VTTI

SAFETY BENEFITS OF A CARRIER-IMPLEMENTED SLEEP APNEA PROGRAM FOR COMMERCIAL MOTOR VEHICLE DRIVERS

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Background

Obstructive sleep apnea (OSA)

Highly prevalent in obese populations (45%)

Problematic for CMV drivers

- Excessive daytime sleepiness
- Impacts vigilance, judgement, and cognitive and executive functions
- Impairs attention, concentration, and memory

90% of people with OSA undiagnosed

Estimated to affect ~1 million CMV drivers (Burks et al. 2016)

Partial Obstruction

Blocked Airway

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- Medical Examination Report for Commercial Driver Fitness Determination
- Untreated OSA is a disqualifying medical condition
- Drivers hesitant to disclose symptoms
  - 85% of CMV drivers that screened high for OSA answered negatively (Parks et al. 2009)

DRIVER HEALTH HISTORY *(continued)*

Do you have or have you ever had:	Yes	No	Not Sure
1. Head/brain injuries or illnesses *(e.g., concussion)*	☐	☐	☐
2. Seizures/epilepsy	☐	☐	☐
3. Eye problems *(except glasses or contacts)*	☐	☐	☐
4. Ear and/or hearing problems	☐	☐	☐
5. Heart disease, heart attack, bypass, or other heart problems	☐	☐	☐
6. Pacemaker, stents, implantable devices, or other heart procedures	☐	☐	☐
7. High blood pressure	☐	☐	☐
8. High cholesterol	☐	☐	☐
9. Chronic (long-term) cough, shortness of breath, or other breathing problems	☐	☐	☐
10. Lung disease *(e.g., asthma)*	☐	☐	☐
11. Kidney problems, kidney stones, or pain/problems with urination	☐	☐	☐
12. Stomach, liver, or digestive problems	☐	☐	☐
13. Diabetes or blood sugar problems	☐	☐	☐
Insulin used	☐	☐	☐
14. Anxiety, depression, nervousness, other mental health problems	☐	☐	☐
15. Fainting or passing out	☐	☐	☐
16. Dizziness, headaches, numbness, tingling, or memory loss	☐	☐	☐
17. Unexplained weight loss	☐	☐	☐
18. Stroke, mini-stroke (TIA), paralysis, or weakness	☐	☐	☐
19. Missing or limited use of arm, hand, finger, leg, foot, toe	☐	☐	☐
20. Neck or back problems	☐	☐	☐
21. Bone, muscle, joint, or nerve problems	☐	☐	☐
22. Blood clots or bleeding problems	☐	☐	☐
23. Cancer	☐	☐	☐
24. Chronic (long-term) infection or other chronic diseases	☐	☐	☐
25. Sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring	☐	☐	☐
26. Have you ever had a sleep test *(e.g., sleep apnea)*?	☐	☐	☐
27. Have you ever spent a night in the hospital?	☐	☐	☐
28. Have you ever had a broken bone?	☐	☐	☐
29. Have you ever used or do you now use tobacco?	☐	☐	☐
30. Do you currently drink alcohol?	☐	☐	☐
31. Have you used an illegal substance within the past two years?	☐	☐	☐
32. Have you ever failed a drug test or been dependent on an illegal substance?	☐	☐	☐

- Positive Airway Pressure (PAP)
  - Treated drivers not disqualified
    - 4 hrs/night for 70% of nights
  - Dose-response effect between use and therapeutic response
  - Medical community recommends use for most/all of sleep period

Study Purpose

- To support findings of Burks et al. (2016)
  - Retrospective cohort analysis
  - *n* = 1,613 OSA; *n* = 2,016 control drivers
  - OSA drivers who did not adhere to PAP had 5x greater crash rates vs. controls
  - PAP-adherent drivers had similar crash rates to controls

Nonadherence with Employer-Mandated Sleep Apnea Treatment and Increased Risk of Serious Truck Crashes

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Study Objectives: To evaluate the effect of an employer-mandated obstructive sleep apnea (OSA) program on the risk of serious preventable truck crashes.
Methods: Data are from the first large-scale, employer-mandated program to screen, diagnose, and monitor OSA treatment adherence in the US trucking industry. A retrospective analysis of cohorts was constructed: polysomnogram-diagnosed drivers (OSA positive n = 1,613, OSA negative n = 403) were matched to control drivers unlikely to have OSA (n = 2,016) on two factors affecting crash risk, experience-at-hire and length of job tenure; tenure was matched on the date of each diagnosed driver's polysomnogram. Auto-adjusting positive airway pressure (APAP) treatment was provided to all cases (i.e. OSA positive drivers); treatment adherence was objectively monitored. Cases were grouped by treatment adherence: "Full Adherence" (n = 682), "Partial Adherence" (n = 571), or "No Adherence" (n = 360). Preventable Department-of-Transportation-reportable crashes/100,000 miles were compared across study subgroups. Robustness was assessed.
Results: After the matching date, "No Adherence" cases had a preventable Department of Transportation-reportable crash rate that was fivefold greater (incidence rate ratio = 4.97, 95% confidence interval: 2.09, 10.63) than that of matched controls (0.070 versus 0.014 per 100,000 miles). The crash rate of "Full Adherence" cases was statistically similar to controls (incidence rate ratio = 1.02, 95% confidence interval: 0.48, 2.04; 0.014 per 100,000 miles).
Conclusions: Nontreatment-adherent OSA-positive drivers had a fivefold greater risk of serious preventable crashes, but were discharged or quit rapidly, being retained only one-third as long as other subjects. Thus, the mandated program removed risky nontreatment-adherent drivers and retained adherent drivers at the study firm. Current regulations allow nonadherent OSA cases to drive at another firm by keeping their diagnosis private.
Commentary: A commentary on this article appears in this issue on page 961.
Keywords: APAP, commercial motor vehicle operator, CPAP, motor carrier, obstructive sleep apnea, OSA, preventable crash, PSG, screening, truckload
Citation: Burks SV, Anderson JE, Bombyk M, Haider R, Ganzhorn D, Jiao X, Lewis C, Lexvold A, Liu H, Ning J, Toll A, Hickman JS, Mabry E, Berger M, Malhotra A, Czeisler CA, Kales SN. Nonadherence with employer-mandated sleep apnea treatment and increased risk of serious truck crashes. *SLEEP* 2016;39(5):967–975.

Research Objectives

Evaluate the safety benefits of two OSA programs for CMV drivers

- Collaborate with FusionHealth®, a population sleep health provider
  - OSA diagnostic and tx data
- Work with two leading U.S. carriers with OSA programs
  - Driver and safety data

Methods: Recruitment

- Recruited two for-hire fleets
  - Clients of FusionHealth®
  - Sleep health programs in place for at least 2 years
- Documented programs
  - Screening
  - Testing and diagnostics
  - Treatment
  - Compliance

Methods: Data Sources

- OSA Screening, Diagnostic, Treatment
  - Screening, testing, and treatment dates
  - Symptomology, risk factors
  - AHI, PAP daily usage
- Driver Employment
  - Hire and term (if applicable) dates
  - OSA and cohort drivers
- Carrier crashes
  - OSA and cohort drivers
  - Date, crash narrative
  - Injuries, fatalities
  - Reviewed by research team, assigned crash types:
    - Claims-only
      - Property damage, off-road, minimal damage
    - On-road
      - On primary or secondary roads
    - Preventable (fleet determined)

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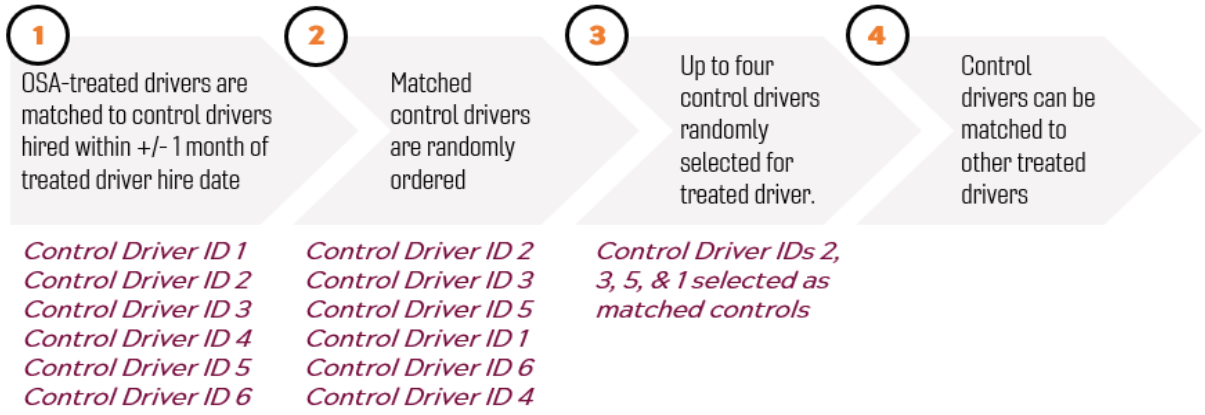
Methods: Driver Variables

- Treatment adherence
  - Usage in minutes/day
  - Scored as full, partial, no adherence
    - % days with ≥ 4 hrs PAP usage of treatment period days
      - Full: ≥ 70%
      - Partial: >0%, <70% of treatment period days
      - No: 0%

- Matched Cohort Drivers
  - Not diagnosed with OSA
  - Matched with OSA drivers within 1 month of hire date
  - All matches randomized
  - Up to four cohort drivers matched with one OSA driver



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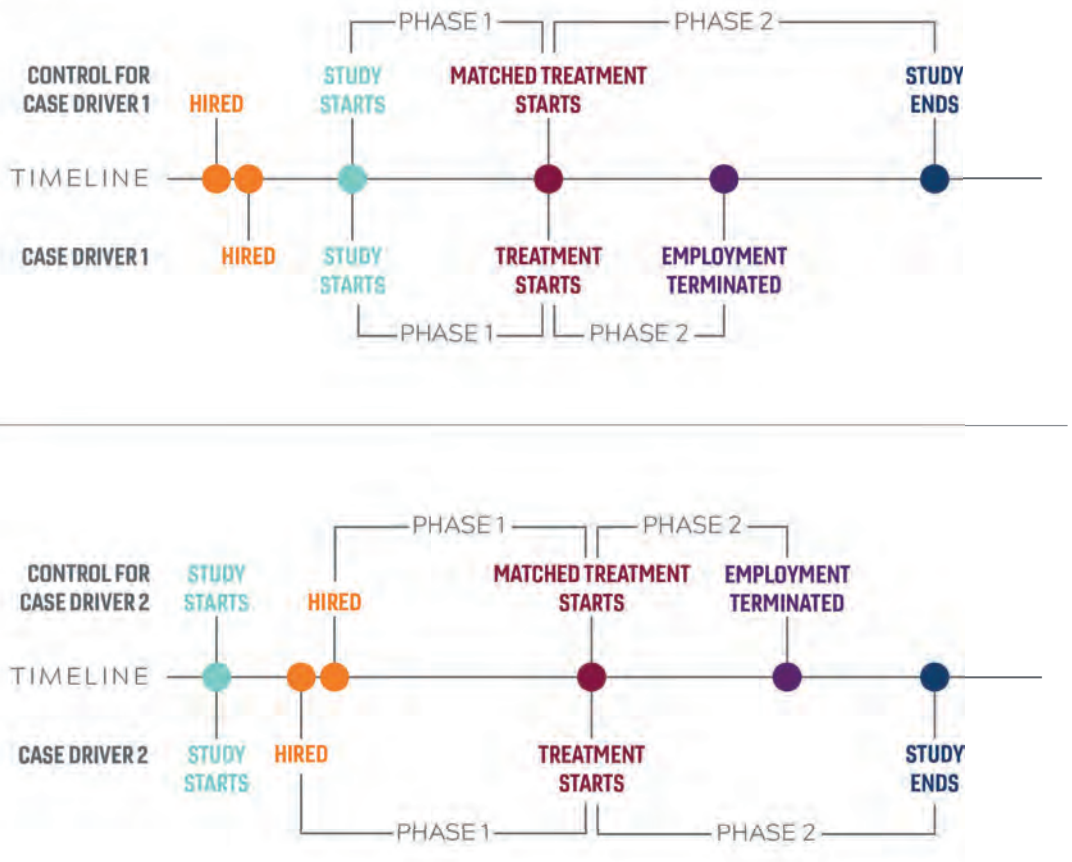
Methods: Driver Exposure



Methods: Analyses

Safety performance by PAP adherence and usage	• Negative binomial regression model • Poisson regression models
Safety performance pre- and during treatment for drivers with prior crash	• Negative binomial mixed-effect model
Matched cohort analysis of safety performance	• Negative binomial regression model

Carrier A

RESULTS

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Descriptives and Crash Counts

- *n* = 633 OSA drivers
- 97% of drivers had full PAP adherence
- Mean AHI = 35.2 events/hr
- Mean BMI = 35.7 kg/m^2
- Mean company tenure = 11.13 yrs

Table 7. Crash counts by adherence group and study phase for Carrier A.

Driver Adherence Group and Study Phase	Claims-only Crash Count	On-road Crash Count	Preventable Crash Count
All Adherence, Before Treatment	2,834	955	1,104
All Adherence, During Treatment	1,318	375	454
Full Adherence, Before Treatment	2,782	938	1,082
Full Adherence, During Treatment	1,30	374	450
Partial Adherence, Before Treatment	52	17	22
Partial Adherence, During Treatment	10	1	4

*crash categories not mutually exclusive

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Safety Performance for Drivers with Crash Prior to Treatment

- *n* = 559
- Drivers with full PAP adherence reduced their risk of on-road crashes and preventable crashes from before treatment to during treatment phase

Table 8. Negative binomial model results comparing before and during treatment phases for Carrier A drivers with at least one crash in the before treatment phase.

Comparison	Crash Type	RR	95% CI
Full Adherence: Before vs. During Treatment	On-road	0.80*	(0.69, 0.93)
Full Adherence: Before vs. During Treatment	Claims-only	0.92	(0.84, 1.00)
Full Adherence: Before vs. During Treatment	Preventable	0.80*	(0.71, 0.90)

** indicates statistically significant result*

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Safety Performance Before and During Treatment by Usage

- Reduced crash rates during PAP treatment for on-road and preventable crashes for drivers averaging 6-8 hrs PAP/night
- No difference in crash rates before vs. during treatment for any crash type for other PAP usage sessions

Table 11. Crash rates before and during PAP treatment for drivers averaging 6 hours to 8 hours of PAP usage in a 24-hour period.

Crash Type	Pre-treatment Average Crash Rate per 1,000 Days (SD)	During Treatment Average Crash Rate per 1,000 Days (SD)	RR	95% CI
On-road	0.65 (0.95)	0.58 (1.91)	0.7867*	(0.6666, 0.9284)
Claims-only	1.99 (2.19)	2.03 (2.82)	0.9428	(0.8604, 1.0331)
Preventable	0.75 (0.99)	0.67 (1.76)	0.7529*	(0.6419, 0.8830)

** indicates statistically significant result*

Carrier B

RESULTS

Descriptives and Crash Counts

- *n* = 382 OSA drivers
- 91% of drivers had full PAP adherence
- Mean AHI = 39.4 events/hr
- Mean BMI = 36.7 kg/m^2
- Mean company tenure = 8.9 yrs

Table 24. Crash counts by adherence group and study phase for Carrier B.

Driver Adherence Group and Study Phase	Claims-only Crash Count	On-road Crash Count	Preventable Crash Count
All Adherence, Before Treatment	305	223	212
All Adherence, During Treatment	249	142	130
Full Adherence, Before Treatment	278	207	194
Full Adherence, During Treatment	224	124	109
Partial Adherence, Before Treatment	27	16	18
Partial Adherence, During Treatment	25	18	21

*crash categories not mutually exclusive

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Comparing Full and Partial Adherence Crash Rates

- Full and partial adherence OSA drivers had similar crash rates before beginning PAP
- During treatment, full adherence drivers had lower rates of on-road and preventable crashes

Table 25. Carrier B average crash rates per 100,000 days exposure, with negative binomial regression models comparing full and partial adherence groups for the before treatment phase by crash categories.

Crash Category	Full Adherence Driver Average Crash Rate/100,000 Days (SD)	Partial Adherence Driver Average Crash Rate/100,000 Days (SD)	RR	95% CI
Claims-only	82.09 (298.51)	114.95 (244.55)	0.73	(0.47, 1.15)
On-road	52.09 (113.71)	41.90 (101.97)	0.97	(0.55, 1.70)
Preventable	48.95 (102.54)	44.13 (79.14)	0.81	(0.46, 1.41)

Table 26. Carrier B average crash rates per 100,000 days exposure, with negative binomial regression models comparing full and partial adherence groups for the during treatment phase by crash categories.

Crash Category	Full Adherence Driver Average Crash Rate/100,000 Days (SD)	Partial Adherence Driver Average Crash Rate/100,000 Days (SD)	RR	95% CI
Claims-only	136.58 (402.51)	194.92 (480.53)	0.66	(0.39, 1.11)
On-road	50.62 (117.75)	171.54 (487.65)	0.50*	(0.27, 0.91)
Preventable	80.74 (367.20)	273.74 (664.99)	0.36*	(0.21, 0.63)

** indicates statistically significant finding*

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Safety Performance for Drivers with Crash Prior to Treatment

- *n* = 248
- Preventable crash rates reduced during treatment for full adherence OSA drivers
- No difference in on-road or claims crashes before vs. during treatment for any adherence level

Table 27. Negative binomial model results comparing before and during treatment phases for Carrier B drivers with at least one crash prior to beginning treatment.

Comparison	Crash Type	RR	95% CI
All Adherence: Before vs. During Treatment	On-road	0.89	(0.70, 1.13)
All Adherence: Before vs. During Treatment	Claims-only	1.01	(0.83, 1.22)
All Adherence: Before vs. During Treatment	Preventable	0.71*	(0.54, 0.93)
Full Adherence: Before vs. During Treatment	On-road	0.88	(0.68, 1.14)
Full Adherence: Before vs. During Treatment	Claims-only	1.05	(0.86, 1.29)
Full Adherence: Before vs. During Treatment	Preventable	0.71*	(0.54, 0.93)
Partial Adherence: Before vs. During Treatment	On-road	1.10	(0.44, 2.74)
Partial Adherence: Before vs. During Treatment	Claims-only	0.48	(0.19, 1.21)
Partial Adherence: Before vs. During Treatment	Preventable	0.78	(0.28, 2.16)

** indicates statistically significant result*

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Matched Cohort Analysis

- *n* = 1,493 matched cohort drivers
- During treatment, full adherence drivers had lower preventable crash rates vs. matched cohort drivers
- No difference before PAP treatment

Table 36. Carrier B treatment period crash rates per 100,000 employed days, with negative binomial regression model results comparing treatment crash rates of control drivers and full and partial adherence drivers.

Adherence Level	Crash Type	Control Driver Average Crash Rate per 100,000 Employed Days	Treated Driver Average Crash Rate per 100,000 Employed Days	Control to Treated RR	95% CI
Full Adherence	Claims-only Crashes	111.28	138.52	0.93	(0.77, 1.11)
	On-road Crashes	61.46	50.88	0.93	(0.74, 1.18)
	Preventable Crashes	72.57	82.24	0.77*	(0.61, 0.97)
Partial Adherence	Claims-only Crashes	159.40	196.29	1.17	(0.70, 1.94)
	On-road Crashes	63.35	174.20	1.56	(0.92, 2.64)
	Preventable Crashes	123.71	277.56	1.78	(0.95, 3.34)

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Discussion

- >90% of drivers from both carriers showed full PAP adherence
  - Only 42% of drivers had full PAP adherence (Burks et al., 2016)
  - Important role of technology in compliance monitoring

- Safety benefits of PAP for full-adherence drivers
  - Lower rate of on-road (50%) and preventable (64%) crash rates during treatment vs. partial adherence drivers (Carrier B)
  - Benefits pronounced for drivers with a crash prior to full-adherence PAP treatment
    - On-road and preventable crashes reduced 20% (Carrier A)
    - Preventable crashes reduced 29% (Carrier B)

Discussion

- Dose-response safety benefit of PAP use
  - 6-8 hrs/night of PAP reduced on-road (21%) and preventable (25%) crashes (Carrier A)
  - Supports existing literature
- During PAP treatment, fully adherent drivers showed reduced rate of preventable crashes compared to matched cohort (Carrier B)
  - Not replicated for Carrier A
    - Possible inherent differences between OSA and control cohorts that impacted safety (but not affected by OSA or PAP)
- Low counts of partial adherence drivers made it difficult to investigate safety outcomes
  - 2.5% (Carrier A) and 9.2% (Carrier B)
    - vs. 35% in Burks et al. (2016)

Key Takeaways

- Exceptional PAP adherence rates are encouraging
- Full PAP adherence was associated with reductions in on-road and preventable crashes (Carrier B)
- Pronounced safety benefits of PAP for drivers with prior crash
- Dose-response safety benefits of PAP (Carrier A)
- Fleets should focus on:
  - identifying OSA drivers through effective screening programs
  - providing PAP treatment
  - monitoring PAP compliance
  - providing support to assist drivers in maintaining OSA compliance

Thank you!
Questions?

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Matched Cohort Analysis-Carrier A

- *n* = 2,397 matched cohort drivers
- Before and during treatment, OSA drivers showed higher crash rates vs. control drivers

Table 15. Carrier A before-treatment period crash rates per 100,000 employed days, with negative binomial regression model results comparing before-treatment crash rates of control drivers and full adherence drivers.

Adherence Level	Crash Type	Control Driver Average Crash Rate per 100,000 Employed Days	Treated Driver Average Crash Rate per 100,000 Employed Days	Control to Treated RR	95% CI
Full Adherence	Claims-only Crashes	197.95	219.31	1.15*	(1.11, 1.20)
	On-road Crashes	74.32	69.23	0.96	(0.89, 1.03)
	Preventable Crashes	90.23	87.45	1.13*	(1.05, 1.21)

** indicates statistically significant result*

Table 17. Carrier A treatment period crash rates per 100,000 employed days, with negative binomial regression model results comparing treatment crash rates of control drivers and full adherence drivers.

Adherence Level	Crash Type	Control Driver Average Crash Rate per 100,000 Employed Days	Treated Driver Average Crash Rate per 100,000 Employed Days	Control to Treated RR	95% CI
Full Adherence	Claims-only Crashes	156.37	203.32	1.41*	(1.28, 1.55)
	On-road Crashes	50.07	61.61	1.33*	(1.16, 1.53)
	Preventable Crashes	70.83	72.53	1.34*	(1.17, 1.53)

** indicates statistically significant result*

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Safety Performance Before and During Treatment by Usage-Carrier B

- On-road crashes increased during PAP for drivers averaging 2-4 hrs use/night
- Claims crash rates increased during PAP for drivers averaging 4-6 and 6-8 hrs use/night
- Preventable crash rates increased during PAP for drivers averaging 4-6 hrs use/night

Table 28. Crash rates before and during PAP treatment for drivers averaging 2 hours to 4 hours of PAP usage in a 24-hour period.

Crash Type	Pre-treatment Average Crash Rate per 1,000 Days (SD)	During Treatment Average Crash Rate per 1,000 Days (SD)	RR	95% CI
On-road	0.39 (0.73)	2.35 (5.50)	2.8247*	(1.5300, 5.2149)
Claims-only	1.24 (2.16)	0.82 (2.02)	0.9515	(0.5337, 1.6961)
Preventable	0.78 (1.33)	2.18 (5.42)	1.4067	(0.7847, 2.5215)

** indicates statistically significant result*

Table 29. Crash rates before and during PAP treatment for drivers averaging 4 hours to 6 hours of PAP usage in a 24-hour period.

Crash Type	Pre-treatment Average Crash Rate per 1,000 Days (SD)	During Treatment Average Crash Rate per 1,000 Days (SD)	RR	95% CI
On-road	0.57 (1.61)	0.73 (1.91)	1.1216	(0.8754, 1.4371)
Claims-only	0.99 (3.41)	1.72 (4.80)	1.3168*	(1.0852, 1.5977)
Preventable	0.50 (0.98)	1.21 (4.85)	1.2988*	(1.0129, 1.6654)

** indicates statistically significant result*
-- indicates not controlling for driver with random intercept term due to modeling errors

Table 30. Crash rates before and during PAP treatment for drivers averaging 6 hours to 8 hours of PAP usage in a 24-hour period.

Crash Type	Pre-treatment Average Crash Rate per 1,000 Days (SD)	During Treatment Average Crash Rate per 1,000 Days (SD)	RR	95% CI
On-road	0.43 (1.14)	0.43 (0.96)	1.0971	(0.8176, 1.4720)
Claims-only	0.87 (1.55)	1.36 (3.01)	1.3298*	(1.0916, 1.6199)
Preventable	0.56 (1.50)	0.72 (2.78)	1.0479	(0.7882, 1.3932)

** indicates statistically significant result*

Limitations

- Inability to complete analyses and interpret meaningful results for the partial PAP adherence group due to low driver counts
- Treatment period limited ability to explore safety benefits with long-term PAP use
- Unable to explore factors attributed to increased crash risk with PAP use
  - sleep duration, cognitive impairment, EDS, treatment efficacy
- Matched cohort drivers not OSA-negative

Future Research

- Evaluate a larger cohort of drivers and longer observation period of PAP treatment
- Explore weekly safety performance for additional analysis options
- Investigate variation in PAP adherence over study weeks