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Utility of home sleep apnea testing in high-risk veterans

Alyssa Cairns[1] · **Kathleen Sarmiento**[2] · **Richard Bogan**[1,3,4]

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Abstract
Purpose Many Veterans Affairs Medical Centers (VAMCs) have implemented home sleep apnea testing (HSAT) in lieu of traditional in-lab testing to establish a timely and cost-sensitive diagnosis of obstructive sleep apnea (OSA). However, concern remains for the sensitivity and specificity of said technology in this population as many veterans are at increased risk for many of the comorbid conditions that can limit the accuracy of HSAT results. Hence, the purpose of this study is to evaluate rate of incongruent outcomes (e.g., negative HSAT results despite high clinical symptomology) as well as differences in study quality metrics and predictors of OSA between veteran sleep patients and general sleep patients being evaluated by a home sleep test.
Methods A random sample of HSAT outcomes from 1500 veterans and 1500 general sleep clinic patients was retrieved from a repository of anonymized HSAT outcomes from 2009 to 2013. General sleep clinic data were from patients referred for home sleep testing from a variety of clinical practices across North America, whereas VAMC patients were tested using a central dissemination process. All patients were tested for OSA using the Apnea Risk and Evaluation System (ARES), an HSAT that simultaneously records airflow, pulse oximetry, snoring, accelerometry, and EEG. Sample differences and rates of comorbidities, HSAT outcomes, predictors of OSA, and pretest OSA risk information were evaluated between groups. The presence of OSA was defined as an apnea-hypopnea index (AHI; using 4% desaturation criterion) of ≥5 and ≥15 events per hour. Sample differences in predictors of OSA were evaluated using logistic multiple regression.
Results Veterans (91.3% male) were more likely to report comorbidities, especially depression, insomnia, hypertension, diabetes, restless legs syndrome (RLS), and use of sleep and pain medications compared to general sleep clinic patients (57.1% male). Despite differences in the rate of medical comorbidities, no differences were observed between groups with regard to rates of positive studies, study integrity indicators, or predictors of OSA. Veterans, on average, had 30 min less recording time compared to those in the general clinic sample ($p < .01$). However, these differences did not impact the amount of the record that was deemed valid nor were veterans more likely to have wakefulness after sleep onset. Predictors of OSA for both groups included advancing age, and increased measures of adiposity (neck circumference and BMI). Mean AHI and respiratory disturbance index (RDI) were statistically similar for both groups and were similar for sleep stage and position.
Conclusions Home sleep apnea testing for the diagnosis of OSA appears to yield similar results for VAMC patients deemed at high risk for OSA as it does with general sleep clinic patients.

Keywords Home sleep test · Veteran · Portable monitor · HSAT

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Introduction

Obstructive sleep apnea syndrome (OSA) is a serious medical condition associated with impairment in nearly all performance, cognitive, emotional, and health-related domains [1] as well as significant increases in direct and indirect medical costs [2]. In the general population, OSA has been estimated to occur in up to 9% of women and 17% of men [3]. However, the prevalence of OSA is estimated to be up to four times higher in veterans as they are older, mostly male, and more likely to engage in lifestyle choices (e.g., use tobacco and alcohol) that increase the risk for sleep-disordered breathing [4–6]. Research has generally suggested that the prevalence of OSA in veterans ranges between 16 and 36%, depending on sample characteristics and how OSA is measured and defined [7–9]. Unfortunately, many Veterans Affairs Medical Centers (VAMCs) are plagued by limited numbers of sleep-trained personnel and in-laboratory diagnostic resources, leading to long wait times and a likely gross underestimation of the true prevalence of OSA in veterans [9].

To improve access to care, many VAMCs have implemented home sleep apnea testing (HSAT) in lieu of traditional in-lab testing to establish the diagnosis of OSA. Home sleep apnea tests are limited channel devices designed to test for the presence of sleep-disordered breathing in the patient's home. Home sleep apnea tests vary in terms of technical methodology and complexity, but typically acquire data on airflow, heart rate, oxygen saturation, and respiratory effort/movement. Home sleep testing can be a reliable, valid alternative for carefully screened patients with a high pretest probability of moderate to severe OSA without underlying complicating sleep/wake disorders or other significant medical conditions that may hinder accurate results [10]. Because veterans are at an increased risk for many of the comorbid conditions currently recommended as exclusion criteria for HSAT eligibility [10] including congestive heart failure [11], pulmonary disease [12], insomnia [5, 13], and restless legs syndrome [5], concern remains for the sensitivity and specificity of HSAT devices in this population. Thus, the purpose of this study is to evaluate differences in rate of incongruent outcomes (e.g., negative HSAT results despite high clinical symptomology), study quality metrics, and predictors of OSA between veterans and general sleep clinic patients being evaluated by home sleep testing.

Methods

Device and definitions

All patients were tested for OSA using the Apnea Risk and Evaluation System (ARES). The ARES model 610 consists of a head-worn Unicorder©, integrated OSA risk assessment, web-based data management platform, study quality review, and physician interpretation. The ARES simultaneously records airflow by nasal pressure via nasal cannula, oxygen saturation (SpO_2) and heart rate by forehead reflectance pulse oximetry, snoring via acoustic microphone, and head position/movement via forehead accelerometry. Electroencephalogram data is recorded from two frontal lobe derivations (FP1 and FP2) which is used to discriminate rapid eye movement (REM) from non-REM sleep [14]. The device's algorithm estimates sleep time using surrogate behavioral indicators of quiescence (non-movement and regularity in nasal flow and/or snoring) [15].

The ARES model 610 and associated autoscoring algorithm has demonstrated adequate sensitivity (.98) and specificity (.84) when compared to simultaneously recorded polysomnography (PSG) using an apnea-hypopnea index (AHI) cutoff of ≥5 events per hour (4% desaturation) [16]. Automated respiratory event analysis scores obstructive events as apnea when flow is reduced by ≥90% for ≥10 s and a hypopnea when flow is reduced by ≥50% for ≥10 s and is associated with a ≥4% desaturation. Flow-limited events are scored when a hypopnea terminates with ≥1 surrogate arousal indicators (abrupt movement, snoring, or pulse rate) and a ≥1% desaturation. Flow limited events scored by the ARES approximate respiratory effort-related arousals (RERAs) acquired via attended PSG. The AHI and RDI are tabulated as the average number of apneas and hypopneas (4%) per hour of valid recording time and the average number of apneas, hypopneas, and flow-limited events per hour of valid recording time, respectively. For the ARES, valid recording time is defined as the length of the sleep period [time in bed] minus periods where the person appears to be awake after sleep onset (gross movements) and periods of poor signal integrity.

Quantification of pretest OSA risk

The ARES pretest screening questionnaire quantifies OSA *risk* (none, low, high) based on self-reported symptoms of OSA (snoring, witnessed apneas, and sleepiness) as well as anthropomorphic risk factors (BMI and neck circumference) and common comorbid medical risk factors (hypertension, diabetes, cardiovascular disease, and stroke) [17]. Data on sleepiness is acquired from the Epworth Sleepiness Scale [18]. The screener also inquires about potentially contraindicated sleep/wake conditions (insomnia, restless legs syndrome [RLS], and narcolepsy) as well as medical conditions that may reduce the accuracy of HSAT (lung disease, insomnia, etc.) The questionnaire has demonstrated adequate sensitivity (.94) and specificity (.79) compared to outcomes from the ARES using an AHI 4% cutoff of ≥5 events per hour in high-risk patients [17].

Data collection

A random sample of 3000 studies was selected from SleepMed's repository of anonymized HSAT test outcomes. A sample of 1500 studies were selected from the general population of ARES studies conducted between 2009 and 2013, which at the time was comprised of over 300K studies. An additional 1500 studies were randomly selected from the ARES veteran database, which at the time was comprised of approximately 3300 studies conducted between 2009 and 2013. All studies from both samples were conducted using the ARES model 610 and were ordered and interpreted by a variety of providers including board-certified sleep specialists, pulmonologists, neurologists, general practitioners, dentists, etc. All data were autoscored by an automated algorithm [16] and human-edited by a registered sleep technologist prior to physician interpretation.

All patients in the VA sample were tested using the *SleepMed at Home* model for home sleep testing. The *SleepMed at Home* model is an alternative to traditional deployment of home sleep testing out of the physician's office, which was the method used for the general clinic sample. In the *SleepMed at Home* model, an ARES is physician-ordered and mailed from a central location to the patient's home for use. Prior to the device being sent to the patient's home, a human coach calls the patient to instruct them on fitting and use as well as answer any questions the patient may have. A coach then recontacts the patient the morning after to evaluate study completeness and subjective testing adequacy. The patient would be instructed to complete an additional night if, for example, the device fell off mid-sleep or if the patient had difficulty sleeping comfortably. It is important to note that approximately 50% of the VA sample had a default order to complete two consecutive nights as opposed to the traditional single night as per standard in the general clinic sample. When more than one study night is collected, study outcomes are automatically aggregated over the number of study nights collected (AHI, RDI, recording time, etc.). The device is then returned to the same central location for data processing and human editing. Upon evaluation from a central IRB, the study was deemed exempt from human subjects review.

Data analyses

After random sampling, the two samples were merged into one smaller database for statistical analyses using SPSS 23.0 (SPSS Inc., Chicago, IL). Descriptive analyses were completed to analyze the shape, central tendency, and dispersion of all variables. Because the samples were unequally comprised of males, all analyses were split by sex. Differences in continuous variables were analyzed using univariate analysis of variance (ANOVA), and differences between nominal or dichotomous variables were analyzed using chi-square (χ^2). Logistic multiple regression was conducted to evaluate predictors of OSA for each analytic group. Effect sizes (phi coefficient (Φ), eta squared (η^2), and odds ratios (OR) with Nagelkerke R^2) were calculated to estimate comparison robustness because a power analysis was not conducted. All comparisons were two-tailed and P values <.05 were considered statistically significant.

Results

Demographics and medical comorbidities

The vast majority of the VAMC sample consisted of males, whereas there was a more even distribution of males and females in the general clinic sample (Table 1). Females in the VAMC sample were younger and leaner than females in the general clinic sample (Table 1). Both males and females in the VAMC sample were more likely to report clinical levels of sleepiness (ESS ≥10). Patients in the VAMC sample were more likely to report a history of depression and use of sleep and pain medications (Table 2). Controlling for sex, VAMC patients were over three times as likely to report a history of depression compared to those in the general clinic sample (OR 3.5 [95% CI 2.9–4.2]; χ^2 (2, 2873) = 218.9, $p < .001$; $R^2 = .10$). The prevalence of self-reported depression in female veteran patients was strikingly high at 62.3%. Likewise, controlling for sex, VAMC patients were 3.1 ([95% CI 2.5–3.8]; χ^2 (2, 2873) = 135.6, $p < .001$; $R^2 = .07$) and 2.6 ([95% CI 2.2–3.2]; χ^2 (2, 2873) = 96.9, $p < .001$; $R^2 = .05$) times more likely to report use of sleep and pain medications compared to the general clinic sample, respectively. Males, but not females in the VAMC sample, were more likely to report a history of hypertension, insomnia, diabetes, and restless legs syndrome compared to the general clinic sample (Table 2). The samples were not significantly different for self-reported lung disease, stroke, and heart disease.

HSAT outcomes

Despite differences in the rate of medical comorbidities, no differences were observed between groups with regard to HSAT test outcomes. Mean AHI and RDI were statistically similar for both groups and were similar for sleep stage and position (Table 3). As one can see in Fig. 1, modal sleep apnea severity was "mild", and approximately 42% of both groups had AHI's in the moderate to severe range. Any differences observed in test outcomes were attributable to sex differences in that females (regardless of group) generally had test results indicative of less severe OSA (Table 3).

Table 1 Demographics of VA and general sleep clinic samples of patients being tested for OSA using HSAT

	Overall $n = 3000$	General sample $n = 1500$ (57.1% male)	VA sample $n = 1500$ (91.3% male)	Analyses[a]
Age (yr)	53.0 ± 14.2	53.1 ± 14.8	52.8 ± 13.5	GxS: F(3, 2748) = 16.4; $p < .001$; $\eta^2 = .01$
Female	51.9 ± 14.6	**52.9 ± 15.1**	**47.1 ± 11.0**	F: $\eta^2 = .02$
Male	53.3 ± 14.0	53.2 ± 14.8	53.4 ± 13.6	M: n/s
BMI (kg/m^2)	34.9 ± 7.4	37.6 ± 8.0	32.6 ± 6.0	GxS: F(3, 2748) = 56.6; $p < .001$; $\eta^2 = .02$
Female	39.6 ± 8.3	**41.1 ± 7.8**	**33.3 ± 7.3**	F: $\eta^2 = .14$
Male	33.3 ± 6.4	**34.9 ± 6.9**	**32.5 ± 5.9**	M: $\eta^2 = .03$
Neck circumference (in.)	16.8 ± 3.1	16.4 ± 4.0	17.3 ± 1.9	S: F(1, 2871) = 149.0; $p < .001$; $\eta^2 = .07$
Female	**15.2 ± 3.8**	15.3 ± 4.1	14.9 ± 2.2	
Male	**17.4 ± 2.6**	17.2 ± 3.6	17.5 ± 1.8	
ESS	10.0 ± 5.7	**9.0 ± 5.4**	**10.9 ± 5.8**	G: F(2, 2869) = 26.8; $p < .001$;$\eta^2 = .03$
Female	9.4 ± 5.5	9.0 ± 5.4	11.3 ± 5.3	
Male	10.2 ± 5.7	9.0 ± 5.4	10.8 ± 5.8	
ESS ≥10 (%)	48.6%	44.6%	56.6%	$\chi^2 = (1, 3000) = 41.8$, $p < .001$, $\Phi = 0.12$
Female	47.0%	**42.1%**	**50.6%**	F: $\Phi = 0.12$
Male	52.0%	**44.9%**	**56.3%**	M: $\Phi = 0.11$

Values represent mean ± standard deviation

BMI body mass index, *ESS* Epworth Sleepiness Scale

[a] Analyses represent univariate ANOVA (continuous variables) with pairwise comparisons for significant interaction effects; G: main effect of group (VA vs. general clinic); S: main effect of sex; GxS: interaction of group by sex; chi-square analyses (dichotomous variables) split by sex (F: differences between females; M: difference between males); bolded numerical values represent comparisons that reached statistical significance.

Predictors of OSA

Both groups had similar predictors of OSA (defined as AHI ≥5) and included advancing age, neck circumference, and obesity (BMI ≥30 kg/m^2). These factors remained robust predictors even after controlling for sex and various medical conditions (Table 4). Sex was a significant independent predictor of OSA in the general sample but not in the VAMC sample. Medical conditions that one typically associates with OSA (e.g., hypertension, diabetes, and heart disease) were robust predictors of OSA for both groups in unadjusted models, but lost predictive strength after controlling for age, sex, and measures of adiposity. In neither group was sleepiness (ESS >10), depression, insomnia, nor use of pain medication associated with OSA. Interestingly, in the VAMC sample only, use of sleep medication was associated with less risk for OSA.

Rate of incongruent outcomes

More patients in the VAMC group were deemed at *high risk for OSA* using the ARES OSA risk questionnaire compared to the general sample (97.0 vs. 88.6%; $\chi^2 = (1, 3000) = 75.2, p < .001$). Of these *high-risk* individuals, approximately 80% of both groups had an AHI ≥5, and approximately 45% had an AHI ≥15 (Fig. 2).

This means that approximately 20% of those deemed at *high risk* in both groups had normal overall AHI's (AHI ≤5). However, this group with "incongruent outcomes" (normal AHI despite high risk for OSA) did have slightly elevated RDI's (mean = 9.2 ± 4.7), especially in REM (mean = 14.0 ± 10.4). A multivariate logistic regression analysis revealed that, controlling for various comorbidities, study quality parameters, and age, unique predictors of this incongruent outcome were female sex (OR 2.54 [95% CI 1.93–3.33]; $\chi^2 = 44.6, p < .001$), a BMI <30 (OR 1.71 [95% CI 1.30–2.25]; $\chi^2 = 14.7, p < .01$), and use of sleep medication (OR 1.61 [95% CI 1.21–2.14]; $\chi^2 = 10.5$, $p < .01$). Group did not account for significant variance in this phenotype. Another incongruent outcome was an abnormal AHI in the absence of pretest risk for OSA. This group was very small and did not vary by group (31 had an AHI ≥5 and 11 had AHI ≥15; Fig. 2). Advancing age was the only unique predictor of this phenotype in adjusted multivariate logistic regression models, accounting for 42% of the variance (OR 1.13 [95% CI 1.05–1.21]; $\chi^2 = 12.2, p < .001$). The majority of those with an AHI ≥5 had AHI's in the mild range (mean AHI = 13.5 ± 9.4).

Table 2 Self-reported medical conditions: VA and general sleep clinic samples

Medical conditions[a] (%)	Overall $n = 3000$	General sample $n = 1500$ (57.1% male)	VA sample $n = 1500$ (91.3% male)	Analyses[b]
Hypertension	51.2%	45.0%	57.4%	$\chi^2 = (1, 2873) = 35.3, p < .001, \Phi = .11$
Female	45.1%	45.9%	41.2%	F: n/s
Male	53.3%	**44.3%**	**58.9%**	M: $\Phi = .13$
Depression	34.9%	25.7%	44.1%	$\chi^2 = (1, 2873) = 99.7, p < .001, \Phi = .19$
Female	42.9%	**38.9%**	**62.3%**	F: $\Phi = .18$
Male	32.1%	**15.8%**	**42.3%**	M: $\Phi = .27$
Insomnia	19.7%	17.5%	21.9%	$\chi^2 = (1, 2873) = 6.6, p < .05, \Phi = .05$
Female	23.9%	23.3%	26.7%	F: n/s
Male	18.2%	**13.1%**	**21.4%**	M: $\Phi = .13$
Sleep medication	24.8%	16.6%	33.0%	$\chi^2 = (1, 2873) = 98.3, p < .001, \Phi = .19$
Female	26.4%	**22.2%**	**46.6%**	F: $\Phi = .20$
Male	24.3%	**12.4%**	**31.7%**	M: $\Phi = .21$
Diabetes	21.8%	17.7%	25.9%	$\chi^2 = (1, 2873) = 24.1, p < .001, \Phi = .09$
Female	18.6%	19.0%	16.8%	F: n/s
Male	22.9%	**16.8%**	**26.7%**	M: $\Phi = .11$
Heart disease	14.7%	13.3%	16.0%	n/s
Female	12.3%	12.6%	10.7%	
Male	15.5%	13.9%	16.5%	
Restless legs	13.0%	10.7%	15.3%	$\chi^2 = (1, 2873) = 11.1, p < .005, \Phi = .06$
Female	14.1%	13.2%	18.3%	F: n/s
Male	12.6%	**8.9%**	**15.0%**	M: $\Phi = .08$
Lung disease	8.9%	8.2%	9.6%	n/s
Female	9.4%	9.3%	9.9%	
Male	8.7%	7.4%	9.6%	
Stroke	4.3%	3.7%	4.9%	n/s
Female	3.0%	3.3%	1.5%	
Male	4.8%	4.0%	5.3%	
Pain medication	22.6%	15.1%	30.1%	$\chi^2 = (1, 2873) = 87.5, p < .001, \Phi = .17$
Female	20.9%	**19.4%**	**28.2%**	F: $\Phi = .08$
Male	23.2%	11.9%	30.3%	M: $\Phi = .21$

[a] % endorsed yes to "have you been diagnosed or treated for any of the following conditions?"

[b] Analyses represent chi-square analyses to test for group differences (VA vs. general clinic). Analyses were also split by sex (F: differences between females, M: difference between males) if overall chi-square was significant; bolded numerical values represent comparisons that reached statistical significance.

Study quality metrics (Table 5)

Because patients in the VA sample were more likely to have more than one night of data collection, number of study nights was added as a covariate to all analyses of study quality. As seen in Table 5, VAMC patients, on average, had 30 min less recording time compared to those in the general clinic sample. However, these differences did not impact the amount of the record that was deemed valid (i.e., valid recording time) nor were VAMC patients more likely to have wakefulness after sleep onset.

Table 3 HSAT outcomes: VA and general clinic samples

Breathing Data	Overall $n = 3000$	General sample $n = 1500$ (57.1% male)	VA sample $n = 1500$ (91.3% male)	Analyses[a]
AHI (events/h)	18.3 ± 18.8	17.8 ± 18.9	19.0 ± 18.7	S: F(1, 2976) = 74.6; $p < .001$; $\eta^2 = .02$
Female	**12.7** ± **15.0**	13.0 ± 15.2	11.2 ± 13.6	
Male	**20.3** ± **20.0**	21.4 ± 20.6	19.6 ± 18.9	
RDI (events/h)	28.8 ± 20.6	28.3 ± 20.7	29.3 ± 20.5	S: F(1, 2976) = 76.6; $p < .001$; $\eta^2 = .02$
Female	**22.5** ± **18.1**	22.8 ± 18.3	20.8 ± 17.0	
Male	**31.0** ± **21.0**	32.4 ± 21.5	30.1 ± 20.6	
Supine AHI	22.5 ± 23.0	21.8 ± 23.0	23.2 ± 22.9	S: F(1, 2976) = 77.2; $p < .001$; $\eta^2 = .03$
Female	**15.2** ± **18.6**	15.5 ± 18.7	14.2 ± 17.7	
Male	**25.0** ± **23.8**	26.6 ± 24.7	24.1 ± 23.1	
Supine RDI	34.2 ± 25.5	33.5 ± 25.7	34.8 ± 25.3	S: F(1, 2976) = 78.7; $p < .001$; $\eta^2 = .03$
Female	**26.0** ± **22.9**	26.3 ± 23.0	24.8 ± 22.4	
Male	**37.0** ± **25.8**	38.9 ± 26.3	35.8 ± 25.4	
REM AHI	22.8 ± 23.8	21.7 ± 23.7	23.9 ± 23.8	S: F(1, 2976) = 56.0; $p < .001$; $\eta^2 = .02$
Female	**16.3** ± **19.6**	16.7 ± 20.2	14.5 ± 15.9	
Male	**25.1** ± **24.7**	25.5 ± 25.3	24.8 ± 24.3	
REM RDI	34.9 ± 25.2	34.1 ± 25.2	35.8 ± 25.2	S: F(1, 2976) = 43.7; $p < .001$; $\eta^2 = .02$
Female	**28.9** ± **23.1**	29.3 ± 23.5	27.1 ± 20.5	
Male	**37.0** ± **25.6**	37.7 ± 25.8	36.6 ± 25.4	

Values represent mean ± standard deviation; heart rate (beats per minute) and oxygen saturation ($SP0_2$) acquired from forehead reflectance pulse oximetry; bolded numerical values represent comparisons that reached statistical significance.

AHI apnea-hypopnea index, *RDI* respiratory disturbance index

[a] S: main effect of sex

Discussion

Home sleep apnea testing for the diagnosis of OSA appears to have similar results for high-risk VAMC patients as it does with general sleep clinic patients. This conclusion is based on the finding that predictors of OSA, rates of positive studies in high-risk patients, and study quality indicators were very similar for both groups. This is encouraging in light of the use of a

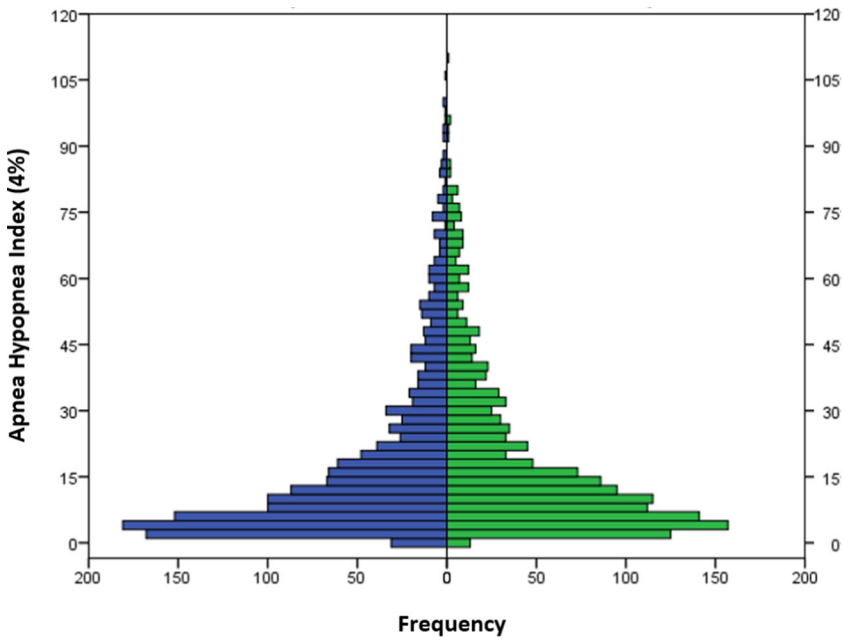

Fig. 1 Apnea-hypopnea index distribution as per HSAT outcomes: comparison between VAMC patients and general clinic samples

Table 4 Adjusted Logistic Regression Analyses of Predictors of OSA (AHI ≥ 5)

	Analyses[a]							
	General sample				VA sample			
Predictor	β	χ^2	p	Odds ratio [95% CI]	β	χ^2	p	Odds ratio [95% CI]
Age (yr)	0.05	80.8	$p < .001$	1.05 [1.04–1.07]	0.05	64.2	$p < .001$	1.06 [1.04–1.07]
Obese[b]			n/s		0.53	8.6	$p < .01$	1.70 [1.19–2.42]
Neck Circ. (in.)	0.15	18.5	$p < .001$	1.17 [1.09–1.25]	0.24	19.4	$p < .001$	1.23 [1.14–1.41]
Sex (male)	.72	18.7	$p < .001$	2.05 [1.48–2.85]			n/s	
Sleep medication			n/s		0.62	9.0	$p < .01$	0.62 [0.46–0.85]

[a] Model controls for hypertension, heart disease, diabetes, and stroke

[b] BMI ≥30 kg/m^2

nontraditional deployment of diagnostic testing in VAMC patients who are at a higher risk for comorbid medical conditions including congestive heart failure, moderate to severe pulmonary disease, neuromuscular diseases, and spinal cord injuries, all which may compromise the accuracy of home testing. Further, it has also become widespread practice for VAMC providers to refer patients for HSAT in the presence of a variety of other comorbidities including mood disorders, PTSD, insomnia, arrhythmias, glaucoma, nocturia, or when nearly any sleep-related complaint arises such as snoring and sleep disturbance. These patients are often found to have sleep-disordered breathing on home testing and while they face the same barriers to compliance as the general population, often benefit from treatment. More data is thus needed on the use of HSAT in those with contraindications and exclusions, as existing guidelines could be expanded with sufficient evidence.

The higher prevalence of comorbidities in veterans compared to general clinic populations was remarkable, particularly the use of medications to treat pain and insomnia. The use of chronic opiates in veterans places them at greater risk of respiratory depression and ventilatory instability [20]. Veterans may also be at risk for more complicated sleep management as their high report of depression and use of sleep medication may indicate undiagnosed insomnia or other concomitant mental health conditions. The finding that male sex was not a predictor of OSA for veterans is likely due to insufficient power due to very few females in the sample. The finding that OSA was less prevalent in veterans that endorsed the use of sleep medication may indicate another underlying primary sleep/wake disorder.

The result that roughly 20% of both samples had AHI's within normal limits despite presenting with high clinical risk for OSA is important as it could mean a false positive pretest screening, another primary sleep disorder (because of the high use of sleep medications in veterans), or mild sleep-disordered breathing (based on the elevated RDI)

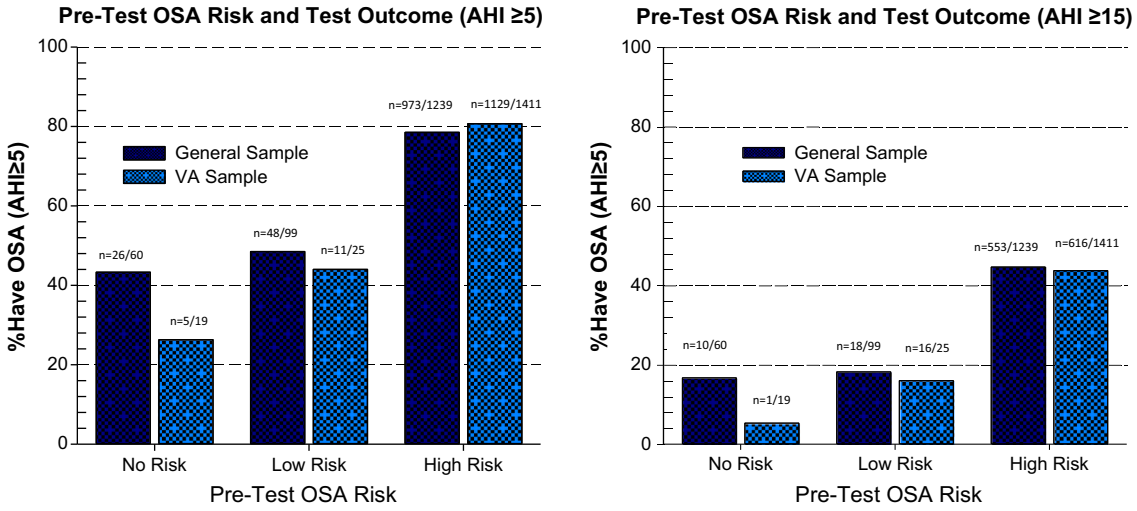

Fig. 2 Pretest risk for OSA compared to actual HSAT study outcomes

Table 5 Study quality metrics

	Overall	General sample	VA sample	Analyses[a]
Total recording time[b]	5.9 ± 1.6	6.2 ± 1.5	5.7 ± 1.7	G: $F(1, 2925) = 7.3$; $p < .01$; $\eta^2 = .00$
Female	6.2 ± 1.4	6.3 ± 1.4	5.8 ± 1.6	
Male	5.8 ± 1.6	6.1 ± 1.5	5.7 ± 1.7	
Total sleep time[c]	5.1 ± 1.5	5.2 ± 1.4	4.9 ± 1.6	n/s
Female	5.2 ± 1.4	5.3 ± 1.4	4.9 ± 1.5	
Male	5.0 ± 1.6	5.2 ± 1.5	4.9 ± 1.6	
Valid recording time[d]	5.0 ± 1.5	5.2 ± 1.4	4.9 ± 1.6	n/s
Female	5.2 ± 1.4	5.3 ± 1.4	4.9 ± 1.5	
Male	5.0 ± 1.6	5.1 ± 1.5	4.9 ± 1.6	
% Record awake[e]	15.2 ± 10.8	15.7 ± 10.8	14.8 ± 10.8	n/s
Female	16.0 ± 11.1	16.2 ± 11.2	15.4 ± 10.8	
Male	15.0 ± 10.7	15.4 ± 10.5	14.7 ± 10.9	

[a] G: main effect of group, controlling for number of study nights collected

[b] Duration of the recording from when the patient turns the device on to when the patient turns the device off

[c] Duration of the recording where the device deems the person to be asleep based on behavioral indicators (i.e., actigraphy, breathing regularity or presence of apneas/hypopneas, and snoring)

[d] The length of total sleep time minus gross movements and periods of poor signal integrity (denominator of AHI and RDI)

[e] Based on actigraphy

that warrants more comprehensive evaluation and management. Further, the finding that females were more likely to manifest this phenotype may highlight the potential need for sex appropriate screening algorithms [19]. It is unknown if these patients went on to have an attended PSG, PAP therapy for mild OSA, or clinical correlation. These data warrant further investigation. Likewise, in both samples, there was a small group of patients with no risk factors that had abnormal AHI's. Because the majority of these patients had mild OSA, this suggests either a false positive HSAT result or the presence of another risk factor not identified using traditional screening questions.

These data support published guidelines [10] that HSAT is most efficiently used when the patient is deemed at high clinical (pretest) risk for OSA. This conclusion is based on the finding that HSAT outcomes were most reliably positive when clinical risk of OSA was high. Ann important finding of this study, which is unique to HSAT devices utilizing EEG monitoring and accelerometry, is the calculation of both AHI and RDI. Table 3 presents data demonstrating the AHI and RDI in REM, non-REM, and supine/non-supine positioning for both populations. Most HSAT devices do not allow for the monitoring of state-specific breathing or more subtle flow-limited events accompanied by increased sympathetic activity. As such, outcomes from this device may more closely approximate the AHI and RDI calculated on in-lab polysomnography. However, the limitations of type 3 monitoring are critical to understand, since further testing may be indicated if results are negative.

Although this study represents one of the largest comparisons of veterans versus general patients using home testing, there are limitations and/or interpretational considerations to be mindful of when drawing conclusions. First, it is important to consider the results in light of the sample differences in data collection methods. The VAMC service had additional supports in place (e.g., coaching, quality telephone calls, multiple nights when necessary, etc.) that may or may not have been in place when the HSAT was deployed from the physician's office. Also, the vast majority of patients referred for HSAT through the VAMC program were males assessed as being at high-risk for having OSA (89% general, 97% veteran). We do not know from these results whether veterans with nontraditional risk factors (namely females) can be reliably assessed using HSAT as the number of patients referred who were low- or no-risk were insufficient. Also, the general population sample may have included veterans who did not elect or qualify to receive their care through the VA, but were exposed to the same risk factors and likely afflicted by similar medical comorbidities as their VA-based peers. Lastly, it is important to note that other devices may record respiratory effort in order to discriminate between central and obstructive events. Although the ARES can be outfitted with a respiratory belt, this feature is not standard and as such none of the data in this study was collected with effort.

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Compliance with ethical standards

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Conflict of interest Dr. Cairns and Dr. Bogan are employed by SleepMed, Inc., the manufacturer of the ARES device (used to test all patients in this sample). Dr. Cairns and Dr. Bogan have received research funding from Jazz pharmaceuticals, and Dr. Bogan is a consultant as well as a member of the speaker's bureau for Jazz pharmaceuticals. Dr. Sarmiento has no conflicts to disclose.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration.

Informed consent As this study was a retrospective analysis of anonymized data and no identifying information about patients was available, informed consent was not obtained.

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