**EPIDEMIOLOGY**

### The Economic Cost of Sleep Disorders

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**Study Objectives:** To determine the economic cost of sleep disorders in Australia and relate these to likely costs in similar economies.

**Design and Setting:** Analysis of direct and indirect costs for 2004 of sleep disorders and the fractions of other health impacts attributable to sleep disorders, using data derived from national databases (including the Australian Institute of Health and Welfare and the Australian Bureau of Statistics).

**Measurements:** Direct health costs of sleep disorders (principally, obstructive sleep apnea, insomnia, and periodic limb movement disorder) and of associated conditions; indirect financial costs of associated work-related accidents, motor vehicle accidents, and other productivity losses; and nonfinancial costs of burden of disease. These were expressed in US dollars ($).

**Results:** The overall cost of sleep disorders in Australia in 2004 (population: 20.1 million) was $7494 million. This comprised direct health costs of $146 million for sleep disorders and $313 million for associated conditions, $1956 million for work-related injuries associated with sleep disorders (net of health costs), $808 million for private motor vehicle accidents (net of health costs), $1201 million for other productivity losses, $100 million for the real costs associated with raising alternative taxation revenue, and $2970 million for the net cost of suffering.

**Conclusions:** The direct and indirect costs of sleep disorders are high. The total financial costs (independent of the cost of suffering) of $4524 million represents 0.8% of Australian gross domestic product. The cost of suffering of $2970 million is 1.4% of the total burden of disease in Australia.

**Keywords:** Sleep disorders, obstructive sleep apnea, periodic limb movement disorder, insomnia, costs

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**INTRODUCTION**

ADEQUACY OF SLEEP IS A FUNCTION OF ITS DURATION, TIMING, AND QUALITY. PARTIAL SLEEP LOSS IS COMMON IN MANY SEGMENTS OF OUR SOCIETY.1 Suboptimal timing of sleep occurs with evening and night shiftwork, which conflicts with the circadian increase in sleep propensity overnight and corresponding daytime decrease when sleep is attempted. Impaired quality can result from disruption caused by specific sleep disorders, such as obstructive sleep apnea (OSA), periodic limb movement disorder, and insomnia.

While clinicians and scientists familiar with these disorders understand their impacts on health and well being, there has been no previous attempt to comprehensively determine the economic costs associated with sleep disorders. The purpose of this study was to determine the nature and magnitude of these costs, including the direct health costs of managing these sleep disorders and associated medical conditions; the indirect financial costs of associated work-related injuries, motor vehicle accidents (MVA), and lost production; and the nonfinancial costs derived from loss of life quality and premature death. While the analysis was of Australian costs (expressed in United States dollars), it is likely that the findings could be applied to other countries with similar Organisation for Economic Cooperation and Development member economies.

**METHODS**

Prevalence of Sleep Disorders and Their Contribution to Other Conditions

A literature search was used to establish the prevalence of common sleep disorders and epidemiologic evidence for the “attributable fractions” of other health impacts associated with these sleep disorders. This was undertaken for cardiovascular disease, diabetes, depression, MVA, and workplace injuries. Australian data were used when available and sufficiently robust. When they were not available, data from populations with similar demographics were utilized.

Estimation of Direct Health Costs of Sleep Disorders

Direct health costs include all expenditure within the Australian health system. These were derived from recurrent cost data for 2000 to 2001 extrapolated to 2004 based on demographic growth and inflation. They included costs of hospital care, health practitioners, pharmaceuticals, diagnostic tests, health aids and appliances, aged care, research, community and public health, and capital and administration.

Estimation of the Direct Health Costs of Conditions Associated with Sleep Disorders

The attributable fractions of the various conditions associated with sleep disorders listed above were calculated using standard methods (see Appendix) and applied to derive the proportion of
their costs due to disordered sleep. The attributable fractions calculations were based on the odds ratio of having the health impact with (relative to without) disordered sleep. For cardiovascular disease and diabetes, attributable fractions were calculated in relation to having OSA only because there was no a priori reason to link these to all causes of disordered sleep. For accident risk and depression, they were calculated in relation to all sleep disorders because these are likely to be related to sleep disruption independent of cause. Incorporation of odds ratios that control for other factors ensures that the associations are derived independent of potential confounding conditions.

**Estimation of the Indirect Costs**

Indirect costs are those other financial and nonfinancial costs that are not health costs. The financial costs include the nonhealth costs of work-related injuries and road accidents; lost production though premature workforce separation, absenteeism, low productivity, and premature mortality; and the real economic costs (distortionary and administrative) that arise from the need to then raise alternative taxation revenue and make higher welfare payments (rather than the income transfers themselves). The nonfinancial costs derive from loss of healthy life—premature death and loss of life quality. These were analyzed in terms of burden of disease using disability adjusted life years4 to which a monetary value was assigned using the “value of a statistical life”5 discounted to calculate the value of a life year.

All costs were expressed in United States dollars ($), using 2004 Organisation for Economic Cooperation and Development purchasing power parity of 72.8 United States cents per Australian dollar.

**RESULTS**

**Prevalence of Sleep Disorders and Their Contribution to Other Conditions**

Chronic primary sleep disorders were conservatively estimated to affect 6% of the population. The most common was OSA, affecting 4%.6,7 While chronic insomnia affects 5% of Australians,8 it has been estimated that only 25% of such cases (1.25% overall) are attributable to a primary disorder,9 the balance being secondary to medical, psychiatric, circadian, or other sleep disorders. Periodic limb movement disorder is another common disorder affecting approximately 3.9% of the population,10 25% of which are estimated to be primary and/or warrant treatment, yielding a prevalence of 1%. The remaining cases of periodic limb movement disorder include mild forms and/or are secondary to other disorders (e.g., iron deficiency) or their treatment (e.g., antidepressants). Narcolepsy affects less than 0.05%.11 Although relatively common in children, parasomnias that are regular, persistent, require treatment, and/or are independent of other sleep disorders (such as OSA) are uncommon in adults.

While the prevalence of childhood sleep problems is high, particularly parasomnias and OSA in the first decade, there are insufficient robust data to calculate all their associated costs.

There is strong evidence for an association between OSA and cardiovascular diseases such as stroke and heart attack12 via the established hypertension linkage.13 OSA is also associated with congestive heart failure, with a prevalence of up to 11% in such populations.14,15 With diabetes, 23.8% of patients have moderate OSA.16 In all forms of the sleep disorder, 25% of patients exhibit some form of depression.17 A strong association also exists between disordered sleep and accidents, with the odds of injury from an MVA being 7.2 times greater and odds of a work-related accident 3.1 times greater with OSA that without.18,19

**Direct Health Costs of Sleep Disorders**

**Hospital**

Total inpatient costs of sleep disorders for 2004 were estimated to be $44.2 million (Australian Institute of Health and Welfare hospital morbidity special data request). A breakdown is given in Table 1. These were based on International Classification of Diseases-10 codes for primary diagnosis of hospitalization to conord with the International Classification of Sleep Disorders.

**Health Practitioners**

Using data from the Australian Bettering the Evaluation and Care of Health primary-care database, an estimated 1.6% of primary-care general-practitioner encounters are for “sleep disturbance” as the problem managed, predominantly insomnia.20 When adjusted for the number of problems managed per consultation, annual general-practitioner costs were estimated to be $26.6 million. Of these patients, 4.26% were referred to medical specialists and 0.66% to other health practitioners, with costs of $16.4 million and $0.6 million, respectively.

**Table 1—Direct Health Costsa of Sleep Disturbances in 2004, Independent of Comorbidities**

<table>
<thead>
<tr>
<th></th>
<th>$, million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inpatient hospital costsb</td>
<td>44.2</td>
</tr>
<tr>
<td>General practitioner costs</td>
<td>26.6</td>
</tr>
<tr>
<td>Specialists</td>
<td>16.4</td>
</tr>
<tr>
<td>Other health practitioners</td>
<td>0.6</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>8.8</td>
</tr>
<tr>
<td>Pathology</td>
<td>1.0</td>
</tr>
<tr>
<td>Diagnostic imaging</td>
<td>0.2</td>
</tr>
<tr>
<td>Outpatient</td>
<td>10.0</td>
</tr>
<tr>
<td>Aged care</td>
<td>8.3</td>
</tr>
<tr>
<td>Dental</td>
<td>6.6</td>
</tr>
<tr>
<td>Research</td>
<td>2.5</td>
</tr>
<tr>
<td>Unallocated costs c</td>
<td>20.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>145.6</td>
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</tbody>
</table>

aCosts of polysomnography are included within the inpatient, outpatient, and specialist components and are estimated to be $22 million. The “unallocated” component includes the costs of aids and appliances and may be conservative, as it is based on the average share of appliances across all health disorders, while the Australian market for continuous positive airway pressure devices and accessories alone is estimated to be $22 million in 2004.

bRelated to OSA (25%), other sleep-related breathing disturbance (14%), sleep-related epilepsy (14%), periodic limb movement disorder (1%), circadian rhythm disorders (11%), nonorganic sleep-wake disorders (6%), other insomnias (2%), alcohol-related sleep disorders (3%), other sleep disorders (5%), nocturnal cardiac ischemia (7%), nocturnal asthma (3%), nasal obstruction (4%).

cCapital, community and public health, administration, aids, and appliances.
Pharmaceutical, Pathology and Diagnostic Imaging

For 85.8% of sleep-disturbance problems managed, 1 or more medications were prescribed, of which 76% were hypnotics, 17.4% anxiolytics, and 4.5% antidepressants, with an estimated cost of $8.8 million. Of those with patients with a sleep-disturbance problem, 4.2% were referred for pathology tests and 0.19% for diagnostic imaging, costing $1.0 million and $0.2 million, respectively.

Total Direct Health Costs

The average percentage of inpatient relative to total allocated health costs is 35.3%. Factoring up total inpatient expenditure of $44.2 million by 100/86 gives an estimated allocated health expenditure for sleep disorders of $125.3 million. Factoring up by a further 100/86 to account for costs not allocated by disease (e.g., capital goods, community and public health, health administration, health aids and appliances, including continuous positive airway pressure devices [see Table 1 footnote]) yields total health costs for 2004 of $145.6 million. Table 1 gives a breakdown, including costs identified above plus costs of outpatient clinics, dental treatments, and research.

Direct Health Costs of Conditions Caused by Sleep Disorders

Calculation of the attributable fractions of conditions associated with sleep disorders allows the proportions of their management costs due to disordered sleep to be estimated.

Attributable Fractions for Disease

Assuming a prevalence of hypertension of 30% and an odds ratio for hypertension in patients with OSA of 2, the fraction of cases of hypertension attributable to OSA was estimated to be 2.1%. Using the linkages established between hypertension and various cardiovascular diseases enabled the percentages attributable to OSA to be calculated as follows: 0.5% ischemic heart disease, 0.7% stroke, 2.1% hypertensive heart disease, 0.9% renal disease, and 0.2% peripheral vascular disease. Conservatively, other potential links between OSA and cardiovascular diseases were not included.

The fraction of diabetes attributable to OSA was estimated to be 2.9%, assuming a prevalence of diabetes of 7.6% and an odds ratio for diabetes in patients with OSA of 1.91. The fraction of depression attributable to disordered sleep was estimated to be 8.3%, assuming a prevalence of depression of 5.1% and an odds ratio for depression in patients with disordered sleep of 2.85.

Attributable Fractions for MVA and Workplace Accidents

Assuming an annual probability of an injury from a MVA of 1.3% and an odds ratio of MVA with disordered sleep of 2.52, the fraction of MVAs attributable to sleep disorders is 7.6%. The fraction of workplace injuries attributable to sleep disorders was estimated to be 9.1%, assuming an annual probability of a workplace accident of 4.5% and an odds ratio of accident with disordered sleep of 3.0.

Cost Implications

Applying these fractions to global expenditure on the respective conditions allows the direct health expenditure attributable to their sleep-disorders component to be derived. This was estimated to be $269 million. As with direct costs for sleep disorders themselves, factoring this up by 100/86 to account for recurrent “unallocated” health costs (see “Total Direct Health Costs” above) yielded a total cost for conditions associated with sleep disorders for 2004 of $313 million (Table 2).

Indirect Costs of Sleep Disorders

Financial Costs

Work-Related Injuries:

The total 2004 cost of work-related injuries, excluding disease and health costs, is estimated to be $21.5 billion. Applying the fraction attributable to sleep disorders (9.1%, see above) yields an
estimated cost from sleep disorders of $1.96 billion, net of health costs.

**Motor Vehicle Accidents:**

The total 2004 cost of MVAs, excluding health costs, ($10.6 billion) was estimated from 1996 data. Applying the fraction of MVAs attributable to sleep disorders (7.6%, see above) to this figure yielded a sleep-disorders component of $808 million, net of health costs.

**Other Production Losses:**

The 2001 National Health Survey suggests that patients with cardiovascular disease are employed in the workforce 3% less than the age-standardized average. Assuming the same proportion for other chronic illnesses, we estimate that 36,026 people with sleep disorders and 4065 with related conditions are absent from the workforce. This equates to lost earnings of $1144 million, with an estimated further 5% loss ($57 million) from absenteeism and lower productivity. Associated foregone taxation revenue of $349 million yields administrative costs of $100 million in raising alternate taxation revenue and making welfare payments (28.75% marginal cost of tax collection distortions and system administration).

**Nonfinancial Costs: Burden of Disease:**

Applying attributable fractions derived earlier and using proportionality of health costs to proxy proportionality of disease burden, we estimated 37,848 disability adjusted life years are associated with sleep disorders. Of these, 32% are attributable to sleep disorders themselves, 30% to work-related and private MVAs, 22% to depression, 9% to cardiovascular disease, and 6% to diabetes.

To cost the 37,848 disability adjusted life years, we multiplied by the value of a life year of $118,344, derived by discounting the value of a statistical life of $2.7 million at a rate of 3.3% over 40 years. This yielded an estimated $4479 million for the annual gross cost of suffering associated with sleep disorders. The net cost of $2970 million is this figure less costs borne by individuals, comprising their contributions to health costs ($92 million), work-related injury costs ($757 million), MVA costs ($127 million), and other production losses from decreased workforce participation ($533 million).

**Discussion:**

Sleep disorders are a large and underrecognized problem. There has been no previous attempt to comprehensively evaluate their economic cost. Previous analyses have concentrated on health costs without accounting for the indirect financial and nonfinancial costs, which our analysis demonstrates predominate. We estimate that more than 6% of the Australian population has a chronic sleep disorder, with a total cost of $7.5 billion in 2004. In 2004, the population of Australia was 20.1 million; the equivalent cost for a population of the size of the United States (293 million in 2004) would have been $109 billion.

OSA and insomnia are the most common of these disorders and have substantial associated morbidity. Sleep disorders contribute to a range of other health and social problems, including 9.1% of work-related injuries, 8.3% of depression, 7.6% of MVAs, 2.9% of diabetes, and 2.1% of hypertension. Indeed, sleep disorders rank in the top 10 risk factors for other health conditions in Australia, exceeding well-known risks to health such as alcohol or unsafe sex.

The total financial costs of sleep disorders ($4.5 billion) represent 0.8% of gross domestic product or $225 per Australian and $3750 per Australian with a chronic sleep disorder in 2004. The suffering and premature death associated with sleep disorders is estimated to impose an additional nonfinancial cost of $3 billion. This represents 1.4% of the total burden of disease in Australia. The major financial costs are those associated with the effects of disturbed sleep on cognitive and psychomotor function, namely motor vehicle and work-related injuries and productivity losses. The fact that the direct health costs of sleep disorders ($146 million) are only 2% of the $7.5 billion total cost of these disorders in Australia suggests that too little is being spent on prevention and treatment to reduce the huge tail of indirect cost impacts. Total health expenditure on sleep disorders themselves ($146 million) plus conditions caused by sleep disorders ($313 million) is of a similar magnitude to asthma, which is a national health priority. While these are Australian data, the per capita costs are likely to be similar in other Organisation for Economic Cooperation and Development and equivalent economies.

Central to our analysis was the “attributable fractions” methodology (see Appendix). This was used to calculate the proportion of diseases (e.g., hypertension) and other conditions (e.g., work-related accidents) attributable to disordered sleep. The method takes into account the prevalence of the condition, the prevalence of the relevant sleep disorder or disorders, and the odds ratio that relates them and accounts for potential confounding variables. Uncertainty associated with the calculation is related to uncertainty associated with these factors. We attempted to account for this by using only data sources for which a strong evidence base existed and making conservative determinations of prevalence. For example, in determining the prevalence of chronic insomnia, we discounted published prevalence described for a range of ages by a factor of 4 to account for insomnia secondary to other conditions. We applied a similar discount to the prevalence of period limb movement disorder. We used an overall prevalence for OSA of 4%, consistent with Australian and US data, recognizing that it may be lower among young adults but higher in older age. We conducted a sensitivity analysis to quantify the effect of variation in this important variable. Variation in OSA prevalence from our estimate of 4% overall to 3% to 5% and, thus, an overall prevalence of sleep disorders from 6% to 5% to 7% changed the attributable fractions for work-related accidents from 9.1% to 7.7% to 10.3%; for MVAs, from 7.6% to 6.5% to 8.7%; for depression, from 8.3% to 7.1% to 9.5%; for diabetes, from 2.9% to 2.2% to 3.6%; and, for hypertension, from 2.1% to 0.8% to 4.0% (including the effect of varying the odds ratio for hypertension from 2 to 1.42 to 2.9, according to the described range of values from the Wisconsin Sleep Cohort Study). The variation in OSA prevalence also changed the burden of disease from 1.4% of total disability adjusted life years to 1.2% to 1.7%. The associated variation in total costs was $870 million to $1019 million (i.e., a range from $6.62 billion to $8.51 billion overall).

Our analysis primarily relates to the financial impacts of chronic sleep disorders. It does not, because of paucity of data, cost the long-term financial impact of childhood sleep disorders, such as learning or behavioral problems. Neither, for the same
reason, does it account for social costs, such as caregiver costs, or cognitive disturbance or mood changes. Conservatively, it only considers cardiovascular consequences of sleep disorders that are related though hypertension, although there is growing evidence of direct cause-effect relationships between OSA and myocardial infarction or stroke.\(^7\) It does not account for poor sleep behaviors secondary to shiftwork or sleep deprivation associated with pressure from work or social commitments. Hence, it is likely that the analysis underestimates the economic impact of disordered sleep, considered in its widest sense, on the community.

While the costs identified are substantial, they are, perhaps, not surprising given the pervasive effects of disordered sleep on cognitive and psychomotor function, which directly translate into accident risk and lost productivity, the major sources of financial cost identified in our analysis. These matters warrant community attention. Sleep is underrepresented on national health agendas despite the availability of a range of proven, cost-effective interventions available for management of sleep disorders.\(^3,4,33\) Priority interventions should include public education, awareness raising, research, and continuing development of cost-effective prevention and treatment options.

**ACKNOWLEDGEMENT**

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**REFERENCES**

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APPENDIX

Estimation of Attributable Fractions

To estimate the attributable fraction of disorder D:
Firstly, the following 2 equations are solved simultaneously for \( p(D|E) \) and \( p(D|\neg E) \):

\[
p(D|E) \cdot p(E) + p(D|\neg E) \cdot p(\neg E) = p(D)
\]

\[
(p(D|E)/(1 - p(D|E))) / (p(D|\neg E) / (1 - p(D|\neg E))) = OR
\]

where:
- \( p(D|E) \) = probability of having D given exposure (E) to sleep disorder
- \( p(D|\neg E) \) = probability of having D given no exposure (\neg E) to sleep disorder
- \( p(E) \) = probability of having sleep disorder (from prevalence data)
- \( p(\neg E) \) = probability of not having sleep disorder (1 - \( p(E) \))
- \( p(D) \) = probability of having D (from prevalence data)
- \( OR \) = odds ratio for having D in presence of sleep disorder (from epidemiologic data)

The probability of having a sleep disorder given D (\( p(E|D) \)) is then derived as follows:

\[
p(E|D) = p(D|E) \cdot p(E) / p(D)
\]

\( p(E) \) is then deducted from \( p(E|D) \) to derive the percentage of D that can be said to be attributable to the sleep disorder (the “attributable fraction”). Using hypertension as an example: \( p(E) = 4\% \), \( p(\neg E) = 96\% \), \( p(D) = 30\% \) and \( OR = 2 \). This yields \( p(E|D) = 0.061 \), i.e., 6.1% of individuals who have hypertension also have obstructive sleep apnea. Given that \( p(E) = 4\% \), the percentage of cases of hypertension that can be said to be attributable to obstructive sleep apnea = 2.1%.

Note that for cardiovascular diseases and diabetes, attributable fractions were calculated in relation to prevalence of obstructive sleep apnea (4%, see Results, under “prevalence of sleep disorders”) alone (i.e., \( p(E) = 4\% \)), as there is no a priori reason to link these disorders to all causes of disordered sleep. For accident risk and depression, they were related to prevalence of all sleep disorders (6%, see Results), as these problems are likely to be related to sleep disruption independent of cause.