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Safety incidents and obstructive sleep apnoea in railway workers

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Background Current evidence is lacking to justify more stringent screening for obstructive sleep apnoea (OSA) in the rail industry. Population-based studies indicate a complex association between body mass index, age, apnoea–hypopnoea index and vehicle crash risk.

Aims To study the association between OSA severity and the occurrence of safety incidents in safety-critical rail workers with a confirmed diagnosis of OSA, and to identify if OSA treatment is associated with the occurrence of fewer safety incidents.

Methods A retrospective medical file audit was conducted on railway workers attending health assessments between 2016 and 2018, who met the criteria to be referred for sleep studies. The association between OSA severity, treatment and the number of incidents in the 3 years before their health assessment appointment was explored using a Poisson log-linear regression.

Results A substantial proportion (44%, 274/630) of railway workers with confirmed OSA had at least one incident in the 3 years prior to appointment. The odds of an incident were significantly reduced in those with moderate OSA compared with severe OSA (odds ratio [OR] 0.79, 95% confidence interval [CI] 0.64–0.98), but not those with mild OSA (OR 0.97, 95% CI 0.76–1.24). There was a statistically significant relationship between combined OSA severity and treatment status, where the likelihood of an incident increased in those with severe untreated OSA compared with those receiving treatment (OR 1.75, 95% CI 1.16–2.64).

Conclusions Our results suggest that more stringent screening to identify severe OSA early, and close surveillance of treatment of those with severe OSA, should be considered.

Introduction

The National Transport Commission (NTC) is an Australian body that leads transport reform to improve road, rail and intermodal safety and regulation, and it publishes the National Standard for Health Assessment of Rail Safety Workers (the Standard) [1]. During the revision of the Standard leading to the publication of the third edition in 2017, it was proposed that the current triggers for obstructive sleep apnoea (OSA) testing may be insufficient, allowing OSA cases to remain undetected. The NTC undertook consultation and the consultation report [2] recommended that further research be undertaken to quantify and describe the risk of undiagnosed OSA.

Prior to 2012, the assessment of rail safety-critical workers for sleep disorders relied on the Epworth Sleepiness Scale (ESS) [3], a widely used questionnaire to screen for OSA in the general population. The prevalence of OSA in Australian train drivers was found to be 2% in 2009 [4]. The 2012 edition of the Standard introduced physiological screening criteria for OSA (body mass index [BMI], hypertension and diabetes mellitus) to the health assessment of safety-critical rail workers, and required workers with severe OSA to be satisfactorily treated before they could return to safety-critical work. In 2015, Colquhoun *et al.* re-evaluated the prevalence of OSA in rail workers and found that the introduction of new national screening criteria had led to the prevalence of OSA increasing to 7% [5]. A recent population study of the prevalence of OSA estimates it to be 47% in middle-aged men and 25% in middle-aged women [6]. Prevalence studies indicate an increased prevalence of OSA with increasing age, with a significant prevalence in the working-age population [6–8].

While the impact of undiagnosed OSA or milder forms of OSA on motor vehicle accidents (MVAs) has not been studied broadly in the general population, limited evidence shows an increased risk of accidents even in those with mild OSA [9]. Studies investigating the impact of OSA on workplace injuries and safety-critical workers, other than commercial vehicle drivers, are limited. Accattoli *et al.* found that blue- and white-collar workers with OSA reported more impairment in work performance, such as difficulty with memory, vigilance, concentration, performing monotonous tasks, responsiveness, learning new tasks and manual ability [10]. These impairments would be of concern in individuals performing safety-critical work and raise concern that the current Standard [1], which mandates treatment only for workers with severe OSA, could be inadequate. The NTC consultation report [2] also refers to a series of rail investigation reports into train crashes in countries outside

Key learning points

What is already known about this subject:

- Population-based studies have demonstrated an association between obstructive sleep apnoea and increased vehicle crash risk.
- Recent rail investigation reports into causes of train crashes have shown links to underdiagnosed obstructive sleep apnoea and railway incidents.
- The Australian National Transport Commission reported in 2018 that the current triggers for obstructive sleep apnoea testing among rail workers may be insufficient, allowing obstructive sleep apnoea cases to go undetected.

What this study adds:

- Railway workers with moderate obstructive sleep apnoea had a statistically significant reduced risk of safety incidents compared with those with severe obstructive sleep apnoea.
- There was an increased risk of safety incidents in those railway workers with severe untreated obstructive sleep apnoea in comparison to workers with treated obstructive sleep apnoea.
- Most workers who met the screening criteria for a sleep study referral had moderate (27%) or severe (57%) obstructive sleep apnoea on initial diagnosis, indicating that the current screening criteria are more likely to detect advanced stages of obstructive sleep apnoea.

What impact this may have on practice or policy:

- More stringent screening is required to support earlier identification of obstructive sleep apnoea among railway workers.
- More stringent surveillance of the treatment of those railway workers with severe obstructive sleep apnoea is necessary to minimize the risk of rail safety incidents.

Australia that show links between undiagnosed sleep apnoea and rail safety incidents [11–13].

The purpose of this study is to determine if an association exists between OSA severity and the frequency of safety incidents in safety-critical railway workers. If such a link is found, it would support the case to implement more stringent treatment standards for safety-critical workers with OSA to improve employee and public safety. The primary aim of this study is to explore the association between the severity of OSA at the time of diagnosis and safety incidents in those employees with a confirmed diagnosis of OSA.

Methods

A retrospective audit was conducted of the medical files of all safety-critical rail workers employed by the study rail transport operator and attending pre-employment, periodic or triggered health assessments from 2016 to 2018, and who met the screening criteria to be referred for a sleep study. The audit was carried out on 727 safety-critical workers and included a review of 1224 health assessments conducted during the study period. Study inclusion criteria included a confirmed diagnosis of OSA from the sleep study or pre-existing OSA recorded in the clinical notes. Patients were excluded if, following referral for a sleep study, they were found not to have OSA (see Figure 1). Twenty-seven patients were therefore excluded after testing negative for OSA. A further 70 were excluded who attended a pre-employment health check and lacked safety data in the 3 years prior. The data analysis included information from 630 safety-critical workers.

Demographic data extracted from patient records included age, gender and occupation (e.g. train driver, guard, signaller). Clinical data included BMI, blood pressure and a history of cardiovascular risk factors (e.g. smoking status, hypertension, heart disease, diabetes mellitus). Additionally, cardiac risk level (CRL) was recorded [14], as well as Alcohol Use Disorders Identification Test (AUDIT) [15], Kessler Psychological Distress Scale (K10) [16] and ESS scores [3]. Information was extracted from the sleep study results, specifically the apnoea–hypopnoea index (AHI) [17,18] at the time of diagnosis, the date(s) of sleep studies and, if applicable, the date that treatment commenced. The Chicago criteria were used to classify OSA severity (AHI <5 defined as normal, 5 to <15 as mild, 15–30 as moderate and >30 as severe OSA) [19]. The CRL is calculated using the absolute cardiovascular disease risk calculator published by the National Vascular Disease Prevention Alliance [14]. It is used for general population screening in Australia and assesses the risk of a cardiovascular event in the next 5 years. The cardiovascular risk calculator incorporates additional risks for Aboriginal and Torres Strait Islander populations. Other factors such as symptoms, family history, history, comorbidities such as obesity, sleep apnoea, depression and work factors may also be taken into consideration by assessing health professionals when assessing cardiovascular risk. The CRL calculator is a similar tool to the Framingham calculator used in the Canadian rail medical rules [20] and the atherosclerotic cardiovascular disease calculator [21] used in the USA for population screening. The QRISK3 [22] is used in England for population screening and incorporates the additional risk of cardiovascular disease posed by wider ethnic groups, inflammatory conditions, mental health conditions, chronic kidney disease and erectile dysfunction.

To link patient records with relevant safety incident records, the principal investigator (M.A.), who accessed the medical files, provided names and employee numbers of patients with a confirmed diagnosis of OSA to the Chief Health Officer of the rail transport operator (A.C.). Following data linkage, the data set was subsequently de-identified. Three safety incident data categories were identified for safety-critical workers: (i) signal passed at danger; (ii) train crew (TC) incidents—collision, derailment, speeding, failed to stop, overrun, stop short; and (iii) injury reported through various systems. Data for all three incident categories were available from 2013 onwards, allowing

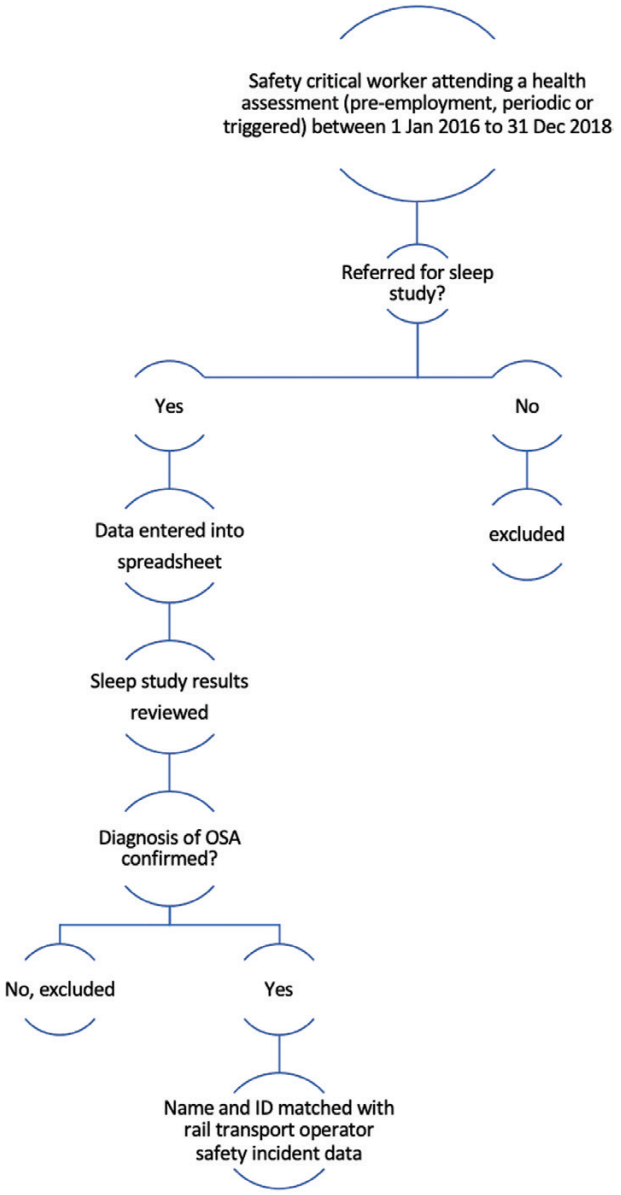

Figure 1. Participant flowchart.

calculation of the number of safety incidents during the 3 years before the health assessment.

Individual consent to access health records for audit or research purposes was obtained from all participants at the time of their health assessment. Additionally, a waiver of consent was sought and permission to audit medical files was granted by both the clinical governance committee of the health service provider and externally by the Bellberry Ethics Committee.

Results from the first appointment attended during the period 2016–2018 were analysed to determine if there was an association between the severity of OSA (categorized as mild, moderate and severe according to the AHI) and recorded safety incidents in the 3 years before the health assessment. The analysis also examined the relationship between treated OSA and safety incidents. Analyses of the univariate associations between worker demographic or clinical data and the number of safety incidents (none, one, two or more) were explored using Chi-square analyses for categorical data and the non-parametric Kruskal–Wallis test for continuous data (e.g. age, BMI). The univariate association between either severity of OSA or severity and treatment for OSA and history of at least one safety incident was analysed using a Poisson log-linear regression. A subsequent regression analysis was used to determine whether this univariate relationship between OSA severity and safety incidents remained after accounting for potential confounding variables, such as other demographic and clinical variables. The distribution of continuous data was explored using the one-sample Kolmogorov–Smirnov test, and where data deviated significantly from a normal distribution, summary data are reported as medians and interquartile ranges (IQR); except where all medians were zero and the reporting of means considered more informative in terms of recognizing data patterns. All analyses were conducted using SPSS version 25 (IBM Corp), and *P*-values less than 0.05 were considered statistically significant.

Results

A total of 716 employees were referred for sleep studies and a further 11 were noted to have pre-existing OSA. Of these 727 employees, 27 (4%) were found not to have OSA and so were excluded from subsequent analysis. The remaining 700 safety-critical workers with newly confirmed (n = 689) or pre-existing (n = 11) OSA had a total of 1096 health assessments carried out between 2016 and 2018. Seventy individuals attended a pre-employment appointment and were also excluded from further analyses due to the absence of safety incident data before diagnosis. Forty-four per cent of the remaining 630 employees had at least one incident in the 3 years prior to the initial appointment, with 22% having two or more. Among those with at least one incident, the median was 1.5 (IQR 2, range 1–8). Demographic data of the study sample are presented by the number of safety incidents in Table 1.

The analysis of the ESS scores found that 99% reported a score <10, which is in the normal range for daytime sleepiness. The analysis of the cardiovascular risk indicated that 39% had a moderate to high risk of a cardiac event in the next 5 years.

OSA severity was recorded for 81% (n = 512/630) of employees. Where severity was known, 16% (82) were noted as having mild OSA, 27% (137) moderate and 57% (293) severe. Based on AHI, 17% (76) had mild OSA, 27% (122) had moderate OSA and 57% (257) had severe. Where OSA diagnosis, severity and treatment were recorded, the majority were treated (86%, 458/535), with 7% (36) mild and untreated, 5% (27) moderate and untreated and 3% (14) severe and untreated.

There was not a linear relationship observed between OSA severity and the mean number of safety incidents (see Table 2); however, the odds of safety incidents occurring were lower in those individuals with moderate OSA compared with severe OSA (odds ratio [OR] 0.79, 95% confidence interval [CI] 0.64–0.98). The inclusion of age, gender and BMI in the Poisson model did not impact this relationship.

When data were analysed according to the treatment status and OSA severity (i.e. treated, untreated mild OSA, untreated moderate OSA and untreated severe OSA) as shown in Table 2, the mean number of safety incidents for the severe untreated category was 1.7 (95% CI 0.8–2.6). The Poisson log-linear regression indicated a significant relationship between OSA severity/treatment and incident number in the 3 years before

Table 1. Demographics of railway workers, by number of safety incidents in the 3 years before health assessment

	Total (*N* = 630)	No incidents (*n* = 356)	One incident (*n* = 137)	Two or more (*n* = 137)	*P*-value[c]
Male, *n* (%)	575 (91)	324 (91)	126 (92)	125 (91)	0.94
Employment category, *n* (%)					**<0.001**
Driver	191 (30)	74 (21)	32 (23)	85 (62)	
Maintenance crew	157 (25)	114 (32)	34 (25)	9 (7)	
Guard	132 (21)	50 (14)	49 (36)	33 (24)	
Other[a]	150 (24)	118 (33)	22 (16)	10 (7)	
Age, median (IQR)	51 (13)	52 (13)	51 (15)	51 (15)	0.53
BMI, median (IQR)	38 (9)	37 (9)	38 (9)	39 (10)	0.74
Systolic BP, median (IQR)	135 (20)	135 (21)	137 (19)	136 (17)	0.92
Diastolic BP, median (IQR)	82 (12)	82 (13)	83 (12)	81 (12)	0.89
Heart disease, *n* (%)	34 (5)	17 (5)	7 (5)	10 (7)	0.53
Diabetes, *n* (%)	125 (23)	75 (24)	26 (23)	24 (19)	0.42
Smoking status, *n* (%)[b]					0.84
Current	61 (13)	29 (12)	13 (15)	19 (15)	
Past	80 (18)	46 (19)	14 (16)	20 (16)	
Cardiovascular risk, *n* (%)[b]					0.60
Moderate (10–15%)	64 (27)	33 (26)	15 (33)	16 (24)	
High (>15%)	28 (12)	15 (12)	7 (15)	6 (9)	
ESS, *n* (%)					
Mild to severe (>10)	2 (0.3)	0	0	2 (1.5)	**0.019**
AUDIT, *n* (%)					
Harmful consumption	1 (0.2)	0	1 (0.7)	0	0.67
K10 psychological distress, *n* (%)					
Moderate to very high	26 (4)	13 (4)	8 (6)	5 (4)	0.52

BP, blood pressure. *P*-values in bold indicate statistical significance.
[a]Other included station staff, signaller, network operations, other onboard crew and shunters.
[b]Smoking status recorded for *N* = 457, cardiovascular risk status recorded for *N* = 239.
[c]Linear-by-linear association Chi-square for AUDIT and ESS comparisons.

Table 2. The association between OSA severity and the frequency of safety incidents

Factor	Category	*n*	Mean[a] number of safety incidents (95% CI)	OR (95% CI)	*P*-value
Model 1				**Unadjusted OR**	
OSA severity	Severe	293	1.04 (0.9–1.2)	*Reference*	–
	Moderate	137	0.82 (0.6–1.1)	0.79 (0.64–0.98)	**0.035**
	Mild	82	1.01 (0.7–1.3)	0.97 (0.76–1.24)	0.821
Model 2				Unadjusted OR	
Treatment status and OSA severity	Treated	458	1.0 (0.8–1.1)	*Reference*	–
	Untreated mild OSA	36	0.9 (0.4–1.3)	0.88 (0.61–1.26)	0.485
	Untreated moderate OSA	27	0.5 (0.2–0.9)	0.53 (0.31–0.90)	**0.019**
	Untreated severe OSA	14	1.7 (0.8–2.6)	1.75 (1.16–2.64)	**0.008**

P-values in bold indicate statistical significance.
[a]Estimated marginal mean.

appointment (likelihood ratio Chi-square = 13.84, df = 3, *P* = 0.003). The likelihood of an incident was increased in those with severe untreated OSA compared with those receiving treatment (OR 1.75, 95% CI 1.16–2.64), and significantly reduced in those with moderate untreated OSA (OR 0.53, 95% CI 0.31–0.90) compared with those receiving treatment (see Table 2). The inclusion of age, gender and BMI in the Poisson model did not impact this relationship.

Discussion

This study found a statistically significant reduced risk of safety incidents in those with moderate versus severe OSA, and increased risk in those with severe untreated versus treated OSA. The study sample consisted of predominantly male employees mainly working as drivers, guards and maintenance workers. These railway workers had multiple comorbidities including

high BMIs (median 38), a raised cardiac risk level (27%) and diabetes (23%). In contrast, most showed a very low risk of alcohol dependence and psychological distress on self-reported screening tests. The workers have likely underreported symptoms on the ESS, reflected by the high number of normal results in those diagnosed with OSA, which was a trend observed by Colquhoun *et al.* in 2012 [5]. This would indicate that ESS alone as a screening tool for OSA is not sufficient in this setting.

We found a trend towards increased risk of safety incidents in those with severe sleep apnoea, similar to population studies indicating a higher risk of MVAs with higher AHIs [23]. Multiple studies have shown a complex association between BMI, age, AHI and crash/MVA risk and some studies indicate that the AHI alone may not be a good predictor of crash risk [23,24]. Karimi *et al.* suggest that the risk of a vehicle crash is difficult to predict in individual patients with sleep apnoea due to the complexity and multifactorial nature of crash risk, and others indicate that risk factors such as age, alcohol, sleep duration, shift work, drugs, other medical conditions and long annual driving distance have not been consistently assessed [23,25].

Resta *et al.* found that severe obesity, even in the absence of OSA, was associated with sleep-related disorders and excessive daytime sleepiness and suggested the findings may relate to multiple factors such as mechanical effects on breathing and endocrinological or metabolic circadian abnormalities [17]. Multiple comorbidities including high BMI were present in our study population and therefore such multiple factors may be implicated. On the other hand, the low risk of psychological distress and alcohol use reported by this study population is likely to be due to underreporting on self-reported questionnaires. Therefore, although this study showed a high prevalence of OSA and other comorbidities in a sample of rail safety workers, further investigation into the interaction of the above factors is required to understand the association of these factors with safety incident risk in a larger population of rail workers. Other risk factors that may be associated with safety incidents such as shift duration, long annual driving distance, job demands, job stress and fatigue management systems were not explored in this study [23].

Colquhoun *et al.* found that the introduction of objective clinical risk factor measures to the Standard in 2012 had a high predictive value in screening rail workers for OSA [1,5] and subsequently, in this study, we found that the majority of those who screened positive for OSA were found to have moderate (27%) and severe (57%) categories of OSA on initial diagnosis, indicating that the current screening criteria are likely to detect advanced stages of OSA. The results indicate an increased risk of safety incidents in workers with severe OSA. Therefore, based on the results of this study, more stringent screening to identify severe cases of OSA early is recommended to reduce the safety risk posed by severe cases of OSA. Given the limited number of mild cases of OSA detected in this study, their impact on safety incidents is unclear, although logically the impact should be less than is the case for severe OSA. Further study in a larger sample may assist to understand any safety risk posed by mild OSA.

The results of this study also indicated that the likelihood of an incident was increased in those with severe untreated OSA compared with those receiving treatment, and correlates with other studies that have shown a reduction in crash risk with the treatment of OSA [23]. Therefore, closer follow-up of those diagnosed with severe OSA, including a review of treatment recommendations and treatment duration, is recommended.

In both models of analysis, moderate OSA appeared to be associated with lowered risk of safety incidents. Further study of the relationship between moderate OSA, comorbidities and other risk factors associated with safety incidents is required to understand the impact of moderate OSA on safety incidents and implications on screening criteria.

The sample size of this study was limited due to several reasons. Firstly, the medical file audit was confined to 2016–18 due to system and medical services provider changes over the years. Secondly, safety incident data were limited from 2013 onwards due to a lack of recorded TC incidents before that. Thirdly, calculations such as rates of safety incidents were limited by the lack of availability of employee commencement dates. Fourthly, considering the rare occurrence of safety incidents, in this study all safety-critical employment categories were included, even though some safety-critical incident data were only recorded for drivers and guards. These limitations will be taken into consideration when designing a follow-up study.

In conclusion, this study found a statistically significant reduced risk of safety incidents in those with moderate versus severe OSA, and increased risk in those with severe untreated versus treated OSA. More stringent screening to identify severe OSA early, and close surveillance of treatment of those with severe OSA, is therefore supported by this study. Further research is necessary to confirm these findings and to assess whether the increased risk of safety incidents begins at a lesser level of severity.

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Competing interests

G.L. completed the bulk of the analyses for this manuscript as a paid consultant. A.C. is Chief Health Officer of the rail transport operators involved in this study.

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