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ORIGINAL ARTICLE

Comparison of a home sleep test with in-laboratory polysomnography in the diagnosis of obstructive sleep apnea syndrome

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Abstract

Background: In-laboratory, polysomnography (PSG) is the gold standard for diagnosing obstructive sleep apnea syndrome (OSAS). However, the long waiting list and sleeping at a hospital make patients hesitate to undergo the examination, thereby delaying diagnosis. During coronavirus disease 2019 (COVID-19) pandemic, sleep labs are almost closed, and the delay is worsening. The home sleep test (HST) enables subjects to be tested at home, a familiar and comfortable environment, without a long waiting list. This study assessed the accuracy of a type III HST in diagnosing OSAS in the Taiwanese population and identified factors affecting the diagnostic accuracy.

Methods: This retrospective study included 67 patients with clinically suspected OSAS. All patients were allocated to receive both PSG and the HST. The apnea-hypopnea index (AHI) measured through PSG was used as the standard. The sensitivity, specificity, and accuracy of the HST in diagnosing and evaluating the severity of OSAS were analyzed.

Results: Among the 67 patients, no significant difference was noted in the average AHI values obtained using PSG and the HST ($p = 0.103$). The AHI obtained from HST was significantly correlated with that obtained from PSG, with the correlation coefficient being 0.779 ($p < 0.001$). The sensitivity, specificity, and accuracy of the HST in diagnosing OSAS were 94.9%, 62.5%, and 91.0%, respectively, and 80.0%, 74.1%, and 77.6% in diagnosing moderate to severe OSAS. Furthermore, the difference in AHIs measured using the two tests were positively correlated with the severity of sleep apnea.

Conclusion: The HST used in preliminary screening of patients with suspected OSAS achieved an accuracy of >90%. For patients with moderate to severe OSAS, the accuracy was below 80%. Therefore, for patients who receive an OSAS diagnosis through the HST, arrangement of PSG is recommended for determining the severity of the OSAS and giving proper treatment.

Keywords: COVID-19; Pandemic; Polysomnography

1. INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is the most common sleep disorder. According to the Wisconsin Sleep Cohort Study conducted in 2013, 33.9% of men and 17.4% of women aged 30–70 years in the United States have at least mild OSAS (apnea-hypopnea index [AHI] ≥ 5), whereas ≈13% of men and 6% of women have moderate to severe OSAS (AHI ≥ 15).[1] In 2015, Franklin and Lindbergh[2] reviewed 11 studies published between 1993 and 2013 on the prevalence of OSAS and estimated that this prevalence was 22% in men and 17% in women. Benjafield et al[3] estimated that nearly 1 billion adults aged 30 to 69 years worldwide have OSAS, with the prevalence exceeding 50% in some countries. They also estimated that the prevalence of OSAS in people aged 30 to 69 years in Taiwan (AHI > 5) was approximately 23.6%. In 2008, Chuang et al[4] indicated that the prevalence of OSAS in Taiwan was approximately 2.6%, with the separate values of 3.4% for men and 1.9% for women. This prevalence is considerably lower than that reported in other related studies, which may indicate that many OSAS cases may be undiagnosed in Taiwan. Studies have suggested that a high percentage of OSAS cases remain undiagnosed and untreated.[5,6]

OSAS can affect the quality of life, reduce work efficiency, and increase the risk of traffic accidents. It can also cause cardiovascular and cerebrovascular problems, leading to increased risks of heart failure, coronary artery disease, stroke, and diabetes.[2,7] Therefore, early diagnosis and treatment are necessary. The gold standard for diagnosing OSAS is in-laboratory polysomnography (PSG), which requires the patient to sleep in a hospital's sleep laboratory. However, due to the high prevalence of the disease, patients often need to wait for several months for examination. In addition, sleeping in the sleep laboratory of a hospital at night is inconvenient. Consequently, many patients hesitate to undergo the examination, which may delay diagnosis, leading to more

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severe problems. To overcome these challenges, the home sleep test (HST) has been developed. Compared with PSG, the HST has the following advantages (Table 1): (1) the ability to test patients in their homes within their natural sleeping environment, (2) ease of use and less interference, (3) low cost, and (4) a short waiting time. Currently, there are 60 sleep centers in Taiwan. The average waiting time for PSG is usually several months and sometimes even up to a year. For HSTs, the waiting time is usually as short as less than two weeks. However, the HST has diagnostic limitations and cannot be used to diagnose central sleep apnea, hypersomnolence disorder, or sleep-related movement disorders.

Traditionally, the American Academy of Sleep Medicine (AASM) has classified sleep testing into four types based on the availability of sleep technicians, type, and number of parameters detected.[8] A type I sleep test is performed in a sleep center with the assistance of a sleep technician and usually records at least seven parameters, namely an electroencephalogram, an electrooculogram, a chin electromyogram, an electrocardiogram, airflow, respiratory effort, and blood oxygen saturation. Type II sleep testing differs from type I testing in that type II testing is performed in the subject's home without the assistance of a sleep technician. Testing types III and IV are also performed in the subject's home, but in type III testing, at least four parameters are recorded, whereas in type IV testing, only up to two parameters are recorded. This study compared the diagnostic efficiency of type III HST and PSG for OSAS in a Taiwanese population. Moreover, we investigated whether a type III HST can replace PSG in the early diagnosis of OSAS and identified the factors affecting whether a home-based HST is suitable for patients.

During the coronavirus disease 2019 (COVID-19) pandemic, several surveys revealed that the vast majority of in-laboratory sleep studies were closed.[9,10] Therefore, employing HST to evaluate OSAS patients in COVID-19 era plays a much important role than before.

2. METHODS

This study was approved by the Institutional Review Board (IRB) of Kaohsiung Veterans General Hospital, Taiwan (IRB: KSVGH20-CT2-02). The requirement for informed consent was waived because all identifying information was removed from the data set before analysis. This retrospective study included 67 patients from the Kaohsiung Veterans General Hospital (KSVGH) with clinically suspected OSAS between October 2018 and November 2019. The patients who had received a diagnosis through International Classification of Diseases, ninth revision, diagnostic code 786.09 (other respiratory system abnormalities) or 780.51 (insomnia with sleep apnea, unclear) and who received both PSG and an HST were included in the study. All patients underwent a type III HST at home and were subsequently tested with PSG in our hospital. The time interval between the type III HST and PSG was less than three months. The following patients were excluded: (1) patients younger than 20 years of age (2) patients with a diagnosis of central sleep apnea, and (3) vulnerable patients as defined by the IRB. Vulnerable patients are those who require greater protection than normal against the potential risks of participating in research. The vulnerable populations include but not limited to children, minors, pregnant women, prisoners, employees, critically ill, unconscious, disabled individuals, elderly people, ethnic minorities, international research, and economically and educationally disadvantaged.[11]

Subjective data were collected using the Epworth Sleepiness Scale (ESS), snoring, tiredness, observed apnea, high BP, BMI, age, neck circumference, and male gender (STOP-BANG) questionnaire, and Berlin questionnaire. We used Somté PSG (Compumedics Inc., Australia) as the PSG apparatus and ApneaLink Air (ResMed Inc., Australia) as the type III HST apparatus, which could record five parameters, namely respiratory effort, pulse, oxygen saturation, nasal flow, and snoring. The parameters recorded in PSG and the HST in this study were shown in Table 2. PSG was performed in the sleep center at KSVGH with the assistance of an attendant. After receiving instructions from a technologist before the type III HST, each patient wore an HST device at their home for one night. The AHI values obtained from the PSG and HST for the same patient were noted. The differences between two values obtained from same persons were compared using the paired-samples t test, and the correlation between the two values was analyzed using linear regression. With the PSG results as the standard, the sensitivity, specificity, and accuracy of the HST in diagnosing OSAS and assessing the severity of OSAS were analyzed through cross-tabulation. The standardized coefficient (β) of independent variables was used to compare the strength of the effect of each individual independent variable with that of each dependent variable. Statistical analysis was performed using SPSS (SPSS Inc., Chicago, IL). A $p < 0.05$ was considered statistically significant.

3. RESULTS

We analyzed 67 patients with suspected OSAS—54 men (80%) and 13 women (20%). All of them had snoring and sleep apnea witnessed by family or friend. Their mean age was 47.9 ± 12.7 years, and their mean body mass index (BMI) was 27.4 ± 4.7 kg/m^2. The average score in the ESS questionnaire was 9.6 ± 4.9, and that in the STOP-BANG questionnaire was 4.1 ± 1.3. On the basis of the Berlin questionnaire scores, 42 participants were classified as the high-risk group for sleep apnea, and 13 were classified as the low-risk group. The average AHI measured using PSG was 26.5 ± 20.8, and that measured using the HST was 23.8 ± 19.5 (Table 3). The paired-samples t test revealed no significant difference between the two AHI values measured using PSG and the HST for the

Table 1

Comparison of the characteristics of PSG and the HST

	PSG	HST
Clinical application	The gold standard for the diagnosis of obstructive sleep apnea, as well as other non-obstructive sleep disorders	Can only be applied to obstructive sleep apnea
Cost	High	Low
Convenience	Low	Great
Sleep quality	Poor	Good
Waiting time	Long	Short

HST = home sleep test; PSG = polysomnography.

Table 2

Parameters measured using PSG and a type III HST (ApneaLink)

	PSG	ApneaLink™
Respiratory Sound	+	+
Oronasal flow	+	+ (nasal flow)
Pulse oximetry	+	+
Respiratory effort	+	+
EEG	+	–
EOG	+	–
EKG	+	–
Leg motion detector	+	–
Body position	+	+

EEG = electroencephalogram; EKG = electrocardiogram; EOG = electrooculogram; HST = home sleep test; PSG = polysomnography.

Table 3

Clinical characteristics of patients with suspected OSAS receiving PSG and an HST

Items	Mean ±SD or N (%)	Range
Age, y	47.9 ± 12.7	21-85
Gender (male/female)	54 (80%)/13(20%)	
BMI, kg/m^2	27.4 ± 4.7	18.4-46.2
ESS (scores)	9.6 ± 4.9	1-22
STOP-Bang (scores)	4.1 ± 1.3	1-7
Berlin questionnaire(high/low risk)	42/13	
AHI(PSG)	26.5 ± 20.8	0.5-81.9
AHI(HST)	23.8 ± 19.5	1.0-85.5

AHI = apnea-hypopnea index; AHI(HST) = AHI measured by HST; AHI(PSG) = AHI measured by PSG; BMI = body mass index; ESS = Epworth Sleepiness Scale; HST = home sleep test; OSAS = obstructive sleep apnea syndrome; PSG = polysomnography. STOP-Bang = STOP-BANG questionnaire.

same patient (p = 0.103). Linear regression analysis revealed a significant correlation between the two AHI values obtained using PSG and the HST, with the correlation coefficient being 0.779 (p < 0.001). The following linear equation was obtained: AHI(PSG) = AHI(HST) × 0.832 + 6.718. After subtracting the mean and dividing by the SD for each observation, standardized regression coefficient (β) as 0.779 is obtained. And the linear equation could be presented as AHI (PSG) = AHI (HST) × 0.779, which allows the predictive model to pass through the original point (R^2 = 0.607; Fig. 1).

The AHI measured using PSG was used as the standard for diagnosing OSAS. The sensitivity, specificity, and accuracy of the HST were 94.9%, 62.5%, and 91.0%, respectively, in diagnosing OSAS (AHI ≥ 5) and 80.0%, 74.1%, and 77.6%, respectively, in diagnosing moderate to severe OSAS (AHI ≥15) (Table 4). The difference in AHI values measured using the two tests was positively correlated with the severity of sleep apnea.

We used standardized beta coefficients to analyze the relationship between each variable and the absolute value of the difference between the two AHI values (Table 5). The variables in the analysis were age, sex, BMI, ESS score, ESS score ≥ 10, STOP-BANG score, STOP-BANG score ≥ 3, Berlin questionnaire classification of high risk, degree of OSAS severity, and moderate to severe OSAS. The analysis results revealed that the absolute value of the difference in AHI was not significantly correlated with the clinical factors such as sex, age, BMI, ESS score ≥ 10, STOP-BANG score ≥ 3, or Berlin questionnaire classification of high risk.

The absolute value of the difference in the AHI was positively correlated with the severity measured using the HST (p = 0.004). In addition, if the patient was diagnosed as having moderate to severe OSAS by using the HST (AHI ≥ 15), the difference in the AHI measured using the HST and PSG was more significant (p = 0.004).

4. DISCUSSION

Despite its high prevalence of OSAS, Taiwan has only approximately 60 sleep centers with limited beds. If OSAS is suspected clinically, the waiting time for receiving PSG is usually several months. Consequently, many patients with potential OSAS delay or even hesitate to undergo an examination, which may lead to a delay in diagnosis and thus ultimately to cardiovascular disease, affecting the quality of life and work performance. To overcome this challenge, the readily available HST can be used as a replacement for PSG.

In 2007, the AASM Task Force developed guidelines for the use of portable monitoring (PM) systems in the diagnosis of OSAS;

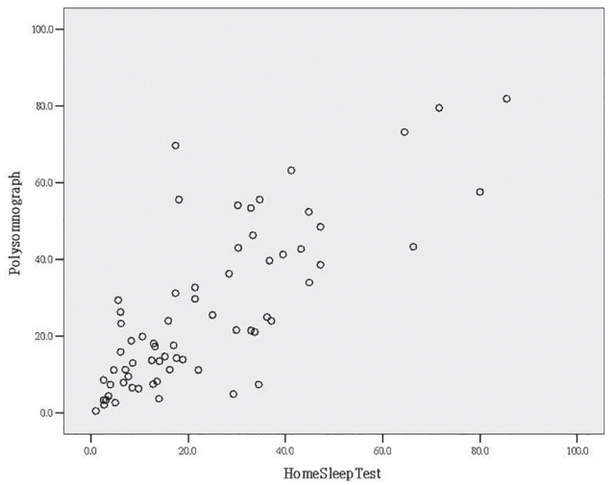

Fig. 1 Apnea-hypopnea index (AHI) values obtained using polysomnography (PSG) and the home sleep test (HST) were highly correlated; the linear equation was AHI(PSG) = AHI(HST) × 0.779 (R^2 = 0.607).

these guidelines recommended that for a comprehensive sleep evaluation, the HST is a suitable alternative to PSG in patients with a high pretest probability of moderate to severe OSAS without significant comorbid medical conditions.[12] PM may be considered if PSG is impossible due to immobility or critical illness and may also be used to monitor a patient's response to non–continuous positive airway pressure treatments, including oral appliances, upper airway surgery, and weight loss. This guideline, updated in 2017, indicates that the HST can be used in the diagnosis of OSAS in adult patients with suspected moderate to severe OSAS if no nonobstructive sleep-disordered breathing or nonrespiratory sleep disorder(s) is suspected.[13] Therefore, an increasing number of studies have assessed the accuracy of the HST in diagnosing OSAS.

The HST can take four forms. A type II HST differs from PSG in that it is conducted at home and does not involve monitoring by a sleep technician. In theory, a type II HST is the most suitable alternative to PSG in the diagnosis of OSAS. However, a study highlighted that nearly one-third of individuals undergoing a type II HST might not complete the examination due to difficulty in operating the equipment.[14] The equipment used in a type III HST has fewer channels, is smaller and lighter, is more convenient to carry, and is easier to operate than that used in a type II HST. Therefore, patients are more receptive to completing a type III HST. Other study also found that because the HST involves the subjects sleeping in their own home, higher sleep efficiency (82% vs 75%, p < 0.001) and longer total sleep time (412 vs 365 min, p < 0.001) are achieved.[15] In addition, a type III HST has fewer restraints, which reduces the impact of sleeping posture on the AHI.

The 2017 guidelines for OSAS diagnosis reported seven studies that compared the performance of type III HSAT devices and PSG devices.[16–22] The results revealed that for OSAS (AHI ≥ 5) diagnosis in a high-risk population, the HST device had accuracy 84% to 91%, but when AHI ≥ 15, the accuracy of OSAS diagnosis was 65%–91%. Our study demonstrated that the accuracy of the type III HST in diagnosing OSAS (AHI ≥ 5) was 91.0% but that in diagnosing moderate to severe OSAS (AHI ≥ 15) was only 77.6%. The diagnostic accuracy obtained in our study is within the range reported previously. In line with previous studies, our study found that the HST has low accuracy in diagnosing moderate to severe OSAS. Notably, the seven studies included in the 2017 OSAS guidelines mainly investigated non-Asian ethnic groups; three were conducted in America, three were conducted

Table 4

Sensitivity, specificity, and accuracy of the HST in diagnosing OSAS (AHI ≥ 5/h) and moderate to severe OSAS (AHI ≥ 15/h)

AHI	Sensitivity, %	Specificity, %	Positive PV, %	Negative PV, %	Accuracy, %
AHI ≥ 5	94.9	62.5	94.9	62.5	91.0
AHI ≥ 15	80.0	74.1	82.1	71.4	77.6

AHI = apnea/hypopnea index; HST = home sleep test; OSAS = obstructive sleep apnea syndrome; PV = predictive value.

in Europe, and one studied a Japanese ethnic group in Asia.[22] Several studies have shown that the prevalence and severity of OSA in Asian populations have increased compared with those of Caucasians. Anatomical craniofacial characteristics unique to Chinese individuals, such as retrognathia, have been identified as possible risk factors for OSA.[23,24] In addition, previous studies reported that race is related to differences in PSG results. Ong KC and Clerk AA. have demonstrated a higher AHI for a given BMI in Asian cohorts compared to Caucasians.[25] Jonathan et al[26] demonstrate that Chinese individuals with moderate to severe OSA have a unique polysomnographic phenotype characterized by more apneas, longer obstructive events, and less hypoxemia. Postulated mechanisms include differing upper airway anatomy, control of breathing, or lung reserve.

Therefore, more studies are urgently needed to validate the accuracy of the HST in Asian populations. Our results revealed that the type III HST has high diagnostic accuracy in Taiwanese populations.

Studies have shown that scoring variability between technologists, the first night effect, and sleeping posture may be factors affecting the difference in AHI values obtained using an HST versus PSG.[27–29] A Japanese study conducted by Yin et al[22] proposed that factors affecting the accuracy of a type III HST include the length of recording time, sleep posture, and OSAS severity. A short HST recording time is usually not sufficient for evaluating OSAS; moreover, a considerable difference is obtained between AHI values measured using the HST and PSG. They recommend a recording time of at least 6.5 hours of sleep to minimize errors. During a PSG test, the body is more physically restricted, forcing the patient to remain in a supine sleeping position. Studies have shown that during PSG, the supine time is increased by 56% compared with that during normal sleep without PSG equipment.[29] Therefore, PSG may overestimate the severity in some patients with positional OSAS. Yin et al[22] discovered that the severity of OSAS affects the accuracy of the HST. It is reflected by standardized regression coefficient (β) as 0.931 which is greater than 0.[22] In our study, similar trend with a positive β value of 0.779 is noted. We found that the absolute value of the difference between the AHI values measured using the two tests is positively correlated to OSAS severity as measured using the HST. If the OSAS diagnosed using the HST is more severe, the difference in the AHI between the two tests is more significant. This may help to explain why the accuracy of OSAS diagnosis dropped in moderate to severe group. Although Yin's series show the more severe the OSAS (AHI > 50/h), the smaller the difference between the AHI values obtained from the HST and PSG. It is probably owing to some special condition for limited numbers in this group. Ito and Ikeda investigated the accuracy of a type III HST in diagnosing OSAS and found that the more severe the OSAS (AHI > 30), the difference in the AHI between type III HST and PSG may increase.[30] This is also evidence supporting our findings.

Studies have indicated that patients with OSAS who develop COVID-19 may have higher risk of morbidity and mortality than those without OSAS. A Finnish study of 445 patients found that patients with OSAS are at higher risk of hospitalization due to COVID-19.[31] Maas et al[32] also discovered that among patients with COVID-19, OSAS was associated with increased risk of hospitalization and approximately double the risk of respiratory failure. Therefore, patients with OSAS should avoid going to the hospital to prevent contracting COVID-19 in hospital. In addition, during the COVID-19 pandemic, many sleep centers were closed, which made in-laboratory PSG impossible. Patients could use telemedicine for an initial consultation, after which an HST could be used as the preferred method of diagnosis to avoid contact with others. In the United States and India, most patients were evaluated for sleep apnea by using the HST during the COVID-19 pandemic.[10,33] However, the AASM recommends waiting 72 hours between the reuse of HST devices as well as intensive sanitization of devices before and after use.[34,35] Thus, HST may be an alternative to PSG in the noncontact era of the COVID-19 pandemic.

This study has limitations. First, the sample size was not large. Second, the type III HST and PSG were not conducted together on the same night. It is more reasonable to arrange PSG and

Table 5

Relationship between the absolute value of the difference between the AHIs measured using HST and PSG and other variables

Variables	Crude regression coefficient (B)	SE	Standardized coefficient (β)	*p*
Age, y	–0.040	0.094	–0.053	0.673
Gender (female)	–0.380	3.017	–0.126	0.900
BMI	0.238	0.252	0.116	0.348
ESS (scores)	0.226	0.291	0.111	0.441
ESS (scores≧10)	2.768	2.806	0.141	0.329
STOP-BANG (scores)	0.417	1.057	0.056	0.695
STOP-BANG (scores≧3)	6.621	5.060	0.182	0.197
Berlin (high-risk)	0.284	3.156	0.012	0.929
OSAS degree (HST)[a]	3.220	1.075	0.348	0.004*
OSAS mod-severe (HST)[b]	6.697	2.272	0.343	0.004*

AHI = apnea-hypopnea index; BMI = body mass index; ESS = Epworth Sleepiness Scale; HST = home sleep test; OSAS = obstructive sleep apnea syndrome; PSG = polysomnography STOP-BANG = STOP-BANG questionnaire.

[a]OSAS degree (HST): According to the HST results, the severity of OSAS is divided into four degrees: none, mild, moderate, and severe.

[b]OSAS mod-severe (HST): moderate to severe OSAS diagnosed by HST.

*$p < 0.05$.

HST on the same night to reduce the different effects of sleep posture, sleep efficiency, sleep depth, and the physical condition of the subjects on the recording when using the two methods. Third, each participant may have had a different level of familiarity with the operation of the type III HST equipment. Fourth, this is a retrospective study. Due to the use of previously registered data, there may be missing data. Therefore, additional prospective studies with more participants are needed to verify the diagnostic accuracy of a type III HST.

In conclusion, HST can be used for preliminary screening of patients with suspected OSAS, with its accuracy found to be >90%. For patients with moderate to severe OSAS, the accuracy was close to 80%. Therefore, for patients with OSAS diagnosed using an HST, the arrangement of PSG is recommended to determine OSAS severity and give proper treatment.

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