

Sleep for heart health: investigating the relationship between work day sleep, days off sleep, and cardiovascular risk in Australian train drivers

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Abstract: Cardiovascular disease (CVD) risk in train drivers is associated with health conditions that can result in sudden incapacity. Drivers are at high risk on several CVD risk factors with research suggesting that sleep may predict CVD risk, however this relationship has not yet been explored. This study investigated the link between sleep and CVD risk, in relation to hours of work day and days off sleep. N=309 Australian drivers completed a cross-sectional survey. A CVD risk score was calculated by summing scores from behavioural and biomedical risk factors. Sleep was most frequently cited as the main reason for decline in perceived health status. Main analyses showed that shorter work day sleep ($M=5.79$ h) was a significant predictor of increased CVD risk ($p=0.013$). This relationship was moderated by days off sleep, such that when days off sleep ($M=8.17$ h) was higher, the effect of work day sleep on CVD risk was weaker ($p=0.047$). Findings indicate the amount of sleep a driver obtains on non-work days may compensate for adverse health outcomes. Successful management of fatigue in safety critical occupations appears essential not only for the prevention of safety hazards, but also for the long-term health of shift workers. Further investigation is warranted.

Key words: Occupational health, Risk, Safety, Sleep, Transportation

Introduction

Diseases of the heart and blood vessels (cardiovascular disease, CVD) are the largest cause of deaths from non-communicable disease worldwide¹. In Australia, the

health and economic burden of CVD exceeds that of any other disease group, with an estimated 3.7 million Australians affected by one or more long-term cardiovascular conditions in 2012². For transport industries, addressing the challenge of CVD risk in safety critical workers is an urgent priority. For example, a growing body of evidence demonstrates that truck drivers are at increased risk from heart disease and related conditions, which presents a serious safety hazard in addition to considerable burden to the individual worker^{3,4}. However, very little research to

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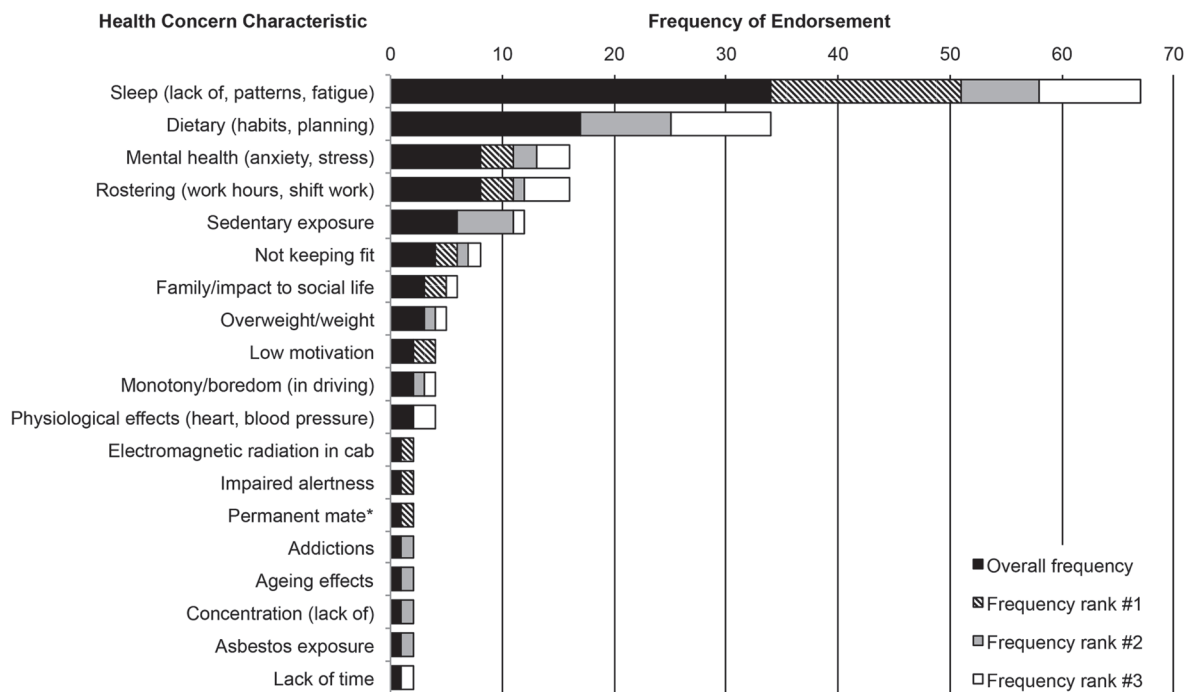
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date has been conducted in the rail industry. Like trucking, train driving is associated with known health-risk factors, such as high occupational sitting exposure; limited access to health resources; ongoing stress from time pressure and task demands, and fatigue from long hours and shift work^{5, 6}. Furthermore, train drivers (also known as locomotive engineers in North America) demonstrate elevated rates of obesity in comparison to the general population; a trend that continues to rise despite the introduction of periodic health assessment and monitoring⁷. These risks are associated with health conditions that can result in sudden incapacity, as evidenced by the Australian Waterfall Rail Incident in which the driver of a high-speed train suffered a cardiac arrest, resulting in seven fatalities⁸. There is therefore an increasing imperative to identify predictors of CVD risk in train drivers, in order to inform future countermeasures to mitigate risk.

Although many characteristics—including age, family history and socio-economic status—are linked to the development or progression of chronic disease, CVD risk is typically understood in terms of behavioural and biomedical factors⁹. Behavioural risk factors are health behaviours that include smoking, high alcohol consumption, low physical activity levels and low fruit and vegetable intake; whereas biomedical risk factors are expressed as

body measurements and include overweight and obesity, high blood pressure, abnormal blood lipids such as high cholesterol, and impaired fasting glucose⁹. While these risk factors are considered independent predictors of disease, they also have an interactive effect, meaning that the presence of multiple risk factors increases the risk of disease¹⁰. Furthermore, a synergistic relationship exists between biomedical risks and behaviours; for instance, incidences of obesity, high blood pressure and cholesterol are closely linked to diet, activity and alcohol levels⁹. Behavioural risk factors are considered modifiable and therefore suitable targets for health promotion.

Another behavioural risk factor that is often overlooked as an important contributor to health outcomes is sleep. In a recent national study undertaken across Australia, sleep not only emerged as the single greatest health concern, it was most frequently ranked as a top-priority against all other considered health concerns (Fig. 1). Sleep is a universal behaviour that is controlled by both circadian processes and the homeostatic drive for sleep, which increases with increasing periods of wakefulness and decreases during sleep¹¹. Epidemiological studies have shown that self-reported sleep of less than 6–7 h per night is associated with an increased incidence of CVD^{12, 13}. This is supported by an extensive review based on ag-



*Permanent mate refers to the practice of working with the same co-driver in networks where there are two-driver operations

Fig. 1. Stacked frequency of responses to top three train driver industrial health concerns in a recent study⁶.

gregated data from participants across several continents, which reported that elevated CVD risk is most strongly associated with sleep durations of less than six hours, in comparison to sleep durations of 7 and 8 h¹⁴). Similar associations exist between shorter sleep and incidence of individual risk factors for CVD, including higher rates of obesity and hypertension^{11, 14}).

As well as the deleterious effects of shorter sleep, there is also evidence that the specific risk profile of shift workers is different to those working standard daytime hours. The strongest evidence for this comes from a large meta-analysis of 34 studies and >2 million participants, which found that shift work was positively associated with both heart attack and stroke¹⁵). Potential mechanisms by which shift work may lead to CVD include physiological changes due to circadian disruption, and long-term alterations to neuroendocrine and cardiometabolic stress responses¹⁶). In relation to behavioural pathways, shift workers alter meal and snack timing, which can exacerbate circadian misalignment, negatively impacting on metabolic function¹⁷). Shift workers are also more likely to choose high-sugar and carbohydrate foods¹⁸). Physical inactivity is more prevalent in shift workers¹⁹), as is alcohol use, which is often used as an aid to sleep²⁰). Smoking, which has been identified as a strategy to remain alert, is also more prevalent in this cohort²¹). Thus, shift workers are likely to be exposed to CVD risks from forced disruption of the sleep-wake cycle; short/disrupted sleep patterns associated with work schedules, and the subsequent behavioural adaptations that have implications for long term health.

Finally, the degree to which shift workers are able to recover between shifts is poorly understood¹⁶). The health deficits associated with the chronic reduction of sleep are thought to be dose-dependent, resulting in a cumulative 'sleep debt' that occurs over time²²). In turn, 'catching up' on lost sleep may help to compensate for the negative effects of prolonged preceding waking. Research has shown that extended sleep following periods of chronic sleep debt can exert improvements in cognitive and neurobehavioural function^{23, 24}). However, recovery sleep in relation to physical human health has rarely been studied outside the domain of athletic performance, despite the global prevalence of sleep patterns involving sleep restriction on work days, followed by sleep extension on non-working days²⁵). Moreover, to our knowledge, no research to date

has explored whether extended sleep on days off can exert a protective effect in terms of chronic disease risk in shift workers.

Research aim

In summary, sleep is considered a top industrial health concern by train drivers, and evidence suggests that it may be a direct predictor of CVD risk in train drivers. However, this relationship has not been previously explored in the extant literature. The broad aims of the current study are to provide a preliminary exploration of the role of sleep as a salient health priority from a driver perspective; assess the relationship between work day sleep and CVD risk, and explore the potential compensatory effect of extended days off sleep. Given the dearth of literature in the area, we tentatively hypothesise that: (1) work day sleep will significantly predict CVD risk; and that (2) the relationship between work day sleep and CVD risk will be moderated by the amount of sleep obtained by drivers on days off work.

Methods

Subjects, design and procedure

Train drivers ($n=309$) were recruited through advertisements on industry and union forums across five Australian states, and invited to voluntarily participate in an online survey about train driver health^a. The advertisements included a URL to an anonymous, cross-sectional survey accessed via the survey platform Qualtrics. Upon following the link, participants were provided with information about the study, and informed consent was gained via survey commencement. The survey took approximately 20 min to complete. No information was collected that could identify individual drivers or link them to their place of work. Incentives were offered in the form of a prize draw to win one of five iPads. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Human Research Ethics Committee of Central Queensland University (Approval no. H15/03-039).

Measures

The survey began with descriptive items including age, years of train driving experience and typical number of

^a A total of 6,966 train drivers were reportedly employed in the 2018 financial year²⁶). Note that exact numbers of train drivers are difficult to obtain given that estimates typically cover multiple job roles and this figure also includes tram drivers.

total hours worked weekly. Height and weight items were recorded to calculate Body Mass Index (BMI). To gain a broad assessment of how personal health status was perceived over time and in comparison to others, drivers were asked to rate on a 5-point scale from 1 (*poor*) to 5 (*excellent*): (1) their current health; (2) their health five years ago; (3) the health of a typical driver of the same age, and (4) the health of a typical person of the same age who is not a train driver. An open-ended question invited them to give reasons for any perceived change in personal health over the last five years. Participants were then asked to rank six behavioural health priorities (smoking, diet, physical activity, alcohol, sitting time, sleep) in order of importance, from 1 (*highest priority*) to 6 (*lowest priority*). Typical sleep duration was assessed by asking drivers to record the average hours and minutes of sleep obtained in a 24 h period on (1) work days, and (2) days off work.

A total CVD risk score was calculated for each participant by summing the scores from seven behavioral and biomedical component risk factors, based on those identified by the Australian Institute of Health and Welfare⁹⁾ ^b. Risk factors were: tobacco smoking (*current daily smoking of tobacco*); insufficient physical activity (*<150 mins of moderate or vigorous physical activity over 5 or more sessions per week*); excessive alcohol consumption (*lifetime risk=more than 2 standard drinks per day*); inadequate fruit and vegetable consumption (*<2 daily serves of fruit and <5 daily serves of vegetables*); overweight and obesity (*overweight BMI=25–29.99, obese BMI≥30*); high blood pressure, and high cholesterol^c. Each individual risk factor was worth one point (1=risk factor present; 0=risk factor not present), resulting in a possible total CVD risk score ranging from 0–7.

Statistical analysis

Prior to the main analyses, descriptive statistics of the sample are presented, followed by data on driver perceptions of health status. Between-group comparisons of current health status, prior health status, and the perceived health status of others were performed using *t*-tests. The main analyses, testing the relationship between sleep and CVD risk, were conducted using the PROCESS macro for SPSS²⁷⁾ with 5,000 bootstrapped bias corrected resamples. The first regression model tested the relationship between

hours of work day sleep and CVD risk (Model 1: simple model). A moderation analyses then tested the hypothesis that hours of days off sleep would moderate the relationship between work day sleep and CVD risk (Model 2). Interaction effects were decomposed by tests of slope differences to assess the conditional effects of the relationship at low (−1SD), mean, and high (+1SD) levels of the moderator. The Johnson-Neyman region of significance test, which identifies the point along the moderator where the relationship transitions between statistically significant to nonsignificant, was also calculated. The effects of age were controlled in each regression model.

Results

Sample characteristics

The survey was commenced by 456 respondents. There were missing data on key variables of health ratings (current, 5 yr prior, typical similar train driver, typical similar non-train driver), sleep (work day, days off), or CVD risk score for 147 respondents, leaving $n=309$ for analysis. The average age of drivers was 45 yr. On average, BMI scores were in the obese range. Average train driving experience was 14 yr, with average weekly work hours at 45 h (range 10–68 h). Average reported work day sleep was approximately 6 h, which was significantly lower than sleep on days off, which was more than 8 h ($t_{308}=-28.05$, $p<0.001$) (Table 1).

Mean CVD Risk score was 3.7, just above the midway point on the 7-point scale (Table 1). This indicates that on average, drivers reported almost 4 individual risk factors for CVD. Nearly all participants reported inadequate fruit and vegetable intake. Three quarters reported insufficient physical activity to support health. Nearly half the sample consumed alcohol at levels indicative of lifetime health risk. Almost one third reported a diagnosis of high blood pressure, and approximately one quarter reported high cholesterol levels. One in eight respondents identified as smokers, with average cigarette consumption at 35 per day ($SD=15.14$). In comparison to population statistics, drivers reported less smoking and higher fruit and vegetable intake than the general population, but higher rates of risky drinking and insufficient physical activity. The current sample had higher rates of overweight and obesity

^b The AIHW⁹⁾ also includes impaired fasting glucose in their list of identified risk factors, but because this condition remains largely undiagnosed in the general population, and self-report data relies upon respondents' knowledge of their health status, this risk factor was not included in the total CVD risk score.

^c Diagnosed high cholesterol level was used as a general proxy for dyslipidaemia.

Table 1. Means and standard deviations (SD) for descriptive and study variables

	Mean	SD	Train driver sample %	Population norm %
Age (yr)	44.97	10.65		
BMI (kg/m ²)	30.86	5.72		
Train driving experience (yr)	14.42	12.01		
Work per week (h)	44.78	14.48		
Work day sleep (h)	5.97	1.07		
Days off sleep (h)	8.17	1.21		
CVD risk score (7-point scale)	3.65	1.28		
Smoking			12.9	22.1
Physical inactivity ^a			75.4	54.7
Excessive alcohol ^b			48.9	29.3
Inadequate fruit and veg ^c			89.0	95.8
Overweight and obesity ^d			87.5	76.7
High blood pressure			28.2	28.8
High cholesterol ^e			23.6	39.2 ^f

CVD risk score is followed by the component variables that were used to calculate the score (each worth one point). BMI: Body Mass Index; CVD: Cardiovascular disease risk score (2015): ^a<150 min of moderate or vigorous physical activity over 5 or more sessions per week; ^blifetime risk=more than 2 standard drinks per day²⁸); ^c<2 daily serves of fruit and <5 serves veg; ^doverweight BMI=25–29.99, obese BMI≥30²⁹); ^eproxy for dyslipidaemia in the CVD risk score⁹). All population norm comparisons based on average% from male 35–44 and 45–55 age groups in AIHW⁹), except ^eAustralian Bureau of Statistics³⁰); ^fhypertension with blood pressure above 140/90.

than the population norm, but self-reported rates of blood pressure and high cholesterol were comparable or lower, respectively (Table 1).

Driver health ratings and health priorities

Drivers were asked to rate: (1) their current health status ($M=2.78$, $SD=0.88$), (2) their health status five years prior ($M=3.17$, $SD=0.91$), (3) the current health status of a typical train driver of a similar age ($M=2.20$, $SD=0.74$), and (4) the current health status of a typical non-train driver of a similar age ($M=3.29$, $SD=0.70$). Drivers rated their current health mid-range (between ‘fair-good’) on the 5-point scale. This rating was significantly lower than their health 5 yr ago ($t_{308}=-6.22$, $p<0.001$) and the perceived health of a similar non-train driver ($t_{307}=-8.08$, $p<0.001$). In contrast, they rated their current health significantly higher than other train drivers ($t_{308}=10.64$, $p<0.001$) (Fig. 2).

Of the 309 respondents, 144 (47%) reported a negative change in personal health status over the last five years, 108 (35%) reported no change, and 57 (18%) reported an improvement. Of those who reported a negative change, 61% reported it was due to shift work and/or rosters, and 29% commented directly on sleep loss and fatigue issues as reasons for decline. Examples of open-ended quotes describing the reasons for a negative change in health status include:

“Shift work resulting in lack of sleep, interrupted sleep,

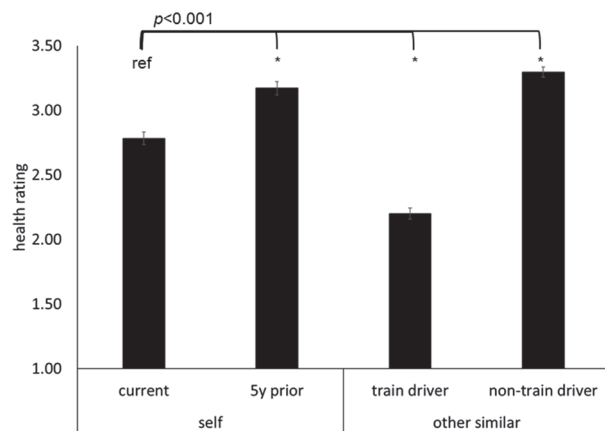


Fig. 2. Mean health ratings (y-axis, 5-point scale) with standard error bars for health (1) current; (2) in 5 y prior; (3) of a typical similar train driver; and (4) of a typical similar non-train driver (x-axis, left to right). *indicate significant differences from current health ratings (ref), $p<0.001$.

no sleep patterns. Shift work resulting in loss of friendships through no pattern to work, no annual leave available and affecting mental health and wellbeing”.

“Shift work limits social & physical opportunities to participate or enjoy in. Also the mental aspect can be an issue, for example personal relationships & personal wellbeing has to be juggled more with the nature of the industry of start times, work load, mental concentration &

improper sleep patterns & constant shift changes”.

Of the 57 participants who reported that their health had improved over the past five years, the majority (>90%) reported that this was due to making an effort to change their lifestyle, often after experiencing poor health. Typical examples of quotes include:

“I have started being careful about my nutrition, and found a sport I am passionate about”.

“I got very large with poor control over diet and managing a healthy intake. Lack of on the job activity and poor food led to a 8 kilo gain. I then noticed this and joined a local gym. Changed my diet and actively monitor my personal health”.

When asked to rank their health priorities (smoking, diet, physical activity, alcohol, sitting time, sleep) from one to six, sleep was most frequently ranked as the top (most important) health priority, with 46% of drivers choosing this as their number one health priority (Fig. 3).

Relationship between sleep and CVD risk

The main analyses were conducted using the procedure outlined in section 2.3. In Model 1 (simple model), sleep on work days was a significant predictor of CVD risk score ($p=0.013$), such that every hour reduction in sleep was associated with a 0.2 point increase on this 7-point scale (Table 2). This model explained 8% of the variance. In Model 2, there was a significant work day sleep*days off sleep interaction term ($p=0.047$) such that when days off sleep was higher, the effect of work day sleep on CVD risk was weaker (Table 2). This model explained 10% of

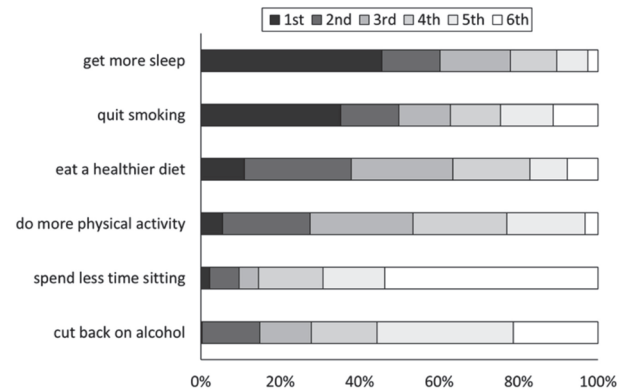


Fig. 3. Rank order of health priority for train drivers from 1st (black) to 6th (white).

the variance. Further exploration of the interaction effect revealed that once respondents reported 8.709 h or more sleep on days off, the relationship between work day sleep and CVD risk was no longer significant (Fig. 4).

Discussion

This study aimed to preliminarily investigate the health status of train drivers, and explore the potential link between sleep and CVD risk. Consistent with previous research findings (e.g.⁶) the findings show that sleep is the primary health concern of drivers, and, as expected, the amount of sleep obtained on work days was found to significantly predict total CVD risk score. Furthermore, our findings are the first to suggest that the amount of

Table 2. Summary of models for the relationship between sleep and CVD risk score, controlling for age

Model 1 ($R^2=0.08$)	coeff	se	t	p	LLCI	ULCI
Constant	3.21	0.50	6.47	<0.001	2.22	4.17
Age	0.03	0.01	4.83	<0.001	0.02	0.05
Work day sleep	-0.16	0.07	-2.49	0.013	-0.29	-0.03
Model 2 ($R^2=0.10$)						
Constant	7.37	2.35	3.14	0.002	2.75	11.98
Age	0.03	0.01	4.82	<0.001	0.02	0.05
Work day sleep	-0.94	0.39	-2.41	0.016	-1.71	-0.17
Days off sleep	-0.50	0.28	-1.80	0.072	-1.05	0.05
Work day sleep*day off sleep	0.09	0.05	1.99	0.047	0.00	0.18
Conditional effect of x on y at:						
Days off sleep=6.96 (mean-1SD)	-0.30	0.09	-3.24	0.001	-0.48	-0.12
Days off sleep=8.17 (mean)	-0.19	0.07	-2.76	0.006	-0.32	-0.05
Days off sleep=9.38 (mean+1SD)	-0.08	0.08	-0.91	0.361	-0.24	0.09

Lower panel displays simple point estimates of the effect of work day sleep on CVD risk score at the mean \pm standard deviation of day off sleep to illustrate the work day sleep*days off sleep interaction effect. coeff: model coefficient; se: standard error, LLCI: lower limit 95% confidence interval; ULCI: upper limit 95% confidence interval; SD: standard deviation.

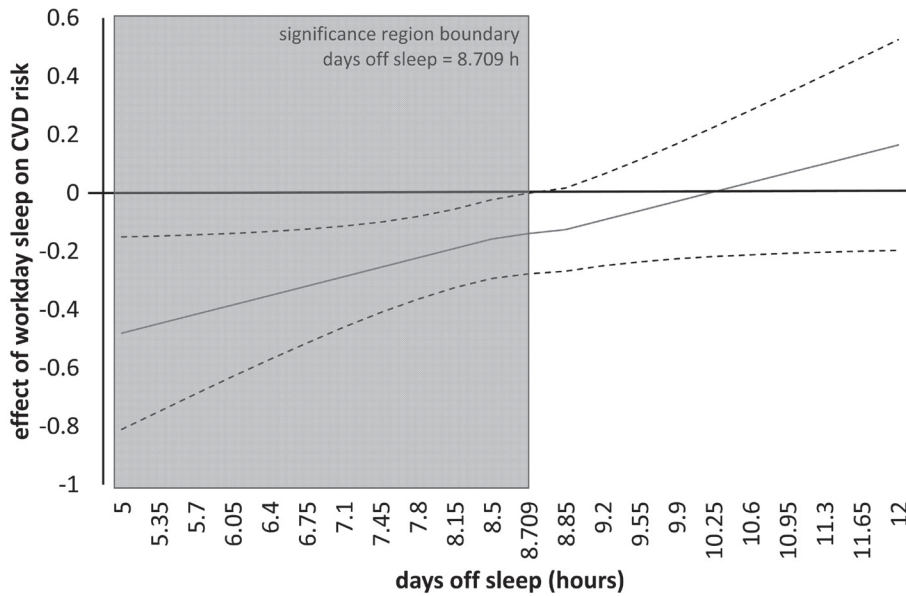


Fig. 4. Johnson-Neyman plot for visualising the work day*days off sleep interaction effect for cardiovascular disease (CVD) risk score.

sleep a driver typically obtains on non-work days may compensate for adverse health outcomes. Drivers’ typical hours of days off sleep impacted the model such that the relationship between work day sleep and CVD risk was weaker when days off sleep was higher, suggesting that longer durations of days off sleep may have a protective effect. Our hypotheses were therefore supported.

It is of considerable concern that the train drivers in our sample reported almost four individual CVD-related risk factors on average. The presence of multiple risk factors has a multiplicative effect on the development and progression of disease; for example, an inactive smoker with high blood pressure is more than eight times at risk of a major cardiovascular event than a person with none of these risk factors³¹). This concern is exacerbated by the finding in the current study that—in line with previous work showing increased health risk in drivers^{5, 6, 32, 33})—respondents reported considerably higher rates of physical inactivity, excessive alcohol consumption, and overweight and obesity than the population norm. In addition, the detrimental effects arising from poor sleep are recognised globally, to the extent that the American Centre for Disease Control considers the progressive decline in sleep duration to be a public health epidemic¹⁴). Our findings therefore speak to the idea that sleep should be routinely examined as a behavioural risk factor for CVD, particularly for occupational groups working long and irregular hours. The average hours of work day sleep reported in

the current study were just below 6 h, which means that approximately half our sample reported sleep at levels associated with elevated CVD risk (strongest for sleep durations ≤ 6 h)¹⁴).

An interesting contribution to this debate is the finding that increasing days off sleep to a minimum of 8.7 h appears to offset risk. This opens the future possibility for shift workers to counter sleep debt and associated harms by ‘balancing’ work day sleep with consistent and adequate recovery sleep. However, the mechanisms underlying the relationship between sleep and health are complex with many potentially contributing factors, and a number of questions remain. Consistent with previous work¹⁴), the current findings relate specifically to sleep duration rather than sleep intensity: to date, there is little consensus as to whether deep, intense sleep may have a higher ‘recovery value’ than sleep duration alone³⁴). Further, although we found a compensatory effect for days off sleep averaging 8.7 h or more, long sleep durations (≥ 10 h) (as well as short durations, ≤ 6 h) have also been shown to be positively associated with coronary heart disease risk³⁵). Therefore, it seems that caution is warranted for extreme hours of sleep in either direction. Nevertheless, such estimates are based on overall average sleep durations signalling chronic short or long sleepers. In our sample, even with an average sleep duration of nearly 9 h on days off, the short work-day sleep durations (approximately 6 h) still result in a relatively low average sleep duration overall. The impact

of variable sleep durations should be investigated. Of concern perhaps, is the potential circadian misalignment that may accompany changes in sleep. For example, evidence in non-shift working populations suggests compensatory sleep on weekends is often delayed³⁶, and may be associated with circadian phase delays and subsequent increased workday sleepiness³⁷. The potential circadian impact of changes to sleep timing and length on days off for shift workers, who are already misaligned, is unknown. Future experimental and longitudinal work should aim to address these questions directly, to better inform practical recommendations for industry and health promotion.

In order to create healthier working environments within the rail industry, and in shift working occupations more generally, it is recommended that shift schedule designers should aim to minimise insufficient sleep by allowing sufficient time between shifts for recovery. Sleep loss and circadian disruption have been considered within the context of Fatigue Risk Management Systems in many industries, including rail, with a focus on performance risk, accident and injury^{38, 39}. Improved education and training, at the operational and the worker level, is needed to communicate the importance of sleep; not just for safety, but also for personal health. Behavioural risks should be addressed in terms of optimal eating times and food choices; finding opportunities for structured physical activity, and discouraging the use of tobacco and alcohol to regulate fatigue. However, it is also important to acknowledge that social and family life impact sleep outcomes. Qualitative interviews with train drivers have found that chronic voluntary sleep curtailment on days off is widespread in order to maximise family and leisure time^{6, 32}. Drivers, especially those with dependent children, often forgo sleep to prioritise family commitments and 'make the most' of their time off. Thus, tackling the association between sleep and health risk in shift workers is likely to require a multi-faceted approach that may include examination of work-family policy and provisions alongside Fatigue Risk Management Systems, with an understanding that time off work does not simply mean time for sleep, particularly for those with care duties.

A number of limitations should be acknowledged. Although the survey was nationally representative in the administering country, the cross-sectional design restricts the interpretation of findings to associations rather than cause and effect. The associations found in the current study provide preliminary evidence to inform future longitudinal investigations in this area. Collection of additional data that seek to explain the underlying, systemic and complex

causal structure of the problem, including the recruitment of larger sample sizes and prospective follow-ups, are needed in future work.

There are also limitations inherent in the use of self-report measures. The calculation of a composite CVD risk score based on self-reported behavioural and biomedical component risk factors is an established method used in national health surveys⁹. Nonetheless, there are limitations as to how well these risk factors predict actual rates of CVD. In addition to issues around the accuracy of self-report data, it is possible that some individual factors (e.g. smoking) pose a greater CVD risk than others (e.g. inadequate fruit and vegetable intake). It is therefore recommended that future large-scale work pay closer attention to the weighting of CVD risk factors, as well as validating these findings using traditional and novel objective biomarkers. Future work should also more closely consider the implications of part time work and shift roster design, which may influence the opportunity to obtain non-work day sleep. Although all drivers in the study were shift workers, the small-scale design of the study did not allow a detailed examination of shift type. However, as very few drivers (<5%) reported working fewer than 35 h per week, we can be cautiously optimistic that part time work had little bearing on the findings in this preliminary investigation.

Finally, in the current study, every care was taken to assure participants of the anonymity of their responses. However, train drivers are generally fearful of the occupational repercussions of being flagged 'at risk' in health assessments³⁶, which may set the habit for socially desirable responding. It is also important to note that adult health guidelines vary between countries; the United States, for example, stipulates an average of 2–3 cups of vegetables and 2 cups of fruit per day for health, in contrast to the 2 fruit and 5 vegetable daily servings recommended in Australia. This should be acknowledged when generalising individual and total CVD risk levels internationally.

Conclusion

In conclusion, this study presents novel findings on the interplay between work day sleep, days off sleep, and CVD risk in train drivers. While a number of questions remain, the findings indicate that the successful management of fatigue in safety critical occupations is essential not only for the prevention of safety hazards, but also for the long term preventative health of shift workers. Future research on the role and scope of recovery sleep is needed

to build on these preliminary findings, in order to realise the potential for improving work schedules and reducing health risk in train drivers and other high-risk workers.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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