ORIGINAL ARTICLE

Comparing in-lab full polysomnography for diagnosing sleep apnea in children to home sleep apnea tests (HSAT) with an online video attending technician

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Abstract

The main study aim was to compare the validity of children sleep apnea data obtained from standard polysomnography (PSG) to a home sleep apnea test (HSAT) accompanied by an attending online video technician. Our study population was comprised of 100 children, 54 boys and 46 girls, ages 3–11 (average age 5.2, SD 1.2) assigned randomly either to in-lab full PSG or to a HSAT with real-time, online technical support to rule out obstructive sleep apnea (OSA). A t test comparison did not yield significant differences between data obtained from the in-lab PSG and HSAT with real-time, online, technical support for any of the following measures: Apnea–Hypopnea Index, Oxygen desaturation Index, baseline O2, or minimum O2 parameters. However, a significant difference was found for time in bed and total sleep time, which was significantly longer in the HAST. Online HSAT can provide a safe, convenient and a reliable way to perform sleep studies in young children for diagnosing OSA in their familiar home environment.

Keywords Child · Polysomnography · HAST · OSA · Online

Introduction

Obstructive Sleep Apnea (OSA) in children is a recognized childhood health disorder with an estimated prevalence ranging from 1 to 5% [1, 2]. The clinical manifestations usually include snoring, disrupted sleep, restlessness, sweating and salivation during sleep, and excessive daytime sleepiness or hyperactivity and irritation [3, 4]. OSA in children is characterized by irregular, partial, or complete obstruction of the upper airways during sleep, with the disruption of normal ventilation and sleep patterns caused usually by hypertrophy of the adenoids and tonsils. Risk factors include obesity, neuromuscular disease, Down syndrome, and micrognathia [3, 5]. Continuous quality sleep is essential for growth, development, good health, and well-being. Left untreated, OSA can lead to adverse health, developmental, and behavioral outcomes [5–7]. Considering the high prevalence of OSA and its deleterious consequences, access to early and accurate diagnosis is critical.

Overnight, in-laboratory, technician-attended polysomnography (PSG) is considered the gold standard for diagnosing OSA in children [2, 8]. PSG provides objective measures of sleep quality, sleep architecture, respiratory parameters, and an index of the breathing disturbance during sleep. The fact that PSG can measure not only AHI but also more parameters make it useful for diagnosing sleep disorders in children, such as sleep abnormalities, electromyographic abnormalities, and the presence of periodic limb movements. However, the in-lab PSG test has some distinct limitations and disadvantages, especially for diagnosing OSA in children. In particular, in-lab PSG does not simulate the child's sleep in his or her familiar home environment. Moreover, placement of multiple sensors and electrodes by an unfamiliar technician in a strange room and bed can be stressful to young children and many times impairs not only their cooperation but also the quality of sleep that the PSG test purports to measure [9]. In addition, hospital-based diagnostic testing limits access to families living far from centrally located medical diagnostic services.

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Beyond these difficulties, the coronavirus (COVID-19) pandemic has reduced access to in-lab PSG more generally, as healthcare providers paused many non-urgent health care services to decrease the risk of infection, especially in hospital environments. This led to near-complete closure of sleep laboratories and clinics during lockdowns around the world. As a result, concerns about lab-based sleep studies now include not only questions of their efficacy, but also of their safety. As a result, the Home Sleep Apnea Test (HSAT) for children is increasingly considered as an alternative to in-lab PSG.

In contrast to adults, where home sleep tests for diagnosis of OSA is the common practice, the clinical use of HSAT in children is not well-established. In particular, there are few studies comparing the effectiveness of HSAT to PSG for diagnosing OSA in children. This shortcoming is significant, as the use of HSAT has the potential to improve the validity of the sleep study while reducing possible exposure to infectious diseases during overnight hospital stays. In addition, making HSAT more widely available can increase access to needed sleep studies for children.

The 2017 American Academy of Sleep Medicine (AASM) Position Paper summarized four published articles focusing on the technical feasibility of HSAT for evaluating OSA in children. The paper concluded that the validity of the home test depends on the training of the person who places the sensors, and is reduced when the sensors were placed by untrained caregivers instead of trained professionals [8].

To assess the validity of data obtained from HSAT, this study tested the impact of providing home caregivers with prior training as well as the support, in real time, of an attending online video technician on the night of the sleep study. The technician guided them set up the system, place the sensors, and then monitored the child throughout the night using a web camera. Comparing the data obtained from these assisted home sleep studies to those obtained in standard PSG studies, we hypothesized that HSAT with attending online technician can provide valid and reliable way for diagnosis sleep apnea in children.

Methods

Participants

100 children, 54 boys and 46 girls, ages 3–11 (average age 5.2, SD 1.2) assigned randomly either to in-lab full polysomnography or to a home sleep apnea test (HSAT). All children were referred to a sleep study to rule out sleep apnea.

Polysomnography

For in-lab full polysomnography we used a standard in-lab Somnoscreen–PSG-type sleeping test device (Somnomedics, Germany). Sleep channels included: electroencephalography (EEG), electro-oculography (EOG), leg and chin electromyography (EMG), nasal flow, chest and diaphragm breathing, snoring, electrocardiography (EKG), heart rate, blood oxygen saturation, body position, and video.

HSAT

For the home sleep apnea test (HSAT) we used a Somnotouch home sleep testing system (Somnomedics, Germany). Sleep channels included: nasal flow, chest and diaphragm breathing, snoring, heart rate, blood oxygen saturation, activity, body position, and online video recording using a Xiaomi 360 web-camera and portable Wi-Fi card.

Procedure

In-lab PSG

The sleep testing room was a standard test room at the Sleep Medicine Research Center at Assuta Medical Center. The child and his or her parents were invited to the sleep center at 8:00 PM. A skilled and trained technician interviewed the parents about the medical history of the child and then connected the child to the full PSG system in the sleep lab. The technician monitored the child's sleep throughout the night from the control center in the sleep lab. The next morning, the parents completed a standard satisfaction questionnaire. Sleep data were analyzed by a skilled and trained sleep technician in accordance with the AASM guidelines (AASM 2007). We calculated continuity and architecture sleep parameters in addition to breathing and oximetry parameters, including the number of apnea and hypopnea, apnea–hypopnea index (AHI), baseline and minimum saturation, the number of desaturations, the percentage of sleep time with O_2 levels below 90% saturation, and the percentage of time spent snoring.

HSAT

The parents came without the child to the sleep center at Assuta Medical Center on the evening of the sleep study to meet a professional sleep technician for 20–30 min. During the meeting, the technician reviewed the child's medical history and then taught the parents how to set up the system for conducting the home sleep study. After practicing what they learned, the parents returned home with the home sleep test

system, including a digital video camera. Using real-time video, the technician guided the parents at home, while they set up the system and placed the sensors on their child.

After the parents completed the setup, the technician monitored the child's sleep throughout the night using the digital web camera. If there were any technical issues, such as a problem with the attachment of a sensor, the technician telephoned the parents and guided them as they made necessary corrections. It is important to note that the online observation of the technician is not only to maintain the accuracy of the recording, but also to detect sleep symptoms, such as snoring, body movement, awakening, paradoxical breathing and cervical hyperextension in apnea children. After the child woke up the next morning, the parents removed the sleep system and returned it to the sleep center for analysis. The parents were asked to complete a satisfaction questionnaire similar to that filled out by parents after PSG.

Sleep studies were included in data analysis if at least 70% of the information collected during the study was valid. For the HSAT studies, a professional scoring technician calculated the total sleep time (TST), time in bed (TIB), sleep efficiency (SE), number of apnea and hypopnea, apnea–hypopnea index (AHI), baseline and minimum saturation, the number of desaturations, the percentage of time below 90% saturation, and the percentage of time spent snoring.

Results

T tests for independent samples using SPPS (Ver.24) found no significant differences in the demographic profiles of the children in the PSG and HSAT groups (gender and age), in the success ratio, or in the OSA diagnosis between the sleep studies conducted with in-lab PSG and HSAT (Table 1).

Table 2 presents the Apnea–Hypopnea Index (AHI), Oximetry Disorder Index (ODI), Baseline blood saturation (Baseline O_2), minimum blood saturation (minimum O_2), percentage time of blood saturation below 90% (TIB90%), time in bed in minutes (TIB), and total sleep time (TST). Again, t test comparisons found no significant differences between the in-lab PSG and HAST in any of these parameters with the exception of one: time in bed (TIB) and total

Table 1 Demographic, success ratio, and the percent diagnosed with OSA: in-lab PSG vs. HSAT

	In-lab PSG	HSAT	p value
Gender (M/F)	23/27	27/23	N.S
Age (SD)	5.4 (1.2)	5.7 (1.4)	N.S
Success ratio	47/50 (94%)	46/50 (92%)	N.S
OSA diagnosis	28%	31%	N.S

Table 2 Breathing disorder index (AHI), oximetry parameters (ODI), time in bed (TIB) and total sleep time duration (TST)

	In-lab PSG Average (SD)	HAST Average (SD)	p value
AHI	2.7 (2.94)	2.5 (3.51)	N.S.
ODI	2.7 (3.50)	2.4 (2.92)	N.S.
Baseline O_2	96.7 (4.53)	96.9 (4.60)	N.S.
Minimum O_2	90.5 (2.68)	90.1 (3.17)	N.S.
TIB90%	0.03 (0.07)	0.04 (0.07)	N.S.
TIB (min)	400.8 (51.74)	453.2 (48.46)	$p < 0.05$
TST (min)	364.7 (47.10)	416.9 (44.59)	$p < 0.05$

AHI Apnea–Hypopnea Index, *ODI* Oximetry disorder index, *Baseline O_2* Baseline blood saturation, *minimum O_2* minimum blood saturation, *TIB90* percentage time of blood saturation below 90%, *TIB* Time in bed in minutes, *TST* Total sleep time

sleep time (TST) was significantly longer in the HSAT group than in the PSG group.

Survey results indicated that parents were very satisfied with HSAT. In general, the parents gave high scores for the HSAT. They reported that the night reflected a regular night of the child, the setup was friendly and easy, and the technician was available and pleasant (Table 3).

Discussion

This study found no significant differences between data obtained from in-lab full PSG and HAST in all breathing and oximetry parameters for diagnosis of sleep breathing disorder (SBD) in children. It is important to note that the majority of children are referred to sleep laboratories to rule out sleep-related breathing disorders [10], making it important that evaluations focus on child breathing and oximetry channels and video (picture and sound). These results support those from previous studies that found no differences between HAST and in-lab PSG for evaluating OSA in children. For example, Goodwin et.al report no differences in PSG performed within 2 months after HSAT in the respiratory parameters [11]. Jacob et al. performed both a HSAT and PSG within 1 week for diagnosis of OSA in children and revealed good correlation between the two types of studies [12]. Finally, Alonso-Alvarez and colleagues compared simultaneous HSAT to PSG and found no significant differences in total number of apneas or hypopneas between the HSAT and the PSG, or in-laboratory respiratory polygraphy studies [13]. However, these studies did not address the concern that data validity can be affected by the training of those who set up the home sleep system. This study addressed this shortcoming by providing the attendance, supervision, and support of a

Table 3 Parent HSAT satisfaction rankings

Does the sleep study night reflect a regular night of sleep for your child?	4.4/5
How satisfied are you with the technician's service and support?	4.9/5
Did the child fully cooperate with the HAST?	4.6/5
From your point of view, is the HAST complicated to preform?	1.7/5
How satisfied are you from the HAST?	4.6/5

1 very low; *2* low; *3* neutral; *4* high; *5* very high

real time online video technician, yielding reliable data in a setting more favorable to the accurate diagnosis of OSA in children.

The gold standard for the diagnosis of obstructive sleep apnea (OSA) in children is in-laboratory polysomnography (PSG) [2, 8]. One major reason for the preferability of in-lab sleep study is the demand for a skilled technician during the setup phase and to control the sleep study. In our HSAT we used an online technician that was an all-night attendant, using a web video camera, to monitor the sleep study. We find that the parent's guidance before the sleep study and the technician's online video supervision during the setup of the system on the child, and online monitoring during the night, can replace the physical attendance of technician. Additional support for the value of HSAT comes from the fact that there were no significant differences in the failure rate of sleep studies between in-lab full PSG and HSAT with an online technician, indicating that there was no observed advantage for the physical attendance of the technician over the online attendance.

Finally, significantly longer sleep times of the children in HSAT with online support indicates that sleep is better in a child's natural environment, improving the quantity and the validity of data obtained from the home sleep study. This addresses one of the major challenges for in-lab sleep studies for children. Although home sleep apnea testing is widely used in adults to diagnose OSA [14], its use in children has been much more limited, reflecting concerns about its validity for accurately measuring the duration of sleep time. A major challenge with HSAT in children is the difficulty in determining the sleep time without using EEG, EOG, and EMG channels. Actigraphy is suggested as a reasonable technique for measuring sleep due to its high accuracy (85–90%) and sensitivity—the ability to correctly identify sleep (90–97%). Marino et al. concluded that actigraphy is a useful and valid means for estimating total sleep time with some limitation in specificity (the ability to correctly identify alertness) [15]. Yet, specificity has been higher in studies of nocturnal sleep-in children (54–77%) [16]. In our data, the time in bed (TIB) and the total sleep time (TST) were significantly longer in HAST compared to in-lab PSG. In our HAST we calculated time in bed (TIB) and total sleep time (TST) using two more channels besides activity: position and video. We believe that the combination of these three channels is more sensitive and specific than activity only. It needs to be evaluated in more studies.

The HAST system that we used in our study didn't include EEG channels, therefor we couldn't score arousals index and we couldn't score RERA and Hypopnea events which are based on the arousal response. This limitation in our study led us to use the definition of hypopnea to be a decreased of 50–70% in three channels of breathing (flow, thorax and abdomen) followed by oxygen blood desaturation. In addition, since we didn't used EEG channels in the HSAT studies we scored sleep or awake using the position and the activity channels and the online video report of the technician.

A major question with in-lab full polysomnography is, "Does the sleep study in the sleep lab reflect the regular sleep of the child?" From our extensive experience in the Assuta Medical Center sleep lab, some children will experience major problems sleeping in an unfamiliar environment and not in their own bed. Moreover, even when they succeed in falling asleep in the sleep lab, their sleep does not simulate that experienced at home.

The parents' responses to the study questionnaire supports our hypothesis that home sleep studies improve the validity of sleep data collected to diagnose OSA in children. From the parent's answers we observed a high rate of similarity between the HSAT night and a regular night for the child. Moreover, parents report high cooperation from the child for the sleep study at home and high satisfaction from the HSAT in general.

Although the coronavirus pandemic (COVID-19) advanced the use and legitimacy of telemedicine in many areas in medicine, its advantages in diagnosing OSA in children are significant. With the real-time online attendance of a sleep technician, this study showed that home sleep studies can provide data of equal quality to in-lab PSG while improving the quality and duration of a child's sleep, reducing in-hospital exposure to infectious disease, and improving access to diagnostic services for families living far from centrally located medical services.

Taken together, these advantages of HSAT, when supervised by a real-time online technician, suggest that it should be the first choice for diagnosing OSA in children.

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