


Article

Validation of Oximetry for Diagnosing Obstructive Sleep Apnea in a Clinical Setting

Kazuki Ito ^{1,2}, Masahiro Uetsu ³ and Hiroshi Kadotani ^{1,3,*} 

¹ Department of Sleep and Behavioral Sciences, Shiga University of Medical Science, Seta Tsukinowa-cho, Otsu, Shiga 520-2192, Japan; momo3@belle.shiga-med.ac.jp

² Department of Anesthesiology, Shiga University of Medical Science, Seta Tsukinowa-cho, Otsu, Shiga 520-2192, Japan

³ Sleep Outpatient Unit for Sleep Apnea Syndrome, Nagahama City Hospital, 313 Ohinui-cho, Nagahama, Shiga 526-0043, Japan; muetsu@nagahama-hp.jp

* Correspondence: kadotanislleep@gmail.com; Tel.: +81-775483632

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Abstract: A large epidemiological study using oximetry to analyze obstructive sleep apnea (OSA) and metabolic comorbidities was performed in Japan; however, reliability and validity of oximetry in the Japanese population remains poorly understood. In this study, oximetry data from the epidemiological study were compared with data from clinically performed polysomnography (PSG) and out-of-center sleep testing (OCST) in epidemiological study participants who later attended our outpatient units. The oxygen desaturation index (ODI) from oximetry showed a moderate positive relationship (correlation coefficient $r = 0.561$, $p < 0.001$) with apnea/hypopnea data from PSG/OCST. The area under the receiver operating characteristic curve showed moderate accuracy of this method in the detection of moderate-to-severe or severe OSA. However, the optimal ODI thresholds to detect moderate-to-severe OSA and severe OSA were the same (ODI > 20.1). Oximetry may be a useful tool for screening moderate-to-severe or severe sleep apnea. However, it may be difficult to set an appropriate threshold to distinguish between moderate and severe sleep apnea by oximetry alone.

Keywords: epidemiology; obstructive sleep apnea; oximetry; polysomnography; correlation; ROC curve; Bland-Altman plot; home sleep apnea testing

1. Introduction

Obstructive sleep apnea (OSA) is a common sleep disorder [1,2]; its prevalence is estimated to be as high as 14% in Japan [2]. OSA is an independent risk factor for a variety of adverse metabolic disease states, including hypertension, type 2 diabetes, dyslipidemia, and metabolic syndrome [3–8].

Overnight polysomnography (PSG), which is analyzed by a specialized technician, is the gold standard for OSA diagnosis [9]. However, PSG is time- and labor-intensive, and, consequently, waiting times can be substantial [10]. To increase accessibility to diagnostic resources for early detection, the unattended recording of some physiological signals at home has been encouraged [9,11]. Oximetry, one of the simplest methods to obtain physiological signals, has the potential to be a cheaper, more accessible alternative diagnostic tool to screen for OSA, especially in large-scale studies. Many studies using oximetry have investigated the accuracy of the oxygen desaturation index (ODI) as a metric for OSA diagnosis; however, variability has been reported in the specificity (≈ 40 –100%) and sensitivity (≈ 30 –100%) of ODI measurements in oximetry [12,13]. These variations may come, in part, from different study designs. Some studies have compared oximetry data obtained as a part of PSG recordings to apnea events analyzed from the same PSG recordings [14–19]. Others have compared oximetry data with data from simultaneous PSG [20–22]. These methods may be suitable for developing

and comparing algorithms or devices; however, they are not informative enough for clinical settings. In Japan, oximetry is performed during regular annual medical examinations for screening of OSA in clinical settings. After the screening, patients with suspected OSA visit hospitals or clinics with ODI reports and undergo out-of-center sleep testing (OCST) or PSG for diagnosis.

Few studies have compared PSG and oximetry data from different nights [23,24]. Golpe et al. [23] performed a retrospective analysis of 127 patients suspected of having sleep apnea in Spain, in which both home oximetry and PSG were performed. This study compared PSG and oximetry data collected 12.8 ± 10.1 months apart and found that the correlations between the apnea–hypopnea index (AHI) and desaturation indices were not high, with an $r = 0.58$ for ODI at 3% (3%ODI), $r = 0.60$ for desaturations for 4%, and $r = 0.50$ for time spent at saturations below 90%. That study also found that oximetry had a high specificity (0.97) for confirming sleep apnea in patients with high pre-test probabilities of OSA; however, its sensitivity (0.29) was not adequate. Chu et al. [24] performed another prospective, cross-sectional study among 107 hemodialysis patients in Australia, in which PSG was performed only when oximetry presented abnormal results. Ninety-three patients completed nocturnal oximetry, with 65 having abnormal results (3%ODI ≥ 5). Thirty-six patients underwent both oximetry and PSG, with both evaluations being performed on the night after a dialysis session in order to minimize the influence of fluid overload on respiratory function. The time period between oximetry and PSG performance was not presented in the study; however, the average wait time for a non-urgent in-laboratory PSG in Australia is ≤ 68 weeks. The 3%ODI measured from home oximetry and the AHI measured with in-lab PSG were positively correlated ($r = 0.62$, $p = 0.0001$).

Matsumoto et al. [25] published a large epidemiological study (the Nagahama Study) in Nagahama, Japan, in which 7713 participants underwent pulse oximetry in their homes to screen for sleep apnea. In this study, home fingertip oximetry worn on the nondominant wrist was performed with wrist actigraphy. Using actigraphy, OSA was assessed by measuring 3%ODI corrected for sleep duration. Prevalence of moderate (actigraphy-modified 3%ODI: 15–30) and severe OSA (actigraphy-modified 3%ODI ≥ 30) were 10.1% and 2.0%, respectively. This study also found that comorbidities like hypertension, diabetes, and metabolic syndrome were independently associated with moderate-to-severe OSA. As a preliminary study, Matsumoto et al. [25] compared simultaneous in-lab PSG with oximetry and actigraphy among 32 participants. Actigraphy-modified 3%ODI ($r = 0.99$, $p < 0.001$) was more comparable to the AHI recorded from PSG than the non-modified 3%ODI ($r = 0.92$, $p < 0.001$).

In this study, we aimed to compare oximetric data obtained in the Nagahama Study with sleep apnea-related diagnostic data from our clinical setting. Since our clinical unit is the only one in Nagahama that can perform in-lab PSG, Nagahama study participants with suspected sleep apnea were encouraged to consult at our unit. In this study, we compared OSA diagnostic data obtained in our clinical setting to the oximetry data obtained in the Nagahama Study. Since oximetry is much less invasive than monitoring systems currently in use, it is important to determine whether this home-based test can reliably screen for and detect OSA. Importantly, our study sought to evaluate the usefulness of previously performed oximetry data in clinical settings.

2. Results

ODI data were available for 119 of the 129 participants in the Nagahama Study, and these were included in our study (Figure 1). The characteristics of participants that were either included or excluded from the study were similar (Table 1).

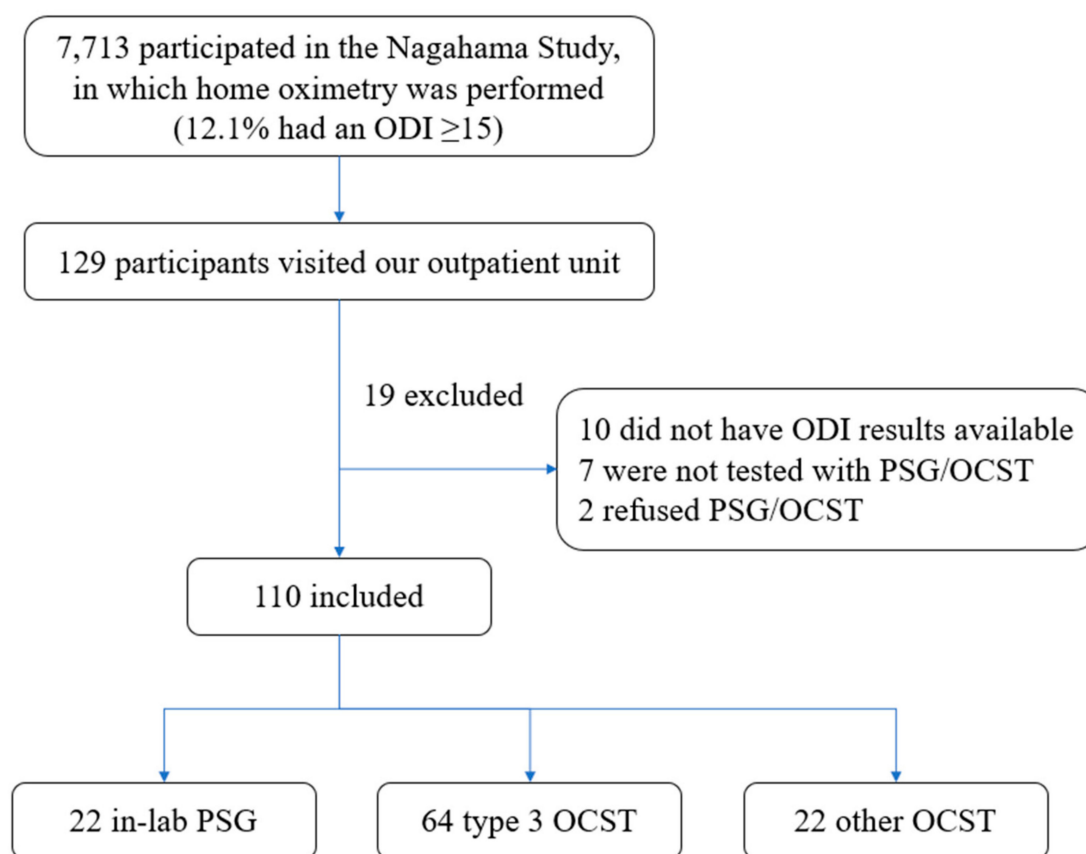


Figure 1. Flow diagram of the participants. ODI: oxygen desaturation index; PSG: polysomnography; OCST: out-of-center sleep testing.

Table 1. Patient characteristics. Characteristics of included and excluded participants were compared.

	Included	Excluded	<i>p</i> -Value
n	110	19	
Age, y	67.6 ± 10.3	69.6 ± 6.00	0.413
Sex, male %	69.1	63.2	0.609
BMI ¹ , kg/m ²	24.6 ± 4.07	24.7 ± 3.04	0.908
ESS ²	6.43 ± 4.41	5.68 ± 3.07	0.482
AIS ³	3.64 ± 3.15	3.58 ± 2.57	0.940
PHQ-9 ⁴	2.34 ± 3.18	1.92 ± 1.85	0.648
REI ⁵ /AHI ⁶ , per h	28.1 ± 15.0	28.1 ± 17.4	0.999
Hypertension, %	53.6	57.9	0.732
Diabetes, %	16.4	15.8	0.740
Dyslipidemia, %	33.6	31.6	0.861
Mental disorders, %	6.6	0	0.343

¹ BMI: body mass index; ² ESS: Epworth sleepiness scale; ³ AIS: Athens insomnia scale; ⁴ PHQ-9, Patient Health Questionnaire-9; ⁵ REI: respiratory event index; ⁶ AHI: apnea-hypopnea index.

Evaluation of the relationship between ODI and AHI/REI revealed a moderate positive relationship (correlation coefficient $r = 0.561$, $p < 0.001$) (Figure 2a). The Bland–Altman plot suggested that oximetry had systematic errors when compared with PSG or OCST (Figure 2b). Slopes of the regression equations for Bland–Altman plots of PSG, type 3, and “others” versus ODI were -0.809 (95% CI: -1.150 to -0.469), -0.794 (95% CI: -1.069 to -0.519), and -0.590 (95% CI: -0.922 to -0.259), respectively (Figure 3a–c).

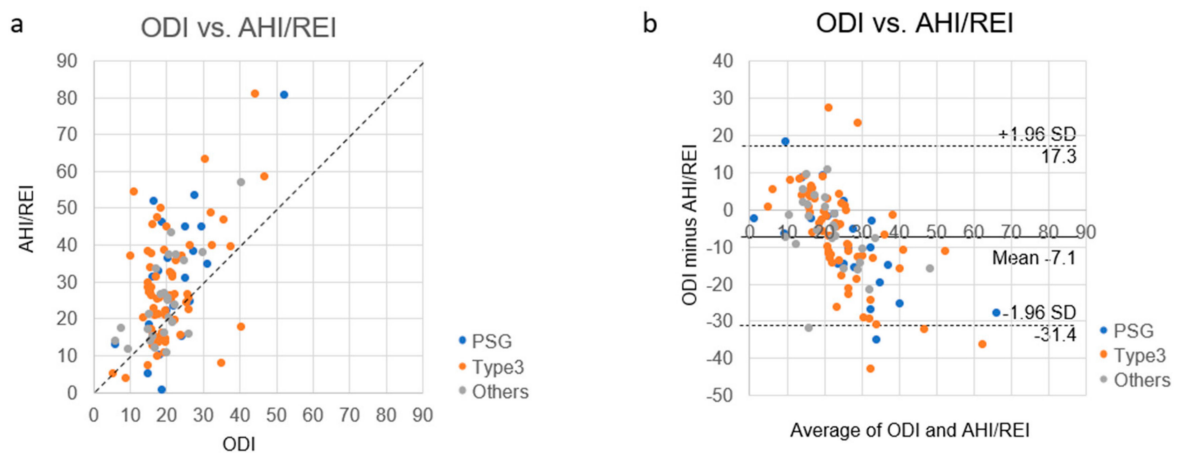


Figure 2. Oxygen desaturation index (ODI) obtained in the Nagahama Study versus apnea-hypopnea index (AHI), analyzed by polysomnography (PSG), and respiratory event index (REI), analyzed by out-of-center sleep testing (OCST) obtained in the clinical setting. (a) A scatter plot and (b) a Bland–Altman plot were generated to compare ODI and AHI/REI. Blue dots represent AHI from polysomnography (PSG), orange dots represent REI from type 3 OCST (Type 3), and gray dots represent REI from 2–3 channel OCST (Others).

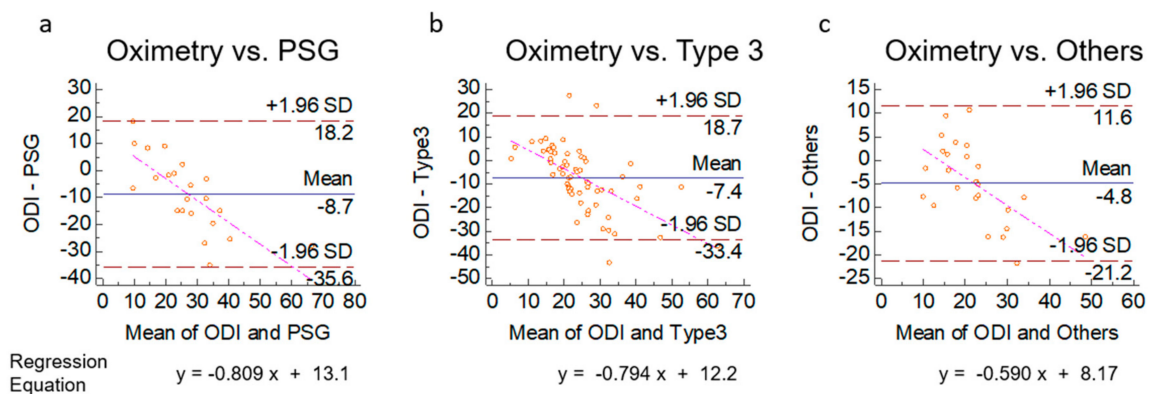


Figure 3. Bland–Altman plots and their regression equations to compare the oxygen desaturation index (ODI) vs. respiratory event index (REI) analyzed with out-of-center sleep testing (OCST) and apnea-hypopnea index (AHI) analyzed with polysomnography (PSG). ODI from oximetry (Oximetry) was compared with (a) AHI from PSG, (b) REI from type 3 OCST (Type 3), and (c) REI from 2–3 channel OCST (Others).

The area under the ROC curve (AUC) serves as an overall measure of a diagnostic test’s accuracy. The AUC values suggested that ODI offered a moderate level of accuracy to detect both moderate-to-severe (0.736) and severe (0.708) OSA (Figure 4a,b). The Youden index was used to calculate the optimal ODI thresholds to detect moderate-to-severe OSA (ODI > 20.1) and severe OSA (ODI > 20.1).

According to the previously obtained oximetry data from the epidemiological study, 8.2%, 80.0%, and 11.8% of patients were diagnosed with mild, moderate, or severe OSA (Table 2), respectively. According to PSG/OCST data obtained in our clinical setting, 16.4%, 40.9%, and 40.0% of the same patients were clinically diagnosed with mild, moderate, or severe OSA (Weighted Kappa = 0.238), respectively.

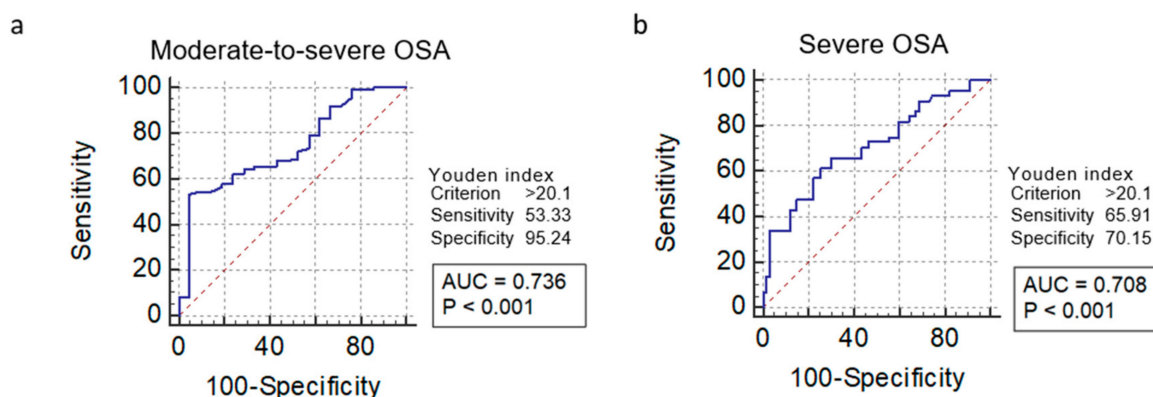


Figure 4. Comparison of moderate-to-severe and severe obstructive sleep apnea (OSA) using the area under the receiver operating characteristics curve (AUC) and Youden index for the oxygen desaturation index. Receiver operating characteristic (ROC) curves were constructed to compare the diagnostic performance of ODI to detect moderate-to-severe (AHI/REI ≥ 15) (a) or severe (AHI/REI ≥ 30) OSA (b).

Table 2. Sleep apnea severity distribution from oxygen desaturation indices (ODIs) obtained in the Nagahama Study and apnea-hypopnea indices (AHIs)/respiratory event indices (REIs) obtained in the clinical setting.

	Oximetry ODI				Total	%
	0-5	5-15	15-30	≥ 30		
0-5	0	2	1	0	3	2.7
5-15	0	3	14	1	18	16.4
PSG ¹ /OCST ²	0	2	42	1	45	40.9
AHI/REI	0	2	31	11	44	40
total	0	9	88	13	110	
%	0	8.2	80	11.8		

¹ PSG: polysomnography; ² OCST: out-of-center sleep testing.

When we compared REI/AHI and ODI derived from the same recordings (ODI from OCST with REI and ODI from PSG with AHI), correlation coefficients were 0.917 and 0.901, respectively (Figure 5a,b). When ODI from the first night of OCST was compared with REI from the second night, the correlation coefficient r was 0.804 ($p < 0.001$) (Figure 6a). When ODI from the second night with OCST was compared with REI from the first night, the correlation coefficient r was 0.725 ($p < 0.001$) (Figure 6b). Therefore, correlations between REI/AHI and ODI were best when ODI and AHI/REI were analyzed from the same recordings, followed by the same device on different days, and worst with different devices on different days.

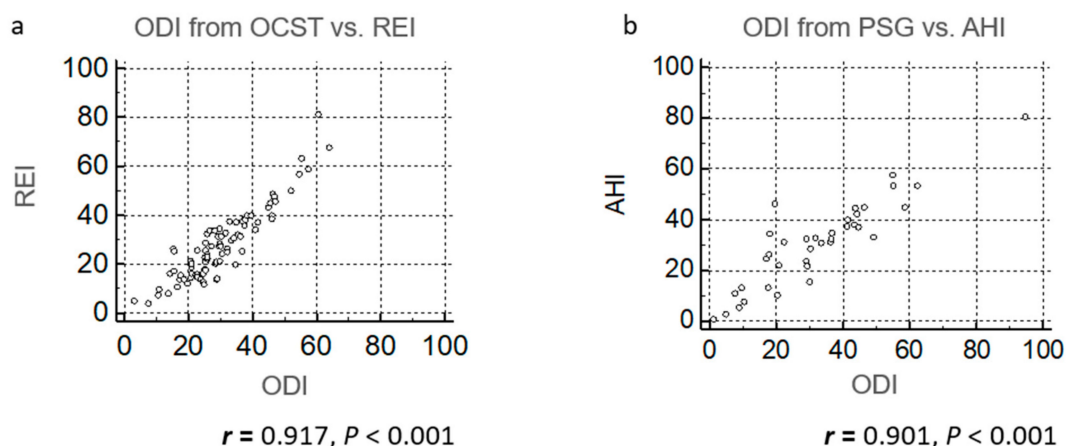


Figure 5. Scatter plots of oxygen desaturation index (ODI) vs. respiratory event index (REI) analyzed with out-of-center sleep testing (OCST) and apnea-hypopnea index (AHI) analyzed with polysomnography (PSG) from the same recording. Oximetry was performed as a part of PSG or OCST. (a) ODI from OCST was compared with REI and (b) ODI from PSG was compared with AHI.

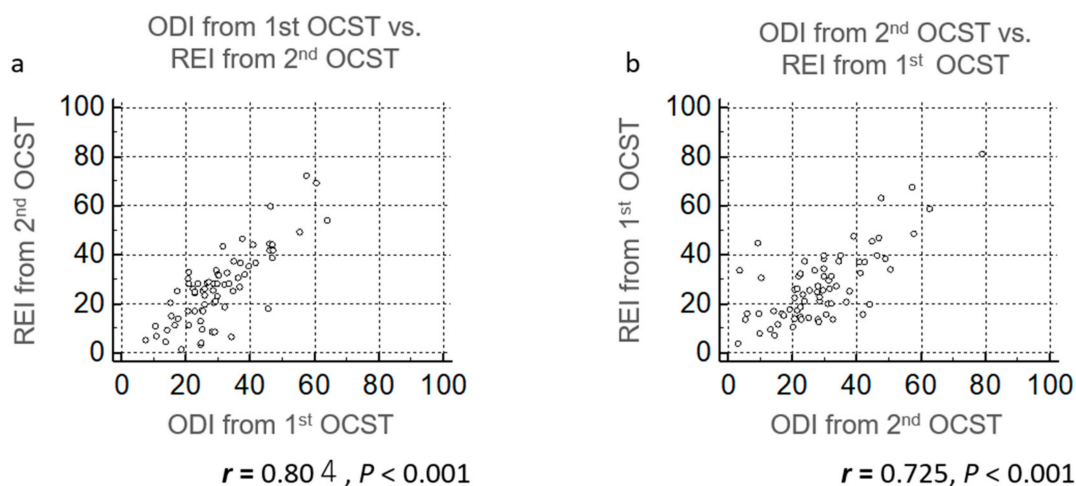


Figure 6. Scatter plots of oxygen desaturation index (ODI) vs. respiratory event index (REI) analyzed with out-of-center sleep testing (OCST) from different recordings. Two nights of OCST were performed. (a) ODI from the first night was compared with the REI from the second night and (b) ODI from the second night was compared with REI from the first night.

3. Discussion

We compared OSA diagnostic data obtained in our clinical setting to oximetry data obtained in the Nagahama Study.

The slopes of the regression equations of the Bland–Altman plots (Figure 3) suggested similarities in the agreement of the clinical sleep tests, especially between PSG and type 3 OCST. The slope comparing oximetry and type 3 OCST (Figure 3b) was -0.794 , which was between -0.809 (Figure 3a: oximetry vs. PSG) and -0.590 (Figure 3c: PSG vs. others). We did not directly compare PSG and OCST in the same patients in this study; however, the slope data suggested that increasing the number of monitoring channels from two or three in “Others” to four (as in the type 3 OCST) may provide more accurate data that is similar to PSG, the gold-standard test [9,26].

The differences in the correlation coefficients between our data ($r = 0.561$, $p < 0.001$) (Figure 2a) and Matsumoto et al. ($r = 0.99$, $p < 0.001$) [25] may be due to differences in settings. Our data compared previously performed oximetry with PSG or OCST that was performed later in a clinical setting. Matsumoto et al. compared ODI with AHI from simultaneously recorded data.

Previous studies compared AHI and ODI from the same recordings, with correlation coefficients reported to range between 0.745 and 0.97 [14–19]. Some studies compared simultaneously performed oximetry and PSG, with correlation coefficients reported to be 0.617–0.95 [20,21], while others independently performed oximetry and PSG [23,24], with correlation coefficients of 0.6 and 0.62. These results suggest that ODI compared with AHI from the same night may provide a better correlation. These trends in correlation coefficients were also found in our data; correlation coefficients between REI/AHI and ODI derived from the same recordings were 0.917 and 0.901, respectively; correlation coefficients between REI and ODI from different nights with the same device were 0.804 and 0.725; and the correlation coefficient between AHI/REI and ODI from different nights with different devices was 0.561.

Our results suggest that diagnostic performance of ODI to distinguish severe OSA from moderate OSA was not as effective as previously reported. The AUC to detect moderate-to-severe OSA (AUC = 0.736) was slightly higher than the AUC to detect severe OSA (AUC = 0.708) (Figure 4). Optimal thresholds to distinguish between moderate-to-severe OSA (ODI > 20.1) and severe OSA (ODI > 20.1) were the same, suggesting that use of ODI to distinguish between moderate-to-severe and severe OSA is difficult. Previous studies have suggested that patients with OSA detected by oximetry have more severe disease than those missed by it [14,23,27]. While these results suggest that oximetry is effective at diagnosing severe OSA, non-severe patients, including those with moderate disease, need PSG examinations for confirmation of their OSA [14].

OSA screening with oximetry is reported to have better performance than screening by questionnaire only [27]. Screening tests with oximetry may help participants to diagnose OSA with a shorter wait time than undergoing PSG in clinical settings [10].

Our study had some limitations. First, the oximetry ODI was not measured simultaneously with PSG/OCST. Comparisons of ODI and AHI/REI from the same recordings showed the best correlation [14–19] (Figure 5), followed by simultaneous recording by different devices [20,21,25]. The correlation was worst when comparing ODI and AHI/REI from different devices on different nights [23,24] (Figures 2a and 6). This may be one reason why the correlation between ODI from previously performed oximetry and AHI/REI in our clinical setting was low (Figure 2a). The time period between oximetry in the Nagahama Study and PSG/OCST in our clinical setting was not clear because the participants only had ODI results and did not remember the exact day of their oximetry monitoring. This study was also performed in a single city in Japan, and the results may not be true for other populations. Moreover, only 11.4% of suspected OSA participants from the original study presented to our outpatient unit. However, it is reported that 11.0 to 16.5% of patients who underwent medical check-ups in Shiga, Japan, consulted referral doctors when recommended based on their results [28]. Thus, our participation rate may be reasonable in this regard.

4. Materials and Methods

4.1. Participants

Among the participants of the Nagahama Study, 12.1% ($n = 933$) had an ODI of ≥ 15 and were advised to undertake clinical sleep tests [25]. From October 24, 2013 to March 19, 2020, 129 participants visited our outpatient unit located at a tertiary care center in the Nagahama City Hospital for evaluation of OSA. Ten patients without ODI data were excluded, leaving 119 patients in our study. One hundred and six patients were reported to have an ODI ≥ 15 , representing 11.4% of the Nagahama Study participants with an ODI of ≥ 15 . The protocol of this study was approved by the Ethics Committees of the Nagahama City Hospital (27–37) and the Shiga University of Medical Science (R2015-229). This study was conducted per the Declaration of Helsinki in 2013. Written informed consent was not obtained because of the retrospective nature of the study. We disclosed the study protocol on the website (<http://www.shiga-med.ac.jp/~hqsuimin/1207.pdf>), and subjects were offered the opportunity to opt out of the study.

4.2. Sleep Tests and Questionnaires

Seven participants were not tested with PSG or OCST because they were not suspected to have sleep apnea, and two other patients refused PSG or OCST. One hundred and ten participants underwent PSG/OCST, and related data were further analyzed (Figure 1).

Twenty-two participants underwent in-lab PSG (Alice 5, Philips Respironics, Inc., PA, USA), 64 underwent type 3 OCST (Morpheus, Teijin, Tokyo, Japan), and 22 underwent 2-3 channel OCST (“Others”) (Figure 1). The type 3 OCST device monitored at least four channels and was defined as technically adequate to diagnose moderate-to-severe OSA [9]. We followed the recommended American Academy of Sleep Medicine (version 2.3) scoring criteria [29,30]. Apnea was defined as the cessation of airflow for at least 10 s, while hypopnea was defined as a reduction in the airflow amplitude or respiratory effort by at least 30%, with an oxygen desaturation value of 3% or greater for at least 10 s. AHI data were derived from the PSG test, while the respiratory event index (REI) was derived from OCST. REI is the term used to represent the frequency of apneas and hypopneas as measured by OCST. For OCST, we generally asked patients to record for two nights due to possible recording issues, a useful strategy for reducing the failure rate of OCST [1]. We had two OCST recordings for most participants, with an interval of 1.40 ± 0.877 days, and we were able to compare ODI and REI results from different nights for these same participants. Results for Figures 2–5 were generated from recordings taken on the first night, while results for Figure 6 incorporated and compared data from both nights. The Japanese versions of the Epworth Sleepiness Scale (ESS) [31,32], Athens Insomnia Scale (AIS) [33,34], and Patient Health Questionnaire (PHQ)-9 [35,36] were used to assess sleepiness, insomnia, and depression, respectively. The ESS has eight items, and patients with an ESS of > 10 were classified as having daytime sleepiness. The AIS has eight items, and patients with an AIS of ≥ 6 or ≥ 10 were classified as having suspected or definite insomnia [37], respectively. The PHQ-9 is a reliable and validated instrument for screening individuals for major depressive disorders. In previous studies, participants with a PHQ-9 ≥ 10 were classified as having depression [35,36].

4.3. Statistical Analysis

Descriptive statistics for clinical characteristics were presented as mean \pm standard deviation. Continuous and categorical variables were evaluated with an unpaired t-test or a chi-square test, respectively. Scatter plots and Bland–Altman plots were generated to compare ODI and AHI or REI. Receiver operating characteristic (ROC) curves were constructed to compare the diagnostic performance of ODI in detecting moderate-to-severe (AHI/REI ≥ 15) or severe (AHI/REI ≥ 30) OSA. Cohen’s kappa was used to analyze the agreement between OSA severities determined by either oximetry or PSG/OCST. A kappa value of 0–0.2 was considered to have essentially no agreement, 0.2–0.4 low agreement, 0.4–0.6 moderate agreement, 0.6–0.8 high agreement, and 0.8–1.0 nearly perfect agreement. Statistical analyses were performed using MedCalc version 19.2.1 (MedCalc Software, Mariakerke, Belgium).

5. Conclusions

Oximetry may be a useful tool for screening patients for moderate-to-severe or severe sleep apnea in large epidemiological studies. However, it may be difficult to set an appropriate threshold to distinguish moderate from severe sleep apnea using oximetry alone.

Author Contributions: Conceptualization, K.I. and H.K.; methodology, H.K.; formal analysis, K.I.; investigation, M.U. and H.K.; resources, H.K.; data curation, M.U. and H.K.; writing—original draft preparation, K.I.; writing—review and editing, H.K.; visualization, H.K.; supervision, H.K.; project administration, H.K.; funding acquisition, H.K. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

AHI	Apnea-hypopnea index
AIS	Athens insomnia scale
AUC	Area under the ROC curve
ESS	Epworth sleepiness scale
OCST	Out-of-center sleep testing
ODI	Oxygen desaturation index
OSA	Obstructive sleep apnea
PHQ	Patient health questionnaire
PSG	Polysomnography
REI	Respiratory event index
ROC	Receiver operating characteristics

References

1. Nakayama-Ashida, Y.; Takegami, M.; Chin, K.; Sumi, K.; Nakamura, T.; Takahashi, K.I.; Wakamura, T.; Horita, S.; Oka, Y.; Minami, I.; et al. Sleep-disordered breathing in the usual lifestyle setting as detected with home monitoring in a population of working men in Japan. *Sleep* **2008**, *31*, 419–425. [[CrossRef](#)] [[PubMed](#)]
2. Benjafield, A.V.; Ayas, N.T.; Eastwood, P.R.; Heinzer, R.; Ip, M.S.M.; Morrell, M.J.; Nunez, C.M.; Patel, S.R.; Penzel, T.; Pepin, J.L.; et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: A literature-based analysis. *Lancet Respir. Med.* **2019**, *7*, 687–698. [[CrossRef](#)]
3. Harada, Y.; Oga, T.; Chin, K.; Takegami, M.; Takahashi, K.I.; Sumi, K.; Nakamura, T.; Nakayama-Ashida, Y.; Minami, I.; Horita, S.; et al. Differences in relationships among sleep apnoea, glucose level, sleep duration and sleepiness between persons with and without type 2 diabetes. *J. Sleep Res.* **2012**, *21*, 410–418. [[CrossRef](#)] [[PubMed](#)]
4. Harada, Y.; Oga, T.; Chin, K.; Takegami, K.I.; Sumi, K.; Nakamura, Y.; Nakayama-Ashida, Y.; Minami, I.; Horita, S.; Oka, Y.; et al. Effects of the presence of hypertension on the relationship between obstructive sleep apnoea and sleepiness. *J. Sleep Res.* **2011**, *20*, 538–543. [[CrossRef](#)] [[PubMed](#)]
5. Peppard, P.E.; Young, T.; Palta, M.; Skatrud, J. Prospective study of the association between sleep-disordered breathing and hypertension. *N. Engl. J. Med.* **2000**, *342*, 1378–1384. [[CrossRef](#)]
6. Nadeem, R.; Singh, M.; Nida, M.; Waheed, I.; Khan, A.; Ahmed, S.; Naseem, J.; Champeau, D. Effect of obstructive sleep apnea hypopnea syndrome on lipid profile: A meta-regression analysis. *J. Clin. Sleep Med.* **2014**, *10*, 475–489. [[CrossRef](#)]
7. Qian, Y.; Xu, H.; Wang, Y.; Yi, H.; Guan, J.; Yin, S. Obstructive sleep apnea predicts risk of metabolic syndrome independently of obesity: A meta-analysis. *Arch. Med. Sci* **2016**, *12*, 1077–1087. [[CrossRef](#)]
8. Senaratna, C.V.; English, D.R.; Currier, D.; Perret, J.L.; Lowe, A.; Lodge, C.; Russell, M.; Sahabandu, S.; Matheson, M.C.; Hamilton, G.S.; et al. Sleep apnoea in Australian men: Disease burden, co-morbidities, and correlates from the Australian longitudinal study on male health. *BMC Public Health* **2016**, *16*, 1029. [[CrossRef](#)]
9. Kapur, V.K.; Auckley, D.H.; Chowdhuri, S.; Kuhlmann, D.C.; Mehra, R.; Ramar, K.; Harrod, C.G. Clinical practice guideline for diagnostic testing for adult obstructive sleep apnea: An American Academy of Sleep Medicine clinical practice guideline. *J. Clin. Sleep Med.* **2017**, *13*, 479–504. [[CrossRef](#)]
10. Safadi, A.; Etzioni, T.; Fliss, D.; Pillar, G.; Shapira, C. The effect of the transition to home monitoring for the diagnosis of OSAS on test availability, waiting time, patients' satisfaction, and outcome in a large health provider system. *Sleep Disord.* **2014**, *2014*, 418246. [[CrossRef](#)]

11. Rosen, I.M.; Kirsch, D.B.; Chervin, R.D.; Carden, K.A.; Ramar, K.; Aurora, R.N.; Kristo, D.A.; Malhotra, R.K.; Martin, J.L.; Olson, E.J.; et al. Clinical use of a home sleep apnea test: An American Academy of Sleep Medicine position statement. *J. Clin. Sleep Med.* **2017**, *13*, 1205–1207. [[CrossRef](#)] [[PubMed](#)]
12. Uddin, M.B.; Chow, C.M.; Su, S.W. Classification methods to detect sleep apnea in adults based on respiratory and oximetry signals: A systematic review. *Physiol. Meas.* **2018**, *39*, 03TR01. [[CrossRef](#)] [[PubMed](#)]
13. Netzer, N.; Eliasson, A.H.; Netzer, C.; Kristo, D.A. Overnight pulse oximetry for sleep-disordered breathing in adults: A review. *Chest* **2001**, *120*, 625–633. [[CrossRef](#)] [[PubMed](#)]
14. Hang, L.W.; Wang, H.L.; Chen, J.H.; Hsu, J.C.; Lin, H.H.; Chung, W.S.; Chun, Y.F. Validation of overnight oximetry to diagnose patients with moderate to severe obstructive sleep apnea. *BMC Pulm. Med.* **2015**, *15*, 24. [[CrossRef](#)]
15. Carmes, K.; Kempfner, L.; Sorensen, H.B.D.; Jennum, P. Novel method for detection of sleep apnoea using respiration signals. *Conf. Proc. IEEE Eng. Med. Biol. Soc.* **2014**, *2014*, 258–261. [[CrossRef](#)]
16. Levendowski, D.J.; Hamilton, G.S.; St.Louis, E.K.; Penzel, T.; Dawson, D.; Westbrook, P.R. A comparison between auto-scored apnea-hypopnea index and oxygen desaturation index in the characterization of positional obstructive sleep apnea. *Nat. Sci. Sleep* **2019**, *11*, 69–78. [[CrossRef](#)] [[PubMed](#)]
17. Ernst, G.; Bosio, M.; Salvado, A.; Dibur, E.; Nigro, C.; Borsini, E. Difference between apnea-hypopnea index (AHI) and oxygen desaturation index (ODI): Proportional increase associated with degree of obesity. *Sleep Breath.* **2016**, *20*, 1175–1183. [[CrossRef](#)]
18. Lin, S.H.; Branson, C.; Leung, J.; Park, L.; Doshi, N.; Auerbach, S.H. Oximetry as an accurate tool for identifying moderate to severe sleep apnea in patients with acute stroke. *J. Clin. Sleep Med.* **2018**, *14*, 2065–2073. [[CrossRef](#)]
19. Ling, I.T.; James, A.L.; Hillman, D.R. Interrelationships between body mass, oxygen desaturation, and apnea-hypopnea indices in a sleep clinic population. *Sleep* **2012**, *35*, 89–96. [[CrossRef](#)]
20. Oeverland, B.; Skatvedt, O.; Kvarner, K.J.; Akre, H. Pulse oximetry: Sufficient to diagnose severe sleep apnea. *Sleep Med.* **2002**, *3*, 133–138. [[CrossRef](#)]
21. Álvarez, D.; Hornero, R.; García, M.; del Campo, F.; Zamarrón, C. Improving diagnostic ability of blood oxygen saturation from overnight pulse oximetry in obstructive sleep apnea detection by means of central tendency measure. *Artif. Intell. Med.* **2007**, *41*, 13–24. [[CrossRef](#)]
22. Gumb, T.; Twumasi, A.; Alimokhtari, S.; Perez, A.; Black, K.; Rapoport, D.M.; Sunderram, J.; Ayappa, I. Comparison of two home sleep testing devices with different strategies for diagnosis of OSA. *Sleep Breath.* **2018**, *22*, 139–147. [[CrossRef](#)] [[PubMed](#)]
23. Golpe, R.; Jiménez, A.; Carpizo, R.; Cifrian, J.M. Utility of home oximetry as a screening test for patients with moderate to severe symptoms of obstructive sleep apnea. *Sleep* **1999**, *22*, 932–937. [[CrossRef](#)] [[PubMed](#)]
24. Chu, G.; Suthers, B.; Moore, L.; Paech, G.M.; Hensley, M.J.; McDonald, V.M.; Choi, P. Risk factors of sleep-disordered breathing in haemodialysis patients. *PLoS ONE* **2019**, *14*, e0220932. [[CrossRef](#)]
25. Matsumoto, T.; Murase, K.; Tabara, Y.; Minami, T.; Kanai, O.; Takeyama, H.; Takahashi, N.; Hamada, S.; Tanizawa, K.; Wakamura, T.; et al. Sleep disordered breathing and metabolic comorbidities across gender and menopausal status in East Asians; the Nagahama Study. *Eur. Respir. J.* **2020**, *56*, 1902251. [[CrossRef](#)]
26. Collop, N.A.; Tracy, S.L.; Kapur, V.; Mehra, R.; Kuhlmann, D.; Fleishman, S.A.; Ojile, J.M. Obstructive sleep apnea devices for out-of-center (OOC) testing: Technology evaluation. *J. Clin. Sleep Med.* **2011**, *7*, 531–548. [[CrossRef](#)] [[PubMed](#)]
27. Behar, J.A.; Palmius, N.; Li, Q.; Garbuio, S.; Rizzatti, F.P.G.; Bittencourt, L.; Tufik, S.; Clifford, G.D. Feasibility of single channel oximetry for mass screening of obstructive sleep apnea. *EClinicalMedicine* **2019**, *11*, 81–88. [[CrossRef](#)]
28. Shiga Prefectural Branch of Japan Health Insurance Association. Data Health Plans of Shiga Prefectural Branch. 2018. Available online: <https://www.kyoukaikenpo.or.jp/~{}{/media/Files/shiga/hyougikai/h28-no04/h28-4-sankou.pdf>. (accessed on 28 July 2020).
29. Berry, R.B.; Brooks, R.; Gamaldo, C.E.; Harding, S.M.; Lloyd, R.M.; Marcus, C.L.; Vaughn, B.V. *The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications, Version 2.3.*; American Academy of Sleep Medicine: Darien, IL, USA, 2016.
30. Kadotani, H. Localization of international standards. *Sleep Biol. Rhythm.* **2020**, *18*, 159. [[CrossRef](#)]
31. Johns, M.W. A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep* **1991**, *14*, 540–545. [[CrossRef](#)]

32. Takegami, M.; Suzukamo, Y.; Wakita, T.; Noguchi, H.; Chin, K.; Kadotani, H.; Inoue, Y.; Oka, Y.; Nakamura, T.; Green, J.; et al. Development of a Japanese version of the Epworth Sleepiness Scale (JESS) based on item response theory. *Sleep Med.* **2009**, *10*, 556–565. [[CrossRef](#)]
33. Soldatos, C.R.; Dikeos, D.G.; Paparrigopoulos, T.J. Athens Insomnia Scale: Validation of an instrument based on ICD-10 criteria. *J. Psychosom. Res.* **2000**, *48*, 555–560. [[CrossRef](#)]
34. Okajima, I.; Nakajima, S.; Kobayashi, M.; Inoue, Y. Development and validation of the Japanese version of the Athens Insomnia Scale. *Psychiatry Clin. Neurosci.* **2013**, *67*, 420–425. [[CrossRef](#)] [[PubMed](#)]
35. Kroenke, K.; Spitzer, R.L.; Williams, J.B.W. The PHQ-9: Validity of a brief depression severity measure. *J. Gen. Intern. Med.* **2001**, *16*, 606–613. [[CrossRef](#)] [[PubMed](#)]
36. Gilbody, S.; Richards, D.; Brealey, S.; Hewitt, C. Screening for depression in medical settings with the Patient Health Questionnaire (PHQ): A diagnostic meta-analysis. *J. Gen. Intern. Med.* **2007**, *22*, 1596–1602. [[CrossRef](#)] [[PubMed](#)]
37. Takami, M.; Kadotani, H.; Nisikawa, K.; Sumi, Y.; Nakabayashi, T.; Fujii, Y.; Matsuo, M.; Yamada, N.; NinJaSleep Study Group. Quality of life, depression, and productivity of city government employees in Japan: A comparison study using the Athens Insomnia Scale and Insomnia Severity Index. *Sleep Sci. Pract.* **2018**, *2*, 1–8. [[CrossRef](#)]



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