

Clinical and economic assessments of a personalized support plan to improve adherence to positive airway pressure therapy in patients with obstructive sleep apnea: a randomized controlled trial in Portugal

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Abstract

Purpose

This multicenter, prospective study evaluated clinical and economic impacts of a personalized support plan for the management of positive airway pressure (PAP) therapy for obstructive sleep apnea (OSA) by home support providers (HSPs).

Methods

Adults with OSA newly prescribed PAP were randomized to a personalized support plan (VitalCare) or standard follow-up. The primary endpoint was mean daily PAP usage over the first 3 months. Secondary endpoints were proportion of adherers and symptom control after 12 months, medical/provider workload, and estimated health economic impact.

Results

107 individuals were analyzed (65 males, aged 57.1 years, mean apnea-hypopnea index 30.4/h). Mean 3-month adherence did not differ significantly between personalized plan and standard care groups (4.61 ± 2.24 vs. 3.85 ± 2.62 h/day; $p = 0.059$). Between-group differences in the proportion of days with PAP usage, individuals with PAP usage ≥ 4 h/day and < 2 h/day at 6 and 12 months significantly favored the personalized support plan. Over one year, patients in the personalized support versus standard follow-up received ≈ 0.4 additional medical consultations and ≈ 1 supplemental provider home visit (and 2.4 other interventions). In the personalized support group, the lower the PAP adherence, the higher the number of interventions. Economic modelling estimated that the higher number of adherers on the personalized support plan would translate to direct and indirect annual savings of €255 and €220/person.

Conclusions

A personalized support plan has the potential to improve adherence to PAP therapy in individuals with OSA managed by HSPs, and modelling suggested that it could contribute to cost savings for the health system.

Introduction

Obstructive sleep apnea (OSA) is the most common form of sleep-disordered breathing, affecting up to a billion adults aged 30–69 years worldwide [1]. In Portugal, about 12.5% of adults this age have moderate to severe OSA [1]. Untreated OSA is associated with increased risk of road traffic accidents [2], cardiovascular [3] and metabolic [4] diseases, impaired cognitive function/dementia [5], reduced health-related quality of life [6], and increased all-cause mortality [7].

The preferred treatment for moderate-to-severe OSA is positive airway pressure (PAP) [8]. PAP splints the upper airway open during sleep and reduces the apnea-hypopnea index (AHI), often to normal levels [8]. In Portugal, PAP therapy is indicated for the treatment of moderate (AHI 15–29 events/h) and severe (AHI $\geq$ 30 events/h) OSA, and mild OSA (AHI 5–14 events/h) with daytime sleepiness and/or cardiovascular comorbidity [9–11]. Equipment supply and installation are performed at home by home support providers (HSPs). The respiratory technician provides training on device use and cleaning, ensures appropriate mask fitting, and performs follow-up ($\geq$ 2 home visits per patient annually) [9–11].

Long-term adherence to PAP is essential for realizing the benefits of therapy [12]. There is a dose-effect relationship between PAP usage and clinical outcomes/healthcare utilization, starting at usage of 2 h/day [13–15]. However, adequate adherence can be difficult to achieve [16], and average PAP usage has remained similar over the last 20 years [17]. In Portugal, the proportion of patients using PAP for $\geq$ 4 h/day in the first year of therapy is 54%–59% [18, 19].

Interventions supporting patients using PAP therapy are associated with clinically relevant increases in device usage [20]. A personalized patient support plan implemented by the HSP was developed to improve PAP usage without increasing medical workload. The plan considers lifestyle and OSA-/PAP-related factors at therapy initiation to determine the frequency and type of contacts.

This study compared the effects of the personalized support plan versus standard follow-up on PAP adherence, symptom control, healthcare professional/HSP workload, and estimated potential economic impact for the Portuguese health system.

Methods

Study design and randomization

This multicenter ($n = 5$), prospective, randomized open-label trial (NCT05246449) was conducted in Portugal from November 2021–December 2023. Participants were randomized 1:1 to undergo HSP management of PAP therapy using a personalized support plan (VitalCare, Air Liquide Healthcare) or standard follow-up. Randomization was stratified by study center and baseline OSA severity. Potential participants were provided with study information during a regular medical consultation; those who provided written informed consent were enrolled. The study protocol was approved by the relevant independent ethics committee at each participating site. The trial was conducted in accordance with the Declaration of Helsinki, and European and local laws.

Study participants

Eligible participants were aged $\geq$ 18 years, had been diagnosed with OSA and newly prescribed PAP therapy, were using a PAP device allowing remote data transmission, and had VitalAire as their HSP. Key exclusion criteria were: obesity hypoventilation syndrome; other sleep disorders; severe chronic

obstructive pulmonary disease (COPD); severe chronic heart failure; and investigator-assessed mental/cognitive inability to use all personalized support plan components.

Interventions by study group

Both groups received medical follow-up according to the clinical routine at each study center. Patients allocated to the personalized support plan group underwent an initial assessment that included evaluation of lifestyle factors (age, employment status, digital behavior, preferred contact channels) and predicted adherence to PAP therapy. The prediction algorithm considered OSA severity (pre-PAP AHI, sleepiness [Epworth Sleepiness Scale (ESS) score] [21]), subjective motivation for PAP therapy (none, low, average, good, very good) [22], and data from the first days of treatment (actual PAP usage and a CPAP perception questionnaire [23]). Based on the information obtained, each patient was assigned to one of six support plans that varied in terms of content (logistic, educational and/or supportive [20]), frequency of interactions, and communication channels (home visits, phone or video calls, mobile app) (**Figure S1**). The assigned plan could be updated during follow-up based on daily teletransmitted PAP usage data, and repeat data from the CPAP perception questionnaire. PAP data were processed through an alerting system to detect non transmission, poor usage and excessive unintentional leakage. Alerts were managed remotely by trained provider nurses who could plan appropriate interventions.

The standard follow-up group received standard PAP services from the HSP. PAP teletransmission was activated but data were not available to the HSP or physician, and did not generate alerts.

Study procedures and data collection

All participants had two study-specific hospital visits: at inclusion before PAP therapy initiation, and at one year. Relevant demographic, disease-related and safety data were collected. The ESS and the modified Thornton Snoring Scale [24] were completed by participants during a phone call with a HSP nurse at 3, 6, and 12 months. Possible ESS scores range from 0–24, with a score > 10 indicating excessive daytime sleepiness. The modified Thornton Snoring Scale evaluates the impact of snoring on quality of life; possible scores range from 0–15, with higher scores indicating more/more problematic snoring and a score ≥ 5 indicating a significant impact on quality of life. Teletransmitted PAP data were collected in the HSP database (Digital BackBone, Air Liquide Healthcare).

Study outcomes

The primary endpoint was average daily PAP usage over first 3 months of therapy. Secondary outcomes included average daily PAP usage and the proportion of adherent individuals (PAP usage ≥ 4 h/day) over 3, 6 and 12 months of follow-up, and residual AHI and changes in symptoms (daytime sleepiness, snoring) at 3 and 12 months. Medical and HSP workload was evaluated using the number of medical consultations and HSP interventions over 12 months' follow-up.

Sample size and statistical analysis

A target sample size of ≥ 100 evaluable participants was defined arbitrarily. This provides 80% power to detect a between-group effect size of 0.57 for the primary endpoint. All analyses were performed on an intention-to-treat (ITT) basis with no extrapolation of missing data. The ITT analysis included participants who started home PAP therapy and had daily teletransmitted data available. For participants who stopped using PAP, average PAP usage was calculated based on daily data available until therapy withdrawal. The primary endpoint was compared between groups using a parametric analysis of variance model adjusted for baseline AHI category and interaction between study group and baseline AHI category. Sankey plots were used to visualize individual changes in predefined adherence categories over time. Statistical analyses were performed using SAS version 9.4; statistical significance was set at 5%.

Health economic model

A health economic model was developed to estimate the potential clinical and economic impacts of higher rate of PAP adherence (device usage ≥ 4 h/day). The model considered differences in the number of clinical events (new cancers, cardiovascular events, road traffic and workplace accidents), healthcare resource use, days off work, and costs (direct and indirect) in adherers versus non-adherers, as described in Català et al. [25] and adjusted to the Portuguese setting. The model driver was the proportion of PAP-adherent individuals in each group over 1 year. More details are provided in **Supplemental Methods** and **Table S1**.

Direct medical costs included medical consultations, and hospital admissions for cardiovascular diseases, occupational and road traffic accidents. Indirect costs included days off work for medical follow-up. Two scenarios regarding the size of the population using the personalized support plan were simulated: individuals currently managed using this program in Portugal ($n = 11,500$), and all individuals having started PAP treatment in Portugal in 2024 ($\approx 28,400$).

Results

Study participants

A total of 113 individuals were randomized between February and October 2022. Of these, six were excluded from the ITT analysis (PAP refusal [$n = 1$], no PAP remote data transmission [$n = 5$]) (Fig. 1). ITT patients characteristics ($n = 107$) were relatively well balanced between groups (Table 1). PAP therapy was predominantly administered through a nasal mask (standard follow-up: 58.8%; personalized support plan: 60.7%) and with similar settings (median minimum–maximum pressures: 6.0–12.5 cmH₂O). Mean follow-up was 11.9 ± 2.5 months. Seven patients stopped PAP therapy before 1 year (four on the standard follow-up and three on the personalized support plan).

Table 1

Baseline demographic and clinical characteristics of the intention-to-treat dataset, overall and by study group

Characteristic	Overall (n = 107)	Standard follow-up (n = 51)	Personalized support plan (n = 56)
Age, years	57.1 ± 11.7	57.6 ± 9.6	56.6 ± 13.4
Male sex, n (%)	65 (60.7)	29 (56.9)	36 (64.3)
BMI, kg/m ²	30.8 ± 5.2	31.5 ± 5.1	30.2 ± 5.3
Tobacco use, n (%)	21 (19.6)	10 (19.6)	11 (19.6)
Regular alcohol consumption, n (%)	13 (12.1)	6 (11.8)	7 (12.5)
Baseline AHI, events/h	30.4 ± 19.9	28.5 ± 18.3	32.2 ± 21.2
AHI < 15 events/h, n (%)	26 (24.3)	14 (27.5)	12 (21.4)
AHI ≥ 15 to < 30 events/h, n (%)	39 (36.4)	18 (35.3)	21 (37.5)
AHI ≥ 30 events/h, n (%)	42 (39.3)	19 (37.3)	23 (41.1)
OSA symptoms			
ESS score	9.9 ± 5.5	10.1 ± 5.5	9.8 ± 5.6
Excessive daytime sleepiness (ESS score ≥ 11), n (%)	42 (42.9)	21 (45.7)	21 (40.4)
Snoring score	5.4 ± 3.5	5.4 ± 3.5	5.5 ± 3.6
Fatigue, n (%)	70 (65.4)	36 (70.6)	34 (60.7)
Unrefreshing sleep, n (%)	51 (47.7)	24 (47.1)	27 (48.2)
Morning headaches, n (%)	39 (36.4)	20 (39.2)	19 (33.9)
Insomnia with frequent awakenings, n (%)	29 (27.1)	15 (29.4)	14 (25.0)
Nycturia, n (%)	25 (23.4)	12 (23.5)	13 (23.2)
Mean number of comorbidities per patient	1.9 ± 1.4	2.2 ± 1.5	1.7 ± 1.2
Data are mean ± standard deviation, or number of participants (%) where the denominator is the number of patients without missing data.			
AHI, apnea-hypopnea index; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ESS, Epworth Sleepiness Scale; OSA, obstructive sleep apnea.			

Characteristic	Overall (n = 107)	Standard follow-up (n = 51)	Personalized support plan (n = 56)
Arterial hypertension, n (%)	58 (54.2)	33 (64.7)	25 (44.6)
Hypercholesterolemia, n (%)	27 (25.2)	12 (23.5)	15 (26.8)
Depression and/or anxiety, n (%)	9 (8.4)	3 (5.9)	6 (10.7)
Type 2 diabetes, n (%)	7 (6.5)	3 (5.9)	4 (7.1)
Asthma or COPD, n (%)	6 (5.6)	5 (9.8)	1 (1.8)
Coronary artery disease, n (%)	4 (3.7)	2 (3.9)	2 (3.6)
Stroke history, n (%)	3 (2.8)	2 (3.9)	1 (1.8)
Gastro-esophageal reflux, n (%)	3 (2.8)	3 (5.9)	0 (0.0)
Atrial fibrillation, n (%)	2 (1.9)	2 (3.9)	0 (0.0)
Data are mean $\pm$ standard deviation, or number of participants (%) where the denominator is the number of patients without missing data.			
AHI, apnea-hypopnea index; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ESS, Epworth Sleepiness Scale; OSA, obstructive sleep apnea.			

Personalized support plan

The predictive adherence assessment found that 38 (74.5%), 10 (19.6%) and 3 (5.9%) individuals in the personalized support plan group were likely to be high, intermediate and low adherers, respectively. Nineteen patients (37.3%) were comfortable using digital tools and 32 (62.7%) were not.

After 1 month, about half of patients had a positive attitude towards PAP therapy, and about 40% expressed difficulties tolerating PAP or the mask (**Table S2**). Higher scores to five questions on the CPAP perception questionnaire (indicating significant difficulty, discomfort or negative attitude towards PAP) were associated with lower 3-month PAP usage (data not shown).

Over 12 months, the mean total number of provider interventions (home visits, interventions at provider location, phone/video calls, mobile application, consumables delivery) was 5.4 ± 2.7 per patient, including a mean 2.9 ± 2.0 home visits. Individuals with low PAP adherence over the first 3 months received more home visits than those with intermediate or high adherence (Table 2).

Table 2

Number and reasons for medical consultations and provider interventions over 12 months by study group in all patients, and in subgroups based on positive airway pressure device mean daily usage category over the first 3 months

MEDICAL FOLLOW-UP	Standard follow-up (n = 51)	Personalized support plan (n = 56)
Number of consultations per patient		
Overall	1.1 ± 1.1	1.5 ± 1.1
Low adherers over first 3 months	0.7 ± 1.0	1.5 ± 1.1
Intermediate adherers over first 3 months	0.6 ± 0.9	1.3 ± 0.9
High adherers over first 3 months	1.5 ± 1.1	1.6 ± 1.1
Reasons for the consultations	n = 56 visits	n = 84 visits
Planned consultations	53	77
Change in PAP settings	1	5
Change in mask type	1	2
Unknown reason	1	0
PROVIDER FOLLOW-UP		
Total interventions* per patient		
Overall	2.0 ± 1.8	5.4 ± 2.7
Low adherers over first 3 months	1.6 ± 1.1	6.0 ± 2.5
Intermediate adherers over first 3 months	1.8 ± 1.4	5.2 ± 3.6
High adherers over first 3 months	2.1 ± 2.0	5.3 ± 2.5
Home visits per patient		
Overall	1.9 ± 1.7	2.9 ± 2.0
Low adherers over first 3 months	1.5 ± 1.2	3.8 ± 1.8
Intermediate adherers over first 3 months	1.8 ± 1.4	3.0 ± 2.6
Data are mean ± standard deviation or number of visits/interventions.		
*Total interventions include home visits, interventions at home support provider location, phone/video calls, application and consumables sent by post.		
PAP, positive airway pressure.		

MEDICAL FOLLOW-UP	Standard follow-up (n = 51)	Personalized support plan (n = 56)
Number of consultations per patient		
High adherers over first 3 months	2.0 ± 1.9	2.6 ± 1.8
Reasons for the interventions	n = 100 interventions	n = 301 interventions
Planned home visit	23	64
Planned phone call	3	83
Planned video call	0	14
Contact through mobile application	0	20
Home delivery of consumables	39	45
Postal sending of consumables	1	10
Nocturnal oximetry/PAP detailed report	14	20
Change of device/parameters	11	20
Visit for difficulties with PAP	5	17
PAP maintenance	4	0
Alert management	0	8
Data are mean ± standard deviation or number of visits/interventions.		
*Total interventions include home visits, interventions at home support provider location, phone/video calls, application and consumables sent by post.		
PAP, positive airway pressure.		

PAP adherence

Mean daily PAP usage over the first 3 months (primary endpoint) was not significantly different between the standard follow-up (3.85 ± 2.62 h/day) and personalized support plan (4.61 ± 2.24 h/day) groups (p = 0.059) (Table 3). The proportion of days with PAP usage and individuals with usage ≥ 4 h/day over the first 3 months were also similar between groups, but the proportion of participants with device usage < 2 h/day was significantly lower in the personalized support plan versus standard follow-up group (p = 0.02) (Table 3). Over the first 6 and 12 months, mean daily PAP usage, proportion of days with PAP usage and participants with device usage ≥ 4 h/day and < 2 h/day differed significantly between groups, in favor of the personalized support plan (Table 3). There was a statistically significant interaction between study group and baseline OSA severity (p ≤ 0.004), with higher PAP usage (average and proportion of adherent

individuals) over 3, 6 and 12 months in the mild or moderate OSA subgroups, but not in those with severe OSA (**Table S3**). Individuals with high adherence during the first month of therapy mostly stayed in the same category at all timepoints whereas intermediate and low adherers shifted between categories more frequently (Fig. 2).

Table 3
Positive airway pressure usage

	Standard follow-up (n = 51)	Personalized support plan (n = 56)	Between-group difference	p-value
PAP usage, h/day				
Over 3 months	3.85 ± 2.62	4.61 ± 2.24	0.88 ^c [-0.03 ; 1.79]	0.059 ^a
Over 6 months	3.86 ± 2.68	4.63 ± 2.18	0.94 ^c [0.03 ; 1.85]	0.042 ^a
Over 12 months	3.86 ± 2.69	4.55 ± 2.14	0.82 ^c [-0.08 ; 1.73]	0.075 ^a
Proportion of days with any PAP usage, %				
Over 3 months	71.2 ± 33.25	80.8 ± 23.0	10.2 ^c [-0.7 ; 21.1]	0.066 ^a
Over 6 months	68.7 ± 33.6	79.6 ± 23.3	12.6 ^c [1.7 ; 23.5]	0.024 ^a
Over 12 months	67.3 ± 34.3	77.2 ± 24.3	11.6 ^c [0.4 ; 22.8]	0.043 ^a
Adherent (device usage ≥ 4 h/day), n (%)				
Over 3 months	25 (50.0)	35 (62.5)	12.5 ^d	0.195 ^b
Over 6 months	23 (45.1)	36 (64.3)	19.2 ^d	0.046 ^b
Over 12 months	25 (49.0)	39 (69.6)	20.6 ^d	0.030 ^b
PAP usage < 2 h/day, n (%)				
Over 3 months	17 (34.0)	8 (14.3)	-19.7 ^d	0.017 ^b
Over 6 months	19 (37.3)	10 (17.9)	-19.4 ^d	0.024 ^b
Over 12 months	18 (35.3)	9 (16.1)	-19.2 ^d	0.022 ^b

	Standard follow-up (n = 51)	Personalized support plan (n = 56)	Between-group difference	p-value
PAP usage, h/day				
Data are mean ± standard deviation, or number of participants (%) where the denominator is the number of patients without missing data.				
^a Analysis of variance model adjusted for baseline AHI category and interaction between study group and baseline AHI category.				
^b Chi-squared test.				
^c Difference between adjusted means and 95% confidence interval in the personalized support plan group versus the standard follow-up group.				
^d Difference between proportion of participants (%) in the personalized support plan group versus the standard follow-up group.				
PAP, positive airway pressure.				

AHI and OSA symptoms

Residual AHI and changes in the ESS and Thornton scores were similar in both groups after 3 months. However, there was a significantly greater reduction in the ESS score from baseline to 12 months and a lower proportion of sleepy patients at 3 and 12 months in the personalized support plan versus standard follow-up group (Table 4).

Table 4
Clinical outcomes

Residual AHI, events/h	Standard follow-up (n = 51)	Personalized support plan (n = 56)	p-value
Over 3 months	2.45 ± 3.35 (n = 47)	2.61 ± 2.85 (n = 56)	0.92 ^a
Over 12 months	2.31 ± 2.80 (n = 51)	2.26 ± 2.21 (n = 56)	0.78 ^a
ESS score change from baseline			
At 3 months	-4.1 ± 4.2 (n = 40)	-5.0 ± 5.0 (n = 47)	0.31 ^b
At 12 months	-5.1 ± 5.9 (n = 39)	-6.2 ± 5.5 (n = 42)	0.047 ^b
Patients with ESS score ≥ 11, n/N (%)			
At 3 months	11/43 (25.6)	3/47 (6.4)	0.018 ^c
At 12 months	8/42 (19.0)	3/43 (7.0)	0.12 ^c
Thornton snoring score change from baseline			
At 3 months	-3.9 ± 3.6 (n = 39)	-4.3 ± 3.9 (n = 47)	0.41 ^b
At 12 months	-4.3 ± 3.1 (n = 39)	-4.7 ± 4.4 (n = 42)	0.37 ^b
Data are mean ± standard deviation, or number of participants [n] over number of participants without missing data for that parameter [N] (%).			
^a Analysis of variance model adjusted for baseline AHI category			
^b Analysis of covariance model (baseline score at inclusion as covariate) adjusted for pre-PAP AHI value			
^c Fisher's exact test			
AHI, apnea-hypopnea index; ESS, Epworth Sleepiness Scale; n, number of patients; N, number of patients without missing data.			

Intensity of medical and HSP follow-up over 12 months

The overall mean number of medical consultations per patient was slightly higher in the personalized support plan versus standard follow-up group (1.5 ± 1.1 vs. 1.1 ± 1.1); between-group differences were slightly greater in intermediate and low adherers. Main reasons for medical consultations were planned medical follow-ups (Table 2). The mean total number of provider interventions per patient was also higher in the personalized support plan versus standard follow-up group (5.4 ± 2.7 vs. 2.0 ± 1.8), with a

mean of one supplemental home visit (Table 2). In the personalized support plan group only, the lower the PAP adherence the higher the number of interventions. Interventions were mainly due to scheduled contacts according to the allocated personalized support plan.

Safety

There were no serious adverse events and thirteen non-serious adverse events during the study (mostly PAP-related side effects), six in the standard follow-up group and seven in the personalized support plan group (see **Supplemental Material** for full details).

Health economic modelling

For the 11,500 patients in Portugal currently managed with the personalized support plan, the clinical events avoided, reduced healthcare resource use and cost savings from a higher proportion of adherent individuals (Table 5) would result in an estimated total annual cost saving of €5.5 million (€2.9 million in direct costs). For all patients starting PAP in Portugal (28,400 patients/year), estimated potential total cost savings could reach €13.5 million (€7.2 million in direct costs). Annual total savings per participant were estimated at €475 (€255 in direct costs) (Fig. 3).

Table 5

Estimated number of clinical events and healthcare resource use avoided, and cost savings, over a 1-year time horizon for the use of a personalized support plan compared with standard follow-up

Clinical events, n	Simulation 1 (n = 11,500)	Simulation 2 (n = 28,400)
New cancer diagnoses	-173	-427
Cardiovascular events	-704	-1,738
Road traffic accidents	-246	-607
Workplace accidents	-13	-32
Healthcare resource use, n		
Specialist care visits	-3,799	-9,381
Emergency room visits	-1,228	-3,032
One-day hospitalizations	-113	-279
Hospital admissions	-787	-1,943
Intensive care unit admissions	-213	-527
Productivity		
Days off work, n	-29,364	-72,516
Costs, million €		
Direct costs*	-2.93	-7.23
Indirect costs**	-2.53	-6.25
Total costs	-5.46	-13.48
Simulation 1: individuals currently managed using the personalized support program (current impact; n = 11,500).		
Simulation 2: implementation of the personalized support plan for all individuals having started positive airway pressure therapy in Portugal in 2024 (approximately 28,400 – Sources: SPMS data investigation (Portuguese Shared Services of the Ministry of Health, EPE), June 2025 and APCSD (Portuguese HSP trade association) figures from 2021).		
*Direct costs include healthcare resource use for the clinical events.		
**Indirect costs include days of work absenteeism for medical follow-up.		

Discussion

The primary endpoint (mean PAP adherence over the first 3 months) did not differ significantly between the personalized support plan and standard follow-up groups. However, over 12 months, there was a significantly higher proportion of days with PAP usage (+ 12%) and people with device usage ≥ 4 h/day (+ 21%), and a significantly lower proportion of patients with adherence < 2 h/day (−19%) and excessive daytime sleepiness in the personalized support plan versus standard care group. There was a slight increase in workload for delivery of the personalized support plan, which was focused on patients with lower PAP adherence. Health economic modelling estimated that the higher number of adherent individuals with personalized support plan management would result in cost savings to the Portuguese health system of about €475/patient in the first year.

Potential reasons for the lack of between-group difference in mean adherence over first 3 months include insufficient statistical power due to the relatively small sample size (overall and in early PAP usage subgroups) and the possibility that 3 months' follow-up was insufficient to detect the full effect of the intervention. In particular, the latter seems likely because the personalized support plan was designed to monitor early adherence and then personalize the content/intensity of follow-up, which would take time to implement and have an impact. Another factor supporting this is that the intervention promoted adherence mostly in those with mild-to-moderate OSA, who often have lower short-term adherence.

To our knowledge, the only previous trial that evaluated the impact of personalized support from HSPs was conducted in Spain [6]. The between-group difference in mean daily PAP usage over 3 months in the intervention versus control group was greater in the Spanish study (+ 1.7 h/day) than in our study (+ 0.9 h/day). However, the between-group difference in the proportion of adherent individuals over 12 months was higher in our study (+ 21%) than in the Spanish study (+ 14%). The Spanish program included the same elements as ours plus a behavioral component, and twelve rather than six distinct personalized support plans. In a meta-analysis, behavioral interventions were more effective (+ 1.3 h/day) than educational/supportive interventions (+ 0.85/+0.7 h/day) for improving PAP usage in adults with OSA [20]. It is therefore possible that addition of a behavioral component to our personalized support plan could improve early PAP adherence. Another potential improvement could be to reduce the number of HSP interventions in high adherers.

The higher number of interventions and contacts in the first year of PAP therapy in the personalized versus standard follow-up group in our study (especially in individuals with low early adherence) is consistent with a French study evaluating the impact of telemonitoring and a pay-for-adherence scheme for HSPs, which found a similarly higher number of interventions for patients with low and intermediate PAP adherence [26]. Over time, a significant proportion of patients changed their adherence, highlighting the need for continuous telemonitoring, as recommended by the American Academy of Sleep Medicine [27]. The combination of telemonitoring-guided interventions and mixed telehealth/home visits could allow a more personalized approach to OSA management, optimizing adherence and HSP/physician resource allocation [28]. The negative individual and societal impacts of non-adherence to PAP therapy [29] mean that the use of a personalized support plan to increase adherence is warranted. Therefore,

available data suggest that there would be benefit in revising current regulations to allow adaptation of HSP interventions (number and modalities) based on patient's needs and preference.

In Portugal, national tenders provide fixed reimbursement to HSPs for PAP-related services. A new reimbursement model was implemented in 2024, including a pay-for-performance system that rewards treatment adherence (but telemonitoring is not reimbursed). The pay-for-performance approach should encourage use of solutions to improve adherence, such as that used in our study. These incentives would be expected to offset the additional expenses for providers related to infrastructure, personalized follow-up, telemonitoring, and extra interventions for non-adherent individuals.

Our health economic modelling suggests that the costs of PAP therapy management with a personalized support plan would be more than offset by the associated cost savings (€255 and €220 for direct and indirect costs, respectively). The data supporting an association between better adherence and lower healthcare resource use in our model (Català et al. [25]) are consistent with US studies [14, 30]. However, the magnitude of the effect in the Spanish study used ($\approx 30\%$) was greater than that in US studies. The potential impact of this on estimated health system benefit needs to be evaluated further. In particular, the use of historical clinical event rates and a high Spanish effect size may lead to optimistic cost-saving estimates, meaning that future real-world Portuguese data are required to validate these economic outcomes. Nevertheless, the Spanish study [25] provided the only relevant European published data.

Key limitations of our proof-of-concept study include a lack of statistical power and the short follow-up duration. However, the current data lay the groundwork for future, larger randomized controlled trials in this area. Furthermore, the ability to draw conclusions regarding health system benefit are limited by the fact that our data come from a model. This approach was more practical than an economic analysis of data from a large randomized trial, and prospective collection of health economic data would have been complex because of the inability to link to a Portuguese claims database. Our findings need to be reproduced in other countries and healthcare models. Finally, another important area for future research is the evaluation of the personalized support plan in patients with highly complex and costly respiratory comorbidities (such as those with obesity hypoventilation syndrome or severe COPD, who were excluded from the current study).

In conclusion, although the primary endpoint finding was neutral, the current results indicate the potential for a personalized support plan to improve adherence to PAP therapy in individuals with OSA managed by HSPs. Furthermore, modelling suggests that this intervention could reduce healthcare resource use and decrease both direct and indirect costs. Additional prospective studies are needed to confirm our results, and real-world data are necessary to validate the predictability of the initial HSP assessment and patient stratification.

Declarations

Funding

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Role of sponsor

Representatives of the study sponsor were involved in the design of the study, data collection and data analysis. The first draft of the manuscript was prepared by HP, SA and JT with the assistance of an independent medical writer funded by Air Liquide Santé International.

Ethics statement

The study protocol was approved by the relevant independent ethics committee at each participating site. All participants provided written informed consent before inclusion in the study.

Author contributions

PMGP is the guarantor. PMGP: conceptualization, methodology, validation, investigation, writing, review and editing of manuscript. HP: statistical methodology and formal analysis, writing, review and editing of manuscript. SA: health economic methodology and formal modelling, writing, review and editing of manuscript. GR: investigation and review of manuscript. FT: investigation and review of manuscript. JM: conceptualization, methodology, validation and review of manuscript. VC: investigation and review of manuscript. HT: regulatory process and review of manuscript. SB: data collection and review of manuscript. AS: conceptualization, methodology, validation, review and editing of manuscript. CM: conceptualization, methodology, validation, review and editing of manuscript. BC: conceptualization, methodology, validation, investigation, writing, review and editing of manuscript. JT: validation, writing, review and editing of manuscript.

The manuscript was reviewed and edited by all the authors. All authors made the decision to submit the manuscript for publication and assume responsibility for the accuracy and completeness of the analysis and the fidelity to the trial protocol.

Competing interests

PMGP has received speaker and consultant fees from AstraZeneca, GSK, Bial, Resmed, VitalAire and Pfizer, and support for meeting attendance from VitalAire, Boehringer and MSD. HP, SA, HT and SB are employees of Air Liquide Santé International. AS is an employee of VitalAire. JT is an employee of Air Liquide Healthcare. GR, FT, JM, VC, CM and BC have no conflict of interest to declare.

Data availability statement

The data are not publicly available due to ethical restrictions.

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References

1. Benjafield AV, Ayas NT, Eastwood PR et al (2019) Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med* 7(8):687–698. [https://www.doi.org/10.1016/s2213-2600\(19\)30198-5](https://www.doi.org/10.1016/s2213-2600(19)30198-5)
2. Udholm N, Rex CE, Fuglsang M, Lundbye-Christensen S, Bille J, Udholm S (2022) Obstructive sleep apnea and road traffic accidents: a Danish nationwide cohort study. *Sleep Med* 96:64–69. <https://www.doi.org/10.1016/j.sleep.2022.04.003>
3. Cowie MR, Linz D, Redline S, Somers VK, Simonds AK (2021) Sleep Disordered Breathing and Cardiovascular Disease: JACC State-of-the-Art Review. *J Am Coll Cardiol* 78(6):608–624. <https://www.doi.org/10.1016/j.jacc.2021.05.048>
4. Reutrakul S, Mokhlesi B (2017) Obstructive Sleep Apnea and Diabetes: A State of the Art Review. *Chest* 152(5):1070–1086. <https://www.doi.org/10.1016/j.chest.2017.05.009>
5. Guay-Gagnon M, Vat S, Forget MF et al (2022) Sleep apnea and the risk of dementia: A systematic review and meta-analysis. *J Sleep Res* 31(5):e13589. <https://www.doi.org/10.1111/jsr.13589>
6. Rudilla D, Perelló S, Landete P et al (2021) Improvement of adherence and quality of life of obstructive sleep apnea under PAP treatment through an intervention based on the stratification and personalization of care plans: a randomized controlled trial. *Rev Patol Respir* 24:125–134. <https://www.doi.org/10.21203/rs.3.rs-757639/v1>
7. Dodds S, Williams LJ, Roguski A et al (2020) Mortality and morbidity in obstructive sleep apnoea-hypopnoea syndrome: results from a 30-year prospective cohort study. *ERJ Open Res* 6(3):00057–2020. <https://www.doi.org/10.1183/23120541.00057-2020>
8. Patil SP, Ayappa IA, Caples SM, Kimoff RJ, Patel SR, Harrod CG (2019) Treatment of Adult Obstructive Sleep Apnea with Positive Airway Pressure: An American Academy of Sleep Medicine Clinical Practice Guideline. *J Clin Sleep Med* 15(2):335–343. <https://www.doi.org/10.5664/jcsm.7640>
9. Diário da República Procedimento de contratação tendente à celebração de acordo quadro para a área da saúde com vista à prestação de Serviços de Cuidados Técnicos Respiratórios Domiciliários. Available at: <https://diariodarepublica.pt/dr/detalhe/anuncio-procedimento/6773-2017-107951636>. Accessed 30 Sep 2024
10. Norma da Direção-Geral da Saúde (2024) Cuidados Respiratórios Domiciliários: Prescrição de Ventiloterapia e outros Equipamentos. Available at: <https://www.dgs.pt/normas-orientacoes-e-informacoes/normas-e-circulares-normativas.aspx>. Accessed 30

11. Serviço Nacional de Saúde (2024) Seguimento nos Cuidados de Saúde Primários de doentes com Síndrome de Apneia Obstrutiva do Sono sob terapêutica com pressão positiva contínua. Available at: <https://www.dgs.pt/directrizes-da-dgs/orientacoes-e-circulares-informativas/orientacao-n-0222014-de-30122014-pdf.aspx>. Accessed 30
12. Gervès-Pinquier C, Bailly S, Goupil F et al (2022) Positive Airway Pressure Adherence, Mortality, and Cardiovascular Events in Patients with Sleep Apnea. *Am J Respir Crit Care Med* 206(11):1393–1404. <https://www.doi.org/10.1164/rccm.202202-0366OC>
13. Gagnadoux F, Bequignon E, Prigent A et al (2024) The PAP-RES algorithm: Defining who, why and how to use positive airway pressure therapy for OSA. *Sleep Med Rev* 75:101932. <https://www.doi.org/10.1016/j.smr.2024.101932>
14. Malhotra A, Sterling KL, Cistulli PA et al (2023) Dose-response relationship between obstructive sleep apnea therapy adherence and healthcare utilization. *Ann Am Thorac Soc* 20(6):891–897. <https://www.doi.org/10.1513/AnnalsATS.202208-738OC>
15. Benjafield AV, Pepin JL, Cistulli PA et al (2025) Positive airway pressure therapy and all-cause and cardiovascular mortality in people with obstructive sleep apnoea: a systematic review and meta-analysis of randomised controlled trials and confounder-adjusted, non-randomised controlled studies. *Lancet Respir Med*. [https://www.doi.org/10.1016/s2213-2600\(25\)00002-5](https://www.doi.org/10.1016/s2213-2600(25)00002-5)
16. Weaver TE (2019) Novel Aspects of CPAP Treatment and Interventions to Improve CPAP Adherence. *J Clin Med* 8(12):2220. <https://www.doi.org/10.3390/jcm8122220>
17. Rotenberg BW, Murariu D, Pang KP (2016) Trends in CPAP adherence over twenty years of data collection: a flattened curve. *J Otolaryngol Head Neck Surg* 45(1):43. <https://www.doi.org/10.1186/s40463-016-0156-0>
18. Alves C, Caminha JM, da Silva AM, Mendonça D (2012) Compliance to continuous positive airway pressure therapy in a group of Portuguese patients with obstructive sleep apnea syndrome. *Sleep Breath* 16(2):555–562. <https://www.doi.org/10.1007/s11325-011-0542-9>
19. Soares Pires F, Drummond M, Marinho A et al (2013) Effectiveness of a group education session on adherence with APAP in obstructive sleep apnea—a randomized controlled study. *Sleep Breath* 17(3):993–1001. <https://www.doi.org/10.1007/s11325-012-0789-9>
20. Askland K, Wright L, Wozniak DR, Emmanuel T, Caston J, Smith I (2020) Educational, supportive and behavioural interventions to improve usage of continuous positive airway pressure machines in adults with obstructive sleep apnoea. *Cochrane Database Syst Rev* 4(4):CD007736. <https://www.doi.org/10.1002/14651858.CD007736.pub3>
21. Johns MW (1991) A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 14(6):540–545. <https://www.doi.org/10.1093/sleep/14.6.540>
22. Duval J, Mouroux C, Foury S, Pépin JL, Bailly S (2024) Patient motivation ranked by caregivers at continuous positive airway pressure initiation is predictive of adherence and 1-year therapy termination rate. *Sleep Breath* 28(2):835–839. <https://www.doi.org/10.1007/s11325-023-02965-3>

23. Balachandran JS, Yu X, Wroblewski K, Mokhlesi B (2013) A brief survey of patients' first impression after CPAP titration predicts future CPAP adherence: a pilot study. *J Clin Sleep Med* 9(3):199–205. <https://www.doi.org/10.5664/jcsm.2476>
24. Sahni N, Arora K, Bansal S, Reddy GVN, Malhotra S, Virk RS (2021) Impact of lifestyle modifications on snoring and mild sleep apnoea patients. *J Laryngol Otol* 135(10):892–896. <https://www.doi.org/10.1017/s0022215121002139>
25. Català R, Villoro R, Merino M et al (2016) Cost-effectiveness of continuous positive airway pressure treatment in moderate-severe obstructive sleep apnea syndrome. *Arch Bronconeumol* 52(9):461–469. <https://www.doi.org/10.1016/j.arbres.2016.02.005>
26. Texereau J, Bailly S, Borel JC, Sabil A, Pépin JL (2024) National implementation of CPAP telemonitoring and a pay-for-performance scheme for homecare providers in France leads to prioritisation of resources to individuals with low therapy adherence: the IMPACT-PAP cohort study. *Arch Bronconeumol*. <https://www.doi.org/10.1016/j.arbres.2024.06.008>
27. Vohra KP, Johnson KG, Dalal A et al (2025) Recommendations for permanent sleep telehealth: an American Academy of Sleep Medicine position statement. *J Clin Sleep Med* 21(2):401–404. <https://www.doi.org/10.5664/jcsm.11438>
28. Aardoom JJ, Loheide-Niesmann L, Ossebaard HC, Riper H (2020) Effectiveness of eHealth interventions in improving treatment adherence for adults with obstructive sleep apnea: meta-analytic review. *J Med Internet Res* 22(2):e16972. <https://www.doi.org/10.2196/16972>
29. Mendelson M, Duval J, Bettega F et al (2023) The individual and societal prices of non-adherence to continuous positive airway pressure, contributors, and strategies for improvement. *Expert Rev Respir Med* 17(4):305–317. <https://www.doi.org/10.1080/17476348.2023.2202853>
30. An J, Glick HA, Sawyer AM et al (2023) Association between positive airway pressure adherence and health care costs among individuals with OSA. *Chest* 163(6):1543–1554. <https://www.doi.org/https://doi.org/10.1016/j.chest.2023.01.025>

Figures

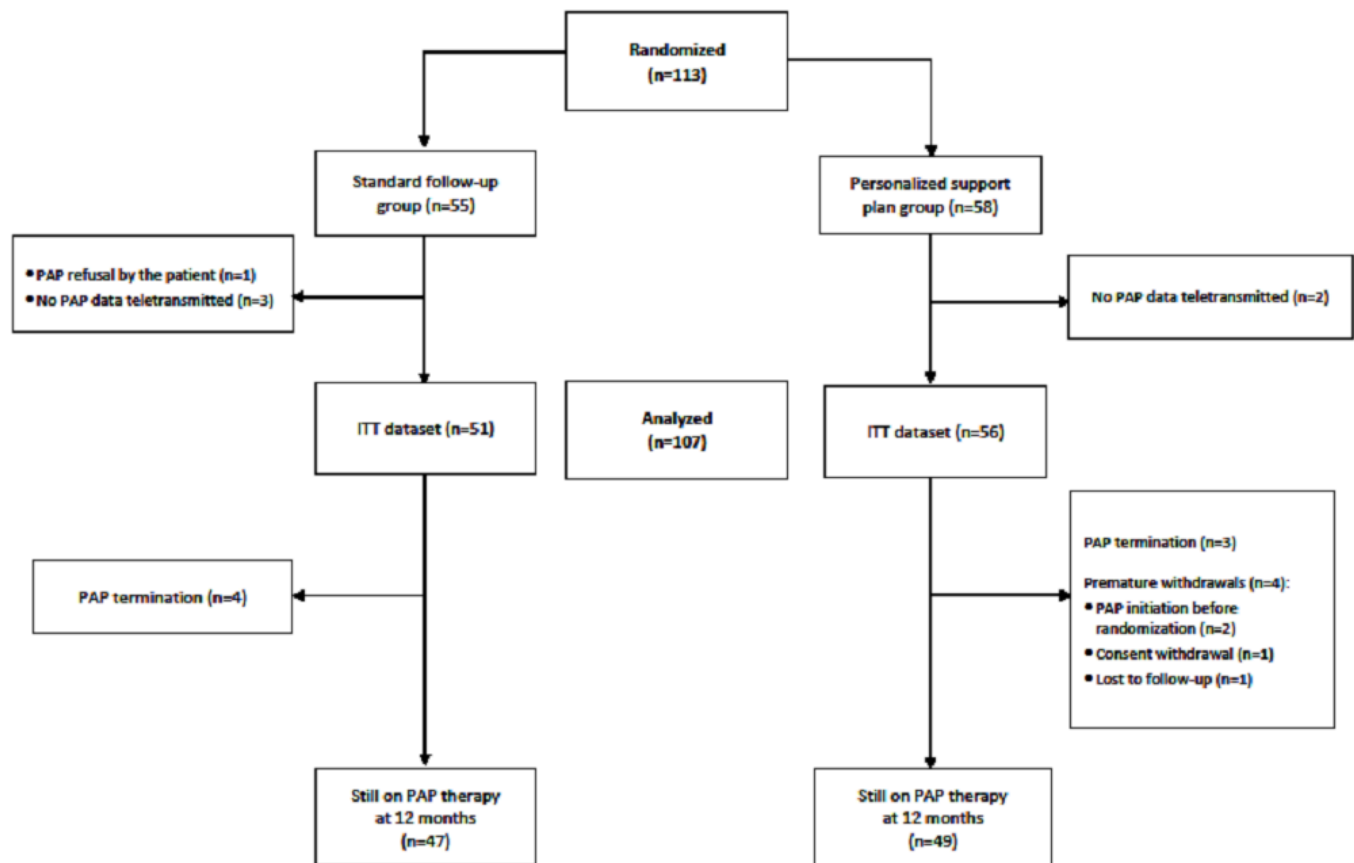


Figure 1

Study flow diagram. ITT, intention-to-treat; PAP, positive airway pressure.

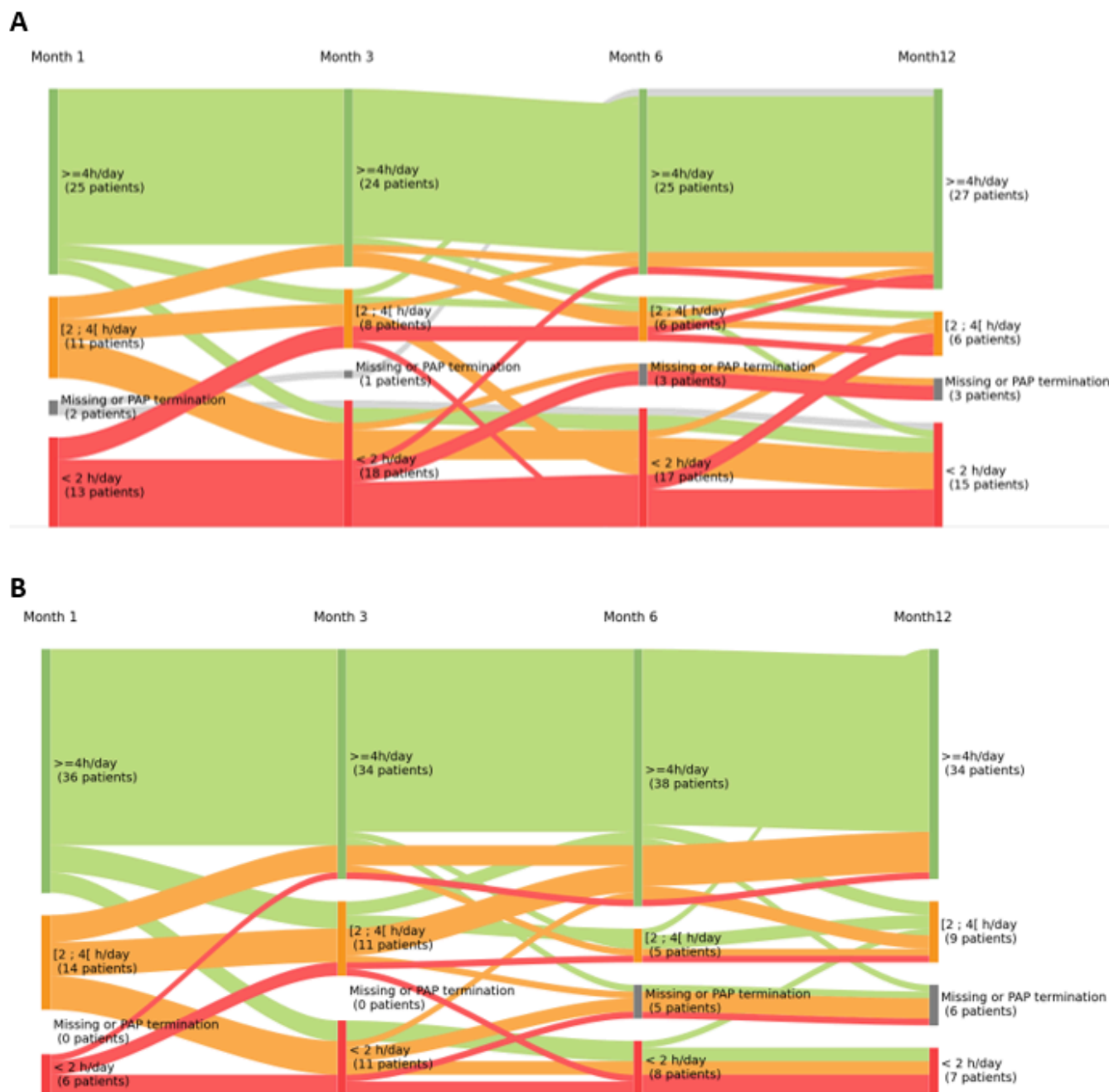


Figure 2

Sankey diagrams showing individual changes in positive airway pressure (PAP) therapy adherence categories over time for the standard follow-up group (**A**) and the personalized support plan group (**B**). The thickness of the lines represents the number of patients. Values '(n patients)' indicate the numbers of patients in each adherence category at each timepoint. Mean daily PAP usage was calculated for each patient to define their adherence category at each timepoint: from therapy initiation to 30 days for Month 1; 31 to 90 days for Month 3; 91 to 180 days for Month 6; and 181 to 365 days for Month 12. Green: average PAP usage ≥ 4 h/day. Orange: average PAP usage ≥ 2 h/day and < 4 h/day. Red: average PAP usage < 2 h/day. Grey: missing data or premature withdrawal.

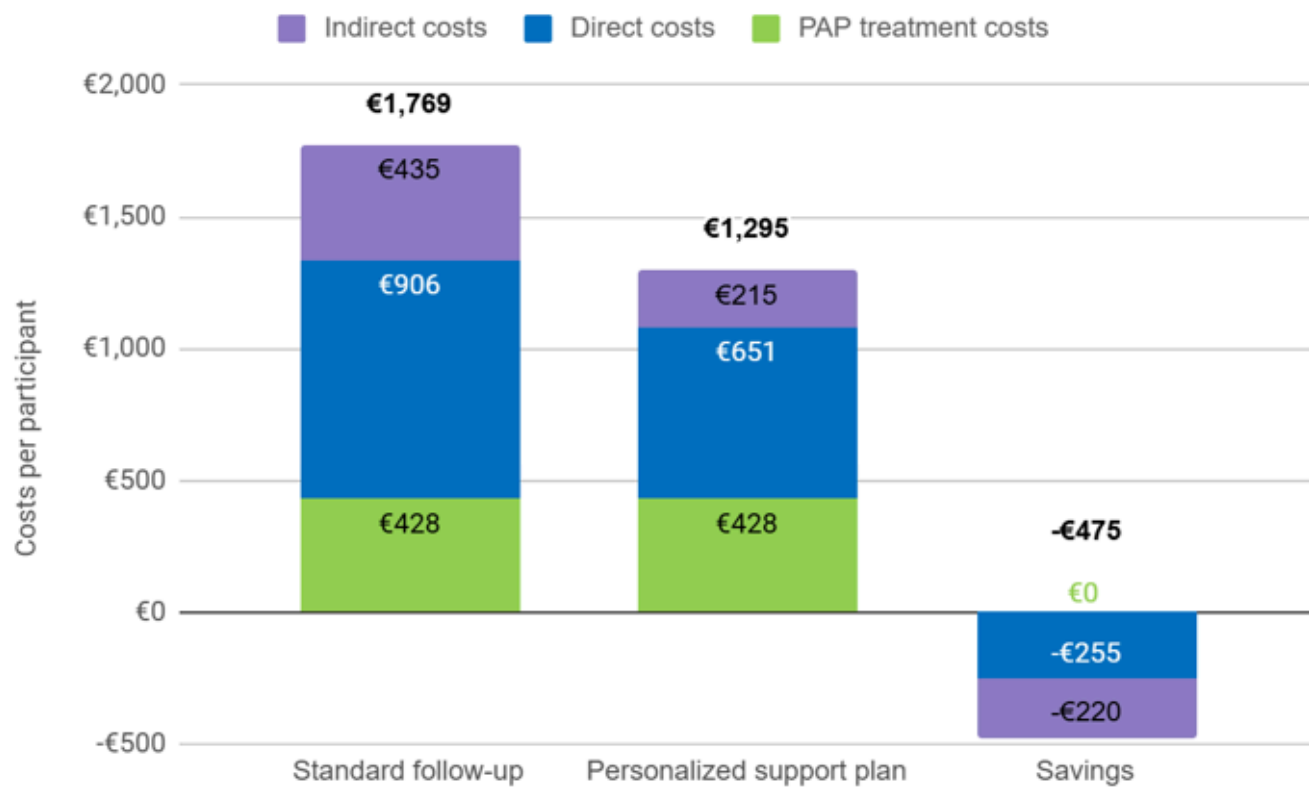


Figure 3

Annual costs per participant by study group from a health system perspective. PAP, positive airway pressure.

Supplementary Files

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