Submission to House of Representatives, Standing Committee on Communications, Transport and the Arts

Managing Fatigue in Transport.

Prepared by Associate Professor Ron Grunstein, Department of Medicine, University of Sydney on behalf of

- **the Centre for Respiratory Failure and Sleep Disorders, Royal Prince Alfred Hospital, Sydney**
- **Sleep Research Group, Institute of Respiratory Medicine, Royal Prince Alfred Hospital, Sydney**
- **Sleep Disorders Service, St Vincent's Health Care Campus, Sydney**

June 14, 1999

Ward E9, Centre for Respiratory Failure and Sleep Disorders, Royal Prince Alfred Hospital, Camperdown, Sydney 2050
Phone: 02-95158630 Fax: 02-93655612 E-mail: rrg@mail.med.usyd.edu.au

“Sleep and watchfulness, both of them, when immoderate, constitute disease”

Hippocrates

Contents

Submission to House of Representatives, Standing Committee on Communications, Transport and the Arts

Managing Fatigue in Transport.

Summary.

- **Fatigue in the transport industry is common**
- **Fatigue is likely to be on the increase as transportation increasingly involves sustained operations involving more monotonous tasks due to technological advances. While mechanical errors may be less with these advances the risk of human error increases.**
- **The main causes of fatigue are sleep loss, time of day effects (night work), medications and sleep disorders which increase the risk of falling asleep.**
- **There is increasing evidence that sleep apnea is an important cause of fatigue related accidents, particularly with driving. Using an attributable risk calculation, 11-46% of motor vehicle accidents in men aged 30-60 could be avoided if sleep apnea was eliminated.**
- **The important cornerstone of managing fatigue involves awareness through "sleep health" promotion.**
- **Recognition and treatment of sleep disorders is also important and may be an area where specific actions would yield measurable outcomes.**
- **The economic cost of fatigue is likely to be higher than the figure quoted by the committee in their call for submissions**
- **The medico-legal, civil and criminal liability related to fatigue in transport remain somewhat untested in Australian law.**
- **Better research is crucial in the area of fatigue and sleep. Research initiatives in fatigue detection and monitoring, basic and applied research are needed. Initiatives such as NHMRC priority funding or specific funding for centres of excellence in fatigue and sleep research are crucial.**
- **Australia is well placed to develop technologies related to managing fatigue which in turn can be exported**

Figures

1. **Just working night shift in a large Midlands factory nearly doubles the accident rate compared with evening and morning shift.**
2. **Fall asleep accidents in North Carolina from 1991 showing the increased rates at night and siesta period**
3. **Circadian variation in heavy lorry accidents in Sweden**
4. **Prevalence of sleep apnea in Wisconsin showing that 24% of working male public servants in that state aged 30-60 have more than 5 breathing pauses per hour of sleep.**
5. **The rate of snoring in a man doubles the wife is present at GP interview (data from Stradling 1989)**
6. **Preliminary data from the Wisconsin cohort showing that in the vast majority of cases asymptomatic sleep apnea increases in severity at 4 year follow up.**
7. **Table of key papers assessing driving accident risk in sleep apnea**
8. **Numbers used in calculation of attributable risk of accidents in sleep apnea (from Connor, 1999)**
9. **Attributable risk of accidents in sleep apnea (from Connor, 1999)**
10. **Influence of body mass index (BMI) on sleep apnea in the Busselton Sleep Survey**

Appendices

A. **Drowsy Driving and Automobile Crashes.** NCSDR/NHTSA expert panel on driver fatigue and sleepiness
B. **The Association between Sleep Apnea and the Risk of Traffic Accidents.** Teran Santos et al from New England Journal of Medicine, 1999
C. **Editorial for The Association between Sleep Apnea and the Risk of Traffic Accidents.** Suratt and Findley from New England Journal of Medicine, 1999
D. **Falling Asleep whilst driving: are drivers aware of prior sleepiness?** An important medico-legal paper which challenges the assumptions the High Court of Australia made in *R v Jiminez*
E. **Paper on underreporting of sleepiness and driving impairment in patients with sleep apnea/hypopnea syndrome.**
F. **Association of road traffic accidents with benzodiazepines**
G. **Legal opinion by Ian Callinan QC -** Sleep Apnoea and Road Safety
H. **An Overview of Sleepiness and Accidents by David Dinges -an excellent review of the subject by a leading US expert**
I. **Information on the US Coast Guard Alertness and Fatigue Research Program**
J. **System Safety in the Marine Transportation Field: The Need for Human Factors Analysis**
K. **Sleep Disorders in the Law of Torts -** a scholarly look at some of the potential legal minefields in the area of fatigue and fatigue management.
L. **A review of Obstructive Sleep Apnea from Australian Doctor**
M. **Promotional Material from American Automobile Association on fatigue**

A. FATIGUE AS A CAUSE OF ACCIDENTS - DROWSY DRIVING

i) Introduction

Since the recognition of fatigue-related transport disasters such as the Challenger accident and the Exxon Valdez or even the Pacific Highway bus crashes a few years ago in Australia, the area of sleepiness and fatigue has assumed greater importance in accident prevention in the transport industry. The issues related to the transport industry also can extend to a wide range of work areas involving shift work ranging from nuclear power industry, service industries and even the gambling industry.

We live in the age of electricity to light our houses and keep us awake, television and round the clock sports coverage to keep us stimulated and the Internet to challenge us yet again. It is estimated that over 20% of individual using the Internet do so now at times when they previously would have been asleep. Therefore we live in not the Ice Age but the Snooze Age.

As part of this submission, I have included in the appendices the full text of the National Centre for Sleep Disorders Centre/ National Highway Traffic Safety Administration (NCSDR/NHTSA) Expert panel on Driver Fatigue and Sleepiness **(Appendix B)**. This recently produced document provides a reasonable, easy to understand approach to the issue of fatigue in transport, though obviously focusing on road transport.

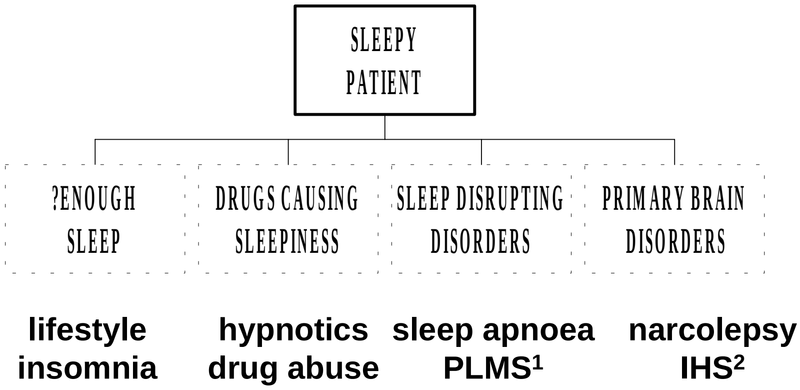
I have used the structure of this document's summary to highlight and expand on key points in areea of fatigue and its management. I have also used fatigue as an operational word which essentially describes a process which ranges from inattention to actual sleep

ii) Biology Of Human Sleep And Sleepiness

Sleep is a neurobiologic need with predictable patterns of sleepiness and wakefulness. Sleepiness results from the sleep component of the circadian cycle of sleep and wakefulness, restriction of sleep, and/or interruption or fragmentation of sleep. This can be classified clinically as shown in the chart above. The loss of one night's sleep can lead to extreme short-term sleepiness, while habitually restricting sleep by I or 2 hours a night can lead to chronic sleepiness. Sleeping is the most effective way to reduce sleepiness.

Sleepiness causes MV crashes because it impairs performance and can ultimately lead to the inability to resist falling asleep at the wheel. Critical aspects of driving impairment associated with sleepiness are reaction time, vigilance, attention, and information processing.

Sleepiness - Various Causes



1. periodic limb movement disorder
2. idiopathic hypersomnolence

Causes of Sleepiness - from a clinicians point of view

iii) Crash Characteristics

Subjective and objective tools are available to approximate or detect sleepiness. However, unlike the situation with alcohol-related crashes, no blood, breath, or other measurable test is currently available to quantify levels of sleepiness at the crash site. Although current understanding largely comes from inferential evidence, a typical crash related to sleepiness has the following characteristics:

• The problem occurs during late night/ early morning or midafternoon.

• The crash is likely to be serious.

- A single vehicle leaves the roadway.
- The crash occurs on a high-speed road.
- The driver does not attempt to avoid a crash.
- The driver is often alone in the vehicle.

iv) Risks For Drowsy-Driving Crashes

Although evidence is limited or inferential, chronic predisposing factors and acute situational factors recognised as increasing the risk of drowsy driving and related crashes include:,

e *Sleep loss.*

Driving patterns, including driving between midnight and 6 a.m.; driving a substantial number of miles each year and/or a substantial number of hours each day; driving in the midafternoon hours (especially for older persons); and driving for longer times without taking a break.

Consumption of alcohol, which interacts with and adds to drowsiness.

Use of sedating medications, especially prescribed anxiolytic hypnotics, tricyclic antidepressants, and some antihistamines

Untreated or unrecognized sleep disorders, especially sleep apnea (SA) and narcolepsy.

These factors have cumulative effects; a combination of them substantially increases crash risk.

v) Sleep Loss and Characteristics of Fatigue Related MVA's

Fatigue is a well recognised and common cause of motor vehicle accidents. It is believed to account for around 16% of fatal crashes in NSW and 30% of rural crashes in NSW (NSW Motor Accidents Authority). It is certainly one of the three commonest causes of motor vehicle accidents and the effect of driver fatigue has been underestimated in the past due to inadequate reporting by police and regulatory authorities.

Surveys of drivers in NSW show that:

- 58% of drivers report having experienced fatigue at the wheel
- 48% have pulled over when driving because of fatigue
- 3% report having had a crash due to their fatigue
- 24% report having nearly had a crash due to their fatigue

Fatigue crashes tend to be severe, partly because fatigued drivers often fail to brake before colliding with something. In 1995:

- 45% of fatigued drivers in crashes were 25 years of age or under
- 41% of fatigued crashes occurred in rural areas (not towns) and 41% in Sydney
- 84% of fatigued drivers were driving cars
- Drivers of trucks are over-represented in fatigue crashes, for example, studies indicate around 30% of fatal heavy vehicle crashes involve fatigue
- Just over one third of fatigue related accidents occurred on work trips, one in four were holiday trips and the remainder were for social reasons

NSW RTA research shows that 62% of fatigue crashes or near crashes occurred when drivers had driven for less than 2 hours, often on everyday trips near homes, where most driving is done. Nevertheless, long periods of driving are fatiguing in themselves, placing drivers at risk even if they were not tired when they started the trip. The fatiguing effects of long hours of driving are often combined, over the length of the trip, with circadian (time of day) propensity to fall asleep (siesta effect), monotony and loss of sleep if the driver has been awake for a long time. The time of day when driving is happening is an important contributor to fatigue with late at night and early morning being the worst times, for example 48% of fatigue crashes occurred between 10pm and 6am. Research shows that almost half of the drivers who had a fatigue crash or near crash said they had not had a full night's sleep the night before.

International fatigue MVA data indicate that

- 15% of Finns report having fallen asleep driving   Acta Neurol Scand 86:337-341 1992
- 20% of US drivers report having fallen asleep at the wheel   USA Better Sleep Council July 1994
- 27% of US fatal accidents are single vehicle not involving alcohol
- 37.4% of fatal crashes in the USA "single vehicle roadway departures"
- in 67% of single vehicle departure crashes no evasive action was taken

Fatigue related accidents are also more likely to be fatal. The NHTSA has found that 30 - 40 per cent of all US truck accidents are fatigue related. Often it is difficult to separate out the effects of fatigue and other potential causes. For example, the effects of fatigue and sedating drugs may be additive in impairing driver performance. Similarly inattention and sleepiness associated with fatigue may be additive to the accident risk associated with speeding. There is also evidence that sleep deprivation may increase risk taking behaviour. A number of papers have shown that disorders which cause excessive fatigue, such as sleep apnea syndrome, are associated with an increased risk of accidents (see below).

As pointed out above, the role of fatigue in any one particular accident may be complex and maybe interrelated with other factors. The likelihood of fatigue related accidents is also linked to other factors such as the individuals circadian rhythms or accumulated lack of sleep. Fatigue related accidents are more common during the night when sleep drive is increased, irrespective of the number of prior hours sleep obtained by the driver.

There is also evidence that accidents will increase mid-afternoon when there is a small peak in circadian propensity for sleep or more markedly at night **(Figures 2,3)**. Just working at night when the body's clock says it should be sleeping is associated with increased risk of accident (**Figure 1**). Secondly, the individuals state relative to existing sleep deprivation or sleep "debt" is an important cause of fatigue. As an individual deprives himself of sleep, there is an increase in the drive or "pressure" for sleep. In this way, sleep drive is homeostatic, like hunger or thirst e.g.. if a person does not eat they become progressively more hungry and similar pattern of function relates to sleep.

Although there is a (probably genetic) inter-subject variability in the effects of sleep deprivation on performance, a progressive decrement in performance and increased likelihood in falling asleep with progressive hours of sleep deprivation exists in all individuals. Generally, the degree of sleep propensity and likelihood to fall asleep whilst driving is a combination of immediate sleep deprivation (past 24 hours) and accumulated sleep deprivation (over preceding week or weeks). Immediate sleep deprivation is more crucial but can be compromised further by accumulated sleep loss over the previous week or weeks.

B. COMBINED EFFECTS OF FATIGUE AND ALCOHOL ON MOTORISTS

"I feel sorry for people who don't drink. When theywake up that's the best they are going to feel all day"

Francis Albert Sinatra

This issue has been addressed by a number of researchers over the past 10 to 15 years. Alcohol has well known effects on vigilance and attention and there is now strong evidence indicating that the vigilance impairing effects of alcohol are exacerbated by sleep loss.

Alcohol and sleep loss interact to produce decrements in performance. This interaction appears to be additive. Increased basal levels of sleepiness enhance alcohol's sedative effects for even moderate alcohol doses. The corollary is also true - extended sleep periods attenuate the sedating effects of alcohol. Other studies have shown that in the normal period of circadian propensity to sleep in the afternoon (siesta period), alcohol producers greater impairment in performance than corresponding alcohol levels tested in the evening. These studies suggest again that alcohol's effects are potentiated at times of increased propensity to fall asleep such as mid-afternoon and during the typical nocturnal sleep period.

In an important study, highly relevant to this particular case, Walsh et al studied the sedative effect of 0.7gm per kilogram of 100% alcohol ingested at 9.30pm. This effect was compared with placebo. This moderate dose of alcohol significantly increased physiological sleepiness in early morning hours even in individuals that are relatively alert at these times ie individuals who normally wake up early and perform well in the morning.

In another study by Horne et al (1991) young women with blood alcohol concentrations within the United Kingdom legal driving maximum underwent a 40 minute monotonous motorway driving task in the early afternoon (increased sleep propensity time) and these results were compared with a 6pm drive (low sleep propensity time). Alcohol significantly affected performance on this task especially during the early afternoon (increased sleep propensity time).

In another study (Roehrs et al 1994), men were all assessed in each of 4 experimental conditions: 8 hour time in bed and placebo, 4 hour time in bed and placebo, 8 hour time in bed and alcohol and 4 hour time in bed and alcohol. In morning testing with breath alcohol concentrations less than 0.05%, sleepiness was still increased. Divided attention task reaction times were increased and simulated driving performance was greatly disturbed with reduced sleep times relative to placebo. In the afternoons with even lower blood alcohol levels of 0.013%, the combination of alcohol and 4 hour time in bed increased sleepiness and disrupted performance on divided attention and simulated driving performance. These results indicated that sleepiness and low dose alcohol combine to impair simulated car driving and that this impairment extends beyond the point which blood alcohol concentrations reach very low levels. This data provides explanation for the incidence of alcohol related motor vehicle accidents at low blood alcohol levels.

In a major review of the effects of alcohol on vigilance, Koelega (et al 1995) extensively reviewed the literature in this area examining 38 studies of which compared effects of alcohol and placebo on vigilance tasks. These studies showed that the main effect of moderate doses of alcohol is on attention and information processing. The capacity to divide and sustain attention is already impaired at blood alcohol levels of 0.02 to 0.03%. Effects of alcohol appear to some extent to be time dependant and are greatest during periods of sleepiness (the early afternoon and after midnight). This author stated that on evidence from the literature on performance the blood alcohol standard for driving should be lowered to 0.02% for driving after midnight and special risk groups (young and less experienced drivers). Interestingly, recent data from New Mexico showed that a percentage of alcohol related fatal crashes increases significantly during the first 7 days after changes in daylight savings times which would provide further support outside of the experimental context for a link between sleep loss and alcohol.

In summary, the effects of alcohol and sleepiness/fatigue are additive. Alcohol promotes sleep onset and potentiates the performance decrement associated with sleep loss. Sleep loss potentiates the performance decrement associated with consumption of even moderate amounts of alcohol.

C. SEDATING MEDICATIONS

Drugs acting on the central nervous system may lead to drowsiness and increased reaction times and thus effect driving performance. In elderly people, benzodiazepines and tricyclic anti-depressants have been associated with increased risks of road traffic accidents causing injury. In a 1993 report commissioned by the European Community Directorate on Transport suggested that at least 10% of people killed or injured in road traffic accidents were taking some sedative/hypnotic medication which could have contributed to the accident. Recently, Barbone and colleagues (1998), found that 1% of Scottish drivers in a first-ever crash were current users of benzodiazepine hypnotics **(Appendix F)**. They found clearly that risk of hypnotic/sedative drugs on crash rates were also present in young drivers. They concluded that users of some sedative/hypnotic drugs (longer half life benzodiazepines and zopliclone) should not drive. Other data indicate that certain newer hypnotic agents such as zolpidem and zaleplon have less effects on daytime performance and improved performance on driving simulators than benzodiazepines. It must also be recognised that many individuals using sedative/hypnotics will have insomnia leading to sleep loss magnifying the fatigue producing effects of their drugs. Obviously the combination of sleep loss, sedative/hypnotic drugs with alcohol is dangerous combination for producing sleepiness and fatigue.

D. NARCOLEPSY

Narcolepsy is a condition of increased sleep drive which probably effects at least 6, 000 Australians. A larger percentage of the population has variants of this condition such as idiopathic hypersomnolence. Sufferers from these conditions have a markedly increased propensity to fall asleep during the day.

There are clear guidelines prohibiting driving by patients with narcolepsy unless their condition is treated by stimulant medication. Unfortunately for some, stimulant medication (dexamphetamine and methyphenidate (Ritalin) causes unacceptable side effects. In these patients , the new non-stimulating wakefulness promoter, modafinil (see below) is available.

E. SLEEP APNOEA - A REVERSIBLE CAUSE OF FATIGUE

"Laugh and the whole world laughs with you. Snore and you snore alone"
Anthony Burgess, British author

Areview of sleep apnea for general practitioners is included in **Appendix L.**

i) What is sleep apnoea?

Sleep apnoea encompasses a spectrum of conditions linked by the loss of a normal pattern of breathing in sleep or in particular stages of sleep. At one end of the spectrum are individuals who snore (perhaps only intermittently) and have no disruption of sleep, so called "simple snorers". The true clinical range of the spectrum includes individuals who snore heavily disrupting their own sleep to patients who literally cannot breathe and sleep at the same time.

Obstructive sleep apnoea (sleep apnoea) is the most common part of the spectrum and is characterised by repetitive pauses in airflow during sleep (apnoea), secondary to collapse of the upper airway at the level of the throat. During apnoeas, futile respiratory efforts occur and the lack of air entry into the lungs results in lack of oxygen in the body. Eventually an apnoea is terminated by brief awakening. In the typical patient, after a few deep breaths (often loud snores) , the cycle of events is repeated as often as 200-600 times per night. As a result of recurrent awakenings, sleep is dramatically fragmented with loss of normal sleep pattern. This, in turn, results in loss of vigilance or even severe sleepiness during the day. Often the sufferer is totally oblivious to the breathing problem and is just aware of daytime sleepiness and fatigue.

ii) Why Do People Snore And Stop Breathing ?

Snoring occurs during sleep when the throat narrows leading to turbulent airflow and vibration of the palate and adjacent upper airway tissues. Apnea occurs when the airway almost or completely closes resulting in cessation of airflow. Most people who snore and have sleep apnea also have a narrow upper airway space awake.

iii) How Common is Sleep Apnoea?

Most middle-aged men snore. In our research in Busselton, Western Australia, snoring, measured by a microphone, occurred in 80% of middle aged men and 25% of women. Studies in Wisconsin, USA and also Busselton have shown that 9% of women and 24% of men stop breathing more than 5 apnoeas per hour of sleep **(Figure 4)**. Sleep apnea is progressive over a 4 year period - many with those with less than 15 apneas per hour of sleep at first diagnosis will become much more severe over a 4 year follow up period **(Figure 6)**.

Risk factors for increased prevalence of sleep apnoea include -

- **Obesity** - particularly fat deposition around the neck (collar sizes > 41cm typically) and abdomen, so called “central obesity”. The risk of sleep apnea in a person with a weight > 120% ideal is about 5-17 times that of a person of ideal body weight.

- **Familial/Genetic** Sleep apnoea aggregates in families. The risk of having sleep apnoea rises progressively with increasing numbers of affected relatives, this risk is ***independent*** of age and obesity. It is possible to be thin and have severe sleep apnea if there is a strong family history of sleep apnea.

- **Age** Sleep apnoea increases in prevalence with age and is commonly recognised in the 5th to 7th decades. High rates of sleep apnoea are recognised in the aged nursing home population. Some of the increase in prevalence with age is due to increased central fat deposition with age. There are very limited data on the prevalence of sleep apnoea in children but studies from Iceland suggest 2-5% of children have clinically significant sleep apnoea.

- **Gender** Sleep apnoea is more common in men with a male:female close to 2.5:1.

- **Race** There is some evidence that young African-Americans have a higher prevalence of sleep apnoea independent of obesity and lifestyle factors. In Australia, we have no data on Aborigines but it is certainly associated with central obesity in this racial group. There appears to be a high rate of sleep apnoea and Mexican-Americans possibly due to obesity. This is also the likely explanation for high rates of sleep apnoea in urbanised Polynesians, in Hawaii, Western Samoa and New Zealand.

- **Tobacco/Alcohol Use** Acute alcohol ingestion promotes apnoea development during later sleep. Some studies have suggested that lifetime alcohol consumption may be a risk factor for the development of sleep apnoea, particularly if accompanied by respiratory failure. Other studies have failed to find a link between lifetime alcohol consumption and sleep apnoea. Data from the Wisconsin Sleep Cohort suggests that smoking history may be a dose -dependent risk factor for sleep apnoea.

- **Upper Airway Morphology** Apart from obesity, conditions causing narrowing of the upper airway will promote the development of sleep apnoea. These include fixed upper airway lesions (e.g. nasal obstruction, enlarged tonsils), big tongue (acromegaly, amyloid, hypothyroidism) or neurological conditions impairing upper airway muscle tone.

iv) Screening for Sleep Apnea

"if somebody has a bad heart, they can plug this jack in at night as they go to bed and it will monitor their heart throughout the night. And the next morning when they wake up dead - there will be a record"
Mark S. Fowler, US FCC Chairman, Washington DC
quoted in the book "The 776 Stupidest Things Ever Said"

Medicare benefits are payable by the Health Insurance Commission for investigation of sleep apnea where clinically appropriate. Medicare generally does not pay for screening investigations i.e. occupational screening for sleep apnea would not attract Medicare payments.

There are several levels of screening a population for sleep apnea. Firstly, targeted **questionnaires** may be used but suffer from subjectivity. A person without a bed partner may not be aware of symptoms of sleep apnea and even those with a bed partner seriously underestimate their snoring **(Figure 5).** Patients with sleep apnea also seriously underestimate their sleepiness and driving impairment prior to treatment **(Appendix E).** Finally, some data exists suggesting that measuring a patients body mass may provide as much practical information on the likelihood of sleep apnea as do detailed questionnaires.

In the past 10 years, a number of devices have been developed that measure breathing at night without simultaneously measuring sleep. These devices are increasingly robust and demonstrate cost savings over full sleep investigation. They are useful for *screening for sleep apnea* but cost utility over full sleep studies has not been demonstrated for investigating symptomatic patients with sleepiness.

v) Treatment of Sleep Apnea

The standard form of treatment for moderate to severe sleep apnea is nasal continuous positive airway pressure (CPAP). This method was developed at Royal Prince Alfred Hospital in 1981 by Sullivan and colleagues and is now the main form of treatment for this condition worldwide. The Australian company, ResMed which developed at of this and subsequent research is now capitalise at over $US 500 million. Other forms of treatment include weight loss, upper airway surgery (removal of soft palate and surrounding tissues and dental splints designed to keep the lower teeth forward preventing the tongue from falling back during sleep.

F. SLEEP APNEA AND DRIVING RISK

In 1968, in a French medico-legal paper, the first suggested link between an increased risk of traffic accidents and the newly "discovered" sleep apnea "syndrome" was reported. However it was not until the mid-1980's that data from Canada and the USA compared actual accident rates from state databases in drivers with and without sleep apnea. These studies found that sleep apnea was associated with a 2-3 -fold increased risk of MVA and as well patients were more likely to have a history of multiple crashes. Subsequent experimental work demonstrated that sleep apnea patients performed poorly on performance tasks relevant to driving (reaction times, divided attention).
Woo et al (1996) examined patients attending the UCLA Sleep Disorders Clinic and found that patients with sleep apnea were 3 times more likely than other patients of falling asleep at inappropriate times and having had a motor vehicle accident in the past 5 years.

Young and coworkers (1997) studied 913 employed public servants in Wisconsin. These public servants were enrolled in a study on the prevalence of sleep apnea and had undergone sleep investigation. Motor vehicle history was obtained from a state wide database of all traffic violations and accidents from 1998 to 1993. Men with 5 or more apneas per hour of sleep were 3.4 to 4.2 times more likely to have a motor vehicle accident than those who did not have sleep apnea. In women, the accident risk increased only in those who had more than 15 apneas per hour of sleep. the likelihood of men and women with more than 15 apneas per hour of sleep were 7.3 times more likely to have a motor vehicle accident than those with less than 5 apneas per hour of sleep.

Barbe et al (1998) compared 60 consecutive patients with sleep apnea and 60 aged and sex matched controls. They compared sleepiness, performance testing and accident rates obtained from insurance data. This study demonstrated that patients had 2.3 times more risk of 1 or more accidents and 5.2 times the risk of multiple accidents in sleep apnea patients compared with controls. These researchers were unable to find an association between performance testing or sleepiness questionaries and accident risk within the sleep apnea patients group.

Recently, Teran Santos and colleagues (1999) conducted a case-control study of the relation between sleep apnea and the risk of traffic accidents. They compared 102 drivers who received emergency treatment at hospitals in Burgos or Santander, Spain, after highway traffic accidents between April and December 1995. The controls were 152 patients randomly selected from primary care centres in the same cities and matched with the case patients for age and sex. As compared with those without sleep apnea, subjects with more than 10 apneas per hour of sleep or higher had an odds ratio of 6.3 (95 percent confidence interval, 2.4 to 16.2) for having a traffic accident. This relation remained significant after adjustment for potential confounders, such as alcohol consumption, visual-refraction disorders, body-mass index, years of driving, age, history with respect to traffic accidents, use of medications causing drowsiness, and sleep schedule. Among subjects with more than 10 apneas per hour of sleep, the risk of an accident was higher among those who had consumed alcohol on the day of the accident than among those who had not. **(see Figure 7, Appendices C, D)**

There is evidence that the decrement in driving performance observed in patients with sleep apnea is reversible with treatment of sleep apnea. Claims have been made for improving driving simulator performance with upper airway surgery but the best data is for nasal continuous positive airway pressure treatment. Use of CPAP, markedly improved performance on a Canadian divided attention driving test compared with baseline values before treatment..

Cassel et al (1996) reported that CPAP treatment reduced the accident rate in 59 patients using CPAP successfully for 1 year. They reported the accident rate reduced from 0.8 per 100,000km driven (untreated) to 0.15 per 100,000km (treated).

From this data, it is clear that patients with sleep apnea are at increased risk of motor vehicle accidents. However there are a number of important research questions unanswered.

1. How can one assess an individuals actual risk? There is variability in sleepiness and driving behaviour amongst patients and we do not appear to have the tools to correctly assess individual risk.
2. There is more data required to show the efficacy of treatment in reducing the accident risk both on a population basis and on simulated driving. To this end, our sleep research group has been working on a computerised Windows NT platform night driving simulator to assess this risk
3. What is the added risk in patients with sleep apnea of alcohol and sleep loss (separate to the sleep fragmentation of sleep apnea)? For example, should patients with diagnosed sleep apnea have a lower level of drug alcohol acceptable or should they be limited in distance driven?
4. It is interesting that in patients with mild sleep apnea accident risk in women is less than that of men in cases of mild sleep apnea possibly there are some gender differences in driving behaviour which may explain this finding.

i) Do Truck Drivers have a high rate of Sleep Apnea ?

There are a number of reasons to suspect that sleep apnea is more prevalent in truck drivers than the rest of the populations. A number of surveys have shown that truck drivers are more obese than an age match controlled population. Moreover many truck drivers are in the high risk group for sleep apnea - middle aged males. A prevalence study in a US trucking company showed that, depending on the threshold level set, sleep apnea occurred anywhere between 40% to 70% of truck drivers in the organisation. Following this, the US Department of Transportation provided funds for a prevalence study in commercial driver licence holders in Pennsylvania. This study revealed that at least 30% of commercial driver licence holders had some degree of sleep apnea. this survey contained very few long distance truck drivers and has been criticised for some potential methodological problems.

Currently, we are involved in a research study examining the prevalence of truck drivers in Victoria, New South Wales and Queensland. This is being done with the full support of the Transport Workers Union in all 3 states and is under way with funding support from a number of different sources.

ii) How many MVA's are caused by sleep apnea?

In order to estimate how many MVA's are caused by sleep apnea, it is necessary to calculate the ***population attributable risk for sleep apnea.***

The Population Attributable Risk (P.A.R.) is the measure of the excess rate of *disease* in a total study population which is attributable to an *exposure*. This measure is useful for determining the relative importance of *exposures* for the entire population and is the proportion by which the incidence rate of the *outcome* in the entire population would be reduced if *exposure* were eliminated.

In this calculation, the Population Attributable Risk is the measure of the excess rate of *motor vehicle accidents* in a total study population which is attributable to *sleep apnea*. This measure is therefore useful for determining the relative importance of *sleep apnea* for the entire population and is the proportion by which the incidence rate of *motor vehicle accidents* in the entire population would be reduced if *sleep apnea* were eliminated. To calculate the total number accidents attributable to sleep apnea in a population, one multiplies the PAR (which will be a fraction less than 1) by the total number of accidents.

For statistical enthusiasts, the calculation for P.A.R. is

P.A.R = F (RR-1) / 1 + F (RR-1)

where F = the prevalence of exposure (sleep apnea in men aged 30-60) in the population (drivers aged 30-60) ; RR = the relative risk of MVA's in individuals with sleep apnea compared with the rest of the population.

Dr Alfred Conner, a clinical epidemiologist from the University of Virginia, Charlottesville, Virginia in a presentation at the 6th International Symposium on Sleep and Respiration held in Banff, Canada March 27-30, 1999 calculated the population attributable risk based on US MVA data and national licensed driver figures His conclusions are summarised in Figures 8-9. He used various relative risk levels for male drivers aged 30-60 found in published peer reviewed papers. Depending on the relative risk used and the prevalence rate of sleep apnea in men aged 30-60 based on Wisconsin Sleep Cohort and other sleep apnea prevalence studies, **Conner estimated that 400,000 - 2.5 million accidents annually in male drivers aged 30-60 were attributable to sleep apnea in the USA**.

Using the same methodolgy, it is possible to estimate how many accidents were attributable to sleep apnea in NSW in 1997. It is important to note Conner used the total number of non-fatal crashes in the US irrespective of injury or damage. The available NSW data is calculated from accidents where i)the accident was reported ii) occurred on a public road iii) involved at least 1 moving vehicle and iv) at least one person was killed or injured or 1 vehicle towed away. Therefore the NSW data uses a much smaller accident rate than Conner's calculation. For example, using Conner's US annual accident rate of 3,774,750 involving men aged 30-60 and then calculating that NSW has a population of 2.5% of the USA, the expected incidence of accidents in this group would be 94,500. However using the more serious accident rate definition above in men aged 30-59 in NSW produces a figure of 25,664 accidents in this age group. The discrepancy in the accident rate in 30-60 year old drivers reflects the comparison of all crashes in Conner's data with the more serious criteria of the NSW data.

In any case the P.A.R. for sleep apnea varies between 12% and 46%. Therefore between 3,080-11,805 serious accidents involving male drivers aged 30-60 are estimated to be attributable to sleep apnea. Using the rate calculated from US data for all crashes, this rises to an estimated 11,340 - 43,470 crashes in NSW attributable to sleep apnea in 1997.

G. ECONOMIC ASPECTS OF MOTOR VEHICLE ACCIDENTS

i) All accidents

Recently the National Highway Traffic Safety Administration (NHTSA) published a technical report examining the economic impact of MVA's in the USA in 1994. The key findings are summarised below (all data in $US) -

- The cost of motor vehicle crashes that occurred in 1994 was $150.5 billion. This total represented the present value of lifetime economic costs for 40,676 fatalities, 5.2 million non-fatal injuries, 3.7 million uninjured occupants and 27 million damaged vehicles. These incidents included both police-reported and unreported crashes. Property damage costs of $52.1 billion accounted for the most significant portion of the total cost, followed by lifetime losses in marketplace production of $42.4 billion.

- Economic cost components include productivity losses, property damage, medical costs, rehabilitation costs, travel delay, legal and court costs, emergency service costs, insurance administration costs, premature funeral costs and costs to employers.

Significant findings on cost included:

- The cost of motor vehicle crashes that occurred in 1994 was $150.5 billion, the equivalent of $580 for every person living in the United States, or 2.2 percent of the US Gross Domestic Product.

- Each fatality resulted in lifetime economic costs to society of over $830,000. Over 85 percent of this cost is due to lost workplace and household productivity.

- The average cost for each critically injured survivor was $706,000 -- nearly as high as for a fatality. Medical costs and lost productivity accounted for 84 percent of the cost for these Maximum Abbreviated Injury Scale (MAIS) level 5 injuries.

- Present and future medical costs due to injuries occurring in 1994 were $17 billion, representing 11 percent of total costs. However, medical costs accounted for 22 percent of non-fatal injury crash costs.

- Lost market productivity totalled $42.4 billion, accounting for 28 percent of total costs, and lost household productivity totalled $12.3 billion, representing 8 percent of total costs.

- Because of their high incidence, crashes of vehicles that sustained only property damage were the most costly type of occurrence, totalling $38.9 billion and accounting for 26 percent of total motor vehicle crash costs.

- Property damage in all crashes (fatal and injury) as -well as property-damage-only crashes totalled $52.1 billion and accounted for 35 percent of all costs, more than any other cost category.

- About 24 percent of medical care costs resulting from motor vehicle crashes are paid from public revenues, with Federal revenues accounting for 14 percent and states and localities 10 percent.

- Roughly 9 percent of all motor vehicle crash costs are paid from public revenues. Federal revenues account for 6 percent and states and localities paid for about 3 percent. Private insurers pick-up 55 percent while individual crash victims absorb about 29 percent. Overall, sources other than the individual crash victims pay about 70 percent of all motor vehicle crash costs, primarily through insurance premiums and taxes. Motor vehicle crash costs funded through public revenues cost taxpayers $13.8 billion in 1994, the equivalent of $144 in added taxes for each household in the United States.

Significant findings on incidence include:

- 5.2 million persons were injured in motor vehicle crashes in 1994; 1. 1 million of these, or roughly 22 percent, were injured in crashes that were not reported to police.

- 27 million vehicles were damaged in motor vehicle crashes in 1994; 86 percent of these were damaged in property-damage-only impacts, with injuries occurring in, or pedestrian injuries caused by, the remaining 14 percent.

- Roughly half of all property-darnage-only crashes and over a fifth of all nonfatal injuries are not reported to police.

An analysis was conducted of trends in motor vehicle crash costs since 1990:

- Inflation increased the cost of motor vehicle crashes by over 16 percent since 1990.

- A variety of factors including increased safety belt use, decreased driving under the influence of alcohol, safer vehicles, and improved roadways reduced the incidence of crashes, death and injury. This offset about half of the potential cost increase due to inflation, leaving costs 8.1 percent higher than in 1990.

- If fatality and injury **rates had remained** at 1990 levels, 1994 crash costs would have been $29.7 billion (or 20 percent) higher than the $150.5 billion measured in this study.

ii) Fatigue-Related MVA Costs

To derive the economic costs of fatigue- related MVA's, one could multiply the total economic cost of MVA's by the proportion of MVA's believed to be due to sleepiness. If one used estimates of either 15 or 30% of accidents being fatigue related, then in the USA in 1994 **the cost of fatigue related accidents ranged from $US 22.6-45.2 billion (0.33-0.66 % of US GDP).**

However in performing an economic analysis, it is important to consider several points generally established regarding fatigue related accidents. Fatigue-related MVA's are more likely to be fatal, more likely to involves young drivers and more likely to involve heavy vehicles. This would suggest the economic cost of fatigue related MVA's is **greater than $US 22.6-45.2 billion.**

There is no recent economic analysis of MVA economic cost in Australia equivalent to the NHTSA report. If one simply assumes that economic cost is proportional to population then the cost of fatigue related accidents in Australia would be in the range of **$A 2-4 billion.** The committee in its call for submissions estimated that "fatigue in the Australian workplace costs up to $1.7 billion". I would question this statement and suggest it is an underestimation.

iii) Sleep Apnea - MVA's Related Costs

It is possible to estimate the economic cost of sleep apnea attributable MVA's. Approximately 28% of drivers are men aged 30-60 and in this age group the attributable risk expressed as a percentage varied from 11% - 46%. This would suggest that sleep apnea attributable MVA's would have an economic cost of $70-600 million depending on prevalence rates and relative risk values used in calculations. Current Medicare expenditure on sleep apnea investigation is approximately $14 million.

H. MEDICO-LEGAL ASPECTS OF FATIGUE AND TRANSPORT

A detailed analysis of this area is beyond the scope of this submission but clealry is an area which should not be ignored by committee members. A paper by O'Keefe on the subject is included in the Appendices **(Appendix K)** as well as the text of a speech by Mr Ian Callinan QC, now of the High Court on the subject of sleep apnea and the law **(Appendix G).**

The medico-legal aspects of fatigue, sleepiness and sleep disorders is ever changing as research findings accumulate.

Key issues include

- the Liability for injuries caused to others when a healthy individual falls asleep or a sufferer of a sleep disorder falls asleep

Various tests are applied in the law of negligence. In criminal law in *R v Jiminez,* the High Court of Australia has held that if a person falls asleep suddenly without clear evidence of prior sleepiness then they cannot be guilty of charges such as negligent driving occasioning death. In **Appendix D**, I include a paper on awareness of prior sleepiness in drivers who fall asleep which certainly calls into question the High Court's ruling in this matter or at least suggests a challenge to this law may be successful.

In the Canadian case of Boomer v Penn where, the driver, a diabetic, was held to an even higher standard of care than the ordinary driver: "A motorist, who suffers from a disability of which he is aware, is under a very heavy duty to take necessary precautions to avoid the possibility of his disability causing him to fall into a condition which would make it impossible for him to discharge the duty of care imposed upon him."

- Liability of an employer if a driver falls asleep

This is currently being tested in several civil actions in Australia. See Appendices G,K for some senior legal opinion. The need for employers to screen their driver for sleep disorders or provide fatigue management programs is not clearly tested in law.

- Liability of products

This would include the liability of manufacturers of treatment devices for sleepiness and sleep disorders ranging from warnings on hypnotic medications to unproven treatments for sleep apnea.

- Liability of medical practitioners

Current fitness to drive guidelines for sleep disorders are fairly stringent but controversial. One must balance the need to diagnose and treat patients confidentially and to encourage patients to present for medical care versus the public interest. The exact liability of medical practitioners who fail to warn or treat a patient with a sleep disorder or who fail to warn transport authorities is unclear.

I. COUNTERMEASURES -"WAKEFULNESS -PROMOTING DRUGS"

Napping and the use of stimulants (typically caffeine) are the most effective countermeasures for fatigue and sleepiness. Other factors such as bright light in the work environment may be important particularly for shift workers trying to adjust to a new sleep phase. Some other countermeasures radio, cold air etc. do not seem to work when properly assessed.

Drowsy driving detection devices based on eyelid closure or blink rates are an area of active research. Such devices are potentially important but should not take the place of appropriate public health strategies. Moreover the medico-legal consequences of one of these devices failing has not been explored.

i) Wakefulness promoting Drugs

Although there is a well know illicit trade in stimulants amongst transport workers, little data is available on controlled use of stimulants in certain fatigue-inducing work environments. Much data in this area is generated by military experimentation and rearely published. The advent of a new class of drug, the "wakefulness promoters" such as modafinil which appears to be relatively side effect free will provide an interesting challenge to the conventional management of fatigue. Already Modafinil is approved for narcolepsy in the USA, Britain and most of Europe and trials are being planned for mild-moderate sleep apnea patients with some degree of sleepiness.

J. FURTHER INFORMATION

In Appendices I, J, further background and resource information is provided for marine transport. An excellent paper on sleepiness and accidents by Dinges is also included (Appendix H)

K. RECOMMENDATIONS

Although recommendations focus on driving, similar recommendations can be made for other aspects of transport.

1. General Strategies to Minimise Fatigue and Sleepiness

Target Population Groups At Highest Risk with Education Materials

Although no person is immune, the following three population groups are at highest risk, based on evidence from crash reports and self-reports of sleep behaviour and driving performance.

- Young people (ages 16 to 29), especially males.

- Shift workers whose sleep is disrupted by working at night or working long or irregular hours.

- Workers involved in monotonous sustained operations

- People with untreated sleep apnea syndrome (SAS) and narcolepsy. Distribution through community health centres, local media, doctors offices. This will also involve recognition that anti-obesity health promotion programs will also be important in reducing the community "load" of sleep apnea.

  Also, there is minimal school education on fatigue and sleepiness in Australia. There are some well developed sleep health programs aimed at various levels of schooling developed in the USA and Israel which could be adapted in Australia. Financial incentives could be offered to develop such programs by special grants. This matter should be referred to the State Ministers of Education.

Publicise Countermeasures

- To prevent drowsy driving and its consequences, the public need information on approaches that may reduce their risks. The public needs to be informed of the benefits of specific behaviours that help avoid becoming drowsy while driving. Helpful behaviours include

(1) planning to get sufficient sleep
(2) not drinking even small amounts of alcohol when sleepy
(3) limiting driving between midnight and 6 a.m.

- As soon as a driver becomes sleepy, the key behavioural step is to stop driving-for example, letting a passenger drive or stopping to sleep before continuing a trip. Two remedial actions can make a short-term difference in driving alertness: taking a short nap (about 15 to 20 minutes) and consuming caffeine equivalent to two cups of coffee. The effectiveness of any other steps to improve alertness when sleepy, such as opening a window or listening to the radio, has not been demonstrated.

.**Road Design**

- Information could be provided to the public and policymakers about the purpose and meaning of shoulder rumble strips, which alarm or awaken sleepy drivers whose vehicles are going off the road. These rumble strips placed on high-speed, controlled-access, rural roads reduce drive-off-the-road crashes by 30 to 50 percent. However, rumble strips are not a solution for sleepy drivers, who must view any wake-up alert as an indication of impairments signal to stop driving and get adequate sleep before driving again.

Shift Work and Fatigue Management

Employers, unions, and shift work employees need to be informed about effective measures they can take to reduce sleepiness resulting from shift work schedules. Countermeasures include following effective strategies for scheduling shift changes and, when shift work precludes normal nighttime sleep, planning a time and an environment to obtain sufficient restorative sleep.

However it is crucial that fatigue management programs are not seen as licences to allow long work hours. No fatigue management program has any value if it trades off education about sleep and fatigue in workers with long work shifts rostered by the employers.

There is disagreement amongst sleep and fatigue researchers about proscriptive work hours such as limiting driving hours for commercial drivers in the Eastern states. In the end there are fundamental economic and legal issues that are best determined by the public and their parliamentary representatives. Some argue that limiting work hours in the transport industry costs money. This can be counter-argued by the cost of fatigue related accidents (see above). One recommendation would be to develop better models of economic analyses of limited versus unlimited driving hours to allow clearer choices for the public in this area.

Educate the Medical and Health Community

A more informed medical community could help reduce drowsy driving by talking to patients about the need for adequate sleep, an important behaviour for good health as well as drowsy-driving prevention.

Initiatives should include

- The detection and management of illnesses that can cause sleepiness, such as sleep apnea and narcolepsy
- Direct health sciences faculties to emphasise education on fatigue, sleepiness and sleep disorders in their curricula. These may require specific programs being developed in some institutions or encouragement of development of bases for academia and teaching in this area. In the US, merit awards with attached funding are offered by the National Centre for Sleep Research (part of the National Institutes of Health) for innovative teaching programs related to sleep and fatigue. At the University of Sydney we have developed a 90 minute workshop built around problem based learning for the first year of the graduate medical program.

Sedatives/Hypnotics

- There should be stronger health promotion amongst the public and health professionals that sedative/hypnotic drugs impair driving
- More emphasis should be given to publicising and funding non-pharmacological treatments for insomnia

to reduce the prescription rates of sedative/hypnotics

- Effect on driving performance and vigilance should be important criteria for assessing PBS listing of sedative/hypnotics rather than cost alone.

Sleep Apnea and other Sleep Disorders

- Clear protection under law in all states should be given to medical practitioners who have reasonable grounds to report drivers with sleep disorders potentially impairing driving
- Screening for sleep apnea using objective criteria (minimum respiratory monitoring during sleep) should be mandatory **at least** for long distance commercial drivers, pilots, air traffic controllers and other high risk occupations if those individuals have a body mass index > 30 on medical examination or in those suspected on medical examination to have sleep apnea. (the figure of Body mass index of 30 is based on our data from Busselton, Western Australia showing that at that level sleep apnea is 5-18 times more common than in those who are normal in weight.(**Figure 10).** These investigations be repeated at 5 yearly intervals. Individuals with positive studies should be assessed and declared fit to work in their occupations by a Commonwealth Department of Health credentialled sleep medicine practitioner.
- Subsidisation of effective therapy for sleep apnea should be introduced in the same way the PBS subsidises medications. Criteria for prescription should follow NHMRC guidelines in this area.
- PBS listing for modafinil or similar non-stimulant wakefulness promoters should not be denied on the basis of cost but only if there are safety issues. The drug should be approved only for the indication of narcolepsy and idiopathic hypersomnolence in individuals who cannot tolerate normal stimulant therapy or in whom such therapy is contraindicated.

Medico-Legal

- Much better statistics on fall asleep accidents are needed. This will involve training at many levels of the police and other investigative forces - some of these programs are in progress.
- Funding of a seminar or conference between the judiciary, police, scientists and clincians to allow clearer exchange in this difficult area.
- A similar approach in describing better fitness to drive guidelines in patients with sleep disorders

Research Funding

The National Institute of Health alone funds over $US100 million dollars in sleep research annually. I estimate the NHMRC funds about 0.5% of that figure. This means, population proportionally, our major medical funding organisation funds twenty times less than the US equivalent. The NIH has its own centre for sleep research which funds specific programs and organises seminars and promotes teaching about fatigue and sleep. In adition to this transportation authorities have funded a number of large research projects in the US.

Given the economic cost of driving accidents alone in the Australia and add to that other fatigue related accidents in other areas of transportation, there is a compelling argument to prioritise research funding in this area. Australia is very competitive internationally in sleep research. We have also benefited from this in commercialisation of sleep research - for example the development of CPAP at our institution spawned ResMed, which is now a major high tech exporter of these machines globally; the development of the Compumedics sleep monitoring systems at Epworth Hospital has lead the company to being named Exporter of the Year in 1998. Its equipment is now used by NASA and the ground breaking Sleep Heart Health study in the USA.

Future challenges in the fatigue area which may be exploited commercially in Australia are methods of assessing sleepiness in the doctor's office or even measuring sleep factors in blood or saliva allowing objective quantification of risk of falling asleep.

We should consider

- Making sleep and fatigue research a NHMRC priority area for funding
- Establishing a centre to promote sleep and fatigue research or provide specific funding for collaborative networks in sleep and fatigue research

Curriculum Vitae of Associate Professor Ron Grunstein

Professor Grunstein is currently Clinical Associate Professor, Department of Medicine,University of Sydney and Senior Staff Physician at the Centre for Respiratory Failure and Sleep Disorders, Royal Prince Alfred Hospital in Sydney. He is also a consultant to the Sleep Disorders Service at St Vincent's Health Care Campus in Sydney.

Professor Grunstein first developed his interest in sleep research as a medical student on an overseas attachment at Stanford University. Subsequently he trained at Royal Prince Alfred Hospital with Professor Colin Sullivan and completed his MD degree by thesis at the University of Sydney and subsequently a PhD at the University of Gothenburg in Sweden.

He has been involved in clinical sleep medicine and sleep research in Australia for the past 20 years. Dr Grunstein was appointed to the first Australian hospital staff position in sleep disorders in 1988 at the Royal Prince Alfred Hospital and has been actively involved in developing the field of sleep medicine in Australia. In 1989, he worked with the Department of Health to establish medical benefits for sleep investigation studies. More recently, he has been involved in maintaining professional standards in sleep investigation by the sleep medicine practitioner credentialling process working with the Department of Health.

As President of the Australasian Sleep Association, Dr Grunstein represented Australian researchers at the symposium on "Working Hours and Sleepiness" at the Karolinska Institute. This symposium emphasised the importance of proper sleep length and quality and limitation of working hours as important components of any work practice regulations. Subsequently, he was involved in a campaign to prevent liberalisation of working hours in the transport industry in the Eastern states. Professor Grunstein also co-ordinates the sleep education component at the University of Sydney graduate medical programme which includes some innovations in teaching prospective doctors about occupational risks of fatigue in the workplace.

Professor Grunstein is currently Education Chair and member of the Governing Council of the World Federation of Sleep Research Societies. In this role, he is now involved in a major task force with W.H.O. aimed at reducing the incidence of sleep disorders impacting on mental health.

Professor Grunstein has been a co-investigator on 9 NHMRC funded sleep research grants as well as receiving funding from a wide range of funding sources. He has written over 50 peer reviewed papers and 18 book chapters on various aspects of sleep research. In 1992-93, he received a National Heart Foundation

Travelling Grant to undertake research at the Department of Pharmacology, University of Gothenburg. He has a strong interest in the applied aspects of research and with Professor Colin Sullivan and colleagues at the Royal Prince Alfred Hospital has been involved in the development of the Sydney based technology company, ResMed which is now a major global force in manufacturing medical products for sleep disorders. Currently, he is involved in a project to develop office based tools for the assessment of sleepiness, in particular driving performance. Current research interests include prevalence of sleep apnea in truck drivers, effects of sleep apnea on the brain, new modes of therapy for sleep apnea and the effects of traffic noise on sleep.