# Evaluation of respiratory rate monitoring performance using a home oxygen monitoring device among patients with interstitial lung disease and chronic obstructive pulmonary disease

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**Abstract.** Background: Home monitoring devices have been developed to measure adherence to home oxygen therapy. In this study, we evaluated the performance of TeleOx®, a commercially available remote monitoring device, in comparison with polysomnography (PSG) in patients with interstitial lung disease (ILD) and chronic obstructive pulmonary disease (COPD) and the factors that affected TeleOx® correct use.
Methods: TeleOx® was connected on the patient or concentrator side. The oxygen flow rates were set at 1, 3, and 5 L/min. Intraclass correlation coefficient (ICC) (2,1) was used to determine the agreement between respiratory rate measured using TeleOx® and that measured using PSG, and the minimum acceptable level of reliability was >0.7. Results: In total, 22 patients (16 with ILD and 6 with COPD) were assessed. In patients with ILD, the detection rate of patients' respiration assessed using TeleOx® did not change according to the device's position. It increased from 53.5% to 79.0% by changing the position from the concentrator to the patient side in patients with COPD. The ICC (2,1) value indicated that TeleOx® had acceptable reliability at oxygen flow rates of 1 and 3 L/min regardless of the device's position in patients with ILD (the concentrator side: 0.9 and 0.82, respectively; the patient side: 0.95 and 0.82, respectively), whereas that did only at the oxygen flow rate of 1 L/min and in connecting TeleOx® on the patient side in patients with COPD (0.73). Conclusion: The monitoring performance of TeleOx® differed according to its position, oxygen flow rates, and patients' diseases.

**Key words:** chronic obstructive pulmonary disease; home oxygen therapy; interstitial lung disease; intraclass correlation coefficient; remote monitoring device; respiratory rate.

## Introduction

Home oxygen therapy (HOT) is a therapeutic option for patients with chronic hypoxemia, congestive heart failure, and pulmonary hypertension worldwide (1). Chronic obstructive pulmonary disease (COPD) and interstitial lung disease (ILD) are the most common indications for HOT (2). In the

1990s, 2 randomized controlled trials showed that HOT was associated with lower mortality according to the duration of daily usage among patients with COPD and severe hypoxemia (3, 4). Recently, Mesquita et al. showed that HOT improved quality of life, as assessed using the Saint George's Respiratory Questionnaire, among patients with COPD who have received HOT for more than 12 h per day (5). Thus, the beneficial effects of HOT are dependent on patient adherence.

Adherence to HOT has been evaluated using clock counter and patient data obtained via interviews or surveys using questionnaires administered to patients or medical staff (6). However, these methods can over- or underestimate actual oxygen use. Recently, remote monitoring devices, which are connected to the oxygen supply system, such as stationary and portable oxygen concentrators, have been developed to more accurately evaluate patient adherence to HOT by monitoring respiratory rate (RR) (7-9). In addition, Yañez et al. reported that RR continuously monitored with a remote device increased before requiring hospitalization due to exacerbations in patients with COPD managed with HOT (7). Thus, continuous monitoring of RR can lead to not only evaluation of patient adherence but also implementation of early therapeutic intervention in patients receiving HOT. However, the accuracy of RR surveillance using home oxygen remote monitoring devices has been evaluated in patients with COPD only (7-9). Respiratory mechanics, such as breathing pattern and inspiration/expiration ratio, differ among respiratory diseases, particularly ILD and COPD, which are major disorders characterized by restrictive and obstructive ventilation impairments, respectively (10). We hypothesized that the accuracy of RR surveillance using home oxygen remote monitoring devices could differ among respiratory diseases. In this study, we examined the performance of a commercially available home oxygen remote monitoring device by comparing it with polysomnography (PSG) and evaluated the factors that affected its performance, including the difference between COPD and ILD, to correctly use the device.

## Methods

### Study design

This was a prospective single-center study at the Kyoto University Hospital. This study aimed to examine the performance of TeleOx® (SRETT, Boulogne-Billancourt, France), a commercially available home oxygen remote monitoring device, and the factors that affected its performance, including the difference between COPD and ILD. Figure 1 shows a flowchart of the study. Adult patients with COPD and ILD, who were suspected of having sleep apnea syndrome (SAS), were included. SAS was evaluated using home sleep apnea tests, such as PULSOX®-Me300 (Konica Minolta Inc., Tokyo, Japan) and WatchPAT® (Itamar Medical LTD., Caesarea, Israel) with or without symptoms, such as snoring and/or daytime sleepiness. PULSOX®-Me300 continuously monitors oxygen saturation and heart rate. WatchPAT® continuously monitors peripheral arterial tone, oxygen saturation, heart rate, and actigraphy. In these tests, patients with a 3% oxygen desaturation index (defined as the number of times the oxygen saturation decreased by 3% or more from baseline per hour) of 5 episodes/hour or more were suspected of SAS and were eligible for the PSG study. Patients with acute exacerbations of COPD, ILD, or comorbidities and those receiving continuous positive airway pressure and noninvasive positive pressure ventilation were excluded. Patients who provided consent for study participation were admitted for two days to the Sleep Unit of Kyoto University Hospital between February 2019 and June 2020. On the first night, patients underwent PSG. On the second night, patients underwent PSG combined with measurement of RR using TeleOx®.

This study was approved by the Kyoto University Graduate School and Faculty of Medicine, Ethics Committee (R1637 and R1748), and informed consent was obtained from all patients.

### TeleOx®

TeleOx® with a diameter of 46 mm and weight of 34 g, is a commercially available remote monitoring device. It is used to assess not only oxygen flow
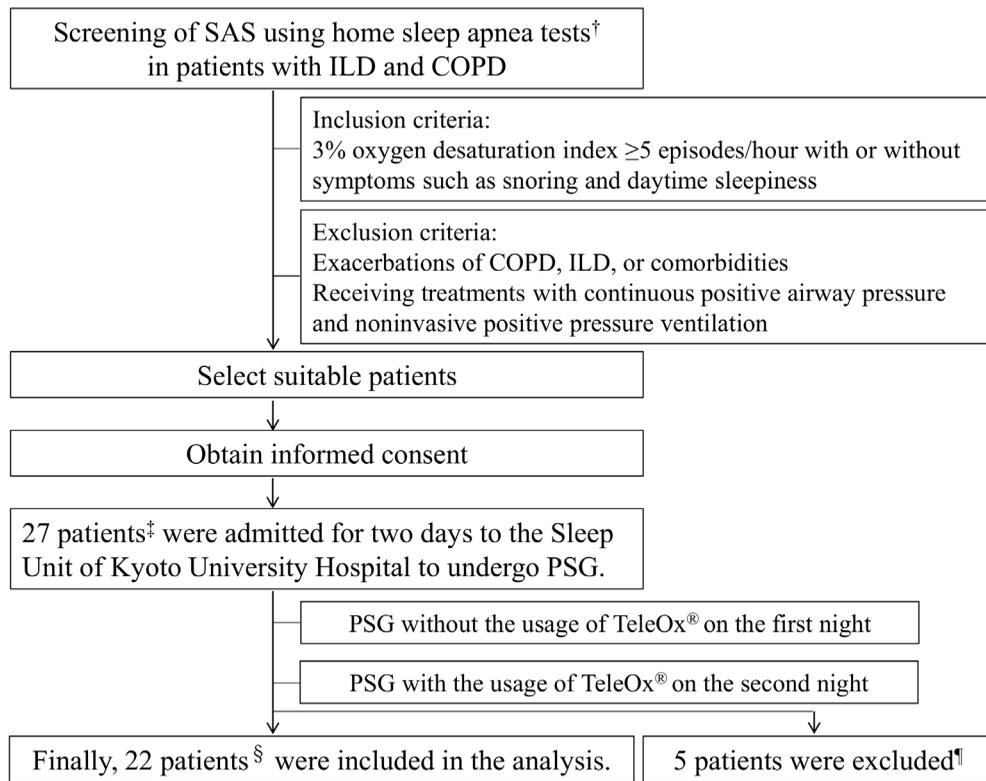
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│  Screening of SAS using home sleep apnea tests†  │
│          in patients with ILD and COPD           │
└─────────────────────────────────────────────────┘
          ┌──────────────────────────────────────────────────────────┐
          │ Inclusion criteria:                                        │
          │ 3% oxygen desaturation index ≥5 episodes/hour with or      │
          │ without symptoms such as snoring and daytime sleepiness     │
          └──────────────────────────────────────────────────────────┘
          ┌──────────────────────────────────────────────────────────┐
          │ Exclusion criteria:                                        │
          │ Exacerbations of COPD, ILD, or comorbidities               │
          │ Receiving treatments with continuous positive airway       │
          │ pressure and noninvasive positive pressure ventilation     │
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│              Select suitable patients             │
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│              Obtain informed consent              │
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│ 27 patients‡ were admitted for two days to the    │
│ Sleep Unit of Kyoto University Hospital to        │
│ undergo PSG.                                       │
└─────────────────────────────────────────────────┘
          ┌──────────────────────────────────────────────────────────┐
          │ PSG without the usage of TeleOx® on the first night        │
          └──────────────────────────────────────────────────────────┘
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          │ PSG with the usage of TeleOx® on the second night          │
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│ Finally, 22 patients § were included in   │   │ 5 patients were excluded¶     │
│ the analysis.                             │   │                              │
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**Figure 1 .** Flow chart of the study. COPD = chronic obstructive pulmonary disease; ILD = interstitial lung disease; PSG = polysomnography; SAS = sleep apnea syndrome. †PULSOX®-Me300 and WatchPAT® . ‡Eighteen patients with ILD and nine with COPD. §Sixteen patients with ILD and six with COPD. ¶Five patients were excluded, because data using TeleOx® could not be obtained, probably due to a network error, dislocation of nasal cannula, and obstruction of oxygen connecting tube.

rate (0.5–5 L/min) but also RR using a pressure sensor and fluidic oscillator flow sensor. A median RR for 1 min (TeleOx®-RR) is outputted every 5 min based on the time interval between two consecutive respiratory cycles. Moreover, TeleOx® outputs three detection statuses of patients' respiration, which are as follows: good, low quality, and no detection. In this study, if the status was good, it was considered that TeleOx® could detect patients' respiration, because RR was displayed as 0 in the status of low quality and no detection.

The use of TeleOx® as an accessory of a stationary oxygen concentrator (HiSanso™5S; Teijin Pharma, Tokyo, Japan) was approved in May 2018 in Japan. We used Hi-Sanso™5S attached with TeleOx® for supplying oxygen during in-laboratory testing with PSG. The oxygen flow rates were set at of 1 (low), 3 (moderate), and 5 (high) L/min via a nasal cannula. TeleOx® was connected on the patient side (Figure 2A) or the concentrator side (10 m apart from a nasal cannula) (Figure 2B). We used oxygen connecting tubes with a total length of 13 m between the nasal cannula and oxygen concentrator (Figure 2). This length was selected for imitating home use.

*PSG*

PSG was performed with Alice 5® (Philips Respironics, Murrysville, Pennsylvania, the USA), which recorded electroencephalogram, electrooculogram, submental and bilateral anterior tibial electromyogram, electrocardiogram, nasal airflow with a nasal pressure cannula, nasal and oral flow with nasal-oral thermistor, respiratory effort with thoracoabdominal piezoelectric belts, oxyhemoglobin saturation with a finger probe, body position with a thoracic belt sensor, and snoring recording with a neck microphone (11).

PSG was performed on the first day while breathing ambient air or oxygen under conditions similar to home surroundings. PSG combined with measurement of RR using TeleOx® was conducted on the second day while breathing oxygen. Oxygen flow rates on the second day were determined according to the results of PSG on the first day as following: In patients who have not received HOT at night and those with the lowest oxygen saturation at 88%–89%, fixed dose of 1 L/min was applied. In patients with the lowest oxygen saturation at 85%–87%, the flow rates were 1 and 3 L/min, and they were changed during PSG. In patients with the lowest oxygen saturation at 80%–84%, flow rates of 3 and 5 L/min were applied, and they were changed during PSG. In patients with the lowest oxygen saturation at <80%, a fixed dose of 5 L/min was utilized. In patients who received HOT (all flow rates at ≤ 1L/min) at night and those with the lowest oxygen saturation at ≥90%, a flow rate of 1 L/min was used. In patients with the lowest oxygen saturation at ≤89%, oxygen flow rates greater than those in the first day (maximum: 5 L/min) were applied.

The American Academy of Sleep Medicine scoring manual version 2.1 was utilized to score PSG recordings (12). Apnea was defined as respiration lasting at least 10 s, characterized by a decrement in airflow of more than 90% from the baseline. Hypopnea was defined by a 30% decrease in airflow for at least 10 s, accompanied by 3% oxygen desaturation from baseline or terminated with electroencephalographic evidence of an arousal. The apnea–hypopnea index (AHI) was calculated as the number of apnea and hypopnea episodes per hour of recording time in bed.

RR obtained using PSG (PSG-RR) was visually measured via breathing signals from the nasal pressure cannula, nasal-oral thermistor, and thoraco-abdominal piezoelectric belts by the same observer (S.H), who were not knowledgeable about the clinical status of patients (13). The time of PSG was synchronized to that of TeleOx®.

*Arterial blood gas*

Arterial blood gas (ABG) analysis was performed before the start of PSG on the first day in supine po-
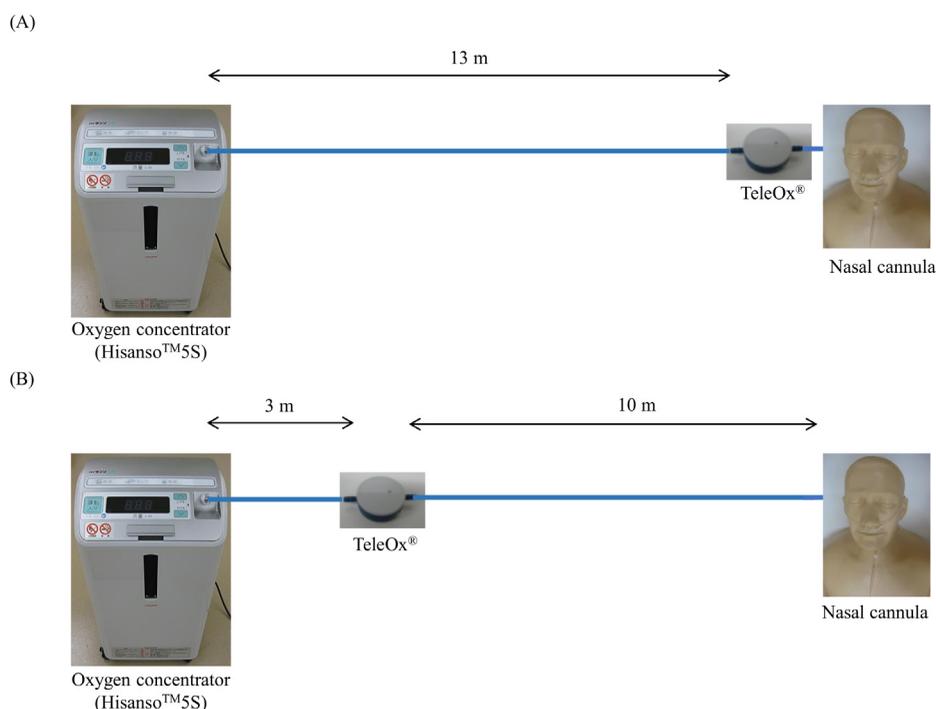


**Figure 2.** TeleOx®'s position between the nasal cannula and concentrator. (A) Concentrator side. (B) Patient side. Oxygen connecting tubes with a total length of 13 m between the nasal cannula and oxygen concentrator were used.

sition while breathing ambient air or supplementary oxygen with similar conditions as home surrounding. Arterial partial pressure of oxygen ($PaO_2$), carbon dioxide ($PaCO_2$), pH, and bicarbonate concentration were measured using an ABG analyzer (RAPIDPoint 500®; SIEMENS Healthineers, Erlangen, Germany).

## Pulmonary function test

The pulmonary function test was performed using CHESTAC-8900® (Chest, Tokyo, Japan). The predicted pulmonary function values were calculated based on the Japanese Respiratory Society guidelines (14).

## Statistical analysis

We set the required number of cases based on a previous report (8). The total recording time of PSG was >8 hours in one night. TeleOx® counts RR every 5 min. Thus, TeleOx® counts RR at more than 96 points during PSG in one patient. In a previous validation study using TeleOx®, RR was evaluated at 1000 points (8). Thus, we calculated that we would need to enroll 10 patients in each disease (COPD and ILD).

Data were expressed as a median (interquartile range). All statistical analyses were performed using JMP Pro 14 software (SAS Institute, Cary, NC, the USA). The Bland−Altman method (15) and intraclass correlation coefficient (ICC) (16) were used to determine the agreement between PSG-RR and TeleOx®-RR. The Bland−Altman plot was presented as a scatter plot in which the x axis showed the average RR obtained using PSG and TeleOx® ([PSG-RR + TeleOx®-RR]/2) and the y axis depicted the difference in RR obtained using PSG and TeleOx® (PSG-RR − TeleOx®-RR). Bias was the mean difference in PSG-RR and TeleOx®-RR. The limits of agreement were the plotted lines within 95% in all points falling on either side of the bias. They were described as ± 1.96 × the standard deviation (SD) around the bias. ICC was calculated using the model of two-way random-effect, type of single rater/measurement, and definition of absolute agreement, which was ICC (2,1). An ICC (2,1) value of >0.7 was considered the minimum acceptable level of reliability.[17]

## Results

### Characteristics of participant

In total, 27 consecutive patients (18 with ILD and 9 with COPD) underwent PSG. However, we could not obtain data using TeleOx® in five patients (two with ILD and three with COPD), probably due to a network error, dislocation of nasal cannula, and obstruction of oxygen connecting tube. Finally, we analyzed 22 patients (16 with ILD and 6 with COPD). The characteristics of patients are shown in Table 1. In 16 patients with ILD, idiopathic pulmonary fibrosis (IPF), chronic hypersensitivity pneumonitis (CHP), connective tissue disease-associated ILD, and unclassifiable ILD were present in one, one, five, and nine cases, respectively. Four patients with ILD did not undergo the pulmonary function test due to a past medical history of pneumothorax. Seven of 16 patients with ILD received oxygen supplementation (0.5–3 L/min), and ABG analysis revealed that the median $PaO_2$ and $PaCO_2$ were 85.2 (68.1–96.4) and 41.5 (35.6–44.9) Torr, respectively. Further, 7 of 16 patients with ILD were managed with oxygen supplementation (0.5–1 L/min), and PSG performed on the first day showed that the median AHI was 18.4 (6.3–41.6) episodes/hour. Nineteen patients were diagnosed with obstructive sleep apnea because AHI was ≥5 episodes/hour, which predominantly included obstructive respiratory events (presence of thoracoabdominal effort) (12), whereas three patients, all of which had ILD and used HOT, were not diagnosed with SAS. In patients with COPD who were breathing ambient air, ABG analysis showed that the median of $PaO_2$ and $PaCO_2$ were 66.9 (62.5–74.3) and 39.8 (35.7–42.6) Torr, respectively. The median AHI on the first day was 16.2 (10.2–21.5) episodes/hour.

### Detection rate of patients' respiration using TeleOx®

Differences in the detection rate of patients' respiration using TeleOx® according to the device's positions, oxygen flow rates, and usage of HOT are shown in Table 2. With total points of 2088 and 646, TeleOx® detected patients' respiration in 75.6% (1578 points) and 70.4% (455 points) of patients with ILD and COPD,

**Table 1.** Clinical characteristics of the patients

|  | ILD (n = 16) | COPD (n = 6) |
|---|---|---|
| Age, year | 72 (61–78) | 73 (71–82) |
| Male, n (%) | 13 (81.3) | 6 (100) |
| Body mass index, kg/m$^2$ | 22.5 (20.5–25.8) | 22.4 (17.5–24.6) |
| Smoking history, never/past, n (%) | 3/13 (12.7/81.3) | 0/6 (0/100) |
| Types of ILD |  |  |
|   IPF, n | 1 | - |
|   CHP, n | 1 | - |
|   Connective tissue disease-associated ILD, n | 5 | - |
|   Unclassified ILD, n | 9 | - |
| Pulmonary function test[†] |  |  |
|   Forced vital capacity, L | 2.24 (1.66–3.02) | 2.64 (2.45–4.04) |
|   % predicted forced vital capacity, % | 75.2 (56.8–87.7) | 89.6 (72.3–120.8) |
|   Forced expiratory volume in one second, L | 1.91 (1.52–2.2.71) | 1.11 (0.67–2.15) |
|   % predicted forced expiratory volume in one second, % | 75.7 (65.4–95.4) | 49.3 (24.8–80.3) |
|   Forced expiratory volume in one second/Forced vital capacity, % | 86.5 (83.3–89.3) | 42.1 (28.0–53.1) |
| ABG[‡] |  |  |
|   pH | 7.42 (7.41–7.44) | 7.41 (7.38–7.43) |
|   PaCO$_2$, Torr | 41.5 (35.6–44.9) | 39.8 (35.7–42.6) |
|   PaO$_2$, Torr | 85.2 (68.1–96.4) | 66.9 (62.5–74.3) |
|   Bicarbonate, mmol/L | 26.0 (23.2–27.7) | 24.6 (21.8–27.7) |
| PSG[§] |  |  |
|   AHI, episodes/hour | 18.4 (6.3–41.6) | 16.2 (10.2–21.5) |
|   Presence of obstructive sleep apnea, n | 13 | 6 |
| Usage of HOT[¶], n (%) | 8 (50) | 2 (33.3) |

ABG = arterial blood gas; AHI = apnea-hypopnea index; CHP = chronic hypersensitivity pneumonitis; COPD = chronic obstructive pulmonary disease; HOT = home oxygen therapy; ILD = interstitial lung disease; IPF = idiopathic pulmonary fibrosis; PaCO$_2$ = arterial partial pressure of carbon dioxide; PaO$_2$ = arterial partial pressure of oxygen; PSG = polysomnography. Data were expressed as median (interquartile range). [†]Four patients with ILD did not undergo the pulmonary function test due to a past medical history of pneumothorax. [‡]Nine and seven patients with ILD underwent ABG analysis while breathing ambient air and oxygen (0.5−3 L/min), respectively. Meanwhile, all patients with COPD underwent analysis while breathing ambient air. [§]Nine and seven patients with ILD underwent PSG while breathing ambient air and oxygen (0.5−1 L/min), respectively. Meanwhile, all patients with COPD underwent analysis while breathing ambient air. [¶]Seven and one patient with ILD received HOT at all times and during exercise, respectively. However, two patients with COPD received HOT during exercise only.

**Table 2.** Differences of detection rate of patients' respiration among TeleOx ®'s position, oxygen flow rates, and usage of HOT

| | Concentrator side | | | | Patient side | | | | Usage of HOT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Oxygen flow rates | | | Total | Oxygen flow rates | | | Yes | No |
| | | 1 L/min | 3 L/min | 5 L/min | | 1 L/min | 3 L/min | 5 L/min | | |
| ILD, points | 75.6 (1578/2088) | 77.8 (794/1021) | 60.4 (131/217) | 61.8 (34/55) | 77.8 (619/795) | 79 (364/461) | 68.6 (155/226) | 92.6 (100/108) | 75.0% (970/1293) | 76.5% (608/795) |
| COPD, points | 53.5 (116/217) | 72.4 (76/105) | 28.6 (18/63) | 44.9 (22/49) | 79.0 (339/429) | 65.1 (136/209) | 94.4 (153/162) | 86.2 (50/58) | 83.5% (186/218) | 62.9% (269/428) |

COPD = chronic obstructive pulmonary disease; HOT = home oxygen therapy; ILD = interstitial lung disease.

respectively. In patients with ILD, the detection rate of patients' respiration obtained using TeleOx® did not completely change according to device's position (concentrator side: 74.2% and patient side: 77.8%). It increased from 61.8% to 92.6% at an oxygen flow rate of 5 L/min by changing the device's position from the concentrator side to the patient side. In patients with COPD, the total detection rate of patients' respiration obtained using TeleOx® increased from 53.5% to 79.0% by changing the device's position from the concentrator to the patient side. In particular, the rate increased from 28.6% to 94.4% and from 44.9% to 86.2% at oxygen flow rates of 3 and 5 L/min, respectively. At an oxygen flow rate of 1L/min, the detection rate of patients' respiration using TeleOx® in patients with COPD and ILD almost did not change based on the device's positions. In patients with ILD, the detection rate of patients' respiration obtained using TeleOx® did not significantly

differ between those with (75.0%) and those without the usage of HOT (76.5%). In patients with COPD, this rate increased from 62.9% in those without the usage of HOT to 85.3% in those with the usage of HOT.

### Comparison of RR obtained using PSG and TeleOx®

In patients with ILD, the Bland–Altman method showed narrow limits of agreement (Figure 3A, B, D, and E), and the ICC (2,1) value indicated that TeleOx® had an acceptable reliability at oxygen flow rates of 1 and 3 L/min regardless of the device's positions (Figure 4A, B, D, and E). By contrast, the Bland–Altman method showed wide limits of agreement (Figure 3C and F), and ICC (2,1) value indicated that TeleOx® had a non-acceptable reliability at an oxygen flow rate of 5 L/min regardless of the device's position (Figure 4C and F). In patients with COPD, the Bland–Alt-
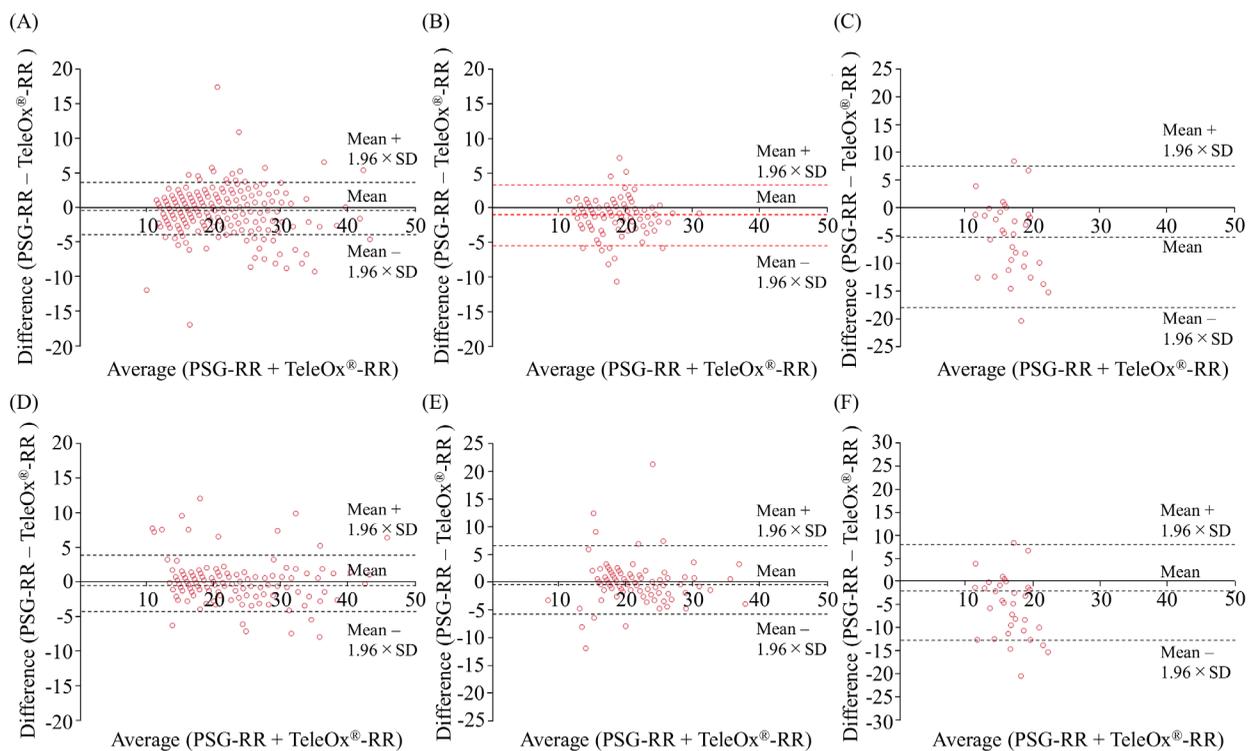


**Figure 3.** Comparison of RR obtained using PSG and TeleOx® connected on the concentrator side (A–C) and the patient side (D–F) using the Bland–Altman method in patients with ILD. A and D, oxygen flow rate of 1 L/min; B and E, oxygen flow rate of 3 L/min; and C and F, oxygen flow rate of 5 L/min. ILD = interstitial lung disease; PSG = polysomnography; RR = respiratory rate; SD = standard deviation. The Bland-Altman method showed narrow limits of agreement at oxygen flow rates of 1 and 3 L/min regardless of TeleOx®'s positions (A, B, D, and E), whereas this method showed wide limits of agreement at an oxygen flow rate of 5 L/min regardless of the device's position (C and F).
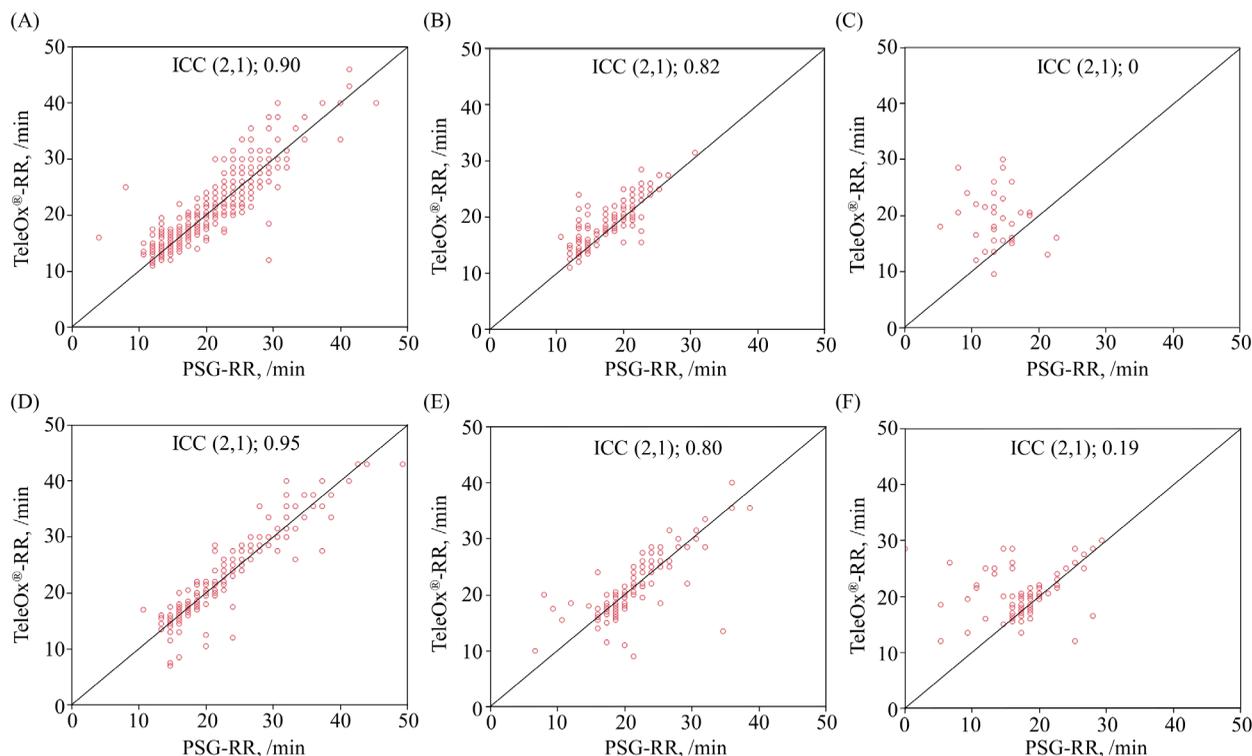
**Figure 4 .** Scatterplots of RR obtained using PSG and TeleOx® connected on the concentrator side (A–C) and the patient side (D–F) in patients with ILD. A and D, oxygen flow rate of 1 L/min; B and E, oxygen flow rate of 3 L/min; and C and F, oxygen flow rate of 5 L/min. ICC = intraclass correlation coefficient; ILD = interstitial lung disease; PSG = polysomnography; RR = respiratory rate. An ICC (2,1) value of >0.7 was considered the minimum acceptable level of reliability (17). The ICC (2,1) value indicated that TeleOx® had an acceptable reliability at oxygen flow rates of 1 and 3 L/min regardless of the device's positions (A, B, D, and E), whereas this value showed that the device had a non-acceptable reliability at an oxygen flow rate of 5 L/min regardless of the device's position (C and F).

man method showed narrow limits of agreement at an oxygen flow rate of 1 L/min regardless of the device position (Figure 5A and D) and at an oxygen flow rate of 3 L/min if the device was connected to the patient side (Figure 5E). The ICC (2,1) value revealed that TeleOx® had an acceptable reliability at an oxygen flow rate of 1 L/min and when the device was connected to the patient side (Figure 6D).

## Discussions

The study presented four important points. First, the detection rate of patients' respiration using TeleOx® increased when the device's position was changed from the concentrator to the patient side in patients with COPD. Second, in patients with ILD, TeleOx® could

accurately monitor RR regardless of the device positions at oxygen flow rates of 1 and 3 L/min. Third, in patients with COPD, TeleOx® could accurately monitor RR by changing the device's position from the concentrator to the patient side at an oxygen flow rate of 1 L/min. Fourth, at an oxygen rate of 5 L/min, TeleOx® did not accurately monitor regardless of the device's position and patients' diseases (COPD versus ILD). Therefore, the accuracy of TeleOx® was acceptable at low and moderate oxygen flow rates in ILD. However, it was low at a high oxygen flow rate regardless of patients' diseases and when the device was connected to the concentrator side in COPD. A previous validation study using TeleOx® did not evaluate the influence of the device's position in monitoring accuracy (8). Although TeleOx® is compact and low weight, its connection near patients can be bothersome. Therefore,
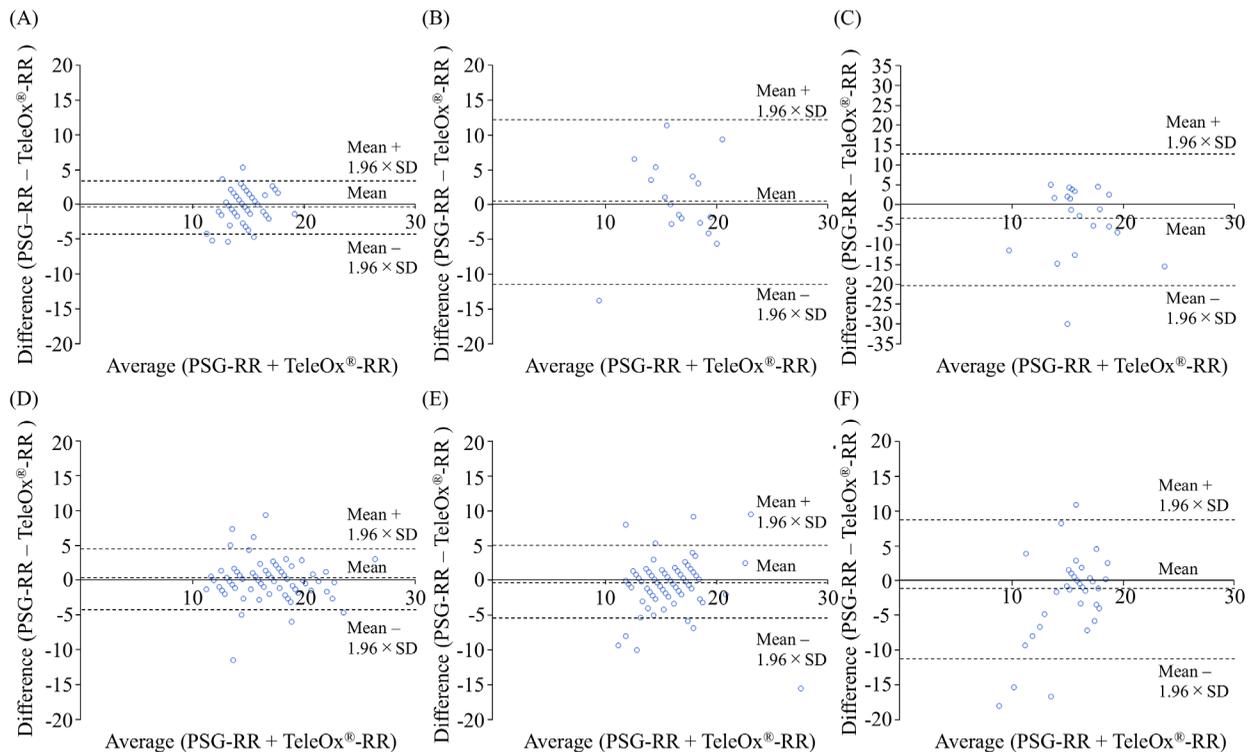
**Figure 5 .** Comparison of RR obtained using PSG and TeleOx® connected on the concentrator side (A–C) and the patient side (D–F) using the Bland-Altman method in patients with COPD. A and D, oxygen flow rate of 1 L/min; B and E, oxygen flow rate of 3 L/min; and C and F, oxygen flow rate of 5 L/min. COPD = chronic obstructive pulmonary disease; PSG = polysomnography; RR = respiratory rate; SD = standard deviation. The Bland-Altman method showed narrow limits of agreement at an oxygen flow rate of 1 L/min regardless of TeleOx®'s position (A and D) and at an oxygen flow rate of 3 L/min if the device was connected to the patient side (E), whereas this method showed wide limits of agreement at an oxygen flow rate of 3 L/min if the device was connected to the concentrator side (B) and at an oxygen flow rate of 5 L/min regardless of the device's position (C and F).

the development of built-in and non-contact remote monitoring devices for HOT is required to more easily and comfortably monitor patients' respiration.

Soler et al. showed that TeleOx® had a high accuracy in monitoring RR in patients with COPD (8). In our study, the accuracy of the device was low. The previous study performed RR monitoring using TeleOx® in France and Western Europe during daytime, whereas we did the same in Japan, East Asia, and during nighttime. Ethnic variations influenced breathing pattern and respiratory mechanics (18). Therefore, difference in race and experimental settings could be associated with varying results between the current study and that of Soler.

Patients with COPD, unlike those with ILD, develop expiratory flow limitation during tidal breathing (19). This flow limitation might result in a lower de-

tection rate of breathing in COPD patients, especially whet set on the concentrator side.

The rate of non-adherence to HOT is relatively high (20). Therefore, to recognize the actual adherence to HOT using remote monitoring devices including TeleOx® can lead to the development of enhanced adherence and compliance strategies, such as adapting the oxygen system according to patients' desires (9). Furthermore, this can identify the actual effect of HOT on mortality and quality of life. Future studies using remote monitoring devices in patients receiving HOT must be conducted to evaluate outcomes, such as quality of life and mortality.

RR is a vital sign, and it should be assessed. However, it has been overlooked in clinical practice, because its measurement is usually based on manual counting. In patients with COPD, RR increased days before re-
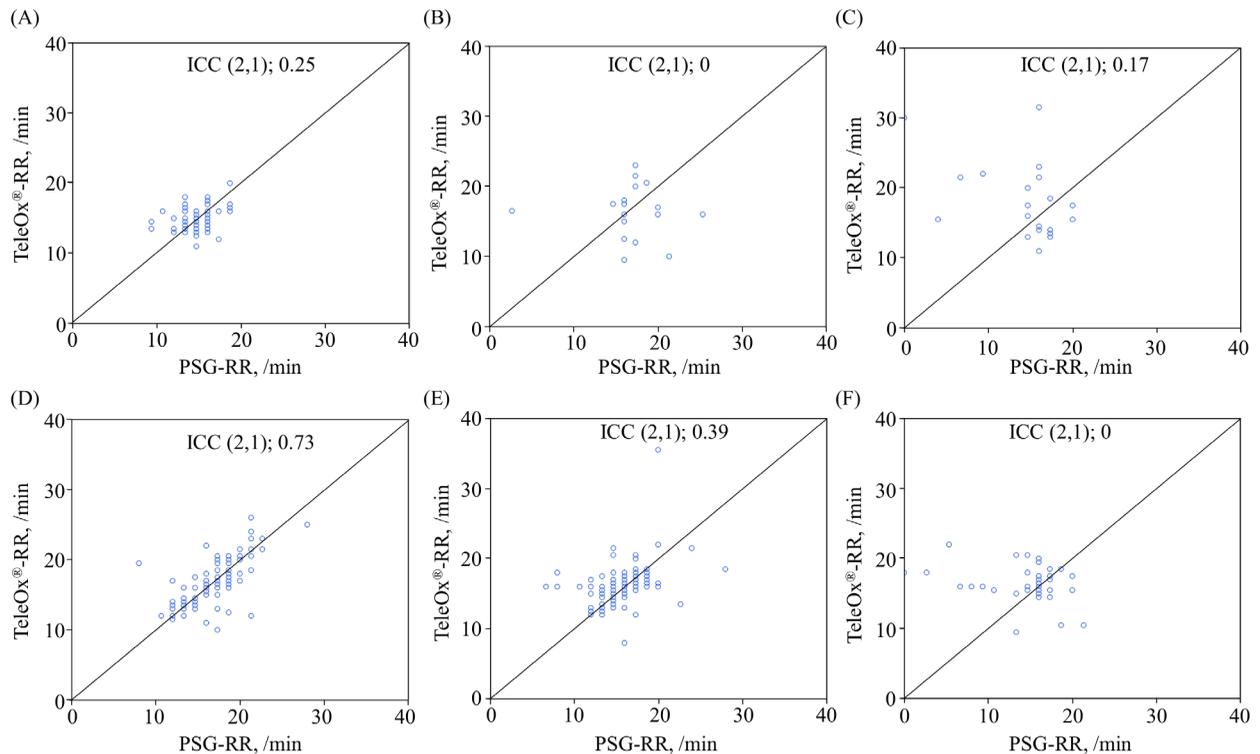
**Figure 6 .** Scatterplots of RR obtained using PSG and TeleOx® connected on the concentrator side (A–C) and the patient side (D–F) in patients with COPD. A and D, oxygen flow rate of 1 L/min; B and E, oxygen flow rate of 3 L/min; and C and F, oxygen flow rate of 5 L/min. COPD = chronic obstructive pulmonary disease; ICC = intraclass correlation coefficient; PSG = polysomnography; RR = respiratory rate. An ICC (2,1) value of >0.7 was considered the minimum acceptable level of reliability (17). The ICC (2,1) indicated that TeleOx® had an acceptable reliability at an oxygen flow rate of 1 L/min and when the device was connected to the patient side (A).

quiring hospitalization due to COPD exacerbation, as described above (7). In addition, in patients with ILD, RR was significantly higher in non-survivors than in survivors, whereas the FVC was significantly lower in non-survivors than in survivors (21). Therefore, continuous monitoring of RR can improve the timely detection and self-management of exacerbations to prevent hospital admissions in patients with chronic respiratory diseases (22).

This study had major several limitations. First, only patients who were suspected of having SAS were included. Second, only a few patients with COPD were included. Third, the monitoring accuracy of Tele-Ox® in patients with other diseases such as pulmonary hypertension and congestive heart failure, which are managed with HOT, was not examined. Fourth, we performed RR monitoring using TeleOx® only during the nighttime because RR during the daytime is affected by activity. Fifth, we did not evaluate the effect

of liquid oxygen on the accuracy of TeleOx®. Sixth, we could not obtain data using TeleOx® in five patients (two with ILD and three with COPD), probably due to a network error, dislocation of nasal cannula, and obstruction of oxygen connecting tube. This result could lead to the notion that TeleOx® cannot detect respiration in some patients receiving HOT. Hence, this device's limitations must be considered. Seventh, as ILD was not limited to IPF but included a wide variety of diseases, disease-specific characteristics of TeleOx® performance were unclear.

The results of this study indicate that the site of connection, oxygen flow rates, and patients' diseases must be considered for the correct usage of TeleOx®. These results will contribute to improvements in home monitoring of patients with ILD and COPD.

**Abbreviations:** ABG = arterial blood gas; AHI = apnea-hypopnea index; CHP = chronic hypersensitivity pneumonitis; COPD = chronic obstructive pulmonary disease; HOT = home oxygen

therapy; ICC = intraclass correlation coefficient; ILD = interstitial lung disease; IPF = idiopathic pulmonary fibrosis; $PaCO_2$ = arterial partial pressure of carbon dioxide; $PaO_2$ = arterial partial pressure of oxygen; PSG = polysomnography; RR = respiratory rate; SAS = sleep apnea syndrome; SD = standard deviation

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