Achieving adherence to positive airway pressure in commercial drivers using an employer-mandated remote management programme

Elizabeth Kneeland[1,2,4], Nadia Ali[2,4], David G. Maislin[2], Yoon Hee Chang[2,3], Joyce Epelboim[2], Brendan T. Keenan[2] and Allan I. Pack[2]

[1]Kneeland Consulting, Philadelphia, PA, USA. [2]Division of Sleep Medicine, Department of Medicine, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, USA. [3]EvergreenHealth Sleep Disorders Center, Kirkland, WA, USA. [4]These authors contributed equally.

Corresponding author: Allan I. Pack (pack@pennmedicine.upenn.edu)

Shareable abstract (@ERSpublications)
Remote assessment of OSA and management of PAP in commercial drivers is feasible and effective. The programme described in this article has wide-ranging applications, particularly in populations and areas with a lack of sleep medicine providers. https://bit.ly/4bjkHyK

Cite this article as: Kneeland E, Ali N, Maislin DG, *et al*. Achieving adherence to positive airway pressure in commercial drivers using an employer-mandated remote management programme. *ERJ Open Res* 2024; 10: 00132-2024 [DOI: 10.1183/23120541.00132-2024].

This article has an editorial commentary: https://doi.org/10.1183/23120541.00634-2024

Received: 8 Feb 2024
Accepted: 13 June 2024

Abstract

Background Obstructive sleep apnoea (OSA) is common in commercial drivers, and associated with increased risk of crashes if untreated, making diagnosis and effective treatment crucial in this population.

Study design and methods This is a retrospective summary of a clinical programme based on telemedicine and remote treatment monitoring developed with a national trucking company to screen new hires in the USA for OSA and implement positive airway pressure (PAP) management. New hires were informed of the programme and consented as part of their employment. Drivers who did not comply with the evaluation or with PAP after diagnosis were removed from driving commercial vehicles by the company or did not pursue further employment.

Results A total of 975 drivers were enrolled. Among screened drivers, 35.5% were cleared without a sleep study, 15.0% were cleared following a sleep study (apnoea–hypopnoea index (AHI) <5 events·h^{-1}), 22.1% had mild OSA (AHI 5–15) and 27.4% had moderate–severe OSA (AHI ⩾15). Those with moderate–severe OSA were more obese (body mass index 36.2±6.3 kg·m^{-2}) and had more comorbidities. Of 269 drivers starting PAP, 160 (59.5%) maintained participation in a care management programme, 80 (29.7%) resigned or were terminated, 23 (8.6%) were cleared to discontinue PAP and six (2.2%) were complex cases requiring transfer of care. Illustrating effectiveness, those that maintained participation had excellent PAP adherence (5.27±1.61 h·night^{-1}; 88.5±12.9% days used; 79.7±17.7% days used ⩾4 h).

Interpretation Remote assessment of OSA and PAP management in commercial drivers is feasible and effective. This approach has wide-ranging applications, particularly in populations and areas with a lack of sleep medicine providers.

Introduction

Obstructive sleep apnoea (OSA) is a prevalent condition characterised by complete or partial breathing pauses during sleep. Primary risk factors for OSA include male sex and obesity [1, 2]. Consequently, OSA is estimated to affect over 2.4 million commercial drivers in the USA [3], a workforce made up primarily of men and in which many drivers have obesity [3–13]. OSA is particularly salient for commercial drivers, since untreated moderate–severe disease is associated with greater risk of falling asleep at the wheel and vehicular crashes [14], greater medical care costs [15] and adverse health consequences [14–21]. Vehicular crashes, in particular, are an immediate danger to drivers with untreated or undiagnosed OSA; accidents from falling asleep at the wheel have a fatality rate similar to that of alcohol-related crashes [22]. Studies have shown an association between likelihood of OSA and increased rate of crashes in commercial vehicle

drivers [23, 24], and a systematic review and meta-analysis showed increased rate of crashes in individuals with OSA [25]. Many countries, but not the USA, have regulations to address this issue [26, 27].

Fortunately, there is an established and effective therapy for OSA, namely, treatment with positive airway pressure (PAP). PAP therapy has been shown to improve health outcomes and excessive sleepiness, thus mitigating the risk of crashes to a level similar to drivers without OSA [22, 28–34]. Thus, for their health and safety on the road, it is imperative to improve the diagnosis and treatment of OSA in commercial drivers. Towards this end, employer-sponsored and employer-mandated sleep apnoea screening programmes have been shown to improve crash rates and reduce overall healthcare spending [15, 33]. Reductions in crash rates only occur, however, in drivers who are adherent to therapy [33]. Thus, focusing on ensuring adherence to PAP, rather than on simply identifying OSA in commercial drivers, is crucial; this was the goal of the programme described herein.

Telemedicine-based sleep care is an effective alternative to the conventional in-laboratory-based and in-person clinic-based sleep apnoea care strategy [35]. In general, telemedicine refers to remote electronic clinical consultations, including the use of video-teleconferencing applications available on smartphones, tablets or computers, and/or *via* telephone call or reviewing wirelessly downloaded data [36]. Given its geographical flexibility and timely access to effective care, telemedicine is in prime position to meet the needs of commercial drivers [37–41]. Technology also exists for remote monitoring of PAP adherence and efficacy (*e.g.*, mask leaks and residual apnoea–hypopnoea index [AHI]) [39, 41]. This facilitates remote management of PAP therapy in drivers to ensure compliance [42–44].

Here, we demonstrate the feasibility of an employer-mandated telemedicine-based programme for OSA screening and ongoing PAP care management. This programme was conducted at the University of Pennsylvania in partnership with a national trucking company in the USA. Drivers being hired by the company were informed of the necessity of being screened for OSA as a condition of employment. If found to have OSA, they had to maintain adherence to PAP therapy to continue driving a company truck. The specifics of this programme and its effectiveness in promoting adherence are described. As the present programme was developed within the constraints of the US healthcare system, specific details may differ in other countries, but the general principles are broadly applicable.

Study design and methods

The present report is a retrospective summary of a clinical programme based on telemedicine and remote treatment monitoring developed with a national trucking company to screen new hires across multiple states in the USA for OSA, diagnose OSA presence and severity, and implement active PAP management. Additional methodological details and protocols for reviewing remote data and incorporating education/interventions are presented in supplementary e-Appendix 1 and e-Appendix 2.

Drivers

All newly hired commercial drivers in eligible states between 14 April 2015 and 1 February 2020 (n=975) participated in the programme. Drivers were initially located in five states (FL, GA, NJ, NC and PA), with the programme expanded to include 10 additional states over time (AL, AR, CA, CO, LA, NM, NY, OH, SC and VA). Figure 1 illustrates the driver disposition from screening to care management enrolment. In consultation with the institutional review board (IRB) at the University of Pennsylvania, it was determined that IRB approval was not required for the retrospective reporting of outcomes of the clinical programme; formal documentation of this determination (*via* e-mail from IRB Reliance Review Manager) was obtained.

Providers

The programme involved two interdisciplinary teams at the University of Pennsylvania – a medical team and a care management team. The medical team (both physicians and nurse practitioners) managed consultations, diagnostic orders and treatment implementation. The care management team (trained sleep technologists) worked with the employer and medical team to facilitate care, monitor treatment compliance and provide education/interventions. Care management pathways were developed and applied using a multi-tiered system to support compliance.

Initial evaluation

Individuals were informed about the requirement to be evaluated for OSA as part of their hiring offer, and consented to participate in the programme as part of their employment. Evaluations included in-person pre-employment history and physical examinations through an occupational medicine company and telemedicine evaluation by sleep medicine providers. Drivers completed web-based questionnaires about their medical history, sleep history and symptoms, and the Epworth Sleepiness Scale (ESS) [45]. During

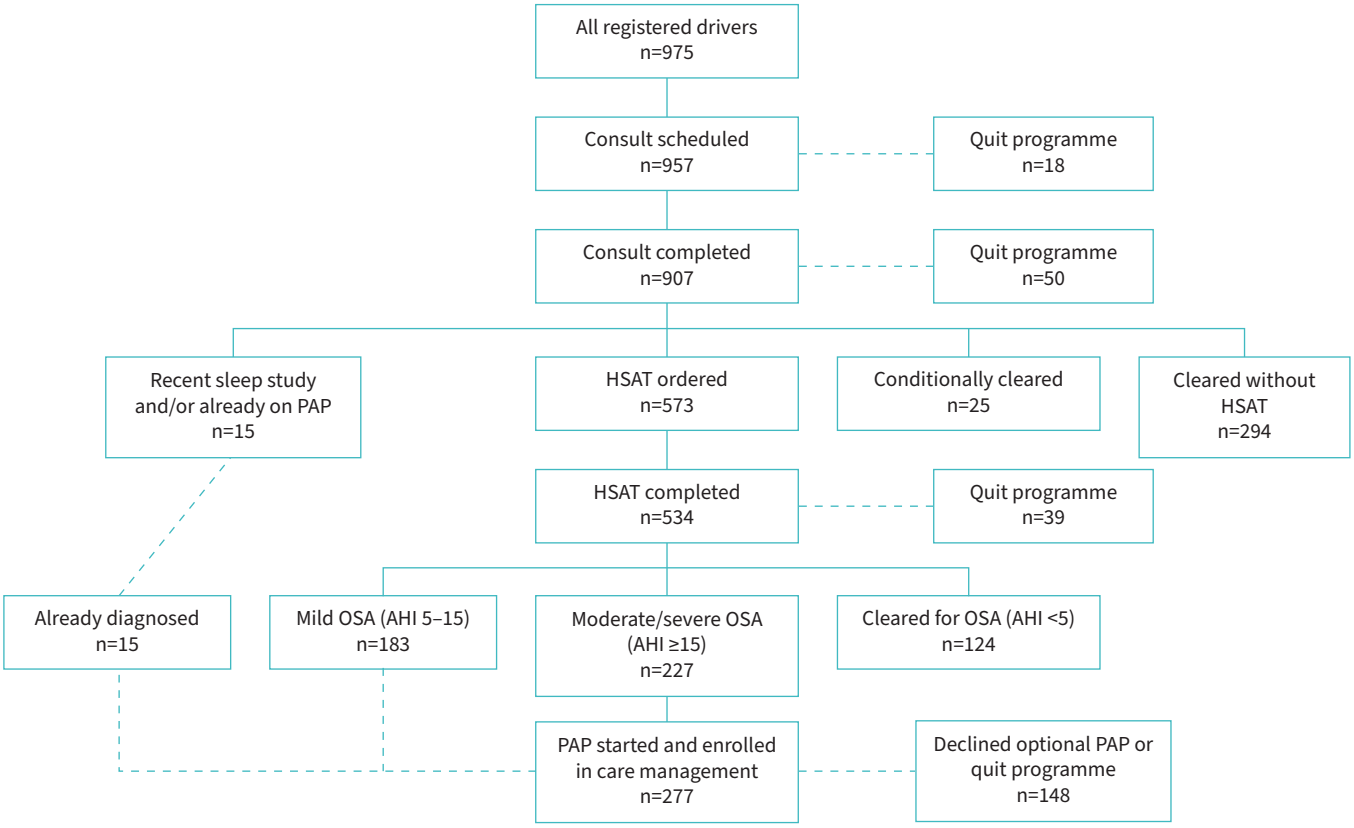

FIGURE 1 Diagram of driver flow through the management programme. PAP: positive airway pressure; HSAT: home sleep apnoea test; OSA: obstructive sleep apnoea.

the initial evaluation with sleep providers, drivers were assessed for risk factors for OSA and given information on risks and recognition of drowsy driving. Drivers at elevated risk for OSA were recommended for and educated on how to perform a home sleep apnoea test (HSAT), which was interpreted by a sleep provider upon completion to determine treatment recommendations. The decision about whether or not to perform a sleep study was made by the clinical provider evaluating a particular driver; providers generally had a low threshold for recommending a sleep study.

Care management

Hardware and software for PAP usage

Drivers starting PAP treatment were set up with auto-adjusting PAP (ResMed S9 or S10) devices provided by the national trucking company through a designated Durable Medical Equipment (DME) company. Hours of usage and effectiveness (residual AHI, mask leak) from the PAP device were sent daily to ResMed's AirView cloud-based server and reviewed by the care management team using standardised protocols.

Care management introductory period

The first 60 days of PAP therapy were defined as the Introductory Period. Interventions in this period involved proactive outreach by the care management team within 2 days of the driver receiving the PAP device, data-driven outreach based on reviews of remote PAP data, and possible repeat telemedicine visits to identify and resolve challenges. By the end of this period, drivers had to obtain compliance with PAP therapy.

PAP efficacy management

Data from the most recent 7 days were reviewed daily (6 out of 7 days) to determine if criteria were met for specific interventions for management of PAP efficacy (supplementary e-Appendix 1), including: large mask air leak, defined as 95th percentile air leak $\geqslant 24\ L{\cdot}min^{-1}$ (from programme initiation until 11 April 2018) or $\geqslant 30\ L{\cdot}min^{-1}$ (after 11 April 2018) for $\geqslant 3$ days; high residual AHI, defined as AHI

⩾10 events·h^{-1} with PAP usage for ⩾3 days; and presence of central apnoea, defined as central apnoea index >5 events·h^{-1} for ⩾1 day.

PAP compliance management

PAP compliance was defined as usage ⩾4 h·day^{-1} for ⩾70% of days within a 30-day window. If usage was <4 h·day^{-1} for ⩾2 days within a 7-day period, a care intervention and outreach was triggered (see supplementary e-Appendix 2). Standardised care management interventions were provided to all drivers calibrated to their level of compliance. After the Introductory Period, drivers with persistent low compliance (despite best efforts of study staff) were referred to the company programme director and appropriate company manager. The company was responsible for determining if subsequent reassignment to non-driving activities or employment termination was warranted. This decision was made by employees of the company, who had oversight of this programme, and the potential for employment termination due to lack of adherence was made clear within the consent provided by drivers as terms of employment.

Statistical methods

Continuous data are summarised using mean±SD or median and interquartile range (IQR). Categorical data are summarised using frequencies and/or percentages. Analysis of variance (ANOVA) was used to compare continuous data among groups, followed by pairwise comparisons if ANOVA $p<0.05$. Changes in compliance/efficacy over time were evaluated using linear mixed effects models. The total number of interventions and percentage of drivers with ⩾1 intervention, as well as the mean number of interventions per driver, per 30 days of participation in the programme (*e.g.*, 30 "driver days"), and per 1 year of participation are summarised. Where calculated, $p<0.05$ was considered statistically significant.

Results

Driver characteristics and matriculation

The clinical programme enrolled 975 drivers who were middle-aged (mean±SD age 43.9±11.2 years), obese (mean±SD body mass index BMI) 31.8±6.3 kg·m^{-2}) and nearly all male (99.0%) (figure 1 and table 1). Despite the high proportion of males and obesity, both risk factors for OSA, only 7.6% had a previous OSA diagnosis, 11.6% reporting frequent snoring, 6.4% frequent loud snoring, 1.2% choking or gasping, and 1.9% witnessed apnoeas. Only 15 (1.5%) drivers reported ever falling asleep while driving, and 2 (0.2%) reported sleep-related motor vehicle accidents. The mean ESS was 2.65±3.09, well below clinical thresholds for excessive daytime sleepiness.

Initial consults with sleep medicine physicians were scheduled for 957 (98%) drivers and completed in 907 (93%) (figure 1); 50 (7%) did not complete the consult and did not pursue employment. Among these 907 drivers, 294 (32%) were determined to be low risk for OSA and did not require further testing. 25 (3%) drivers were "conditionally cleared"; a diet and weight loss regimen was recommended, with reassessment in 6–12 months. 15 (2%) drivers were already using PAP or had a recent sleep study with OSA diagnosis, and were entered into care management. An HSAT was ordered in drivers with a reported OSA diagnosis but no recent sleep study (n=59; table 1).

Sleep studies were ordered on 573 (63%) drivers, 534 (93%) of whom completed an HSAT; the remaining 39 (7%) discontinued the programme and were employed in a non-driving position or did not pursue employment. Despite the initial lack of self-reported symptoms, there was a high rate of OSA among drivers who completed an HSAT, with 124 (23%) negative for OSA (AHI <5), 183 (34%) with mild OSA (AHI 5–15) and 227 (43%) with at least moderate OSA (AHI ⩾15). Drivers diagnosed with OSA were older, more obese and had higher rates of comorbidities than those cleared with or without HSAT (table 2). A total of 277 drivers with OSA agreed to use prescribed PAP therapy and were initiated into care management. These drivers were middle-aged (47.3±9.8 years) and significantly obese (35.9±6.2 kg·m^{-2}), and all 277 were male (table 3).

Overall treatment outcomes, adherence and efficacy

Treatment-related outcomes among drivers initiated into care management are summarised in table 4. Remotely monitored compliance and efficacy data were available on 269 (97%) of the 277 drivers initiated into the programme: 160 (58%) maintained participation in care management for their entire eligible follow-up; 23 (8%) were cleared to discontinue PAP during follow-up; six (2%) had a transfer of care to an accredited sleep centre near where the driver lived due to a complex sleep disorder (*e.g.*, suspicion of narcolepsy); and 80 (29%) resigned or were terminated from the company. Demonstrating efficacy, those who maintained participation had high nightly usage (5.3±1.6 h·night^{-1}), percentage of days used (89±13%) and days used ⩾4 h·night^{-1} (80±18%), and low residual AHI (1.8±1.7 events·hour^{-1}) and 95th percentile leak (18.2±11.4 L·min^{-1}). All adherence and efficacy measures were significantly better in those

TABLE 1 Demographic characteristics of all registered drivers (n=975)

Age years	
N	975
Mean±SD	43.9±11.2
Median (IQR)	44.3 (34.9–52.6)
Male, n (%)	965 (99.0)
BMI kg·m^{-2}	
N	975
Mean±SD	31.8±6.3
Median (IQR)	30.7 (27.3–35.9)
Collar size ins	
N	855
Mean±SD	16.4±1.9
Median (IQR)	16.5 (15.0–17.5)
Race, n (%)	
American Indian/Alaska Native	4 (0.41)
Asian	6 (0.62)
Native Hawaiian or Other Pacific Islander	3 (0.31)
Black or African American	129 (13.23)
White	633 (64.92)
More than one race	30 (3.08)
Unknown/not reported	39 (4.00)
Missing	131 (13.44)
Past diagnosis of high blood pressure, n (%)	277 (28.4)
Past diagnosis of diabetes, n (%)	83 (8.5)
Past diagnosis of high cholesterol, n (%)	93 (9.5)
Past diagnosis of OSA, n (%)	74 (7.6)
Smoking status, n (%)	
Current	115 (11.8)
Former	185 (19.0)
Never	674 (69.2)
Have a regular bed partner, n (%)	740 (76.5)
Snoring ⩾3 times·week^{-1}, n (%)	113 (11.6)
Loud snoring ⩾3 times·week^{-1}, n (%)	62 (6.4)
Choking or gasping ⩾3 times·week^{-1}, n (%)	12 (1.2)
Breathing pauses during sleep ⩾3 times·week^{-1}, n (%)	18 (1.9)
Ever fallen asleep while driving, n (%)	15 (1.54)
Ever had a motor vehicle accident due to falling asleep, n (%)	2 (0.21)
Epworth Sleepiness Scale	
N	973
Mean±SD	2.65±3.09
Median (IQR)	2.0 (0.0–4.0)
AHI events·h^{-1}	
N	544
Mean±SD	20.6±21.5
Median (IQR)	12.7 (5.5–27.8)
O_2 desaturation nadir %	
N	542
Mean±SD	80.2±8.2
Median (IQR)	82.0 (77.0–86.0)

IQR: interquartile range; BMI: body mass index; OSA: obstructive sleep apnoea; AHI: apnoea–hypopnoea index.

who maintained participation in the programme compared to those who resigned or were terminated (see table 4).

Longitudinal treatment compliance and efficacy

Drivers in care management were followed for a median (IQR) of 320 (153–677) days. Table 5 and figure 2 summarise temporal compliance patterns relative to drivers' enrolment date. Measures of PAP compliance and efficacy improved with longer durations of programme participation, including statistically significant increases in mean hours per night on all nights ($p=0.042$) and nights used ($p<0.0001$) and in days used ⩾4 h·night^{-1} ($p<0.0001$) over time, as well as decreases in residual AHI ($p<0.0001$) and 95th percentile leak

TABLE 2 Demographic characteristics of home sleep apnoea test (HSAT)-related subsets of drivers

Characteristic	Cleared without HSAT	Cleared with HSAT (AHI <5)	Mild OSA (AHI 5–15)	Moderate/severe OSA (AHI ⩾15)	Overall p-value
Drivers n	294	124	183	227	
Age years					
N	294	124	183	227	<0.0001[¶,+,§,ƒ,##]
Mean±SD	40.4±10.7	40.5±11.3	45.0±10.5	48.1±9.7	
Median (IQR)	39.4 (32.4–47.7)	39.2 (31.6–48.6)	46.0 (36.3–53.4)	49.0 (41.6–54.9)	
Male, n (%)	290 (98.64)	123 (99.19)	182 (99.45)	227 (100.00)	
BMI kg·m^{-2}					
N	294	124	183	227	<0.0001[#,¶,+,ƒ,##]
Mean±SD	26.6±3.5	32.6±5.3	33.7±5.7	36.2±6.3	
Median (IQR)	26.6 (24.4–28.5)	32.5 (28.5–36.4)	33.1 (29.2–37.6)	35.6 (31.8–40.2)	
Collar size ins					
N	242	108	167	201	<0.0001[#,¶,+,§,ƒ]
Mean±SD	15.4±1.5	16.4±1.4	16.8±1.6	17.0±2.0	
Median (IQR)	15.5 (14.5–16.5)	16.5 (15.5–17.0)	17.0 (16.0–18.0)	17.0 (16.0–18.0)	
Race, n (%)					
American Indian/Alaska Native	1 (0.3)	0 (0.0)	2 (1.1)	1 (0.4)	0.0633
Asian	2 (0.7)	0 (0.0)	1 (0.6)	2 (0.9)	
Native Hawaiian or Other Pacific Islander	0 (0.00)	0 (0.0)	1 (0.6)	2 (0.9)	
Black or African American	31 (10.5)	29 (23.4)	24 (13.1)	22 (9.7)	
White	196 (66.7)	73 (58.9)	115 (62.8)	157 (69.2)	
More than one race	9 (3.1)	6 (4.8)	5 (2.7)	5 (2.2)	
Unknown/not reported	10 (3.4)	1 (0.8)	10 (5.5)	13 (5.7)	
Missing	45 (15.3)	15 (12.1)	25 (13.7)	25 (11.0)	
Past hypertension diagnosis, n (%)	10 (3.4)	39 (31.5)	70 (38.3)	116 (51.1)	<0.0001[#,¶,+,ƒ,##]
Past diabetes diagnosis, n (%)	3 (1.0)	12 (9.7)	16 (8.7)	40 (17.6)	<0.0001[#,¶,+,ƒ,##]
Past high cholesterol diagnosis, n (%)	14 (4.8)	5 (4.0)	25 (13.7)	38 (16.7)	<0.0001[¶,+,§,ƒ]
Past OSA diagnosis, n (%)	1 (0.3)	5 (4.0)	13 (7.1)	28 (12.4)	<0.0001[#,¶,+,ƒ]
Smoking status, n (%)					
Current	50 (17.0)	6 (4.8)	21 (11.5)	25 (11.1)	0.0006[#,¶,+,§]
Former	40 (13.6)	23 (18.6)	48 (26.2)	48 (21.2)	
Never	204 (69.4)	95 (76.6)	114 (62.3)	153 (67.7)	
Regular bed partner, n (%)	222 (76.0)	99 (80.5)	135 (74.6)	178 (79.1)	0.5410
Snoring ⩾3 times·week^{-1}, n (%)	9 (3.1)	10 (8.1)	26 (14.2)	47 (20.7)	<0.0001[#,¶,+,ƒ]
Loud snoring ⩾3 times·week^{-1}, n (%)	4 (1.4)	4 (3.2)	11 (6.0)	31 (13.7)	<0.0001[¶,+,ƒ,##]
Choking/gasping ⩾3 times·week^{-1}, n (%)	0 (0.0)	1 (0.8)	2 (1.1)	8 (3.5)	0.0055[+]
Breathing pauses ⩾3 times·week^{-1}, n (%)	0 (0.0)	0 (0.0)	3 (1.6)	10 (4.4)	0.0004[¶,+,ƒ]
Fallen asleep driving, n (%)	0 (0.0)	4 (3.2)	4 (2.2)	5 (2.2)	0.0474[#,¶,+]
Motor vehicle accident due to falling asleep, n (%)	0 (0.0)	1 (0.8)	1 (0.6)	0 (0.0)	0.3077
Epworth Sleepiness Scale					
N	294	124	183	225	0.0025[¶,+]
Mean±SD	2.11±2.09	2.57±3.07	2.85±3.27	3.05±3.59	
Median (IQR)	2.0 (0.0–3.0)	2.0 (0.0–4.0)	2.0 (1.0–4.0)	2.0 (1.0–4.0)	
AHI events·h^{-1}					
N		124	183	227	<0.0001[§,ƒ,##]
Mean±SD		2.5±1.4	9.6±3.0	38.8±21.2	
Median (IQR)		2.5 (0.0–4.9)	9.4 (5.0–15.0)	32.3 (15.1–106.3)	
O_2 desaturation nadir %					
N		122	183	227	<0.0001[§,ƒ,##]
Mean±SD		86.1±5.1	81.9±6.0	76.0±8.4	
Median (IQR)		87.0 (53.0–93.0)	84.0 (54.0–95.0)	78.0 (51.0–91.8)	

AHI: apnoea–hypopnoea index; IQR: interquartile range; OSA: obstructive sleep apnoea; BMI: body mass index. [#]: p<0.05 comparing Cleared without HSAT to Cleared with HSAT (AHI <5); [¶]: p<0.05 comparing Cleared without HSAT to Mild OSA (AHI 5–15); [+]: p<0.05 comparing Cleared without HSAT to Moderate/Severe OSA (AHI ⩾15); [§]: p<0.05 comparing Cleared with HSAT (AHI <5) to Mild OSA (AHI 5–15); [ƒ]: p<0.05 comparing Cleared with HSAT (AHI <5) to Moderate/Severe OSA (AHI ⩾15); [##]: p<0.05 comparing Mild OSA (AHI 5–15) to Moderate/Severe OSA (AHI ⩾15).

TABLE 3 Demographic characteristics of drivers initiated into positive airway pressure care management (n=277)

Age years	
N	277
Mean±SD	47.3±9.8
Median (IQR)	48.6 (40.2–54.7)
Male, n (%)	277 (100.0)
BMI kg·m^{-2}	
N	277
Mean±SD	35.9±6.2
Median (IQR)	35.6 (31.8–39.3)
Collar size ins	
N	246
Mean±SD	17.2±2.1
Median (IQR)	17.0 (16.0–18.0)
Race, n (%)	
American Indian/Alaska Native	1 (0.4)
Asian	3 (1.1)
Native Hawaiian or Other Pacific Islander	2 (0.7)
Black or African American	27 (9.8)
White	198 (71.5)
More than one race	5 (1.8)
Unknown/not reported	12 (4.3)
Missing	29 (10.5)
Past diagnosis of high blood pressure, n (%)	141 (50.9)
Past diagnosis of diabetes, n (%)	47 (17.0)
Past diagnosis of high cholesterol, n (%)	49 (17.7)
Past diagnosis of OSA, n (%)	44 (15.9)
Smoking status, n (%)	
Current	30 (10.8)
Former	73 (26.4)
Never	174 (62.8)
Regular bed partner, n (%)	214 (77.5)
Snoring ⩾3 times·week^{-1}, n (%)	62 (22.4)
Loud snoring ⩾3 times·week^{-1}, n (%)	38 (13.7)
Choking or gasping ⩾3 times·week^{-1}, n (%)	11 (4.0)
Breathing pauses during sleep ⩾3 times·week^{-1}, n (%)	15 (5.4)
Ever fallen asleep while driving, n (%)	7 (2.5)
Ever had a motor vehicle accident due to falling asleep, n (%)	0 (0.0)
Epworth Sleepiness Scale	
N	276
Mean±SD	3.31±3.77
Median (IQR)	2.0 (1.0–5.0)
AHI events·h^{-1}	
N	277
Mean±SD	32.6±22.8
Median (IQR)	25.1 (14.9–44.2)
O_2 desaturation nadir %	
N	277
Mean±SD	77.1±8.6
Median (IQR)	79.0 (74.0–83.0)

IQR: interquartile range; BMI: body mass index; OSA: obstructive sleep apnoea; AHI: apnoea–hypopnoea index.

(p=0.0005). Drivers participating in the programme at 1 year had mean PAP use of 5.2±2.1 h·night^{-1}, any PAP use on 88% of days and ⩾4 h·night^{-1} of PAP use on 83% of days in the 30 days prior.

Compliance and efficacy interventions

A number of interventions were utilised to help improve and maintain compliance to PAP (supplementary e-Appendix 1). Table 6 summarises interventions classified as Alerts/Warnings, PAP Care & Therapy Support, Escalation or Removed from Truck due to Lack of Compliance. During the programme, there were 2283 Alerts/Warnings interventions, with 80.7% of drivers requiring at least one; drivers experienced

TABLE 4 Overall summary of adherence and efficacy among participating drivers

Characteristic	Total	Transfer of care	Cleared to discontinue PAP	Maintained participation in programme	Resigned or terminated	Overall p-value
Drivers n	269	6	23	160	80	
Days in programme						
N	269	6	23	160	80	0.0001[#,+]
Mean±SD	471±411	398±480	338±229	566±451	324±299	
Median (IQR)	320 (153–677)	251 (129–353)	267 (138–577)	401 (194–860)	239 (82–512)	
Mean hours per night (all nights)						
N	269	6	23	160	80	<0.0001[#,¶,+]
Mean±SD	4.50±2.04	3.60±1.79	2.52±2.09	5.27±1.61	3.60±2.07	
Median (IQR)	4.55 (3.33–6.08)	3.78 (2.96–4.72)	1.96 (0.46–4.30)	5.22 (4.02–6.66)	3.57 (2.19–5.04)	
Mean hours per night (nights used)						
N	269	6	23	160	80	<0.0001[#,+]
Mean±SD	5.41±1.62	4.68±1.00	4.33±1.64	5.92±1.25	4.77±1.89	
Median (IQR)	5.42 (4.60–6.53)	4.76 (4.52–5.16)	4.68 (3.06–5.48)	5.88 (5.06–6.94)	4.88 (3.91–6.28)	
Days used %						
N	269	6	23	160	80	<0.0001[#,+]
Mean±SD	0.840±0.170	0.827±0.128	0.721±0.261	0.885±0.129	0.785±0.182	
Median (IQR)	0.903 (0.752–0.967)	0.837 (0.721–0.949)	0.795 (0.581–0.948)	0.931 (0.819–0.980)	0.810 (0.701–0.939)	
Days used ⩾4 h %						
N	269	6	23	160	80	<0.0001[#,+]
Mean±SD	0.730±0.234	0.723±0.162	0.596±0.296	0.797±0.177	0.633±0.271	
Median (IQR)	0.781 (0.610–0.914)	0.759 (0.591–0.822)	0.687 (0.338–0.876)	0.845 (0.677–0.943)	0.687 (0.450–0.886)	
Residual AHI events·h^{-1}						
N	269	6	23	160	80	0.0003[+]
Mean±SD	2.46±3.56	5.32±4.37	2.54±2.28	1.77±1.67	3.60±5.64	
Median (IQR)	1.36 (0.79–2.75)	4.44 (1.44–9.86)	1.31 (0.81–4.25)	1.26 (0.78–2.18)	1.58 (0.75–3.55)	
95th percentile leak L·min^{-1}						
N	269	6	23	160	80	0.0275[+]
Mean±SD	19.8±13.5	29.7±11.9	19.2±11.5	18.2±11.4	22.6±17.0	
Median (IQR)	17.8 (9.9–26.3)	28.6 (20.9–39.9)	17.7 (8.3–26.9)	16.8 (9.3–24.1)	19.5 (10.3–29.0)	

PAP: positive airway pressure; IQR: interquartile range; AHI: apnoea–hypopnoea index. [#]: p<0.05 comparing Cleared to Discontinue PAP to Maintained Participation; [¶]: p<0.05 comparing Cleared to Discontinue PAP to Resigned/Terminated; [+]: p<0.05 comparing Maintained Participation to Resigned/Terminated.

a mean of 8.49 alerts/warnings during their participation in care management, including 0.54 interventions per 30 driver days of participation and 6.59 interventions per driver year of participation. Similarly, 2889 PAP Care & Therapy Support interventions were performed among 81.4% of drivers, including 10.74 per driver, 0.68 per 30 days of participation and 8.33 per 1 year of participation. Nearly half (45.7%) of participating drivers required the company manager to be alerted about non-compliance/poor PAP use (473 total interventions). During the programme, just 16 (5.9%) drivers were removed from driving due to PAP non-compliance. The incidence rates of both PAP Care & Therapy Support (incidence rate ratio (IRR) 0.86, 95% CI 0.84–0.88) and Escalation (IRR 0.90, 95% CI 0.85–0.94) interventions decreased with longer participation in the programme (see figure 3).

Discussion

In commercial drivers, identifying OSA and then achieving PAP compliance reduces the risk of crashes [33]. Towards this end, we describe the implementation and outcomes of a comprehensive programme to not only screen for and diagnose OSA in commercial drivers, but, importantly, to also ensure PAP compliance among those prescribed therapy. The programme used modern technological approaches, including education *via* web-based videos, web-based questionnaires, telemedicine for assessment, and remote monitoring of PAP adherence and efficacy. For successful implementation, the programme required a strong collaborative approach between the national trucking company, who had a dedicated, knowledgeable programme manager, and the University of Pennsylvania. It also required a clear set of information provided in advance to drivers, who consented to participate in the programme as part of their employment. Individuals understood that the programme was mandatory to be employed as a driver in this company. Ultimately, the programme was able to monitor drivers in multiple states, identify and diagnose new cases of OSA, and both initiate and maintain high adherence to PAP therapy in a large proportion of drivers.

TABLE 5 Compliance and efficacy metrics in 30-day windows over driver follow-up

Characteristic	0–30 days	30–60 days	60–90 days	150–180 days	335–365 days	Change over time period	
						β (95% CI)[#]	p-value
Drivers n	269	263	238	204	128		
Days in programme							
N	269	263	238	204	128	n/a	
Mean±SD	29.8±1.7	58.7±5.0	89.1±4.4	178.4±5.7	364.4±3.0		
Median (range[¶])	30 (11–30)	60 (33–60)	90 (61–90)	180 (152–180)	365 (341–365)		
Mean hours per night (all nights)							
N	269	263	238	204	128	0.05 (0.002–0.10)	0.042
Mean±SD	4.44±2.21	4.63±2.01	4.81±1.96	4.92±2.09	5.23±2.08		
Median (IQR)	4.70 (2.88–6.18)	4.76 (3.33–6.09)	4.90 (3.64–6.22)	5.14 (3.70–6.51)	5.39 (3.95–6.81)		
Mean hours per night (nights used)							
N	266	253	232	193	122	0.12 (0.09–0.15)	<0.0001
Mean±SD	5.17±1.91	5.39±1.55	5.53±1.55	5.89±1.31	6.15±1.26		
Median (IQR)	5.33 (4.15–6.55)	5.44 (4.56–6.53)	5.54 (4.58–6.62)	5.88 (4.91–6.86)	5.99 (5.25–7.05)		
Days used %							
N	269	263	238	204	128	−0.002 (−0.01–0.01)	0.566
Mean±SD	0.851±0.206	0.863±0.187	0.877±0.167	0.856±0.203	0.882±0.177		
Median (IQR)	0.933 (0.800–1.00)	0.933 (0.800–1.00)	0.933 (0.800–1.00)	0.933 (0.767–1.00)	0.967 (0.833–1.00)		
Days used ⩾4 h %							
n	269	263	238	204	128	0.021 (0.013–0.029)	<0.0001
Mean±SD	0.693±0.305	0.727±0.273	0.761±0.246	0.791±0.231	0.826±0.197		
Median (IQR)	0.767 (0.533–0.933)	0.800 (0.567–0.933)	0.833 (0.667–0.967)	0.867 (0.700–0.967)	0.867 (0.733–1.00)		
Residual AHI events·h^{-1}							
N	266	253	232	193	122	−0.31 (−0.40– −0.22)	<0.0001
Mean±SD	3.21±4.16	2.56±3.86	1.98±1.97	1.73±1.96	1.56±1.47		
Median (IQR)	1.96 (0.93–3.83)	1.50 (0.72–2.85)	1.28 (0.69–2.28)	1.25 (0.60–2.01)	1.16 (0.65–2.03)		
95th percentile leak L·min^{-1}							
N	266	253	232	193	122	−0.65 (−1.02– −0.28)	0.0005
Mean±SD	21.7±16.0	20.0±14.7	18.8±13.3	18.7±12.3	19.1±13.4		
Median (IQR)	19.1 (9.9–28.2)	17.4 (9.2–26.5)	17.2 (8.6–25.0)	17.0 (9.4–26.3)	17.1 (9.0–26.4)		

IQR: interquartile range; AHI: apnoea–hypopnoea index. [#]: β-coefficient and 95% confidence interval representing the estimated change in value across time-windows, derived using a linear mixed effects regression analysis accounting for repeated measures within drivers over time; [¶]: range reported instead of IQR to provide more meaningful summary, as 25th and 75th per centiles were equal to median in all cases.

Our study found a high prevalence of moderate–severe OSA in new hires by a national trucking company, consistent with previous studies in commercial drivers [6, 8, 9, 18]. This is not surprising since commercial drivers are predominantly male and have a high prevalence of obesity, including recent estimates of 53.3% having BMI >30.0 kg·m^{-2} and 26.6% having BMI >35.0 kg·m^{-2} [46]; our sample characteristics were consistent with this literature. As commercial driving generally results in a lifestyle with less physical activity and more sedentary time [47, 48], the occupation itself contributes to these higher obesity levels, and by extension the increased risk for OSA and associated cardiometabolic conditions [46, 49, 50]. To mitigate this occupation-specific risk, consideration needs to be given to the industry adopting weight management strategies among drivers; rapidly emerging drugs such as GLP-1 agonists [51] and combination therapies [52] markedly reduce body weight and might be one such approach. The costs of these therapies, however, will be a major barrier to their broad use in this population.

All drivers in this programme were screened by telemedicine visits and filled out detailed questionnaires prior to their assessment by a physician. Some individuals were cleared by the physician without the need for testing; this group was younger and much less obese. For those being tested, studies were done at home with standard equipment and subsequently interpreted by a sleep physician, who determined treatment recommendations. Once diagnosed with OSA, drivers entered a programme to monitor and manage their PAP adherence; after a 60-day introductory period, compliance with therapy was required to continue driving. The care management programme leveraged remote tracking of PAP usage (hours and days of use, *etc.*) and efficacy (residual AHI and mask leak). These data were used to determine the need for specific interventions by the care management team. The frequency of interventions was highest during the introductory period and dropped off as PAP adherence was established. Once adherence was established, it remained high throughout the period of participation in the programme, with mean nightly use of over 5 h

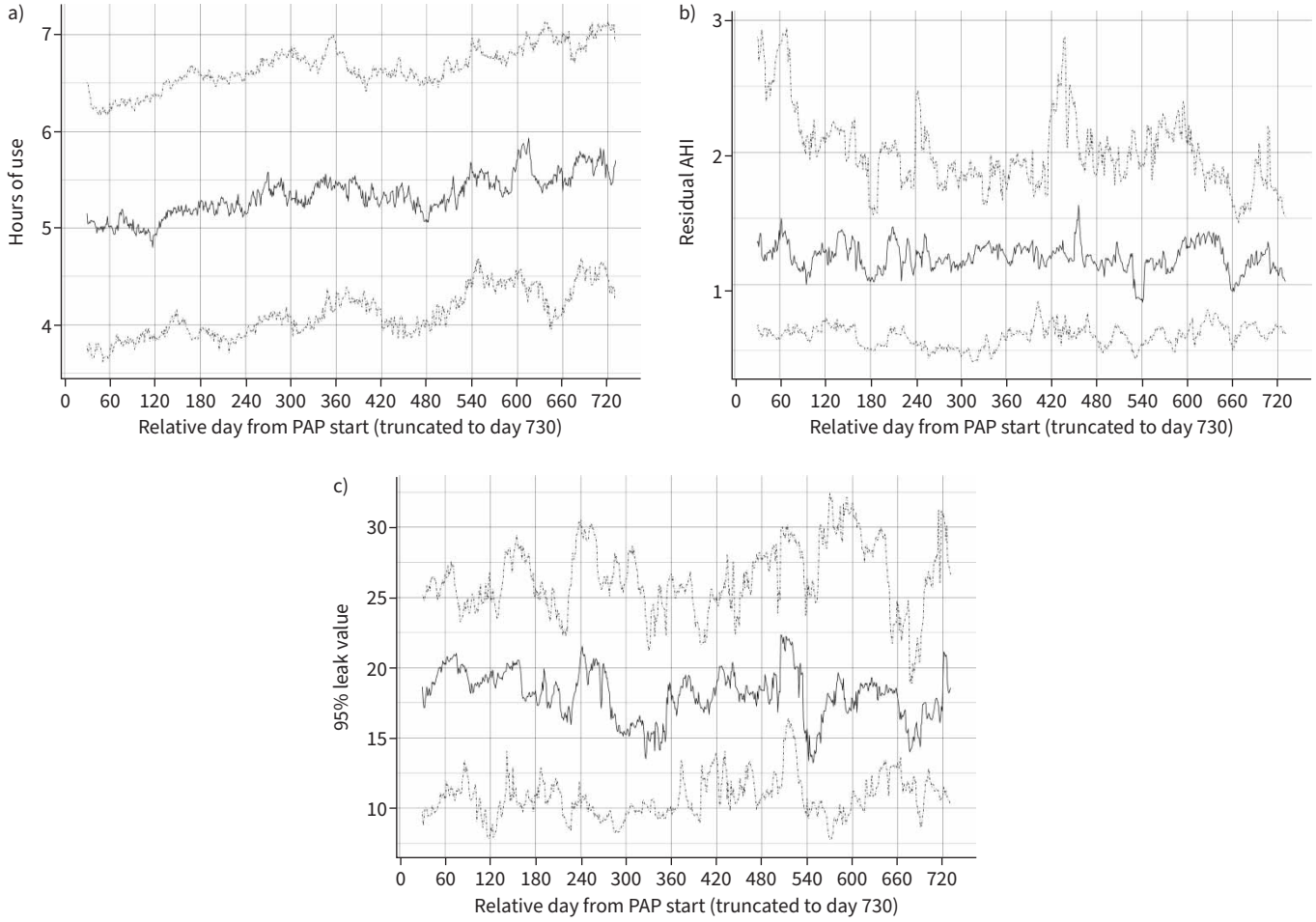

FIGURE 2 Patterns in positive airway pressure (PAP) adherence and efficacy metrics over the first 2 years of driver participation in the care management programme, including a) usage, b) residual apnoea–hypopnoea index (AHI) and c) 95th percentile leak. Data are illustrated as the medians and 25th to 75th percentiles of driver-specific mean values in 30-day windows.

and percentage of nights used of nearly 90%. Thus, the programme was highly effective for ensuring that employed commercial drivers with moderate–severe OSA are compliant with PAP therapy. Notably, the longer-term compliance achieved in this programme was similar to compliance reported in a recent real-world study of PAP compliance in the first 90 days in over 2.5 million patients (5.1±2.5 h·night^{-1}) [53].

There are several barriers to implementing such a programme in the USA, which may or may not generalise to other countries. First, all providers – both physicians and nurse practitioners – are required to obtain licences in each state in which care is provided. Obtaining a state medical licence can be expensive and time consuming (taking up to 12 months in some states). Thus, loss of providers could result in gaps in care while new providers obtain licences. This does not affect the innovative national programme developed in the Veterans Affairs (VA) system [54], since any provider employed by the VA can deliver care to VA patients in any state.

A second barrier is restrictive rules of insurance carriers regarding use of telemedicine, provision of home studies and PAP therapy. We circumvented this with an insurance carve-out agreement in which reimbursement was provided directly by the company, without using an insurance company as an intermediary, thereby eliminating pre-certification requirements that differ by carrier and by driver-reported symptoms upon initial evaluation to assess the need for testing. Thus, successful completion of this type of care management programme will require a commitment and financial investment from the employer. Notably, the increased use and acceptance of telemedicine during the COVID-19 pandemic is likely to lessen this barrier [55].

TABLE 6 Summary of compliance and efficacy interventions

Intervention	Total interventions	n (%)[#]	Mean number of interventions		
			Per driver[¶]	Per 30 driver days[+]	Per 1 driver year[§]
Alerts/warnings	2283	217 (80.7)	8.49	0.54	6.59
PAP Care & Therapy Support	2889	219 (81.4)	10.74	0.68	8.33
Driver education	169	106 (39.4)	0.63	0.04	0.49
DME/supply support	642	165 (61.3)	2.39	0.15	1.85
Mask support	273	121 (45.0)	1.01	0.06	0.79
Pressure support	148	63 (23.4)	0.55	0.04	0.43
Provider support (CM call)	106	68 (25.3)	0.39	0.03	0.31
High leak	1437	122 (45.4)	5.34	0.34	4.15
High AHI	30	18 (6.7)	0.11	0.01	0.09
High CAI	41	5 (1.9)	0.15	0.01	0.12
Re-evaluation	43	32 (11.9)	0.16	0.01	0.12
Escalation	473	123 (45.7)	1.76	0.11	1.36
Requested DM escalation	272	94 (34.9)	1.01	0.06	0.78
DM escalation	101	61 (22.7)	0.38	0.02	0.29
Provider escalation	100	57 (21.2)	0.37	0.02	0.29
Removed from truck due to lack of compliance	19	16 (5.9)	0.071	0.005	0.055

PAP: positive airway pressure; DME: durable medical equipment; CM: care manager; AHI: apnoea–hypopnoea index; CAI: central apnoea index; DM: district manager. [#]: number and percentage of total drivers (n=269) with at least one of the indicated interventions during participation in the care management programme; [¶]: mean number of interventions per driver over their entire time of participation; [+]: mean number of interventions per driver, per 30 days of participation; [§]: mean number of interventions per driver, per 1 year of participation.

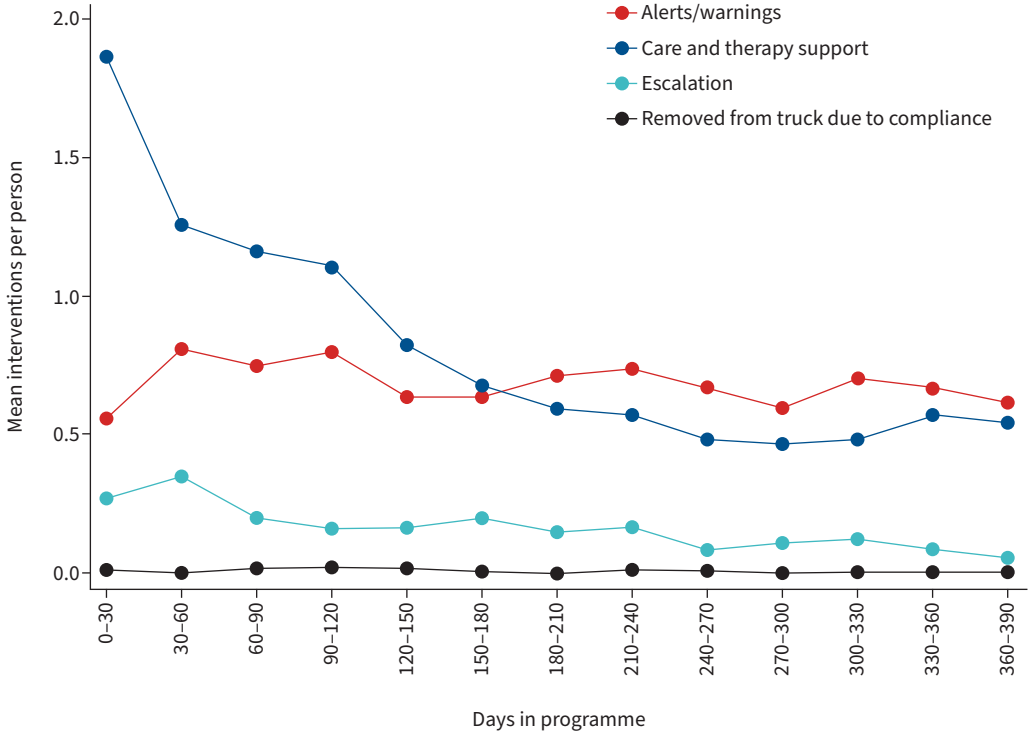

FIGURE 3 Mean number of compliance and efficacy interventions per driver in 30-day windows over the first year of participation. Notably, effort required for care and therapy support decreased with longer duration in the programme.

A third barrier is the perceived negative consequences of being diagnosed with OSA among commercial drivers, which influences willingness to participate and makes self-reported symptoms, which are commonly used to screen for OSA, more unreliable. Supporting this, almost no driver in our sample indicated excessive sleepiness, despite a large proportion of drivers ultimately being diagnosed with OSA and the known impact of undiagnosed OSA on sleepiness [16]. Similarly, very few screened drivers endorsed ever falling asleep while driving or having a traffic accident due to falling asleep; no drivers within the care management programme reported a prior sleepiness-related motor vehicle accident. To overcome this barrier, a programme such as the one described here may be further improved by more objectively assessing the degree of sleepiness and targeting drivers at highest risk. One strategy proposed is to conduct tests of sleepiness such as the maintenance of wakefulness test [56]. While this may improve the ability to identify sleepy drivers, these types of tests are somewhat laborious and time consuming. Further reducing their value, these tests only assess the degree of sleepiness at one moment in time. An alternative and likely more valuable approach is to assess the actual behaviour of drivers while driving [57, 58]. There now exist multiple systems capable of this type of monitoring, although many lack validation [59] and testing in real-world settings [57]. As these approaches mature, consideration should be given to incorporating them into programmes like the one described here. In the absence of reliable symptom data, these techniques could help to differentiate drivers with clinically significant sleep apnoea requiring PAP therapy from those with isolated sleep disordered breathing, who may not require mandated treatment [60, 61]. Future studies focused on approaches to accurately identify those with clinically significant disease are warranted. In the absence of these studies, the lack of reliable symptom reporting among commercial drivers and existing data showing that PAP generally reduces crash risk [30–33] necessitates a more conservative approach in which treatment mandates are based on severity of the AHI alone.

Due to the perceived negative consequences, it is also important to ensure that the HSAT is actually carried out on the driver in question; a number of "chain of custody" technologies have been developed in this regard [13]. While HSAT improves the efficiency and feasibility of a programme such as the one described here, ambulatory studies typically underestimate OSA severity compared to overnight polysomnography due to inclusion of periods of wake in the total recording time used to estimate the AHI. Thus, some drivers in whom PAP was not required due to mild AHI based on the HSAT could have had moderate/severe AHI requiring treatment based on polysomnography. To mitigate this concern, future programmes could incorporate home-based studies with electroencephalogram (EEG), which provide estimates of sleep and wake.

To improve the negative perceptions among drivers, it is important to emphasise the positive benefits of OSA diagnosis and treatment, including known benefits for excessive sleepiness [62], quality of life [63, 64], depression [65] and blood pressure [66, 67]. There are, to our knowledge, no organised educational programmes about OSA for commercial drivers. We were able to explain OSA and the benefits of treatment in the one-on-one sessions with sleep medicine providers. Another strategy could be to use a "peer buddy approach" [68], where the peer buddies are commercial drivers with OSA on PAP that are able to explain OSA and benefits of therapy to other drivers. Importantly, health promotion programmes in commercial drivers have been shown to be effective in other areas, including for obesity [49, 69]. These approaches could be incorporated into programmes aimed at enhancing treatment adherence with PAP among drivers, particularly in the absence of motivations related to employment (as exists in the current programme).

During the course of the programme, we sought to develop a balanced approach to both protect the driver's ability to work and ensure safety on the road, which led to modifications of our treatment and testing protocols. For example, PAP was initially required for any driver with an AHI >5 events·h^{-1}. This was later deemed too strict, as many patients with mild OSA do not experience severe symptoms or consequences and, thus, denying the opportunity for drivers to continue employment due to mild OSA is not supported by current data. Therefore, we changed the protocol so that individuals with mild OSA (AHI >5 and ⩽15 events·h^{-1}) had counselling and were given the choice, rather than requirement, to use PAP. If these drivers declined PAP, we sought to re-evaluate them with another home study after 6–12 months. We also implemented modifications to the testing protocol to ensure successful completion of the HSAT. Initially, there was a >20% failure rate of obtaining data from a single HSAT, requiring a number of repeat studies. In response, the protocol was modified to require 2 consecutive nights of HSAT, as well as having available telemedicine support at night to ensure proper application of the equipment.

New strategies in this area are being driven by large companies with many drivers [7, 33, 34], including the programme described here. There have been attempts to introduce federal regulations by the Federal Motor Carrier Safety Administration, but despite multiple meetings and recommendations of medical advisory groups, none have been introduced. The lack of such regulations in the USA stands in contrast to

existing regulations in many other countries [26, 27]. Notably, there remains some uncertainty in the best way to determine fitness to drive with respect to OSA and sleepiness [26]. An inability to accurately identify those at risk for motor vehicle accidents can limit the effectiveness of such regulations. For example, a recent study from Ontario showed a net benefit of medical fitness to drive policies overall, but no meaningful benefits for sleep apnoea specifically [70]. This was in part due to net increases in crashes among patients with sleep apnoea approved or re-instated as drivers [70]. Such regulations could also have unintended consequences that adversely affect crash rates among commercial drivers, such as older and more experienced drivers (who are at higher risk of OSA [2]) being replaced by younger and less experienced drivers (who have a higher crash risk [71]). Ultimately, while data support relationships of sleepiness and OSA with motor vehicle accident risk [22–25], such regulations should be thought of as interventions and, like any intervention, more studies formally addressing the implementation and effectiveness (or lack thereof) are warranted [27].

Our programme focused on what we believe is fundamentally important – effective treatment. It is not, in our view, sufficient to introduce programmes for screening and diagnosis of OSA without actively managing subsequent therapy. To further demonstrate the importance of ensuring adequate treatment adherence, larger studies with robust monitoring of traffic accidents among participating drivers, as well as objective data on previous crash history, would be beneficial. The clinical programme described here was not designed to robustly evaluate whether there was improvement in motor vehicle accidents (which are expected to occur at very low frequency). Encouragingly, based on the routine review of work-related vehicle accidents by the company safety managers, none of the drivers in the programme had a motor vehicle accident attributed to sleep apnoea.

While this programme was set up specifically for commercial drivers, it is very applicable to efforts in sleep medicine more generally. It is feasible to implement this type of programme in closed health systems with available telemonitoring and dedicated IT infrastructure, such as at the VA and Kaiser Permanente. Large parts of the world that lack adequate sleep medicine services, as documented by the American Academy of Sleep Medicine in the USA [72], could also benefit from this approach to care. While utilising remote data from PAP machines and the remote interventions were labour intensive in the current programme, as staff were required to evaluate data and intervene, the remotely available data and rule-based interventions make these approaches ideal for future automation to improve scalability to these different applications [39].

In conclusion, this employer-mandated OSA screening and management programme was successful in diagnosing and ensuring effective treatment of OSA with PAP therapy among commercial drivers. This programme illustrates the potential to leverage new technology to overcome the current shortage of trained sleep medicine specialists [72]. Hopefully, there will be changes in how sleep medicine is delivered that can take advantage of these new technological approaches.

Provenance: Submitted article, peer reviewed.

Acknowledgements: We acknowledge the strong collaboration with the national trucking company and their support, the regional managers for the company, and the drivers themselves. John Leteria (NeuroCare) provided invaluable advice.

Conflict of interest: The authors have no conflicts of interest.

Support statement: The reported analyses and drafting of this manuscript were in part supported by National Heart, Lung and Blood Institute grants P01 HL094307 and P01 HL160471. Funding information for this article has been deposited with the Crossref Funder Registry.

References

1 Young T, Palta M, Dempsey J, *et al.* The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993; 328: 1230–1235.
2 Young T, Skatrud J, Peppard PE. Risk factors for obstructive sleep apnea in adults. *JAMA* 2004; 291: 2013–2016.
3 Kales SN, Straubel MG. Obstructive sleep apnea in North American commercial drivers. *Ind Health* 2014; 52: 13–24.
4 Sieber WK, Robinson CF, Birdsey J, *et al.* Obesity and other risk factors: the national survey of U.S. long-haul truck driver health and injury. *Am J Ind Med* 2014; 57: 615–626.

5 Abu Dabrh AM, Firwana B, Cowl CT, *et al.* Health assessment of commercial drivers: a meta-narrative systematic review. *BMJ Open* 2014; 4: e003434.
6 Stoohs RA, Bingham LA, Itoi A, *et al.* Sleep and sleep-disordered breathing in commercial long-haul truck drivers. *Chest* 1995; 107: 1275–1282.
7 Berger M, Varvarigou V, Rielly A, *et al.* Employer-mandated sleep apnea screening and diagnosis in commercial drivers. *J Occup Environ Med* 2012; 54: 1017–1025.
8 Gurubhagavatula I, Maislin G, Nkwuo JE, *et al.* Occupational screening for obstructive sleep apnea in commercial drivers. *Am J Respir Crit Care Med* 2004; 170: 371–376.
9 Howard ME, Desai AV, Grunstein RR, *et al.* Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *Am J Respir Crit Care Med* 2004; 170: 1014–1021.
10 Moreno CR, Carvalho FA, Lorenzi C, *et al.* High risk for obstructive sleep apnea in truck drivers estimated by the Berlin questionnaire: prevalence and associated factors. *Chronobiol Int* 2004; 21: 871–879.
11 Talmage JB, Hudson TB, Hegmann KT, *et al.* Consensus criteria for screening commercial drivers for obstructive sleep apnea: evidence of efficacy. *J Occup Environ Med* 2008; 50: 324–329.
12 Parks P, Durand G, Tsismenakis AJ, *et al.* Screening for obstructive sleep apnea during commercial driver medical examinations. *J Occup Environ Med* 2009; 51: 275–282.
13 Gurubhagavatula I, Tan M, Jobanputra AM. OSA in professional transport operations: safety, regulatory, and economic impact. *Chest* 2020; 158: 2172–2183.
14 Tregear S, Reston J, Schoelles K, *et al.* Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis. *J Clin Sleep Med* 2009; 5: 573–581.
15 Potts KJ, Butterfield DT, Sims P, *et al.* Cost savings associated with an education campaign on the diagnosis and management of sleep-disordered breathing: a retrospective, claims-based US study. *Popul Health Manag* 2013; 16: 7–13.
16 Gottlieb DJ, Punjabi NM. Diagnosis and management of obstructive sleep apnea: a review. *JAMA* 2020; 323: 1389–1400.
17 Somers VK, White DP, Amin R, *et al.* Sleep apnea and cardiovascular disease: an American Heart Association/American College of Cardiology Foundation Scientific Statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing. *J Am Coll Cardiol* 2008; 52: 686–717.
18 Pack AI, Maislin G, Staley B, *et al.* Impaired performance in commercial drivers: role of sleep apnea and short sleep duration. *Am J Respir Crit Care Med* 2006; 174: 446–454.
19 McCartt AT, Rohrbaugh JW, Hammer MC, *et al.* Factors associated with falling asleep at the wheel among long-distance truck drivers. *Accid Anal Prev* 2000; 32: 493–504.
20 Hirsch Allen AJM, Bansback N, Ayas NT. The effect of OSA on work disability and work-related injuries. *Chest* 2015; 147: 1422–1428.
21 Kapur V, Blough DK, Sandblom RE, *et al.* The medical cost of undiagnosed sleep apnea. *Sleep* 1999; 22: 749–755.
22 Pack AI, Pack AM, Rodgman E, *et al.* Characteristics of crashes attributed to the driver having fallen asleep. *Accid Anal Prev* 1995; 27: 769–775.
23 Garbarino S, Durando P, Guglielmi O, *et al.* Sleep apnea, sleep debt and daytime sleepiness are independently associated with road accidents. A cross-sectional study on truck drivers. *PLoS One* 2016; 11: e0166262.
24 Dash Nelson G, Rae A. An economic geography of the United States: from commutes to megaregions. *PLoS One* 2016; 11: e0166083.
25 Garbarino S, Guglielmi O, Sanna A, *et al.* Risk of occupational accidents in workers with obstructive sleep apnea: systematic review and meta-analysis. *Sleep* 2016; 39: 1211–1218.
26 McNicholas WT. Sleepiness and driving: the role of official regulation. *Sleep Med Clin* 2019; 14: 491–498.
27 Bonsignore MR, Randerath W, Schiza S, *et al.* European Respiratory Society statement on sleep apnoea, sleepiness and driving risk. *Eur Respir J* 2021; 57: 2001272.
28 Weaver TE, Maislin G, Dinges DF, *et al.* Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep* 2007; 30: 711–719.
29 Hu X, Fan J, Chen S, *et al.* The role of continuous positive airway pressure in blood pressure control for patients with obstructive sleep apnea and hypertension: a meta-analysis of randomized controlled trials. *J Clin Hypertens (Greenwich)* 2015; 17: 215–222.
30 George CF. Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. *Thorax* 2001; 56: 508–512.
31 Sassani A, Findley LJ, Kryger M, *et al.* Reducing motor-vehicle collisions, costs, and fatalities by treating obstructive sleep apnea syndrome. *Sleep* 2004; 27: 453–458.
32 Tregear S, Reston J, Schoelles K, *et al.* Continuous positive airway pressure reduces risk of motor vehicle crash among drivers with obstructive sleep apnea: systematic review and meta-analysis. *Sleep* 2010; 33: 1373–1380.

33 Burks SV, Anderson JE, Bombyk M, *et al.* Nonadherence with employer-mandated sleep apnea treatment and increased risk of serious truck crashes. *Sleep* 2016; 39: 967–975.
34 Burks SV, Anderson JE, Panda B, *et al.* Employer-mandated obstructive sleep apnea treatment and healthcare cost savings among truckers. *Sleep* 2020; 43: zsz262.
35 Kuna ST. Portable-monitor testing: an alternative strategy for managing patients with obstructive sleep apnea. *Respir Care* 2010; 55: 1196–1215.
36 Perednia DA, Allen A. Telemedicine technology and clinical applications. *JAMA* 1995; 273: 483–488.
37 Kuna ST, Gurubhagavatula I, Maislin G, *et al.* Noninferiority of functional outcome in ambulatory management of obstructive sleep apnea. *Am J Respir Crit Care Med* 2011; 183: 1238–1244.
38 Turino C, de Batlle J, Woehrle H, *et al.* Management of continuous positive airway pressure treatment compliance using telemonitoring in obstructive sleep apnoea. *Eur Respir J* 2017; 49: 1601128.
39 Keenan BT, Schwab RJ. Using the remote monitoring framework to promote adherence to continuous positive airway pressure. *Sleep Med Clin* 2021; 16: 85–99.
40 Weinstein RS, Lopez AM, Joseph BA, *et al.* Telemedicine, telehealth, and mobile health applications that work: opportunities and barriers. *Am J Med* 2014; 127: 183–187.
41 Hwang D. Monitoring progress and adherence with positive airway pressure therapy for obstructive sleep apnea: the roles of telemedicine and mobile health applications. *Sleep Med Clin* 2016; 11: 161–171.
42 Colvin LJ, Collop NA. Commercial motor vehicle driver obstructive sleep apnea screening and treatment in the United States: an update and recommendation overview. *J Clin Sleep Med* 2016; 12: 113–125.
43 Gurubhagavatula I, Patil S, Meoli A, *et al.* Sleep apnea evaluation of commercial motor vehicle operators. *J Clin Sleep Med* 2015; 12: 285–286.
44 Watkins MR, Talmage JB, Thiese MS, *et al.* Correlation between screening for obstructive sleep apnea using a portable device versus polysomnography testing in a commercial driving population. *J Occup Environ Med* 2009; 51: 1145–1150.
45 Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991; 14: 540–545.
46 Thiese MS, Moffitt G, Hanowski RJ, *et al.* Commercial driver medical examinations: prevalence of obesity, comorbidities, and certification outcomes. *J Occup Environ Med* 2015; 57: 659–665.
47 Gilson ND, Pavey TG, Vandelanotte C, *et al.* Chronic disease risks and use of a smartphone application during a physical activity and dietary intervention in Australian truck drivers. *Aust N Z J Public Health* 2016; 40: 91–93.
48 Varela-Mato V, O'Shea O, King JA, *et al.* Cross-sectional surveillance study to phenotype lorry drivers' sedentary behaviours, physical activity and cardio-metabolic health. *BMJ Open* 2017; 7: e013162.
49 Olson R, Wipfli B, Thompson SV, *et al.* Weight control intervention for truck drivers: the SHIFT randomized controlled trial, United States. *Am J Public Health* 2016; 106: 1698–1706.
50 Apostolopoulos Y, Lemke MK, Hege A, *et al.* Work and chronic disease: comparison of cardiometabolic risk markers between truck drivers and the general US population. *J Occup Environ Med* 2016; 58: 1098–1105.
51 Iqbal J, Wu HX, Hu N, *et al.* Effect of glucagon-like peptide-1 receptor agonists on body weight in adults with obesity without diabetes mellitus: a systematic review and meta-analysis of randomized control trials. *Obes Rev* 2022; 23: e13435.
52 Nauck MA, D'Alessio DA. Tirzepatide, a dual GIP/GLP-1 receptor co-agonist for the treatment of type 2 diabetes with unmatched effectiveness regrading glycaemic control and body weight reduction. *Cardiovasc Diabetol* 2022; 21: 169.
53 Cistulli PA, Armitstead J, Pepin JL, *et al.* Short-term CPAP adherence in obstructive sleep apnea: a big data analysis using real world data. *Sleep Med* 2019; 59: 114–116.
54 Chang YHA, Folmer RL, Shasha B, *et al.* Barriers and facilitators to the implementation of a novel web-based sleep apnea management platform. *Sleep* 2021; 44: zsaa243.
55 Voulgaris A, Ferini-Strambi L, Steiropoulos P. Sleep medicine and COVID-19. Has a new era begun? *Sleep Med* 2020; 73: 170–176.
56 Philip P, Guichard K, Strauss M, *et al.* Maintenance of wakefulness test: how does it predict accident risk in patients with sleep disorders? *Sleep Med* 2021; 77: 249–255.
57 Howard ME, Cori JM. Time for sleep science to wake up to drowsy driver monitoring. *Sleep* 2023; 47: zsad324.
58 Rosekind MR, Michael JP, Dorey-Stein ZL, *et al.* Awake at the wheel: how auto technology innovations present ongoing sleep challenges and new safety opportunities. *Sleep* 2023; 47: zsad316.
59 Cori JM, Manousakis JE, Koppel S, *et al.* An evaluation and comparison of commercial driver sleepiness detection technology: a rapid review. *Physiol Meas* 2021; 7: 074007.
60 Vakulin A, Chai-Coetzer CL, McEvoy RD. Con: should asymptomatic patients with moderate-to-severe OSA be treated? *Breathe (Sheff)* 2019; 15: 11–14.
61 Altintas N, Riha RL. Non-sleepy obstructive sleep apnoea: to treat or not to treat? *Eur Respir Rev* 2019; 28: 190031.

62 Jenkinson C, Davies RJ, Mullins R, *et al.* Comparison of therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised prospective parallel trial. *Lancet* 1999; 353: 2100–2105.

63 Batool-Anwar S, Goodwin JL, Kushida CA, *et al.* Impact of continuous positive airway pressure (CPAP) on quality of life in patients with obstructive sleep apnea (OSA). *J Sleep Res* 2016; 25: 731–738.

64 Jenkinson C, Stradling J, Petersen S. Comparison of three measures of quality of life outcome in the evaluation of continuous positive airways pressure therapy for sleep apnoea. *J Sleep Res* 1997; 6: 199–204.

65 Ejaz SM, Khawaja IS, Bhatia S, *et al.* Obstructive sleep apnea and depression: a review. *Innov Clin Neurosci* 2011; 8: 17–25.

66 Labarca G, Schmidt A, Dreyse J, *et al.* Efficacy of continuous positive airway pressure (CPAP) in patients with obstructive sleep apnea (OSA) and resistant hypertension (RH): systematic review and meta-analysis. *Sleep Med Rev* 2021; 58: 101446.

67 Shang W, Zhang Y, Liu L, *et al.* Benefits of continuous positive airway pressure on blood pressure in patients with hypertension and obstructive sleep apnea: a meta-analysis. *Hypertens Res* 2022; 45: 1802–1813.

68 Parthasarathy S, Wendel C, Haynes PL, *et al.* A pilot study of CPAP adherence promotion by peer buddies with sleep apnea. *J Clin Sleep Med* 2013; 9: 543–550.

69 Ruettger K, Clemes SA, Chen YL, *et al.* Drivers with and without obesity respond differently to a multi-component health intervention in heavy goods vehicle drivers. *Int J Environ Res Public Health* 2022; 19: 15546.

70 Ma T, Chee JN, Hanna J, *et al.* Impact of medical fitness to drive policies in preventing property damage, injury, and death from motor vehicle collisions in Ontario, Canada. *J Safety Res* 2020; 75: 251–261.

71 Dunn NJ, Soccolich SA, Hickman JS. Commercial Motor Vehicle Driver Risk Based on Age and Driving Experience. Report #20-UI-079. Blacksburg, VA, The National Surface Transportation Safety Center for Excellence, 2020.

72 Watson NF, Rosen IM, Chervin RD, *et al.* The past is prologue: the future of sleep medicine. *J Clin Sleep Med* 2017; 13: 127–135.