered compatible with that shown in the NICE study. In our population, the prevalence of overlap syndrome, i.e. the coexistence of COPD and SDB, was 3.6%. It has been reported that overlap syndrome occurs in 3% of males in Europe [9]. A simple calculation based on the prevalence of COPD in the National Health and Nutrition Examination Survey study (16.8%) and SDB in the Wisconsin Sleep Cohort Study (24%) could estimate a prevalence of overlap syndrome of 4% in males [10, 31, 32]. Thus, our results are comparable to those of previous studies in the USA and Europe.

In this study, the prevalence of SDB (RDI ≥5) was high. It was reported that the prevalence of SDB in 2007–2010 increased by more than 30% compared to 1988–1994 data [33]. In a relatively recent population-based study in a large metropolitan area of South America, the prevalence of SDB in males was 46.5%, determined via lab-based full PSG [34]. In addition, in another recent report from Japan, the prevalence of RDI ≥15 in males was more than 20%, which was almost the same as the prevalence of RDI ≥15 in our cohort [14, 35]. Additionally, another possible reason is that we used a nasal pressure sensor to detect hypopnea. The American Academy of Sleep Medicine reported that a pressure sensor could detect hypopnea, especially slight hypopnea [36]. It was reported that a nasal pressure sensor could detect 25% more respiratory events than a thermistor [37]. In addition, in this study, the measurement was done under usual circumstances. More than half of the subjects in this study took alcohol before sleep and the mean sleep duration was short [14]. These factors might have induced the high prevalence of SDB (RDI ≥5).

In previous population-based studies, patients with overlap syndrome had a poorer quality of sleep and greater nocturnal oxygen desaturation than COPD-only patients [5, 8]. In the present study, unlike in those studies, the degree of airflow limitation in overlap syndrome patients was significantly milder than in the COPD-only patients. This finding might be one of the reasons why we found no differences in sleep quality or nocturnal oxygen saturation between overlap syndrome and COPD-only patients. Considering that characteristics such as age, BMI, and the Brinkman index were not significantly different between our patients with overlap syndrome and those with COPD only, these findings suggest that several parameters of overlap syndrome are the same as those of COPD only in the early stage. Therefore, it could be recommended that SDB in the early stage of COPD be treated before the parameters of overlap syndrome worsen compared to those of COPD only. However, since the number of overlap syndrome patients was small (n = 11), further study with a larger cohort would be needed.

Study Limitations

The present study has a few limitations. First, we could not use the bronchial reversibility test to diagnose COPD. Some patients with other diseases such as bronchial asthma might have been included in the COPD group. Based on information from the patients, 3 of 22 subjects with spirometric obstruction were excluded from the COPD group. Therefore, we made an effort to exclude bronchial asthma patients from the COPD group. Second, we did not perform PSG to verify the portable monitoring device, but this device has been reported to be capable of accurately measuring a wide range of AHI [38], to have a high specificity and sensitivity in comparison with PSG [39], and to provide sufficient quality data to diagnose SDB in unattended home settings [40]. Third, there are no studies comparing polysomnographic data with actigraphic results in COPD. There is a need for more studies to be conducted using actigraphy to confirm if it can really provide new relevant information about sleep disturbance in patients with COPD. However, actigraphy was compared with PSG in patients with sleep disorders such as insomnia and SDB [41]. Also, since we used actigraphy with a sleep diary and portable monitoring, we could obtain more correct data than by using only actigraphy.

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COPD and Sleep Disturbance

Conclusion

We showed using actigraphy and type 3 portable monitoring that COPD patients had impaired sleep quality and nocturnal oxygen saturation even with mild-to-moderate airflow limitations and few sleep-related symptoms. Sleep disturbances in COPD patients were significantly associated with SDB. By treating SDB in COPD patients more appropriately, nighttime symptoms of COPD, which cannot be detected based on ESS or PSQI scores, would be controlled more effectively. Also, such early intervention for SDB in patients with COPD would induce better sleep quality and a better prognosis. We believe that providing early intervention before the overlap syndrome becomes advanced would be advantageous [7].

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