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Review Article

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Home Sleep Apnea Tests for Obstructive Sleep Apnea: Advances, Clinical Utility, Technological Limitations, and the Arising Role of Artificial Intelligence

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ABSTRACT

Home Sleep Apnea Tests (HSAT) for the home-based assessment of Obstructive Sleep Apnea (OSA) may constitute a significant alternative to polysomnography (PSG), which is conventionally performed in sleep laboratories. In recent years, there has been an increasing demand for out-of-laboratory sleep testing, driven by improved accessibility, enhanced patient comfort, and economic considerations. In this systematic review, we analyze the available scientific literature published between 2015 and 2025 concerning diagnostic devices intended for home-based OSA assessment, including specific device subtypes and software solutions utilizing artificial intelligence (AI) algorithms. The results of the analyzed studies indicate that many HSAT devices demonstrate sensitivity and specificity comparable to standard PSG in the detection of moderate and severe OSA. However, persistent limitations must be emphasized, including restricted measurement capabilities such as the absence of full electroencephalography (EEG), electrocardiography (ECG), electromyography (EMG), or electrooculography (EOG) recordings in certain devices, as well as overall variability in the parameters recorded across different systems. Although HSAT devices are currently unable to fully replace conventional polysomnography, this review highlights their substantial potential in OSA diagnostics, particularly in settings with limited access to sleep laboratories. We also underscore the need for further research in this field and for standardization, especially regarding device specifications and measured parameters.

Key Words: Home sleep tests (HSAT), Obstructive sleep apnea (OSA), Otolaryngology, Sleep medicine, Wearable devices, Artificial intelligence

INTRODUCTION

Obstructive sleep apnea (OSA) is defined as a sleep disorder characterized by recurrent episodes of partial or complete obstruction of the upper airway during sleep, leading to oxygen desaturation, nocturnal arousals, and disruption of sleep architecture. This condition is highly prevalent; it is estimated that globally up to one billion individuals may suffer from mild to moderate OSA, illustrating the magnitude of diagnostic and therapeutic challenges associated with this disease.[1] The most commonly reported symptom among patients with OSA is excessive daytime sleepiness; however, only 15–50% of individuals with OSA in the general population actually report this symptom.[2]

Untreated OSA may result in up to a threefold increased risk of cardiovascular and metabolic diseases, including arterial hypertension, cardiac arrhythmias, cardiovascular disease, and type 2 diabetes mellitus, as well as reduced quality of life and impaired daytime functioning compared with the general population.[2,3] Effective therapeutic interventions recommended for OSA include lifestyle modification (weight reduction and increased physical activity), oropharyngeal muscle exercises, continuous positive airway pressure (CPAP) therapy - shown to have a significant impact, among others, on the prevention of hypertension in patients with OSA, mandibular advancement devices used during sleep, surgical procedures aimed at widening the upper airway through modification of pharyngeal soft tissues or the craniofacial skeleton, and hypoglossal nerve stimulation. Currently, no pharmacological interventions with proven clinical efficacy exist.[2]

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The diagnostic method widely recognized as the gold standard for OSA is in-laboratory polysomnography. This examination simultaneously records multiple channels, including EEG, ECG, EOG, EMG, oxygen saturation, airflow, and respiratory effort. Significant limitations of PSG include its time-consuming nature and the high costs associated with maintaining sleep laboratories, which require specialized equipment and highly trained personnel. These factors substantially limit access to diagnostics for many patients, resulting in a high proportion of undiagnosed OSA cases, estimated to reach up to 90%.[3,4]

In response to these challenges, home-based diagnostic methods (HSAT) have been systematically developed, including peripheral arterial tonometry (PAT)-based measurements and wearable technologies that enable sleep quality assessment in the patient's natural environment. These approaches significantly increase diagnostic accessibility, reduce costs, and positively influence patient comfort and willingness to engage in diagnostic management. An additional advantage of HSAT devices is their potential use in predicting disease severity and monitoring progression or exacerbations.

The aim of this review is to summarize the available scientific literature on home-based devices used in OSA diagnostics and to analyze their clinical utility, with particular emphasis on their technological characteristics, validation outcomes, advantages, and potential limitations.

METHODOLOGY

The review includes literature available in the PubMed and Google Scholar databases, using the following keywords: "home sleep apnea test," "wearable device," "OSA diagnosis," "out-of-centre sleep testing," and "home sleep apnea diagnosis." Publications from 2015 to 2025 were included. Meta-analyses, clinical studies, and systematic reviews addressing home-based diagnostic devices for adult OSA were analyzed. Exclusion criteria included publications with insufficient data and studies published in languages other than English.

Following initial screening of titles and abstracts, full-text analysis of selected publications was conducted. Data were extracted regarding device type (HSAT, PAT, wearable), study population, recorded parameters, outcomes - particularly sensitivity and specificity, correlation with PSG, and limitations identified by the authors. The collected results were subjected to qualitative analysis and are presented in the subsequent subsections.

RESULTS

Based on the analysis of the available literature, two subcategories of HSAT devices were identified: PAT-based devices and wearable technologies. These devices differ in the range of recorded parameters, sensitivity and specificity levels, and degree of clinical validation (Table 1).

Classification and Characteristics of Home sleep apnea tests (HSAT)

Home sleep apnea tests include devices capable of recording a limited set of physiological parameters. The most commonly monitored clinical parameters include heart rate, body position, oxygen saturation, airflow, and chest wall movements. The most technologically advanced devices additionally allow recording of EEG, EMG, ECG, and EOG, bringing them closer to the diagnostic gold standard represented by PSG. Analysis of these parameters, supported by advanced computer software, provides up to 99% agreement with standard polysomnography in OSA screening diagnostics.[3,5]

Peripheral Arterial Tonometry (PAT)-Based HSAT

A specific subtype of HSAT comprises PAT-based devices, which are among the most reliable technologies used in home-based OSA diagnostics. Their mechanism of action relies on analyzing autonomic nervous system responses to apnea episodes, manifested in PAT as changes in pulse wave amplitude. PAT-based diagnostic devices stand out due to ease of use, good signal stability, and a unique capability among HSAT devices to indirectly detect arousals. PAT technology has demonstrated high concordance with conventional polysomnography in both apnea detection and disease severity assessment, supporting its potential utility in OSA diagnostics. An additional advantage is that some of these devices are single-use, which may reduce the risk of pathogen transmission.[1]

Wearable Devices (e.g. bands, smartwatches)

Wearable devices are gaining increasing importance in the sleep monitoring technology market. The latest generation of such devices utilizes sensors including photoplethysmography (PPG), PAT, accelerometers, and heart rate variability sensors. Apnea episodes are primarily identified through analysis of changes in the photoplethysmographic signal during the respiratory cycle.

Wearable devices demonstrate lower accuracy in detecting obstructive events compared with other HSAT devices, mainly due to the absence of airflow and respiratory effort measurements in most systems. Consequently, their diagnostic utility is largely limited to disease monitoring and screening. In the coming years, the role of wearable devices in OSA diagnostics may increase significantly, particularly among patients with moderate to high OSA risk and without significant comorbidities.[6,7]

Artificial Intelligence Algorithms (AI-HSAT)

A promising trend in the HSAT market is the implementation of machine learning algorithms enabling automated analysis of signals acquired from home-based device sensors. This allows efficient evaluation of parameters such as PPG microfluctuations, snoring sounds, body movements, and cardiovascular metrics. Through substantial improvements in respiratory event detection, even in devices with limited channels, AI algorithms may significantly enhance the accuracy and diagnostic utility of home-based technologies.[3,8]

DISCUSSION

The Role of Home-Based OSA Diagnostics

The collected evidence supports the notion that home diagnostic devices play an increasingly important role in OSA diagnostics. Owing to their high concordance with PSG, modern HSAT devices may improve long-term OSA detection rates and accelerate referral to treatment, particularly for patients at high risk of severe disease. This is especially relevant given the rising costs of sleep laboratory maintenance and limited access to PSG.

Technological Limitations

Despite high sensitivity and specificity, many HSAT devices still do not provide EEG, EOG, ECG, or EMG assessments, which significantly limits sleep architecture analysis and underscores the diagnostic superiority of PSG. The utility of PAT-based HSAT may be further limited in patients with hypotensive episodes or a history of vasomotor disorders.

Although wearable devices offer high user convenience, they still do not achieve PSG-level sensitivity and specificity. Moreover, studies emphasize the need for caution when applying HSAT technologies in patients with multimorbidity, particularly those with pulmonary disease, heart failure, or suspected central sleep apnea. In such cases, PSG remains the gold standard for OSA diagnosis.

Future Perspectives

One of the most promising development directions in OSA diagnostics is the integration of AI algorithms with signals obtained from HSAT device channels. This may lead to the occurrence of a new generation of home-based "AI-PSG" systems with accuracy comparable to conventional polysomnography. An increasing number of research also highlights the growing role of acoustic analysis, video monitoring, and cardiological biomarkers in OSA diagnostics.

CONCLUSIONS

Home-based diagnostic devices may constitute a valuable tool in patients with suspected OSA. Modern HSAT devices demonstrate very high effectiveness, comparable to polysomnography, in identifying moderate and severe OSA, particularly in patients without significant comorbidities. Wearable devices are useful as screening tools but currently cannot replace HSAT or PSG in OSA diagnosis. Artificial intelligence algorithms have the potential to substantially enhance the accuracy of home-based diagnostic technologies.

Despite evident technological progress in home-based OSA diagnostics, polysomnography remains indispensable in complex cases and those requiring comprehensive neurophysiological sleep assessment. Further validation studies and standardization of home diagnostic methods are necessary before these technologies can become equivalent to standard polysomnography.

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Table 1: Characteristics of devices used in home OSA diagnostics

Type of device	Recorded parameters	Advantages/ disadvantages
HSAT	Depending on the device: SpO_2, respiratory flow, respiratory effort, actigraphy, ECG, EEG, EMG, EOG, heart rate, and snoring	Good agreement with PSG / In some models the absence of ECG or others parametres limits accuracy.
HSAT based on PAT	PAT, SpO_2, actigraphy	Commonly uses a single finger sensor (increases patient comfort and user acceptability), some divices are disposable (allows contamination-free testing)/ The results may be inconclusive in patients with vasomotor disorders.
Wearable devices	PPG, accelerometry, puls	very high patient comfort/ lower accuracy

Abbreviations: HSAT - home sleep apnea tests, PSG - polysomnography, ECG -electrocardiogram, EEG - electroencephalogram, EOG - electrooculogram, EMG - electromyography, PAT - peripheral arterial tonometry, PPG - photoplethysmography, SpO_2- oximetry