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REVIEW ARTICLES

The Effect of Patient-Facing Applications on Positive Airway Pressure Therapy Adherence: A Systematic Review

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Study Objectives: Many patients struggle with adherence to positive airway pressure (PAP) therapy for sleep apnea. In this systematic review we examined the effect that patient-facing applications (PFA)—web-based applications that interact directly with the patient—have on PAP adherence.

Methods: A comprehensive search of PubMed, CINAHL, MEDLINE, and SCOPUS databases was performed. We looked for studies where: (1) patients were adults with sleep apnea initiating PAP therapy for the first time; (2) the intervention was a PFA that incorporated individual PAP use data; (3) the comparison was usual and/or telemedicine care, and (4) outcomes of objective PAP adherence data were recorded.

Results: Seven studies were identified (two randomized trials, one prospective cohort trial, four retrospective cohort studies). Cumulatively the studies enrolled 304,328 patients, with individual enrollment ranging between 61 and 172,678 patients. Six studies showed that PFA use was associated with using PAP for significantly more hours per night (range 0.7–1.3 hours more). PFA cohorts used PAP a greater proportion of nights and had a lower rate of mask leak. There was no difference in apnea-hypopnea index and self-reported measures of symptoms between study groups.

Conclusions: PFA use was associated with improved adherence to PAP therapy. Although this conclusion is based on only two small trials and predominantly observational studies and therefore should be tested in large prospective trials, the PAFs are inexpensive, do not draw on health care resources, and show promise in improving PAP therapy for OSA.

Keywords: internet, obstructive sleep apnea, patient compliance, self-care, self-management, telemedicine

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BACKGROUND

Positive airway pressure (PAP) therapy is the most commonly prescribed treatment for obstructive sleep apnea (OSA), but even when adherence is defined as ≥ 4 hours of nightly use, 46% to 83% of patients are nonadherent.[1] Importance of adherence is underscored by the dose-dependent relationship between PAP adherence and outcomes.[2,3] Therefore, there is a need for successful methods to improve PAP adherence.

Because technology allows objective measurement of PAP usage, challenges with PAP nonadherence have been known for more than 25 years.[4] However, nonadherence is a ubiquitous challenge in the management of chronic diseases. A meta-analysis of 569 studies of nonpsychiatric prescription therapy found an average adherence rate of only 40% for chronic diseases.[5,6] In addition to reducing costs of therapy, simplifying regimens, and creating effective reminder packaging, several studies have emphasized multiple patient-level educational interventions with behavioral support as effective.[7] The major goal of educational and behavioral support is to improve the ability of patients to manage their own illness.[8] Successful self-management requires self-monitoring of symptoms or physiologic processes, decision making to make changes in response to observations from self-monitoring, and problem solving.[9]

Educational and behavioral support to enhance self-management may be provided during in-person visits, or via telemedicine.[1] An intensive in-person program improved PAP adherence by an average of 1.5 h/night compared to usual care, but required very frequent interactions with the patient.[10] Telemedicine is increasingly seen as a tool to deliver cost-effective care while increasing accessibility. Telemonitoring for management of OSA has been shown to improve patient adherence.[11–13] However, these interventions can be labor and resource intensive, and may fail to engage the patient in self-care.

With growing internet access, there is a developing role for web-based patient-facing applications (PFA) to assist patients in self-management of OSA. PFAs do not require interaction with health care providers and give patients direct access to their PAP data in real time. These platforms are commonly equipped with educational material and troubleshooting tips.[14,15] In addition to researcher-developed applications, two examples of PAP manufacturer-developed PFAs are DreamMapper (previously SleepMapper) (Philips Respironics, Murrysville, Pennsylvania, United States) and myAir (ResMed Corp, San Diego, California, United States).[14,16] Because of their content and design, PFAs could potentially help the patient self-manage OSA and improve adherence while decreasing health care resource utilization. The aim of this systematic review was to assess whether patient use of PFAs for PAP therapy affects treatment adherence.

METHODS

Literature Review

A comprehensive search of PubMed, CINAHL, MEDLINE, and SCOPUS was performed from inception until February 2, 2018. No restrictions on language, time, or study design were applied. The search phrase formula, composed of free-text and Medical Subject Headings terms, was: (sleep disordered breathing OR sleep apnea syndromes OR obstructive sleep apnea) AND (patient engagement OR self-monitoring OR mobile applications OR telemedicine OR real-time feedback OR web-based OR access to information OR patient participation) NOT (remote monitoring). Bibliographies of all included studies and the publications citing the included studies were reviewed. Phillips Respironics and ResMed were contacted to inquire about any additional studies not yet indexed.

Study Selection

Studies were eligible if they met the following "PICO" (population studied, intervention, comparison group, outcomes of interest) criteria: (1) population studied was adult (age 18 years or older); (2) population studied was initiating or using PAP therapy for sleep apnea; (3) intervention was using a PFA with access to real-time individual PAP data; (4) comparison groups were either usual care and/or telemonitoring; (5) outcomes included average PAP use (time/night). Exclusion criteria were: (1) intervention did not provide patients with access to PAP data; (2) PAP prescription was not new; (3) publication type was case report, meta-analysis, editorial, review, note, or letter. The title and abstract of publications meeting criteria were screened by two authors, and responsive manuscripts were then reviewed in their entirety, consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis checklist.[17]

Data Collection

We extracted the country, study design, study period, study population and demographic characteristics, interventions, follow-up period, and outcome measures from each publication. Meta-analysis was not performed because of heterogeneity and the small number of studies.

Quality Assessment

Methodologic quality of the studies was assessed independently by two reviewers (G.F.S. and T.I.M; **Table 1**). Study design was assessed based on the Oxford Centre for Evidence-Based Medicine Levels of Evidence.[18] Prospective and retrospective cohort studies were evaluated using the Newcastle-Ottawa Scale.[19] The methodologic quality of the randomized trials was assessed with the Cochrane risk of bias tool.[20]

RESULTS

Study Selection

The literature search identified 315 unique publications, of which 7 met review criteria (**Figure 1**). Two studies were controlled clinical trials,[21,22] one was a prospective cohort study,[23] and four were retrospective cohort studies.[14,15,24,25] The cumulative number of participants was 304,328. Study information and participant characteristics are summarized in **Table 1** and **Table 2**.

The first described PFA for PAP therapy used in a randomized trial was MyCPAP, a tool that enabled patients to review nightly adherence, apnea-hypopnea index (AHI), and mask leak.[21]

The second randomized trial had three study groups: usual care, usual care with access to PAP data, and usual care with access to PAP data and financial incentive.[22] The website only provided the patients with the hours of PAP use. Patients in the financial incentive group received a reward during the first week for each login day and for each night PAP was used for a minimum of 4 hours.[22]

One prospective cohort study recruited participants sequentially by offering Monday clinic patients access to PFA and recruiting Wednesday clinic patients as control participants. Patients who agreed to use the tool were given access to SleepMapper (now DreamMapper).[23]

The four retrospective cohort studies were similar in concept. Hardy et al. retrieved patient data from Philips Respironics' PAP database. The aim was to assess DreamMapper's effect on adherence.[15] Pittard et al. explored the adherence of patients with DreamMapper utilizing the Australian Philips Respironics' database.[25] Woehrle et al.[24] published a retrospective analysis of data from ResMed Healthcare Germany, evaluating the effect of myAir, ResMed's PFA. Uniquely, usual care in this study involved telemonitoring with feedback.[24] A study by Malhotra et al. explored the adherence of patients using myAir from ResMed's United States database.[14]

Average Hours of Use Per Night

All studies showed an increase in nightly PAP use in patients using PFA versus the control groups, with significance ($P < .05$) in six out of seven studies. The difference in average nightly use between the study groups varied between 0.7[21] and 1.3 hours[23] (**Table 3**). According to the study by Kuna et al., financial incentive had no additional benefit on average hours of use at 7 or 90 days.[22]

Percentage of Nights PAP Was Used for Any Amount of Time

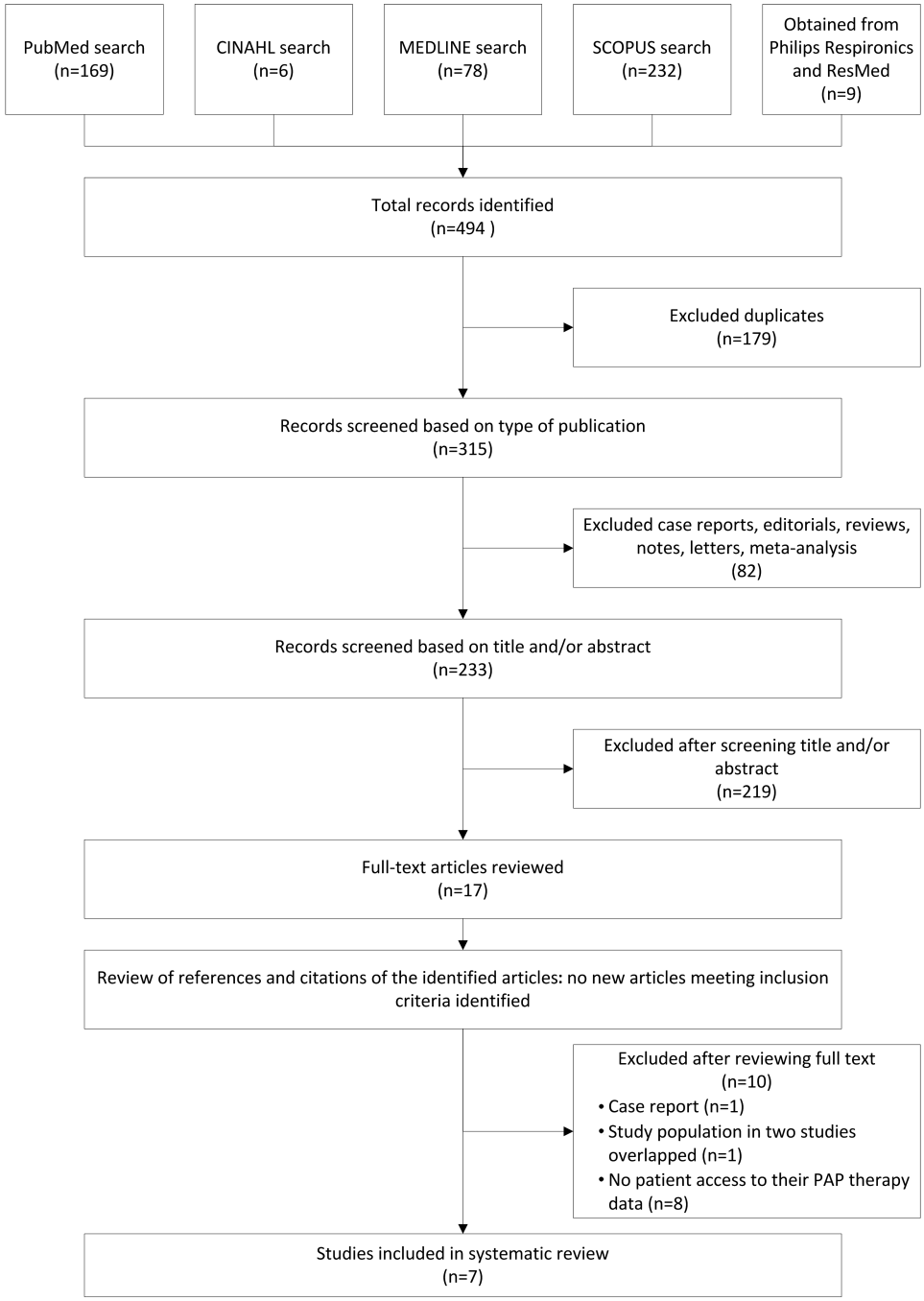
All studies that assessed the number of nights patients used PAP found a significant difference.[15,22–24] According to the study by Hardy et al., at 90 days the PFA cohort used PAP 78.5% of nights versus 62.6% nights in the usual care cohort.[15] An even greater difference was found by Hostler et al., with 78% nights in the PFA group versus 55.5% in usual care.[23] Even at 180 days the PFA group was significantly more adherent[24] (**Table 3**).

Kuna et al. reported a mean number of days per week that PAP device was used. Patients using the PFA with and without financial incentive outperformed usual care group with 5.6 nights per week for both intervention arms as compared to 4.7 nights for usual care ($P < .0001$ and $P < .0001$).[22]

Apnea-Hypopnea Index

Five studies evaluated the effect of PFA on residual AHI measured by the PAP device. Although technically three out of five studies found a lower AHI in the PFA groups and two showed

Figure 1—Flow diagram of study selection.



lower AHI in usual care groups, the AHI was within normal limits (less than 5 events/h) for all groups in all studies after treatment initiation.[14,15,22–24]

Mask Leak

Mask leak was significantly lower in PFA cohorts both at 90 and 180 days, as demonstrated by four studies.[14,15,22,24] Interestingly, the randomized clinical trial by Kuna et al. showed 5.9 L/min less mask leak in the PFA cohort even though patients did not have access to mask leak information or any troubleshooting recommendations[22] ($P < .001$, **Table 3**).

Other Outcomes

Woehrle et al. assessed persistence of PAP therapy by recording the rate of PAP device return to the durable medical equipment provider. The PFA group terminated treatment by 180 days less often (0.6% versus 3.4% in the usual care group, $P < .001$).[24]

Two studies looked at the quality-of-life questionnaires. In the trial performed by Stepnowsky et al., the Epworth Sleepiness Scale (ESS) mean score decreased in both trial arms after 4 months of PAP therapy (usual care from 10.5 ± 5.4 to 6.5 ± 4.2; intervention group from 10.7 ± 5.2 to 7.1 ± 4.5). The

Table 1—Study characteristics.

Study	Study Design	Study Population	Sample Size	Study Groups (n)	Follow-Up (days)	Relevant Outcomes	Levels of Evidence [a]	NOS
Stepnowsky et al. 2013	Randomized controlled trial	Patients with OSA with AHI ≥ 15 events/h initiating CPAP therapy, United States	241	• PFA – MyCPAP [b] (126) • Usual Care (115)	14, 60, 120	• Hours use/all nights • ESS total score • SAQLI • CES-D	2	N/A
Kuna et al. 2015	Randomized controlled trial	Patients with OSA with AHI ≥ 10 events/h initiating PAP therapy, United States	138	• PFA [c] (45) • PFA [c] with financial incentive (39) • Usual care (52)	7, 30	• Hours use/all nights • Hours use/nights used • % nights used • Mask leak (L/min) • AHI (events/h) • FOSQ-10 score • ESS total score • SF-12 (physical and mental health)	2	N/A
Pittard et al. 2015	Retrospective cohort	PAP users in Sleepeasy EncoreAnywhere database, Australia [e]	2,173	• PFA – DreamMapper [d] (459) • Usual care (1,714) • Matched usual care (459)	30, 60	• % of adherent patients [f] • Hours/all nights • Time to adherence	3	6
Hardy et al. 2016	Retrospective cohort	PAP users in EncoreAnywhere database, United States [e]	172,678	• PFA – DreamMapper [d] (85,076) • Usual Care (87,602)	30, 60, 90	• Hours use/all nights • Hours use/nights used • % nights used • % nights used ≥ 4 hours • % of adherent patients [f] • Mask leak (L/min) • AHI (events/h)	3	7
Hostler et al. 2017	Prospective cohort trial	Patients with OSA with AHI ≥ 5 events/h and fatigue/sleepiness initiating PAP therapy, United States	61	• PFA – SleepMapper [d] (30) • Usual care (31)	77	• % nights used ≥ 4 hours • Hours use/all nights • Hours use/nights used • % nights used • AHI (events/h)	3	7
Woehrle et al. 2018	Retrospective cohort with propensity matching	PAP therapy users from ResMed Healthcare database, Germany	1,000	• PFA – myAir [g] (500) • Usual care with telemonitoring (500)	180	• % nights used ≥ 4 hours • Hours use/all nights • Hours use/nights used • % nights used • Mask leak (L/min) • AHI (events/h)	3	8
Malhotra et al. 2018	Retrospective cohort with propensity matching	PAP therapy users from AirView database, United States [h]	128,037	• PFA – myAir [g] (42,679) • Usual care (545,690)	30, 60, 90	• % of adherent patients [f] • Number of days to achieve adherence [f] • Hours use/all nights • Mask leak (L/min) • AHI (events/h)	3	7

[a] Oxford Centre of Evidence-Based Medicine Levels of Evidence.[18] [b] MyCPAP is a researcher-developed patient-facing application that provides patients with their PAP device data, coaching tips, and education. [c] Patients had real-time access to their nightly use PAP data only. [d] DreamMapper (Philips Respironics) is a patient-facing application that provides patients with their PAP device data, coaching tips, and education; previously called SleepMapper. [e] EncoreAnywhere/Sleepeasy EncoreAnywhere (Philips Respironics) is a data management system that allows gathering and sharing of patients' adherence data. [f] Adherence was defined as ≥ 4 hours per night > 70% nights for 30 consecutive days over the first 90 days. [g] myAir (ResMed Corp.) is a patient-facing application that provides patients with their PAP device data, coaching tips, and education. [h] AirView (ResMed Corp.) is a HIPAA-compliant password-protected cloud-based database with patients' PAP device data. AHI = apnea-hypopnea index, CES-D = Center for Epidemiological Studies-Depression Scale short form, CPAP = continuous positive airway pressure, ESS = Epworth Sleepiness Scale, FOSQ-10 = Functional Outcomes of Sleep Questionnaire-short form, OSA = obstructive sleep apnea, NOS = Newcastle-Ottawa Scale, PAP = positive airway pressure, PFA = patient-facing application, SAQLI = Sleep Apnea Quality of Life Index, SF-12 = Health Survey Short-Form 12.

scores were not statistically significantly different between the two groups.[21] Similarly, both groups in the trial performed by Kuna et al. had a decrease in the mean ESS score without any significant difference between the groups. Mean change in usual care was −3.6 ± 4.8 and in the PFA group −3.0 ± 5.4 (P = .604).[22] The Sleep Apnea Quality of Life scores were not statistically significantly different between the trial groups after 4 months of therapy in the trial by Stepnowsky et al. (usual care 4.6 ± 2.6; PFA group 5.1 ± 2.0, P not significant).[21] Neither was there any difference in the results of the Center for Epidemiological Studies - Depression score (usual care 7.1 ± 4.9; PFA group 8.6 ± 5.5, P not significant).[21] The Functional Outcomes of Sleep Questionnaire – short form score improved significantly with PAP therapy in both study groups in the trial by Kuna et al., but the degree of change was not significantly different between the groups (mean change of 1.4 ± 2.5

Table 2—Demographic and baseline characteristics.

Study	Group	Age, years	Male, n (%)	BMI, kg/m²	AHI, events/h	PAP Mode, n (%)
Stepnowsky et al. 2013	PFA	52.7 ± 13.4	N/A	32.6 ± 8.1	36.3 ± 25.0	CPAP 126 (100)
	Usual care	51.5 ± 13.2	N/A	32.4 ± 8.1	36.7 ± 27.3	CPAP 114 (100)
Kuna et al. 2015	PFA	53.2 ± 11.7	30 (66.7)	38.0 ± 7.6	38.1 ± 28.3	N/A
	PFA with financial incentive	49.8 ± 11.7	25 (64.1)	36.5 ± 8.0	35.7 ± 19.8	N/A
	Usual care	49.6 ± 12.7	28 (53.8)	37.5 ± 10.0	39.1 ± 30.1	N/A
Pittard et al. 2015		Not reported	N/A	N/A	N/A	CPAP or APAP
Hardy et al. 2016	PFA	49 ± 13	42,336 (50)*	N/A	N/A	N/A
	Usual care	57 ± 15	32,370 (37)*	N/A	N/A	N/A
Hostler et al. 2017	PFA	44.5 ± 11.3	N/A	N/A	19.3 (10.1–25.3)†	N/A
	Usual care	42.1 ± 6.8	N/A	N/A	18.1 (10.3–29.5)†	N/A
Woehrle et al. 2018	PFA	56 ± 13	437 (87)	N/A	N/A	CPAP 184 (37) Bilevel 1 (0) APAP 303 (61) ASV 12 (2)
	Usual care	55 ± 12	443 (89)	N/A	N/A	CPAP 175 (35) Bilevel 0 (0) APAP 313 (63) ASV 12 (2)
Malhotra et al. 2018	PFA	51.8 ± 13	N/A	N/A	N/A	CPAP 18,161 (42.6) Bilevel 4,841 (11.3) APAP 19,367 (45.4) Missing 310 (0.7)
	Usual care	52.2 ± 13.4	N/A	N/A	N/A	CPAP 36,343 (42.6) Bilevel 9,626 (11.3) APAP 38,768 (45.4) Missing 621 (0.7)

*This study provided the following additional information regarding participant sex: PFA: female 18,422 (22), unspecified 24,318 (28); Usual care: female 21,084 (24), unspecified 34,148 (39). Data are presented as mean ± standard deviation unless otherwise indicated. † = median and confidence interval. AHI = apnea-hypopnea index, APAP = automatic positive airway pressure, ASV = adaptive servoventilation, CPAP = continuous positive airway pressure, OSA = obstructive sleep apnea, PAP = positive airway pressure, PFA = patient-facing application.

in usual care and 1.3 ± 3.0 in PFA group).[22] The Health Survey Short Form 12 - mental health component scores improved after 3 months of treatment in both groups, though the change was only significant in usual care (usual care mean change 0.3 ± 0.4; PFA group mean change 0.2 ± 0.5).[22] Health Survey Short Form 12 – physical component did not improve in either of the groups.[22]

Kuna et al. evaluated frequency of PFA access over time. During the first week 53.0 ± 9.9% of the PAP data access group logged in versus 72.9 ± 6.6% in the financial incentive group. After financial incentive ceased there was no difference between the groups. The proportion of patients who logged in to the PFA steadily decreased over time to approximately 10% at 90 days.[22]

Risk of Bias

The randomized trial by Stepnowsky et al. had a low risk of bias for blinding of outcome assessment, high risk of bias for participant blinding and selective reporting, and unclear risk for other components.[21] The trial by Kuna et al. had low risk of bias in all components except for a high risk of participant blinding.[22] See **Table 4** for details. All cohort studies involved registries where patients self-selected to use or not use PFAs, providing a high risk of bias in cohort construction.[14,15,24,25]

DISCUSSION

The studies indicate that PFAs are associated with improved PAP therapy adherence and reduced mask leaks when compared with usual care models.[14,15,22–26] One study also found a higher therapy persistence rate.[24] These improvements in PAP therapy adherence were similar to those observed in telemonitoring interventions, which have shown 0.4 to 2 hours of increased PAP use per night.[12,13,27,28] Telemonitoring systems require health care provider–initiated patient contact and deployment of health care resources, whereas PFAs engage patients directly without placing additional burden on health care. One study compared outcomes in patients using a telemonitoring system with those using the telemonitoring system plus a PFA.[24] PFA addition resulted in significant improvement in nightly PAP usage and in treatment persistence.[24] PFAs seem to uniquely contribute to improved PAP adherence.

The PFAs included in this review all provided the patients with feedback regarding the pattern and amount of individual PAP usage. In addition, several PFAs incorporated features to enhance self-efficacy skills informed by theories of behavior change. Self-efficacy is confidence in one's ability

Table 3—Results.

Parameter	Study	PFA		Usual Care		*P*	Follow-Up (days)
		Mean (SD)	Total n	Mean (SD)	Total n		
Average Hours of Use Per Night	Stepnowsky et al, 2013	3.9 (2.3)	126	3.2 (2.4)	114	.03	120
	Kuna et al, 2015	4.8 (3)	46	3.8 (3.3)	52	< .0001	90
	Pittard et al, 2015	5 (2.2)	459	3.9 (2.6)	459	.001	60
	Hardy et al, 2016	5 (2.5)	85,077	3.9 (2.5)	87,602	< .001	90
	Hostler et al, 2017	4 (2.4–4.8) [a]	30	2.7 (1.7–3.9) [a]	31	.08	77
	Woehrle et al, 2018	5.4 (1.9)	500	4.2 (2.4)	500	< .001	180
	Malhotra et al, 2018	5.9 (0.01) [b]	42,679	4.9 (0.01) [b]	85,358	< .0001	90
Percent of Nights PAP Was Used for Any Length of Time	Hardy et al, 2016	78.5 (28.5)	85,077	62.6 (35.9)	87,602	< .001	90
	Hostler et al, 2017	78 (22)	30	55.5 (24)	31	< .001	90
	Woehrle et al, 2018	88	500	79	500	< .001	180
Percent of Nights PAP Was Used > 4 Hours	Hardy et al, 2016	65.9 (31.4)	85,077	50.1 (35.8)	87,602		90
	Hostler et al, 2017	78 (22)	30	37 (25)	31	.02	77
	Woehrle et al, 2018	77 (25)	500	63 (32)	500	< .001	180
	Malhotra et al, 2018	83.4	42,679	66.3	85,358		90
Apnea-Hypopnea Index	Kuna et al, 2015	3.4 (4.3)	45	3.2 (3.7)	52	.015	90
	Hardy et al, 2016	3.2 (3.8)	85,077	3.7 (5.1)	87,602	< .001	90
	Hostler et al, 2017	3 (1.6–3.8) [a]	30	2.3 (1.2–5.0) [a]	31	.7	77
	Woehrle et al, 2018	2.8 (3.3)	500	3.1 (3.6)	500	.181	180
	Malhotra et al, 2018	2.7 (0.02) [b]	42,679	3.2 (0.02) [b]	85,358	< .0001	90
Mask Leak (L/min)	Kuna et al, 2015	33.1 (13)	45	39 (26.1)	52	< .001	90
	Hardy et al, 2016	32.1 (15.2)	85,077	32.6 (21.3)	87,602	< .001	90
	Woehrle et al, 2018	2.7 (4)	500	4.1 (5.3)	500	< .001	180
	Malhotra et al, 2018	16.9 (0.09) [b]	42,679	19.4 (0.09) [b]	85,358	< .0001	90

[a] Median (interquartile range). [b] Mean (standard error). Hardy et al performed two separate analyses: "conservative analysis" where any missing data were filled as 0 hours use and "high user analysis" where only participants with complete downloads were included.[15] Only results of "conservative analysis" were included in this review. PAP = positive airway pressure, PFA = patient-facing application, SD = standard deviation.

Table 4—Risk of bias assessment for randomized trials using the Cochrane risk of bias tool.[20]

	Stepnowsky et al. 2013	Kuna et al. 2015
Selection bias (random sequence generation)	Unclear	Low
Selection bias (allocation concealment)	Unclear	Low
Performance bias (blinding of participants and personnel)	High	High
Detection bias (blinding of outcome assessment)	Low	Low
Attrition bias (incomplete outcome data)	Unclear	Low
Reporting bias	High	Low

to change.[29,30] This concept is a part of social cognitive theory, which regards self-efficacy as a major determinant of behavior change.[29] Strong self-efficacy beliefs are associated with the ability to withstand failure and persist in efforts.[30,31] Empirical evidence supports the association between self-efficacy and improved treatment adherence in sleep medicine.[12,32] MyCPAP, DreamMapper, and myAir enhance self-monitoring by providing the patient with easy-to-view reports of trends in usage, and AHI. All three PFAs also supply feedback about mask leak. myAir additionally monitors mask off/on events and gives a summary score based on proprietary weighting of the aforementioned factors. Although MyCPAP provides educational materials and troubleshooting tips, they must be selected by the patient. In contrast, the commercial products serve up educational suggestions based on the monitoring as well as suggestions for selecting intermediate goals of care, possibly better equipping patients to problem solve and to set goals. Perhaps future research could evaluate which features are most important in helping patients achieve their goals of care.

Only two studies explored the effect of PFAs on OSA symptoms.[21,22] The study groups in the trial by Stepnowsky et al. did not differ at baseline in any of these measures. Both groups in this study received identical instruction and education on OSA and PAP. Usual care consisted of follow-up with clinic staff at predetermined intervals. Beyond this, participants were encouraged to call should any issues or concerns arise. The clinical interaction in intervention groups after

PAP initiation was dependent on patient's needs, symptoms, and objectively measured nightly data.[21] In the trial by Kuna et al., all participants received the same usual care with one clinic visit with the sleep specialist after treatment initiation. In this study all patients with any other sleep disorder diagnosis were excluded.[22] Two studies that assessed functional outcomes were small in sample size and perhaps not able to detect differences. As the benefit in using PFA resulted in 0.7 to 1.3 hours more PAP use, it could be that this difference has a minimal effect on symptom improvement. Furthermore, PAP adherence does not always translate into symptom improvement, and the scores could be affected by coexisting conditions.[33] Insomnia, for example, is a known risk factor for PAP nonadherence, though the study by Kuna et al. did try to eliminate confounding due to comorbidities.[34] These findings highlight that even optimally delivered PAP therapy leaves many patients with residual symptoms that require alternative management strategies. The reported slow decline in PAP adherence despite PFAs suggests a need for additional interventions.[22] Perhaps helping patients establish peer support via a forum or discussion board incorporated in the PFA could aid in long-term adherence. Additional studies are needed to determine whether PFAs have an effect on symptoms, quality of life, and clinical outcomes of OSA. No studies have addressed adherence 1 year or longer after PAP treatment was initiated. The study by Woehrle et al. was the only one that looked at adherence as far as 180 days after therapy initation.[24] It will be important to evaluate long-term adherence in future research.

Not all patients with access to PFA will actually use it. In fact, most of the studies enrolled patients if they signed up for access to the PFA, but were not able to assess the actual use of the application. The study by Kuna et al. was the only one that tracked website use and only about half of participants logged in during the first week. The proportion of patients using the website declined with time.[22] It is not unusual for patients to lose interest in internet based interventions.[35] A study assessed long-term use of a patient online portal and found that long-term use could only be predicted by having broadband access at home, high self-rated ability for internet use, and overall online behavior, none of which are easily modifiable.[36] One study indicated that self-selected users of PFA were younger than those who elected not to use a PFA, perhaps reflecting comfort levels with internet and smart-phone technologies.[15]

There are potential non-patient–related barriers to PFA adoption. PFAs require that PAP data be transmitted to a central database wirelessly, enabling patient, provider, and commercial access to usage data. PAP manufacturers use proprietary cloud-based data platforms and utilize different algorithms for respiratory event detection. Therefore, health care professionals may require access to several different databases and because not all patients use the same brand of PAP devices, technical standards are needed to enable aggregation into one's health care record.[37,38] Privacy may also be an issue. While most users in the trial by Stepnowsky et al. stated that they were "not at all" concerned about their information being sent over the internet, telemedicine does present privacy and security concerns.[21,38] Finally, there are practice standard and business model barriers. There are no guidelines regarding who and how frequently patient data should be reviewed, or regarding what ought to be done when adherence is suboptimal.[38] Billing and reimbursement for electronic data review and telemedicine services are not well developed either.[37]

A major limitation of this systematic review is the small number of studies, with only two randomized trials.[21,22] Retrospective studies were subjected to selection bias because it was the patients' choice to use the PFA. Therefore, the results may be confounded because patients who chose to use the PFA may be more invested in their therapy to begin with. The large retrospective studies that primarily relied on PAP cloud data also could not control for multiple baseline factors that can have significant effect on adherence, such as disease severity, comorbidity, or cultural and socioeconomic influences. There was no adjustment for age, severity of sleep apnea, socioeconomic status, education, access to internet, or internet and electronic device comfort level. Another potential confounder in registry studies such as that by Hardy et al. is the possibility that some patients may have been experienced PAP users prior to joining the registry rather than new PAP users.[14,15,25] Such patients might react differently to PFAs than PAP-naïve patients. However, prior studies show that PAP usage patterns are established soon after PAP initiation, and it seems unlikely that providing feedback data and recommendations to experienced users would result in greater improvement in PAP adherence than what was observed in PAP-naïve patients.[22] In addition, improvement in PAP adherence in experienced PAP patients, a successful rescue intervention, would be an even more favorable outcome than anticipated. If PAP-experienced patients made up a significant part of database study populations, the results would likely be biased against improvement in PAP utilization rather than for it. In the study by Hardy et al., the investigators thought this situation was, however, rare (personal communication).[15] Additionally, the "usual care" varies between medical facilities and makes generalization of results difficult. The results of studies that used PAP manufacturer databases are in this regard closest to real life because patients come from many different health care providers.[14,15,24,25]

CONCLUSIONS

The use of PFAs is associated with improved PAP therapy adherence and possibly with improved therapy persistence. Although PFAs are likely to become routinely used, further efforts are needed to identify key features, their effect on outcomes of interest, and which patients would benefit from them most.

ABBREVIATIONS

AHI, apnea-hypopnea index
ESS, Epworth Sleepiness Scale
OSA, obstructive sleep apnea
PAP, positive airway pressure
PFA, patient-facing application

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