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# Adherence to Positive Airway Pressure Therapy in U.S. Military Personnel With Sleep Apnea Improves Sleepiness, Sleep Quality, and Depressive Symptoms



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# Adherence to Positive Airway Pressure Therapy in U.S. Military Personnel With Sleep Apnea Improves Sleepiness, Sleep Quality, and Depressive Symptoms

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**ABSTRACT** Objectives: Obstructive sleep apnea (OSA) is frequently diagnosed in U.S. military personnel. OSA is associated with sleepiness, poor sleep quality, and service-related illnesses of insomnia, depression, post-traumatic stress disorder, and traumatic brain injury. Methods: Observational study of active duty military personnel with OSA and adherence to positive airway pressure (PAP) assessed with smart chip technology. Results: 58 men with mean age  $36.2 \pm 7.7$  years, mean body mass index  $31.4 \pm 3.7$  with mean apnea-hypopnea index (AHI)  $19.1 \pm 19.0$  are reported. 23 (39.7%) participants were adherent to PAP, and 35 (60.3%) were nonadherent. No significant differences in baseline demographics, apnea-hypopnea index, service-related illnesses, or clinical instrument scores. Military personnel adherent to PAP had significantly improved sleepiness ( $p = 0.007$ ), sleep quality ( $p = 0.013$ ), depressive symptoms ( $p = 0.01$ ), energy/fatigue ( $p = 0.027$ ), and emotional well-being ( $p = 0.024$ ). Participants with moderate-severe OSA were more likely to be in the adherent group when compared with participants diagnosed with mild OSA. Conclusions: Military personnel with OSA have low adherence to PAP. Adherence is associated with improved depressive symptoms, sleepiness, sleep quality, energy/fatigue, emotional well-being, and social functioning. Future research should focus on interventions to improve the management of OSA in military personnel.

## INTRODUCTION

Sleep disturbances are the most frequently endorsed symptoms of military personnel who have deployed to Iraq and Afghanistan. From 2000 to 2009, the diagnosis of obstructive sleep apnea (OSA) increased six fold.<sup>1</sup> In more recent studies, OSA is one of the most frequently reported clinical diagnoses among returning service members with sleep disturbances, with rates ranging from 34.5% to 76.8%.<sup>2-4</sup> The clinical characteristics of military personnel with OSA are different from civilians. Specifically, they are sleepier by self-reported scores on the Epworth Sleepiness Scale (ESS) with an average score of  $13^{5,6}$  and tend to have more normal body mass index (BMI).<sup>5,6</sup> Sleepiness in military personnel with OSA is likely multifactorial. In part, this symptom is a consequence of their OSA, but insufficient sleep with an average reported sleep duration of 6 hours<sup>7,8</sup> and comorbid, service-related illnesses, such as anxiety, depression, insomnia, post-traumatic stress disorder (PTSD), or traumatic brain injury (TBI) likely contribute.<sup>2,3,6,7</sup>

Military personnel with OSA are primarily treated with positive airway pressure (PAP) therapy.<sup>9</sup> Similar to the American College of Chest Physicians commercial vehicle guidelines,<sup>10</sup> there are regulations that allow military personnel with OSA, who are AD to PAP, to remain on active duty and deploy to austere environments.<sup>11</sup> However, military personnel have a rigorous profession, which is physically and mentally demanding. They frequently have mission requirements, which result in sleep deprivation that could limit their adherence, as well as the effectiveness of PAP.<sup>7,8</sup> In addition to sleep deprivation, insomnia is a common comorbid diagnosis in military personnel with OSA. In civilians, comorbid insomnia and OSA is associated with decreased rates of PAP adherence.<sup>12</sup>

Adherence to PAP is suboptimal in civilian patients, but even more so in military personnel.<sup>13-15</sup> Reports of PAP adherence in military personnel are limited and have focused on PTSD. Collen et al<sup>15</sup> reported adherence rates of 25.2% in active duty soldiers with PTSD compared with 58.3% in those without PTSD. Another study of veterans with OSA reported adherence rates of 41% in those with PTSD and 70.0% in those without.<sup>16</sup> These findings suggest that active duty status may have a role in adherence. As untreated OSA is associated with sleepiness, poor sleep quality, and increased risks of mental lapses and motor vehicle accidents, PAP adherence may have substantial implications on military medical readiness.<sup>17-19</sup>

In civilians, PAP adherence has been associated with improvements in objective findings and subjective reports. Daytime sleepiness as measured by the ESS was significantly

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improved with adherence to PAP therapy.<sup>20–22</sup> Likewise, studies have demonstrated significant improvements on quality of life measures using the Short Form Health Survey (SF-36). PAP therapy has been shown to improve SF-36 measures of vitality and energy.<sup>23,24</sup> In terms of objective benefits associated with PAP adherence, there are several studies that have suggested a link between PAP adherence and neurocognitive performance and cardiovascular health.<sup>25–29</sup>

Despite the evidence that treatment with PAP improves OSA and sleepiness in civilian patients,<sup>13,30</sup> to our knowledge, there are no studies that have established the effectiveness of PAP therapy in an active duty military population. In this study, we examined PAP adherence rates in active duty military personnel and the effects of PAP adherence on sleepiness, sleep quality, and health-related quality of life. As OSA is associated with service-related illnesses, we also evaluated if symptoms of depression and PTSD improved with adherence to PAP therapy.

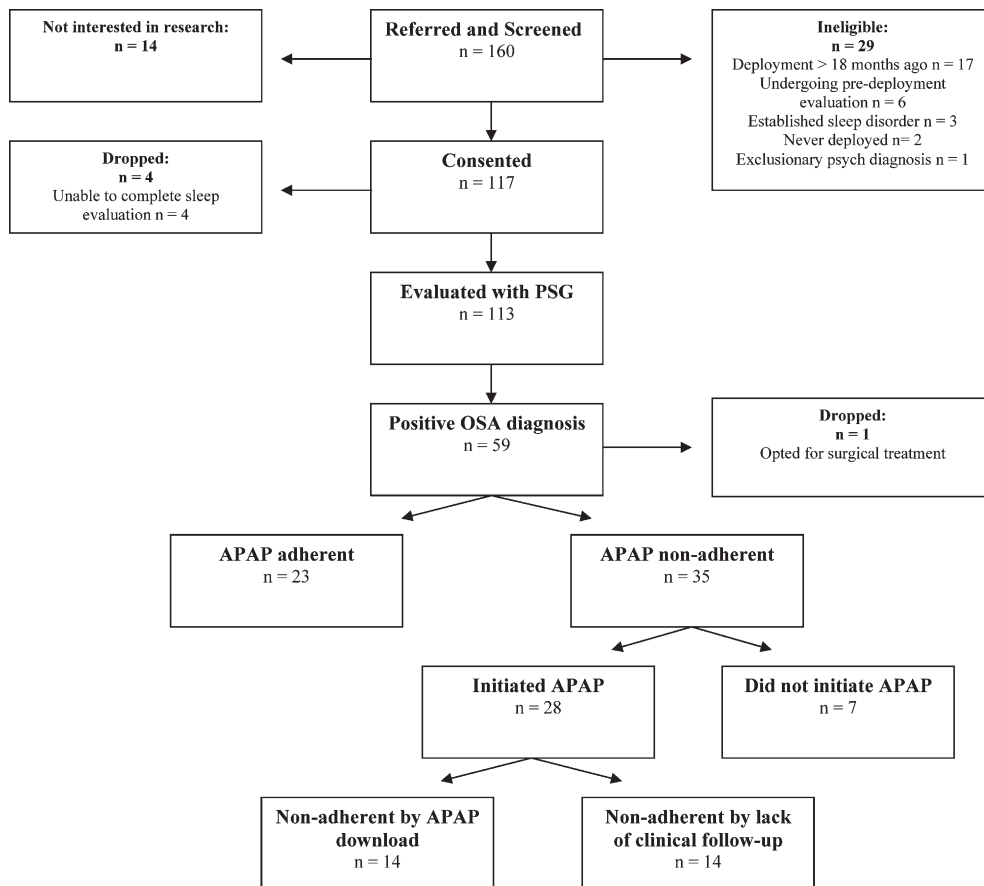
**METHODS**

**Study Design**

We conducted an observational study assessing 58 active duty military personnel who underwent a sleep medicine evaluation

within 18 months of their most recent deployment and were diagnosed with OSA (Fig. 1). From the time of enrollment, participants were followed for a period of 90 days per the study protocol. The baseline clinical assessments were performed at enrollment. The polysomnogram (PSG) was conducted within 4 weeks and participants were seen for follow-up within 2 weeks of the study. The participants were followed in the Sleep Medicine Clinic for PAP therapy adherence and usual clinical care. All clinical appointments were modified as required by the participant’s military duties. This study was a follow-on of our initial larger cohort that assessed sleep diagnoses in military personnel recently returned from deployment.<sup>6</sup>

Participants diagnosed with OSA were treated in accordance with our clinical algorithm. This included counseling and education regarding their diagnosis and discussion of treatment options. Potential clinical efficacy of PAP therapy, a dental orthotic, and surgery are discussed. If a patient elects PAP therapy, it is our standard practice to use autotitrating PAP (APAP) for patients with OSA. Those choosing APAP received routine clinical follow-up, including a PAP therapy data download with an outpatient respiratory therapist 4 to 6 weeks after APAP initiation. If alternate treatment was desired for OSA, the patient was then excluded from the analysis. As this was an observational study, no other



**FIGURE 1.** Consort table.

interventions besides our usual clinical care were performed. The study was approved by the Institutional Review Board at Madigan Army Medical Center in Tacoma, Washington.

### Participants

Participants were a convenience sample of 58 male military personnel who were recruited on presentation to the Sleep Medicine Clinic for evaluation of sleep disturbances. For the current analyses, military personnel were between 20 and 53 years old. Participants were primarily European Americans (65.5% European Americans, 13.8% African-Americans, 6.90% Hispanic/Latino, 1.72% Native Alaskan, 1.72% Pacific Islander, and 10.3% mixed ethnicity), with education ranging from 10 to 20 years (mean = 13.8, standard deviation [SD] = 1.84). The majority were active duty U.S. Army (91.4% Army, 8.62% Air Force), Junior Enlisted (58.6% E1 to E4, 37.9% E5 to E9, and 3.45% Officers), and had deployed from 1 to 20 times (median = 2). For 17.2% of the participants, their last deployment was less than 3 months before enrollment in the study, 3 to 6 months for 12.1%, 6 to 12 months for 34.5%, and 12 to 18 months for 36.2%. The most frequently observed service-related illness was insomnia (63.8%), followed by depression (51.7%), mild traumatic brain injury (mTBI) (41.4%), pain (39.7%), and PTSD (25.9%).

### Measures

Biometric parameters of age, ethnicity, education, branch of service, rank, number of deployments, time since last deployment, BMI, and service-related illnesses of insomnia, PTSD, depression, and mTBI were obtained.

#### APAP Adherence

All patients were offered a trial of APAP with adherence assessed 4 to 6 weeks after initiation of treatment. The most recent 30-day period of use was assessed to determine if the participant was AD. Participants were placed in the AD group if they used APAP more than 4 hours a night for 70% or more of nights during a consecutive 30-day period.<sup>31</sup> Participants who did not meet these criteria were placed in the nonadherent (NAD) group.

#### PTSD Checklist—Military Version (PCLM)

The PCLM was used to assess symptoms of PTSD, with a cutoff score of 50 indicating a positive diagnosis of PTSD and provides the maximum specificity (0.98).<sup>32,33</sup>

#### Quick Inventory of Depressive Symptomatology (QIDS)

The diagnosis of depression, as well as changes in symptoms, was assessed through the QIDS.<sup>34</sup> A score of 11, which is indicative of moderate–severe depression, resulted in a positive screen for this disorder.

#### RAND 36-Item Short Form Health Survey (SF-36)

The SF-36 was used to assess the health-related quality of life in study participants.<sup>35</sup> The SF-36 consists of eight

health concepts: physical functioning, bodily pain, role limitations because of physical health problems, role limitations because of personal or emotional problems, emotional well-being, social functioning, energy/fatigue, and general health perceptions.

#### Pain and mTBI

The bodily pain component of the SF-36 as well as the patients' electronic medical record was used in determining pain diagnosis. A positive screen was rendered by either a score of <70% and a diagnosis in electronic medical record or a low bodily pain score <30% on the SF-36.<sup>36</sup> In accordance with the American Congress of Rehabilitation Medicine criteria,<sup>37</sup> mTBI was diagnosed when an injury was followed by loss of consciousness or alteration of mental state as reported on the Warrior Administered Retrospective Casualty Assessment Tool.<sup>38</sup>

#### PSG Evaluation

All participants underwent a diagnostic attended PSG using standardized techniques we have previously reported.<sup>6</sup> The PSG variables we analyzed included sleep onset latency, rapid eye movement onset latency, total sleep time, wakefulness after sleep onset, sleep efficiency, arousal index, sleep stages (stage N1, stage N2, stage N3, stage R), apnea-hypopnea index (AHI), and maximal desaturation. Sleep diagnoses were rendered in accordance with the International Classification of Sleep Disorders.<sup>39</sup>

#### Epworth Sleepiness Scale

The ESS assessed patients' sleepiness.<sup>40</sup> The participants rated from 0 (would never doze) to 3 (high chance of dozing) how likely they are to fall asleep in eight situations. The total ESS score, ranges from 0 (better) to 24 (worse). A score >10 indicates abnormal sleepiness.

#### Pittsburgh Sleep Quality Index (PSQI)

The PSQI was used to determine sleep quality during the previous month.<sup>41</sup> The PSQI includes 18 questions that yield seven component scores (sleep quality, sleep latency, duration, sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction) rated from 0 (better) to 3 (worse). The total score, ranging from 0 (better) to 21 (worse), is the summation of the component scores. Individuals with a PSQI total score  $\leq 5$  are characterized as good sleepers, whereas scores  $>5$  are associated with poor sleep quality. The PSQI has a sensitivity of 89.6% and a specificity of 86.5% ( $\kappa = 0.75$ ,  $p < 0.001$ ), and an internal consistency  $\alpha = 0.83$ .<sup>41</sup>

### Statistical Analysis

Statistical analysis was conducted with a statistical software package (JMP Pro 9; SAS Institute, Cary, North Carolina). All variables underwent descriptive statistical analysis to

describe our population in terms of demographic characteristics of military personnel. Based on the criteria already described, participants were classified in the AD and NAD groups. First, we assessed the statistical equivalence between the two groups. Then, we performed a nonparametric comparison, based on Wilcoxon rank-sum test, between the AD and NAD groups. The intent was to identify whether the two patient groups differed in demographics (age, BMI), PSG parameters, PCLM, QIDS, SF-36, ESS, PSQI, service-related illnesses (PTSD, depression, mTBI, pain, and insomnia), and OSA.

## RESULTS

Participants were a relatively young, at 36 years of age (20–53 years), cohort of males with an average BMI of 31.4 (SD = 3.7) (Table I). 23 participants (39.7%) were AD with APAP and included in the AD group, whereas 35 (60.3%) NAD participants were included in the NAD

group (Fig. 1). There were no significant differences in baseline values between the participants in the AD and the NAD groups in demographics, PSG parameters, PCL-M, QIDS, SF-36, ESS, and PSQI scores (Wilcoxon rank-sum test,  $p > 0.05$ ). The arousal index did approach significance ( $p = 0.103$ ), elevated in the AD group, likely corresponding to their AHI values. No significant differences were identified in the presence of service-related illnesses (PTSD, depression, mTBI, pain, and insomnia) between the two groups (likelihood ratio test,  $p > 0.30$ ).

Not surprisingly, there were significant differences between the AD and NAD groups in APAP usage (Table II). The AD group used APAP on virtually all nights of the download (mean = 29.9 nights, SD = 8.46) compared to the NAD group, which used APAP on average 10.1 (SD = 10.9) nights of the download (Wilcoxon rank-sum test,  $\chi^2(1) = 25.3$ ,  $p < 0.001$ ). The AD group had a mean nightly usage of 5.46 (SD = .84) hours, whereas the NAD group averaged 2.71 (SD = 1.74)

**TABLE I.** Baseline Demographics and PSG Variables by CPAP Adherence

	All (N = 58)	CPAP AD (n = 23)	CPAP NAD (n = 35)	p-Value <sup>a</sup>
Demographics <sup>b</sup>				
Age, Years	36.2 ± 7.73	37.7 ± 7.96	35.2 ± 7.53	0.252
BMI, kg/m <sup>2</sup>	31.4 ± 3.69	31.8 ± 4.28	31.1 ± 3.29	0.639
Service-Related Illnesses				
PTSD, % (n)	25.9 (15)	26.1 (6)	25.7 (9)	0.975 <sup>c</sup>
Depression, % (n)	51.7 (30)	56.5 (13)	48.6 (17)	0.553 <sup>c</sup>
Pain, % (n)	39.7 (23)	47.8 (11)	34.3 (12)	0.303 <sup>c</sup>
Mild TBI, % (n)	41.4 (24)	47.8 (11)	37.1 (13)	0.420 <sup>c</sup>
Insomnia, % (n)	63.8 (37)	60.9 (14)	65.7 (23)	0.707 <sup>c</sup>
PSG Variables <sup>b</sup>				
SOL, Minutes	9.3 ± 11.8	8.9 ± 8.7	9.5 ± 13.7	0.399
REM Latency, Minutes	105 ± 74.8	108 ± 72.4	100 ± 75.3	0.668
TST, Minutes	418 ± 64.9	406 ± 73.5	425 ± 59.6	0.206
Sleep Efficiency, %	90.7 ± 6.1	88.7 ± 7.0	91.3 ± 5.5	0.117
Stage N1, %	13.2 ± 8.4	14.3 ± 11.5	12.6 ± 5.8	0.980
Stage N2, %	42.9 ± 10.1	41.5 ± 11.4	43.6 ± 9.4	0.883
Stage N3, %	18.6 ± 9.8	18.0 ± 12.3	18.7 ± 8.1	0.193
Stage R, %	18.9 ± 9.7	20.4 ± 14.2	18.1 ± 5.3	0.943
WASO, Minutes	40.9 ± 26.4	45.4 ± 33.5	39.7 ± 20.2	0.893
Arousal Index	25.3 ± 19.1	31.1 ± 25.4	21.8 ± 13.3	0.103
AHI	19.1 ± 19.0	24.1 ± 25.7	15.8 ± 12.7	0.206
Desaturation, %	83.8 ± 6.2	82.7 ± 6.8	84.5 ± 6.0	0.398

BMI, body mass index in kilogram per square meter; SOL, sleep onset latency; REM, rapid eye movement; TST, total sleep time; WASO, wakefulness after sleep onset; AHI, apnea hypopnea index. <sup>a</sup>Nonparametric Wilcoxon rank-sum test for differences between AD and NAD groups. <sup>b</sup>Data are presented as mean ± SD. <sup>c</sup>Likelihood ratio test. \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

**TABLE II.** APAP Adherence Characteristics<sup>a</sup>

	Overall (N = 58)	CPAP AD (n = 23)	CPAP NAD (n = 35)	p-Value <sup>b</sup>
Number of Days Assessed	30.2 ± 7.27	31.1 ± 8.70	28.5 ± 3.57	0.236
Number of Days Used	24.8 ± 10.9	29.9 ± 8.46	16.3 ± 9.37	<0.001***
Mean Nightly Use, Hours	4.39 ± 1.84	5.46 ± 0.84	2.71 ± 1.74	<0.001***
Residual AHI	2.12 ± 2.61	2.02 ± 1.76	2.32 ± 3.85	0.330

<sup>a</sup>Data are presented as mean ± SD. <sup>b</sup>Nonparametric Wilcoxon rank-sum test for differences between AD and NAD groups. \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

hours a night (Wilcoxon rank-sum test,  $\chi^2(1) = 22.8, p < 0.001$ ). 32 patients (55.2%) were diagnosed with mild OSA, whereas 18 (31.0%) had moderate and 8 (13.8%) had severe OSA. Those diagnosed with moderate to severe OSA were more likely to be in the AD group when compared with participants diagnosed with mild OSA (likelihood ratio test,  $\chi^2(1) = 3.99, p = 0.046$ ), see Figure 2.

Next, we investigated how clinical symptoms changed from the baseline to the follow-up assessment by calculating the difference scores (follow-up score – baseline score). This analysis showed that APAP adherence affected QIDS, ESS, PSQI, and the energy/fatigue and emotional well-being indices of SF-36. Specifically, there was a 2.61 decrease in the QIDS scores of the AD group from baseline to follow-up, which was significantly different compared to the NAD group ( $\Delta = 0.09$ , Wilcoxon rank-sum test,  $p = 0.01$ ). Sleepiness, as assessed by the ESS, was reduced in the AD group by an average of 4.88 points, which was significantly decreased compared to the 0.67 points decrease in NAD group ( $p = 0.007$ ). The AD group also decreased the PSQI scores by an average of 5.18 points as compared to the 1.17 points decrease in the NAD group ( $p = 0.001$ ). Military personnel in the AD were significantly more likely to have a normal PSQI score (PSQI  $\leq 5$ : AD = 41.2%; NAD = 6.7%; likelihood ratio test:  $\chi^2(1) = 8.18, p = 0.004$ ). Differences in ESS scores between AD and NAD groups were evident but not statistically significant (ESS  $\leq 10$ : AD = 39.8%; NAD = 28.6%; likelihood ratio test:  $\chi^2(1) = 0.697, p = 0.404$ ). These results are depicted on Figure 3.

Furthermore, APAP adherence affected three quality of life factors on the SF-36. In the AD group, energy/fatigue score increased by 12 points and emotional well-being increased by 8 points, whereas energy/fatigue decreased by 1 point and emotional well-being increased by 1.1 in the NAD group (Wilcoxon rank-sum test,  $p < 0.05$ ). Social functioning showed a trend toward significance between the two groups, with the AD group having an average increase of 4.8 points and the NAD group showing an average decrease of 4 points (Wilcoxon rank-sum test,  $p = 0.087$ ).

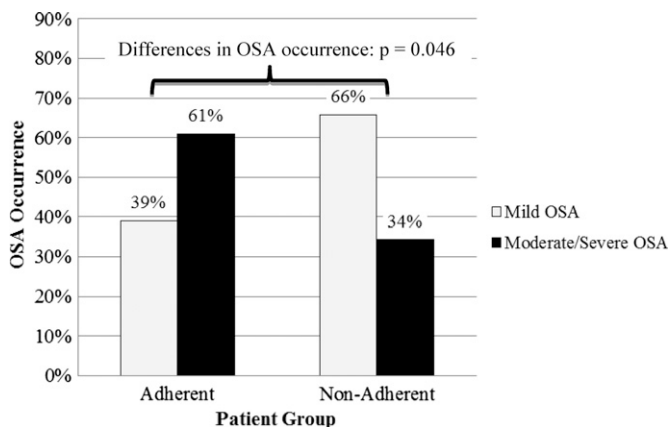


FIGURE 2. OSA severity by CPAP adherence.

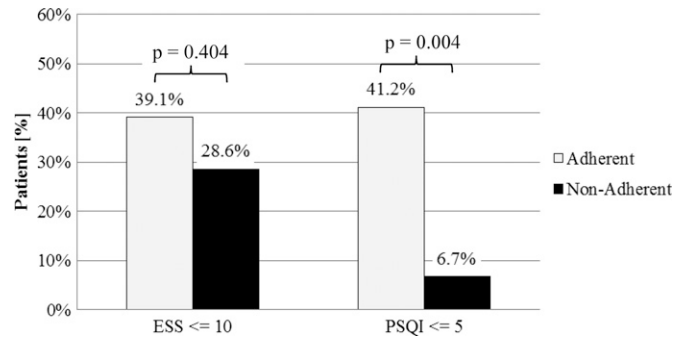


FIGURE 3. Military personnel with normal ESS and PSQI by APAP adherence. Percent of military personnel with normal ESS and PSQI at follow-up for participants who were AD versus NAD with APAP.

These results show that adherence with the APAP use was associated with decreased sleepiness, improved sleep quality, energy/fatigue, emotional well-being, and social functioning. The symptoms' scores in the AD and NAD groups are shown in detail in Table III.

## DISCUSSION

The results of this study indicate a significant association between APAP adherence and improvements of subjective sleepiness, social functioning, and sleep quality in military participants. To our knowledge, this is the first study of PAP adherence to demonstrate these improvements in active duty military personnel. It is not necessarily surprising to see improvements in fatigue, sleepiness, and sleep quality in patients who are APAP AD; however, these improvements occurred in military personnel with substantial comorbid illnesses and short sleep duration. There were also significant improvements in depression by the QIDS, which is consistent with previous literature showing depressive symptom improvements with continuous positive airway pressure (CPAP) treatment.<sup>42,43</sup>

Our results are consistent with civilian studies, which have shown improvements in subjective sleepiness, sleep quality, and quality of life associated with PAP adherence. Previous studies have shown a 4- to 7-point improvement in ESS scores depending on CPAP adherence.<sup>20</sup> These findings correlate with an improvement of greater than 5 points in the ESS and PSQI with our study sample. Likewise, this study confirms previous findings linking PAP adherence with significant improvements in quality of life as measured by the SF-36.<sup>23</sup> AD participants also reported improvements in their energy and emotional well-being. Yet, when looking at the ESS and PSQI, only 39.1% and 41.2% of AD participants had normalized values. This finding suggests that insufficient sleep and comorbid service-related illnesses may contribute to sleepiness and poor sleep quality in military personnel.

Overall, 71% of participants in our study had a comorbid service-related illness. Although the findings show an improvement in depression, they failed to show a significant improvement in PTSD-related symptoms or pain as indicated

**TABLE III.** Improvement of Symptoms in AD versus NAD Military Personnel

	All(N = 58)	CPAP AD(n = 23)		CPAP NAD(n = 35)		Change Score
	Baseline	Baseline	Follow-Up	Baseline	Follow-Up	p-Value <sup>d</sup>
Clinical Instruments						
PCL-M	40.5 ± 16.9	41.3 ± 15.5	39.1 ± 17.5	40.0 ± 18.0	40.9 ± 18.0	0.206
QIDS	10.8 ± 5.03	10.8 ± 4.06	8.22 ± 5.09	10.8 ± 5.63	10.7 ± 6.0	0.010**
SF-36						
Bodily Pain	57.1 ± 25.6	57.7 ± 25.2	57.2 ± 23.6	56.6 ± 26.2	53.4 ± 26.6	0.894
Physical Functioning	75.1 ± 20.3	75.4 ± 19.4	73.7 ± 23.7	75.0 ± 21.1	70.4 ± 24.7	0.200
Physical Role Limitations	49.7 ± 44.2	54.4 ± 44.4	51.1 ± 37.3	46.6 ± 44.5	44.9 ± 43.9	0.938
Emotional Role Limitations	60.9 ± 43.8	59.4 ± 46.0	63.7 ± 42.6	61.9 ± 42.9	56.9 ± 43.9	0.430
Energy, Fatigue	33.0 ± 20.0	31.5 ± 20.6	43.5 ± 24.4	34.0 ± 19.9	32.7 ± 19.3	0.027*
Emotional Well-Being	58.3 ± 22.6	57.4 ± 21.2	65.4 ± 21.8	59.0 ± 23.7	60.6 ± 22.6	0.024*
Social Functioning	64.0 ± 27.4	61.7 ± 28.1	66.5 ± 28.3	65.5 ± 27.2	61.2 ± 29.0	0.087
General Health	56.0 ± 21.4	56.1 ± 18.8	55.9 ± 22.7	56.0 ± 23.3	53.1 ± 22.6	0.225
ESS <sup>b</sup>	13.9 ± 5.28	12.8 ± 4.76 <sup>c</sup>	7.65 ± 4.81 <sup>c</sup>	14.6 ± 5.55	14.0 ± 5.17	0.007**
PSQI <sup>b</sup>	13.0 ± 3.95	12.8 ± 4.20 <sup>c</sup>	7.65 ± 4.53 <sup>c</sup>	13.2 ± 3.87	11.8 ± 3.45	0.013*

<sup>a</sup>Nonparametric Wilcoxon rank-sum test for differences between AD and NAD groups. <sup>b</sup>ESS and PSQI evaluated in 48 participants. <sup>c</sup>Data are presented as mean ± SD. \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

in the PCL-M and SF-36 scores, respectively. Previous studies of nonactive duty patients with PTSD have shown significant improvements in nightmares and symptom presentation with CPAP adherence.<sup>16,44</sup> Approximately one-quarter of the AD (6) and NAD (9) groups were diagnosed with PTSD. With the small number of participants with PTSD and the complex nature of this disease, our study was likely not adequately powered to detect a difference in PTSD symptoms in a subset of the study population with a short duration of APAP therapy. The majority of participants, 66.1%, were obese with a BMI ≥ 30. The prevalence of obesity in the military is 12.9%,<sup>45</sup> which is lower than the prevalence of 32.9% and 35.5% in men and women of the general U.S. population.<sup>46</sup> This comorbid medical disorder, which likely contributed to their OSA diagnosis, should also be part of the treatment plan for patients with OSA.

APAP adherence has been reported to reduce depressive symptoms at both short-term and long-term follow-up.<sup>47</sup> Conversely, nonadherence is associated with depression and anxiety.<sup>48</sup> Means et al<sup>42</sup> reported significant improvements in depression scores, utilizing the Beck Depression Inventory, in patients treated with CPAP, as well as continued improvements of both somatic and affective/cognitive symptoms on the Beck Depression Inventory after 3 months of CPAP treatment. The majority of participants in our study at baseline (51.7%) had symptoms consistent with major depressive disorder with a QIDS score > 11. This finding is consistent with several previous studies documenting the association between OSA and depression.<sup>49–51</sup> Overall, depressive symptoms, as indicated by the QIDS, significantly improved with APAP adherence. Some have suggested that restoration of sleep architecture, resolution of nocturnal hypoxia, and improved daytime symptoms of sleepiness and fatigue may contribute to the resolution of depressive symptoms.<sup>52</sup> This finding, as corroborated by the previously cited work, underscores the importance of integrating behavioral health sur-

veillance for and treatment of OSA, as appropriate treatment can improve depressive symptoms, whereas untreated depression and PTSD may present a significant barrier to PAP therapy adherence.<sup>53</sup>

Among military personnel and veterans, the prevalence of OSA is relatively high but adherence to PAP therapy is low. The PAP adherence rate we report, 39.7%, is similar to the studies by Collen et al<sup>15</sup> (25.2%) and El Solh et al<sup>16</sup> (40%) in soldiers and veterans with PTSD. However, unlike Collen et al, we did not find that the presence of service-related illnesses (PTSD, depression, mTBI, pain, and insomnia) were associated with APAP adherence. This difference could be potentially explained by the low PTSD severity within our sample with a mean PCL-M of 41.3 in our AD group and the participants' proximity to returning from combat within the last 18 months. Likewise, the generally high rate of insufficient sleep in military personnel, which is in part because of their military duties, likely contributes to the relatively short usage of 5.46 hours in our AD group.

Military personnel with moderate to severe OSA in our study had improved APAP adherence. These data are consistent with previous studies demonstrating weak associations between OSA severity and APAP adherence.<sup>54</sup> The implication of these findings though, remains unclear given our small sample size and the high rate of comorbid diseases, which are known to impact APAP adherence. AD participants with more severe disease are more likely to experience recognizable improvements compared to those with mild OSA. The self-realization of these gains may reinforce their adherence.

There are some limitations to address in this study. This was an observational study with a small sample size, which may limit the generalizability of the results. Given the small size, this study was likely underpowered to demonstrate significant relationships between comorbid service-related illnesses and PAP adherence. However, our findings are

consistent with previous civilian studies, which further emphasize their importance. Accommodating the military duties and requirements, this initial study of PAP adherence demonstrated improvements in subjective sleepiness, social functioning, and sleep quality in active duty military personnel. Although definite conclusions cannot be made, follow-up studies should further assess and verify our findings with larger active duty military populations. We used a standardized definition of adherence and did not account for restricted sleep periods due to military requirements. It is possible that the 50% of the NAD group that used APAP were deemed NAD due to this factor. Since this was an observational study on active duty patients receiving treatment for OSA, randomization to a placebo arm receiving sham CPAP was not possible. As sham CPAP has been shown to improve quality of life,<sup>55</sup> it is possible that some of the improvements in the AD group were not exclusively because of positive pressure therapy. Multiple providers prescribed treatment according to our usual clinical algorithm, but not a study algorithm, this could have resulted in variations in practice that not only influenced treatment choices but also adherence to PAP. In addition, patients may have received treatment for other service-related illnesses concurrently which may have contributed to their improved sleep. Importantly though, we demonstrated that within 90 days of clinical evaluation of Soldiers and Airmen with restricted sleep periods and multiple comorbid illnesses, PAP adherence improved their sleep and depressive symptoms.

Sleep disturbances are the signature illness of military service, affecting nearly all active duty military personnel. Military personnel with comorbid service-related illnesses typically have more disturbed sleep and thus are more likely to require a formal sleep medicine evaluation. Diagnosing and treating OSA can improve depressive symptoms, sleepiness, sleep quality, energy/fatigue, emotional well-being, and social functioning.<sup>42,43</sup> Although the military has begun to recognize the importance of sleep, there is little objective data establishing effective treatment regimens and outcomes for this high-risk population. Future research is required to establish OSA treatment protocols for military personnel and veterans and develop multidisciplinary treatment models, which integrate their comorbid service-related illnesses.

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