Title: Recommendations for current and future countermeasures against sleep disorders and sleep loss to improve road safety in Australia

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The Australian National Road Safety Strategy 2011-2020 framed a 19-point action plan targeting a 30% reduction in road deaths by 2020. In achieving a 9% reduction to date, it is likely to fail this target. Sleep disorders and sleep loss did not feature prominently in this strategy, despite their high prevalence and effect on drowsiness and crashes. This article gathers sleep experts to provide recommendations addressing driver education and legislation to assist the response to this public health problem. Developments in drowsiness detection and sleep disorders management are also presented that offer innovative countermeasures that could enhance road safety beyond 2020.

Key words: sleep wake disorders, sleep, accident prevention, safety, transportation

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Introduction

The Australian National Road Safety Strategy was deployed in 2011 with a 19-point action plan to achieve a 30% reduction in road deaths by 2020. To date, a 9.1% reduction in road deaths has been achieved.¹ Acknowledging that there are greater per capita gains with population growth, it's likely this strategy will fall well short of the 30% target by 2020. Moving forward, the National Road Safety Strategy taskforce has invited submissions to assist in developing priority areas for 2020 and beyond. Sleep disorders and sleep loss did not feature prominently in the 2011 action plan, despite high rates of these issues in the community and the known effects they have on driver drowsiness and rates of motor vehicle crashes.²⁻⁴ Historically falling asleep and causing injury or death to another party may have been seen as an involuntary action that precludes negligent behaviour. The position has more recently shifted toward an understanding that defendants know or ought to know that they are (or have been) driving in a drowsy state and this constitutes culpability.⁵ Consequently, countermeasures to minimise drowsy driving are increasingly important. Here we present recommendations that may help address the current shortfall in the desired reduction of road deaths, as well as other approaches under development that, if formally validated, may present future innovative countermeasures to the road safety effects of sleep problems beyond 2020 (Table 1).

Insert 'Table 1' near here

Educating young drivers

Compared to older drivers, young drivers (17 to 25 years) are more vulnerable to alertness failure due to sleep loss⁶ and remain over-represented in sleep/drowsiness-related crashes.^{1, 7} Improved education about drowsy driving and related risk factors has been identified as a crucial mechanism for improving road safety in young drivers.⁸ Specifically, teaching young drivers about what factors increase drowsiness (e.g., short sleep, time-of-day), what the major indicators/symptoms of drowsiness are (e.g., heavy eyelids), as well as the consequences of drowsy driving for drivers and other road users, will assist this high-risk population to make decisions about whether or not they are safe to drive.⁹⁻¹¹ The need for improved drowsy driving campaigns that effectively raise awareness and change attitudes and behaviour in young drivers have been encouraged by the sleep and transport research community in the US.⁸⁻¹⁰ There is now sufficient evidence^{6, 7} and support from sleep and road safety researchers in Australia to trial an education campaign focused on improving young drivers' understanding of the causes, indicators and consequences of drowsy driving. In addition to improving knowledge, effective public behaviour change strategies indicate that education campaigns are most successful when implemented in combination with new policies, legislation and enforcement.⁹ For instance, drowsy driver education implemented at secondary schools may help ensure acceptance and backing of roadside testing for drowsiness in the future (see below). Using similar approaches, previous public health campaigns have demonstrated long-term success in educating and changing behaviour towards drink driving and seat-belt use.

Graduated driver licensing

Graduated driver licensing laws allow new drivers to gain on-road experience before receiving their unrestricted licence. In the US, these laws commonly include a restriction on unsupervised driving (i.e., without a parent or guardian) at night when drowsiness and alcohol use are more common, with driving impairment that is even more severe if these are combined. Night driving accounts for 39% of fatal road accidents in young drivers in the US.⁷ Enforcement of night driving restrictions and penalties for young drivers vary between states. In Massachusetts, as part of the graduated licensing program, strict penalties for infringing laws prohibiting unsupervised night driving were applied along with the introduction of mandatory drowsy driving education for learner drivers. Following these changes, crash rates for drivers aged 16 to 17 years decreased by 18.6% and by 6.7% for drivers aged 18 to 19 years.¹² Based on these findings, and in-line with recommendations by Transport for NSW, Australia should consider introducing new graduated driver licensing laws that restrict unsupervised driving at night for young drivers and combine this regulation with stringent penalties for breaches.

Drowsiness technology development and implementation

Ocular measures are a strong marker of drowsiness related impairment.¹³ Wearable devices track eye and eyelid movements that are affected by drowsiness and can provide continuous monitoring of driver impairment. These devices measure individual driver responses over sustained periods of time for longer distance driving, for which transport workers may be an important target. Ocular measures have been shown to detect drowsiness related impairment

in the laboratory and in instrumented real vehicle studies, with researchers currently validating continuous drowsiness detection technologies in the field to determine the 'threshold' to predict impairment while driving. Although this technology is currently commercially available and adopted by some corporations for industry use, further on-road validation of continuous drowsiness monitoring devices in high-risk populations is required before wider dissemination.

Ocular measures of drowsiness may also be adapted for screening drivers for drowsiness through roadside testing. Roadside testing of drowsiness could be introduced as a brief voluntary driver safety tool located at rest stops. The aim of roadside drowsiness testing is to provide an objective assessment of acute alertness state from which to predict and intervene against the risk of alertness failure.¹⁴ A proposed methodology for the introduction of ocular measures into roadside drowsiness screening is being developed by the Cooperative Research Centre for Alertness Safety and Productivity, with an expected delivery around 2020 in high-risk scenarios (e.g., middle of the night). Although ocular-based alertness tests are promising, they are required to measure for durations that overcome the temporary alerting effect pulling-over to take a roadside test may have for the driver. It is estimated that ten minutes is sufficient. An alerting response could be heightened however in more stress provoking contexts, such as use as an enforcement tool; this requires additional testing and may warrant a separate validation protocol.

In addition to the ongoing refinement and operational validation of drowsiness tests, there is also the need to work with key stakeholders (e.g., police, state and federal government) to ensure roadside technology is practical and cost-effective for large-scale use, and to educate the public on the testing process and appropriate responses to results indicating driver impairment.

Chemical biomarkers of alertness/drowsiness are proposed to be the ideal benchmark for rapid roadside identification of drowsiness impairment. This approach aims to provide a single point-of-care individualised measurement of alertness state based on markers accessible in blood, or other biological samples (e.g., saliva, urine).¹⁴ There are numerous chemical biomarkers that show promising results including lipid and acylcarnitines metabolites, amino acids and biogenic amines.^{14, 15} In response to a 24-h wakefulness protocol, levels of tryptophan, taurine, serotonin, 13 glycerophospholipids, 3 sphingolipids and 8 acylcarnitines were found to be significantly elevated when compared to levels during sleep.¹⁵ Furthermore, scientists also suggest the possibility that combinations of biomarkers may hold the answer to measuring alertness state accurately.¹⁴ Validation of candidate biomarkers is considered a longer-term strategy that requires continued funding to support further laboratory and then on-road testing.

Sleep disorders

Research has suggested that each individual has a trait level of sleepiness which is made up of endogenous factors (e.g., morningness-eveningness).² This trait-level of sleepiness

therefore determines one's vulnerability to sleep loss or sleep disorders. People may exhibit highly varied degrees of sleepiness and cognitive impairment for the same severity of a sleep disorder.¹⁶ Working towards new and more efficient methods for phenotyping sleep disorders is needed to screen and clearly define people at high risk of drowsy driving, especially in high risk populations.¹⁶ Furthermore, government and other regulatory bodies should consider their role in how these methods are implemented in occupational settings to best mitigate accident risk.

In the transport industry, self-report screening tools have shown lower than expected levels of subjective sleepiness and obstructive sleep apnoea (OSA) symptoms,¹⁷ and therefore caution should be exercised if using subjective tests alone for licensing purposes in occupational settings.¹⁶ The use of simple objective criteria (e.g., body mass index, hypertension, diabetes, OSA symptoms) combined with subjective sleepiness however has proven feasible in OSA screening in rail transport, achieving a low-false positive rate.¹⁷ The clinical decision to treat safety critical workers for sleep disorders should also consider their influence on sleepiness and cognitive function.¹⁶ The Maintenance of Wakefulness Test is currently used in safety critical occupations to assess sleepiness, but motivational effects can impact the results of this test when used for licencing purposes.¹⁶ Therefore, more robust clinical measures are needed to predict the long-term risk of impairments (i.e., accidents/errors) related to sleepiness at work.¹⁶ For these safety critical occupations, further research is needed to determine the most appropriate methods to screen and treat sleep disorders, as well as identifying the best government and regulatory pathways for their implementation. Quantitative

electroencephalogram (EEG) measures are related to neurobehavioral dysfunction in healthy subjects.¹⁸ Therefore, the utility of EEG activity (e.g., slowing of EEG during wakefulness) as a predictor of functional impairment in people with OSA is currently being investigated,¹⁸ which may allow for more personalised sleep disorder management approaches that improve sleep health and reduce the risk of accidents in high-risk workplaces.

Conclusion

Sleep problems and daytime consequences of poor sleep are common among Australians and contribute to an increased risk of crashes on our roads. A comprehensive national strategy that improves drowsy driving education and graduated driver licencing laws for young drivers, and supports advancements in drowsiness detection technology and the management of sleep disorders, has significant potential to improve road safety in Australia.

Competing interests statement

Alexander Wolkow reports that he has served as a consultant through his institution to the Sleep Health Foundation. Shantha Rajaratnam reports that he has served as a consultant through his institution to Vanda Pharmaceuticals, Philips Respironics, and Teva Pharma Australia and has, through his institution, received research grants and/or unrestricted educational grants from Vanda Pharmaceuticals, Takeda Pharmaceuticals North America, Philips Lighting, Philips Respironics, Cephalon, and ResMed Foundation as well as reimbursements for conference travel expenses from Vanda Pharmaceuticals. Shantha Rajaratnam is a Program Leader in the Cooperative Research Centre for Alertness, Safety and

Productivity. Clare Anderson has received contract research support from VicRoads, Rio Tinto Coal Australia, National Transport Commission; lecturing fees from Ausmed, Healthmed and TEVA Pharmaceuticals; and reimbursements for conference travel expenses from Philips Healthcare. In addition, she has served as a consultant through her institution to the Rail, Bus and Tram Union, the Transport Accident Commission (TAC) and the National Transportation Committee. She has also served as an expert witness and/or consultant in relation to fatigue and drowsy driving. Clare Anderson is a Theme Leader in the Cooperative Research Centre for Alertness, Safety and Productivity. Mark Howard has received grants from the Cooperative Research Centre for Alertness, Safety and Productivity; has served as a consultant for VicRoads; and received equipment support from Seeing Machines and Optalert. Darren Mansfield reports that he has received grants from Fisher Paykel Pty and Rhinomed Pty.

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Tables

Table 1. Recommendations to address sleep problems and sleep loss to improve road safety.

1.	Improve driver education about the causes, indicators and consequences of drowsy driving.
2.	Introduce a new law prohibiting unsupervised driving at night for young drivers, with stringent penalties for violation; and mandatory drowsy driver education.
3.	Support naturalistic on-road validation of continuous drowsiness monitoring devices in high risk populations (e.g., long/line-haul heavy vehicle drivers).
4.	Introduce validated ocular based roadside testing of drowsiness state firstly as an education tool and then as enforcement tool.
5.	Continued investment in the examination of blood/saliva-based drowsiness biomarkers as a critical step to achieving a roadside chemical biomarker test in the next 5 to 10 years.
6.	Develop clinically validated methods of identifying people with sleep disorders who are at high risk of drowsy driving, and therefore require treatment.
7.	Develop a regulatory framework supporting sleep disorder screening and management in high risk occupational groups.

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