ORIGINAL ARTICLE

The Associations of Insomnia With Costly Workplace Accidents and Errors

Results From the America Insomnia Survey

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Context: Insomnia is a common and seriously impairing condition that often goes unrecognized.

Objectives: To examine associations of broadly defined insomnia (ie, meeting inclusion criteria for a diagnosis from *International Statistical Classification of Diseases, 10th Revision*, *DSM-IV*, or *Research Diagnostic Criteria/International Classification of Sleep Disorders, Second Edition*) with costly workplace accidents and errors after excluding other chronic conditions among workers in the America Insomnia Survey (AIS).

Design/Setting: A national cross-sectional telephone survey (65.0% cooperation rate) of commercially insured health plan members selected from the more than 34 million in the HealthCore Integrated Research Database.

Participants: Four thousand nine hundred ninety-one employed AIS respondents.

Main Outcome Measures: Costly workplace accidents or errors in the 12 months before the AIS interview were assessed with one question about workplace accidents "that either caused damage or work disruption with a value of $500 or more" and another about other mistakes "that cost your company $500 or more."

Results: Current insomnia with duration of at least 12 months was assessed with the Brief Insomnia Questionnaire, a validated (area under the receiver operating characteristic curve, 0.86 compared with diagnoses based on blinded clinical reappraisal interviews), fully structured diagnostic interview. Eighteen other chronic conditions were assessed with medical/pharmacy claims records and validated self-report scales. Insomnia had a significant odds ratio with workplace accidents and/or errors controlled for other chronic conditions (1.4). The odds ratio did not vary significantly with respondent age, sex, educational level, or comorbidity. The average costs of insomnia-related accidents and errors ($32 062) were significantly higher than those of other accidents and errors ($21 914). Simulations estimated that insomnia was associated with 7.2% of all costly workplace accidents and errors and 23.7% of all the costs of these incidents. These proportions are higher than for any other chronic condition, with annualized US population projections of 274 000 costly insomnia-related workplace accidents and errors having a combined value of US $31.1 billion.

Conclusion: Effectiveness trials are needed to determine whether expanded screening, outreach, and treatment of workers with insomnia would yield a positive return on investment for employers.

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INSOMNIA IS A HIGHLY PREVALENT condition[1] that is associated with daytime sleepiness and fatigue,[2,3] psychomotor deficits,[4,5] cognitive impairments,[6] and mood dysregulation.[7-10] Considerable epidemiological research implicates insomnia in impaired workplace functioning, including absence due to sickness,[11,12] injuries,[13] and disability.[14-17] Controlled trials demonstrate that best-practices treatment of insomnia may improve work performance[18-21] and ease symptoms of numerous comorbid conditions.[22-24]

Although such results are sufficiently strong and consistent to rank insomnia among the most costly of all health problems from a workplace human capital perspective, employers have yet to invest widely in workplace insomnia screening and treatment programs. One possible reason is that the adverse workplace effects of insomnia documented to date have consisted largely of effects on employee functioning that are borne by employees rather than employers, with employer costs capped by limits on worker benefits (eg, limits on absence days due to sickness and employer-paid short-term disability benefits) or by insurance (eg, health care costs and long-term disability benefits). Nonetheless, employers should recognize that

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insomnia may significantly influence costs of other important uncapped workplace outcomes, most notably workplace accidents and errors that can involve equipment damage, operational disruptions, and litigation.

Although the relative effects of health problems on these adverse outcomes are rarely investigated, insomnia-related daytime impairments would seem especially pertinent. We are aware of only 2 previous studies that investigated effects of insomnia on workplace accidents or errors, both performed in France. The first, a questionnaire study that compared 240 individuals with severe insomnia and 391 "good sleepers" (ie, people with no sleep problems), documented a significantly elevated rate of workplace accidents among individuals with insomnia.[25] The second study compared 369 respondents meeting *DSM-IV* criteria for insomnia with 369 good sleepers in a general population survey and documented a significantly higher rate of self-reported "serious occupational errors" among subjects with insomnia compared with good sleepers.[26] Although both studies represent important advances in insomnia epidemiology, the external validity of their results was limited by the first study's focus on "severe" insomnia, the use of good sleepers as control subjects in both studies (ie, excluding people with sleep problems of insufficient severity or duration to qualify for a diagnosis of insomnia), and the exclusion of respondents with comorbid conditions. Neither study estimated the magnitude or financial costs of insomnia-related workplace accidents and errors or compared these effects with those of other common chronic conditions.

The present report addresses these limitations by analyzing data from a large US national survey on the associations of insomnia with costly workplace accidents and errors. We estimated the prevalence and costs to employers of these incidents and used simulation to make annualized national projections to the entire US workforce.

METHODS

THE SAMPLE

We obtained the data from the America Insomnia Survey (AIS),[1] a national survey of a probability sample of commercially insured health plan members identified from the HealthCore Integrated Research Database, a large (>34 million members) administrative claims database. The AIS was administered from October 29, 2008, through July 31, 2009, in a stratified probability sample of 10 094 adults (≥18 years old). The sample was restricted to fully insured health plan members identified from the HealthCore Integrated Research Database sample frame. Members had to be enrolled for at least 12 months before the interview to allow medical and pharmacy claims data to be used in substantive analyses. Sample eligibility was also limited to members with a valid telephone number who could speak English and who had no impairment that limited their ability to be interviewed by telephone. The sample was selected with stratification to match the US national census population distribution on the cross-classification of age (18-34, 35-49, 50-64, 65-74, and ≥75 years), sex, urbanicity (census standard metropolitan statistical areas, non–standard metropolitan statistical urbanized areas, and rural areas), and census region (Northeast, South, Midwest, and West). Information about diagnoses or treatment of sleep disorders was ignored in sample selection to make the sample representative of all eligible members.

Potential respondents were informed that the survey was designed "to better understand how health and health problems affect the daily lives of people," that respondents were selected randomly, that participation was voluntary, that responses were confidential, that participation would not affect health care benefits, and that a $20 incentive was offered for participation before obtaining verbal informed consent. The Human Subjects Committee of the New England Institutional Review Board approved these recruitment and consent procedures. The cooperation rate (the rate of survey completion among target respondents with known working telephone numbers, including respondents who were never reached) was 65.0%. The 10 094 interviews were weighted for residual discrepancies between the joint distribution of the sociodemographic and geographic selection criteria in the sample compared with the census population. A total of 7428 AIS respondents were employed or self-employed.

In addition to assessing insomnia, the AIS included many questions about the suspected correlates of insomnia. To reduce respondent burden, some questions were administered only to probability subsamples. One such set concerned physical and mental conditions previously found to be comorbid with insomnia. Self-report questions about these conditions were administered to all AIS respondents reporting any sleep problems plus a random 50% of other respondents. The random subsample was assigned a weight of 2.0 (multiplied by the weight described in the "Sample" subsection of the "Methods" section) in the comorbidity sample to adjust for the fact that they represent only half of those without sleep problems in the full sample. A total of 4991 AIS respondents in this comorbidity subsample were employed or self-employed and constitute the sample used in the analyses reported herein.

MEASURES

Insomnia

Insomnia in the 30 days before the interview was assessed with the Brief Insomnia Questionnaire (BIQ),[27] a 32-question fully structured interviewer-administered questionnaire developed for the AIS to operationalize the inclusion criteria for insomnia from the *DSM-IV-TR*,[28] *Research Diagnostic Criteria/International Classification of Sleep Disorders, Second Edition* (*RDC/ICDS-2*),[29] and *International Statistical Classification of Diseases, 10th Revision* (*ICD-10*),[30] hereinafter referred to as *broadly defined insomnia* or *insomnia*. The cases considered herein meet full symptom inclusion criteria in at least 1 of these systems, which require 1 or more nighttime symptoms (difficulty initiating sleep, difficulty maintaining sleep, early morning awakening, or nonrestorative sleep), daytime distress, daytime impairment (difficulties in performing at work, school, or social activities; making errors; or having accidents), and other criteria that vary across systems. The BIQ is described in more detail elsewhere.[27] The full text of the BIQ, along with diagnostic algorithms, is available at http://www.hcp.med.harvard.edu/wmh/AIS_Study.php. Because the focus of the present report is on workplace accidents and errors in the 12 months before interview, we classified insomnia as present only for respondents who reported that their insomnia had persisted for at least 12 months at the time of interview.

No attempt was made in the BIQ to operationalize the diagnostic hierarchy or organic exclusion rules in *DSM-IV-TR* criteria C through E or to distinguish *DSM-IV-TR* primary insom-

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nia, *RDC/ICSD-2* insomnia disorder, or *ICD-10* nonorganic insomnia from other insomnia phenotypes. Instead, potentially comorbid conditions were assessed separately and used as control variables in analyses of predictive associations of insomnia with workplace accidents and errors. This decision to use comorbid conditions as controls rather than diagnostic exclusions was based on the recommendations of the 2005 National Institutes of Health State-of-the-Science Conference[30] and the 2006 recommendations for a standard research assessment of insomnia.[31]

We performed a clinical reappraisal study with a subsample of AIS respondents that oversampled those with positive findings for insomnia in the BIQ. Clinical experts in sleep medicine performed semistructured interviews to make diagnoses of insomnia according to the definitions and inclusion criteria of the 3 diagnostic systems. Psychometric analyses documented good individual-level concordance of BIQ diagnoses with blinded clinical diagnoses.[27] The sensitivity of broadly defined BIQ diagnoses was 72.6%, specificity was 98.9%, and the area under the receiver operating characteristic curve (a measure of classification accuracy insensitive to disorder prevalence) was 0.86. The Cohen κ was 0.77, a value at the upper end of the range conventionally judged to represent substantial agreement with clinical diagnoses.[32] A more detailed description of the BIQ validation study is presented elsewhere.[27]

Other Chronic Conditions

Data were collected on treated and untreated chronic conditions found previously to have high comorbidity with insomnia.[15,33,34] The HealthCore Integrated Research Database allowed us to have access to de-identified data only on this limited set of diagnoses to protect patient confidentiality. These diagnoses were based on *International Classification of Diseases, Ninth Revision,* codes in medical claims and inferred from pharmacy claims. Claims data were not made available on the diagnosis of insomnia. Untreated conditions were assessed by self-reports in 2 ways. First, we used a chronic conditions checklist based on the list in the US National Health Interview Survey[35] (http://www.hcp.med.harvard.edu/ncs/replication.php). Such checklists have been widely used in epidemiological studies and yield more complete and accurate reports than estimates derived from responses to open-ended questions.[36] Methodological studies have documented good concordance between such checklists and medical records.[37-39] Second, we used a series of validated disorder-specific self-report scales to detect untreated symptom-based conditions.[40-44]

A total of 9 treated and untreated condition clusters were considered, including cardiovascular disorders (ie, hypertension, heart disease), diabetes mellitus, musculoskeletal disorders (ie, arthritis, chronic back and/or neck pain), respiratory disorders (ie, chronic obstructive pulmonary disease, seasonal allergies, other respiratory disorders including chronic bronchitis and emphysema), digestive disorders (ie, gastroesophageal reflux disease, irritable bowel syndrome, urinary-bladder problems), pain conditions (ie, migraine, other frequent or severe headaches, neuropathic pain, any other chronic pain), mental disorders (ie, major depression, a summary measure of other mental disorders), other sleep disorders (ie, sleep apnea, restless legs syndrome), and climacteric symptoms common to perimenopausal women. In each of the 9 cases, we distinguished between treated and untreated conditions.

Workplace Accidents and Errors

Workplace accidents and errors were assessed with questions developed specifically for the AIS. The accident question asked respondents whether they ever in the past 12 months had "a workplace accident that either caused damage or work disruption with a value of $500 or more." The error question asked "Not counting accidents, did you ever in the past 12 months make a big mistake at work that cost your company $500 or more?" A follow-up question to each positive response asked respondents to estimate "the total financial value of all the workplace (accidents/mistakes) you had in the last 12 months." Questions about workplace injuries preceded those about accidents and errors, and the disability costs of injuries were excluded from the estimated costs of accidents.

Employment and Other Sociodemographic Variables

All AIS respondents were asked whether they were employed, self-employed, unemployed and looking for work, students, homemakers, retired, or something else. All respondents who reported they were employed or self-employed were included in the present analysis. Information obtained on respondent age (18-29, 30-44, 45-64, and ≥65 years), sex, and educational attainment (high school graduate or less, some college, college graduate or more) was included as control variables in the analyses. The age categories used herein were different from those used in sample stratification (ie, 18-34, 35-49, 50-64, 65-74, and ≥75 years) because employed respondents have a younger age distribution than others in the sample.

Analysis Methods

We used logistic regression analysis[45] to estimate associations of insomnia with 12-month accidents and errors with and without controls for chronic conditions. We exponentiated logistic regression coefficients and their standard errors to create odds ratios (ORs) and 95% confidence intervals. We used generalized linear models[46] to estimate associations of insomnia with the costs of accidents and errors, with and without controls for chronic conditions. We used the generalized linear models because the linearity and homoscedasticity assumptions of conventional regression analysis were likely to be violated by the highly skewed distributions of accident and error costs. Statistical significance of logistic and generalized linear model regression coefficients was evaluated using .05-level 2-sided tests. Because the AIS data are weighted, the design-based Taylor series method[47] implemented in commercially available software (SAS SURVEY procedures)[48] was used to estimate standard errors and evaluate statistical significance.

Population-attributable risk proportions (PARP) were calculated for the associations of insomnia with workplace accidents and errors using simulation methods that have been described in detail elsewhere.[1,49] Population-attributable risk proportions for incidents is defined as the proportion of observed accidents and errors that would not have occurred under the logistic regression models if insomnia were eradicated and the insomnia coefficients in the models were due to causal effects of insomnia. For example, a PARP for accidents of 7% would mean that 7% of all the observed costly workplace accidents would be predicted not to have occurred if insomnia had not occurred or had been effectively treated. Population-attributable risk proportions for costs are defined similarly as the proportion of all costs of accidents and errors that would not have occurred in the absence of insomnia. The PARP estimates were used to make annualized US population projections combining AIS prevalence estimates with data on the size of the US labor force from the Bureau of Labor Statistics August 2010 Current Population Survey (http://www.bls.gov/cps).

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Table 1. Associations of Sociodemographic Variables With BIQ-Defined and Broadly Defined Insomnia and Costly 12-Month Workplace Accidents and Errors Among Employed AIS Respondents in the Comorbidity Subsample[a]

	OR (95% CI)			
		Workplace Incidents[c]		
	Insomnia[b]	Accidents	Errors	Either
Age, y				
18-29	1.6 (1.1-2.2)[d]	3.0 (0.4-23.6)	1.3 (0.6-3.2)	1.6 (0.7-3.5)
30-44	1.7 (1.3-2.4)[d]	4.5 (0.6-34.2)	2.1 (0.9-4.8)	2.4 (1.1-5.1)
45-64	1.8 (1.3-2.5)[d]	2.6 (0.3-20.0)	1.7 (0.7-3.9)	1.7 (0.8-3.8)
≥65	1 [Reference]			
χ^2_3 Value	16.1[d]	4.5	5.3	8.2[d]
Sex				
Male	0.7 (0.6-0.8)[d]	2.8 (1.4-5.3)	5.6 (3.6-8.6)	4.5 (3.1-6.6)
Female	1 [Reference]			
χ^2_1 Value	28.7[d]	9.6[d]	58.4[d]	64.1[d]
Educational level				
Less than high school	0.9 (0.4-1.8)			
High school graduate	1.2 (1.0-1.3)	1.1 (0.6-2.1)	0.8 (0.6-1.2)	0.8 (0.6-1.2)
Some college	1.2 (1.0-1.5)	1.9 (0.9-4.2)	0.9 (0.6-1.6)	1.1 (0.7-1.7)
College graduate	1 [Reference]			
χ^2_3 Value	6.4	3.0	1.0	1.6

Abbreviations: AIS, America Insomnia Survey; BIQ, Brief Insomnia Questionnaire; OR, odds ratio.

[a]The BIQ is a validated self-report measure of insomnia. Cases identified using the BIQ and broadly defined insomnia include those meeting full inclusion criteria for a diagnosis of insomnia in the BIQ according to at least 1 of the following diagnostic systems: *DSM-IV*; *International Statistical Classification of Diseases, 10th Revision*; and *Research Diagnostic Criteria/International Classification of Sleep Disorders, Second Edition*. Diagnoses were made without organic exclusions or diagnostic hierarchy rules. Only cases with a reported duration of at least 12 months at the time of interview are included in the comorbidity subsample (n = 4991). Analyses are based on a multivariate model in which all 3 sociodemographic variables are included to predict the outcome.

[b]The estimated prevalence of broadly defined insomnia persisting for at least 12 months at the time of interview was 20.0%.

[c]Workplace accidents or mistakes costing the company $500 or more were reported by 4.3% of respondents (1.1% accidents and 3.4% mistakes; some respondents reported both).

[d]Indicates significant association between the sociodemographic variable and the outcome at the .05 level, 2-sided test.

RESULTS

PREVALENCE AND SOCIODEMOGRAPHIC CORRELATES OF INSOMNIA AND WORKPLACE ACCIDENTS AND ERRORS

The estimated prevalence (SE) of broadly defined insomnia with duration of at least 12 months was 20.0% (0.5%) among employed respondents in the AIS comorbidity subsample. Prevalence was significantly higher among workers aged 18 to 29 years (OR, 1.6), 30 to 44 years (1.7), and 45 to 64 years (1.8) than among those 65 years or older (1); lower among men than women (0.7); and not significantly related to educational level (**Table 1**).

The estimated prevalence (SE) of costly 12-month workplace accidents and errors among employed respondents was 4.3% (0.3%), including 1.1% (0.2%) accidents and 3.4% (0.2%) errors (4.3% is less than the sum of 1.1% and 3.4% because some respondents reported both). Accidents and errors had lower prevalence among the small number of employed respondents 65 years or older than among those aged 18 to 64 years, with ORs in the range of 1.3 to 2.6, but the association was statistically significant only for the category of accidents and/or errors. Reported accidents and errors were also statistically more prevalent among men than women, with ORs of 2.8 (accidents) and 5.6 (errors), and not significantly related to educational level.

COMORBIDITY OF INSOMNIA WITH OTHER DISORDERS

As documented in a previous AIS report,[13] insomnia was positively associated (ie, OR > 1.0) with all 18 chronic conditions considered herein among employed respondents and significantly so with 17 of the 18. The ORs ranged from a high of 5.5 with major depression to a low of 1.2 with cardiovascular disorder. The interquartile range (ie, 25th-75th percentiles) of the ORs was 1.4 to 2.5 (detailed results are available from the corresponding author on request).

ASSOCIATIONS OF INSOMNIA WITH WORKPLACE ACCIDENTS AND ERRORS

Respondents with insomnia were significantly more likely than others to report workplace accidents and errors, with ORs of 1.9 for accidents, 1.4 for errors, and 1.5 for either in the model that includes controls for sociodemographics but not for chronic conditions (**Table 2**). The ORs decreased in the model that adds controls for chronic conditions but remained statistically significant for accidents and/or errors (1.4), although not for errors alone (1.3) or accidents alone (1.5). Only the following 3 of the 18 chronic conditions had significant associations with accidents and/or errors: neuropathic pain (accidents),

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Table 2. Associations of BIQ-Defined and Broadly Defined Insomnia and Costly 12-Month Workplace Accidents and Errors Among Employed AIS Respondents in the Comorbidity Subsample[a]

	OR (95% CI)		
	Accidents	Errors	Either
Presence of incidents			
Without controls for comorbidity	1.9 (1.1-3.4)[b]	1.4 (1.0-2.0)[b]	1.5 (1.1-2.1)[b]
With controls for comorbidity	1.5 (0.8-2.8)	1.3 (0.9-1.9)	1.4 (1.0-2.0)[b]
PARP of incidents, %			
Without controls for comorbidity	14.5	6.7	8.0
With controls for comorbidity	10.3	5.8	7.2
Annualized US population projections of incidents (in thousands), estimate[c]			
Without controls for comorbidity	223.3	317.0	481.6
With controls for comorbidity	158.6	274.5	433.4

Abbreviations: AIS, America Insomnia Survey; BIQ, Brief Insomnia Questionnaire; OR, odds ratio; PARP, population-attributable risk proportion.

[a] For a description of the BIQ and broadly defined insomnia, see Table 1. Only cases with a reported duration of at least 12 months at the time of interview are included in the comorbidity subsample (n = 4991). Analyses are based on a multivariate logistic regression model in which insomnia is used to predict the outcome with controls for sociodemographics and with or without controls for comorbidity.

[b] Indicates significant association between insomnia and the outcome at the .05 level, 2-sided test.

[c] These results are based on projection of the results to the total US civilian labor force using population data from the August 2010 Current Population Survey (http://www.bls.gov/cps).

Table 3. Distribution of the Estimated Costs of Accidents and Errors

	Costs, $				
	Mean	Median	SD[a]	Upper Bound[a]	No. of Respondents
Accidents	8102	2000	17 560	100 000	56
Errors	26 188	2500	70 875	1 000 000	172
Either	22 645	2500	66 127	1 000 000	218

[a] The distributions were stabilized by assigning respondents with the top 10% of accidents (n = 5) or errors (n = 17) the mean value for respondents in that upper tail of the distribution, resulting in revised upper bounds of $75 531 for accidents, $288 318 for errors, and $363 848 for either. The SDs reported herein are based on those trimmed distributions. As noted in the body of the text, results were estimated with and without this weight trimming to evaluate the sensitivity of results to extreme values.

sleep apnea (accidents), and emotional disorders other than major depression (accidents and errors), with ORs from 2.4 to 2.9 in multivariate models (detailed results are available from the corresponding author on request).

The PARPs showed that 14.5% of all costly workplace accidents are associated with insomnia. This estimate decreased to 10.3% when controls were introduced for comorbid chronic conditions. The comparable percentages were 6.7% (5.8% with controls) for workplace errors and 8.0% (7.2% with controls) for accidents and/or errors. These PARPs were higher than those for any of the other 3 chronic conditions significantly associated with accidents and/or errors (ie, neuropathic pain, sleep apnea, and emotional disorders other than major depression) because of the much higher prevalence of insomnia than these other conditions (detailed results are available from the corresponding author on request). Annualized US population projections associated with the insomnia PARP estimates are 223 300 people (158 600 with controls) for costly workplace accidents, 317 000 (274 500 with controls) for errors, and 481 600 (433 400 with controls) for accidents and/or errors. These projections can be interpreted as estimates of the numbers of workers who had incidents of this sort that would not have occurred in the absence of insomnia.

COSTS OF THE WORKPLACE ACCIDENTS AND ERRORS ASSOCIATED WITH INSOMNIA

We also examined the costs of accidents and errors. Because our questions stipulated that we were interested only in incidents that cost the company at least $500, the lower end of the cost range was $500 by definition, but the upper end was unbounded. The highest reported costs were $100 000 for accidents and at least $1 million for errors (**Table 3**). Means were $8102 for accidents, $26 188 for errors, and $22 645 for both. The distributions were highly skewed, however, as indicated by the fact that the medians ($2000 for accidents, $2500 for errors, and $2500 for both combined) were considerably lower than the means (detailed distributions are available from the corresponding author on request).

Preliminary analysis of the associations of predictors with the costs of accidents and errors found the best model specification to be a γ (inverse) link function between predictors and outcomes with a variance of prediction errors proportional to the natural log of the predicted values (detailed results of model fit comparisons available from the corresponding author on request). Using this specification, we estimated that insomnia is significantly associated with the costs of accidents and errors but in a rather complex way (**Table 4**). The accidents

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Table 4. Associations of BIQ-Defined and Broadly Defined Insomnia With the Costs of 12-Month Workplace Accidents and Errors Among Employed AIS Respondents in the Comorbidity Subsample[a]

	Accidents (n = 56)	Errors (n = 172)	Either (n = 218)
Cost of incidents, mean (SE), $			
Without controls for comorbidity	–2359 (272)[b]	20 976 (2766)[b]	10 428 (1132)[b]
With controls for comorbidity	–2346 (356)[b]	18 978 (2165)[b]	10 148 (1157)[b]
PARP of costs, %			
Without controls for comorbidity	3.0	25.4	23.4
With controls for comorbidity	2.6	25.9[c]	23.7
Estimated annualized US population projection of costs, $1 million[d]			
Without controls for comorbidity	442.4	30 884.0[c]	31 326.4
With controls for comorbidity	373.8	31 784.0[c]	32 157.8

Abbreviations: AIS, America Insomnia Survey; BIQ, Brief Insomnia Questionnaire; PARP, population-attributable risk proportion.

[a] For a description of the BIQ and broadly defined insomnia, see Table 1. Only cases with a reported duration of at least 12 months at the time of interview are included (comorbidity subsample, n = 4991). The analyses are based on a multivariate generalized linear model with a γ link function and square-root error distribution in which insomnia is used to predict the outcome with controls for sociodemographics and with or without controls for comorbidity.

[b] Indicates significant association between insomnia and the outcome at the .05 level, 2-sided test.

[c] The estimate is higher in the model with controls for significant comorbid conditions despite the fact that no such condition had a negative association with the outcomes. Further analysis showed that this was due to changes in the net associations of the sociodemographics with insomnia and workplace errors, which led to a small net increase in the estimated association of insomnia with the outcomes.

[d] These results are based on projection of the results to the total US civilian labor force using population data from the August 2010 Current Population Survey (http://www.bls.gov/cps).

associated with insomnia have significantly lower costs than other workplace accidents by an average of $2359 ($2346 with controls) per incident. The errors associated with insomnia, in comparison, had significantly higher costs than other workplace errors by an average of $20 976 ($18 978 with controls) per incident. Given the much higher prevalence and average costs of errors than accidents, the total costs of insomnia-related accidents and errors were higher than those of other workplace accidents and errors by an average of $10 428 ($10 148 with controls) per incident. Given that the average cost of workplace accidents and errors was $22 645 and that insomnia accounted for 8.0% (7.2% with controls) of these incidents, average costs were $32 239 ($32 062 with controls) for those due to insomnia and $21 811 ($21 914 with controls) for those not due to insomnia. Given the potential sensitivity of these results to a small number of extreme values, we replicated the analysis using trimmed extreme values but found that the results remained significant and of similar magnitude to the untrimmed results (detailed results of this sensitivity analysis are available from the corresponding author on request).

Estimates of PARP that take into consideration the associations of insomnia with prevalence and costs showed that insomnia was associated with 3.0% (2.6% with controls) of all costs of workplace accidents. This estimate is lower than the 14.5% PARP of accident prevalence (reported in Table 2) because insomnia-related accidents were less costly than other workplace accidents. The comparable percentages were 25.4% (25.9% with controls) of the overall costs of workplace errors and 23.4% (23.7% with controls) of the overall costs of workplace accidents and/or errors. Annualized US population projections associated with these estimates were $442.4 million ($373.8 million with controls) for insomnia-related accidents, $30 884.0 million ($31 784.0 million with controls) for insomnia-related errors, and $31 326.4 million ($32 157.8 million with controls) for insomnia-related accidents and/or errors.

SUBGROUP VARIATION IN THE ASSOCIATIONS OF INSOMNIA WITH ACCIDENTS AND ERRORS

Analyses of statistical interaction found no evidence that the associations of insomnia with workplace accidents or errors varied significantly with respondent age (χ^2_3=0.4-2.4 [P=.49-.94]), sex (χ^2_1=0.0-1.4 [P=.24-.97]), or educational level (χ^2_2=0.3-2.1 [P=.35-.86], noting that respondents with less than a high school education had to be combined with those who had no more than a high school education because of sparse data). In addition, the associations of insomnia with costly workplace accidents or errors did not vary significantly with the number of significant comorbid conditions (χ^2_1=0.1-0.8 [P=.36-.77]) (detailed results of interaction analyses are available from the corresponding author on request).

COMMENT

Given the enormous implications of chronic sleep problems, we should establish accurate statistics on the prevalence and consequences of insomnia in the workplace. Little consensus exists, however, among epidemiological studies regarding the proportion of working people who have insomnia, less still on the effects of insomnia on workplace outcomes, and extremely little on the effects of insomnia on workplace accidents and errors. The AIS estimates are consequently important.

Only one other general population survey of insomnia prevalence among US workers in the past decade has used operationally defined diagnostic criteria to define insomnia: the 2008 National Sleep Foundation Sleep in

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America poll.[50] However, that study was based on a nonprobability quota sample, had an extremely low response rate (17%), and used *RDC/ICSD-2* criteria to diagnose insomnia. Nonetheless, the estimate in that pool that 11.0% of US workers have insomnia approximates the *RDC/ICSD-2* prevalence estimate of 14.0% in the AIS.[1] A large French epidemiological survey also estimated insomnia prevalence among workers,[51] finding that 18.4% of midlevel executives, 20.8% of white collar workers, and 17.9% of blue collar workers met *DSM-IV* criteria for insomnia, excluding cases with comorbid conditions.

As noted in the introduction, we are aware of only 2 previous studies of the associations between insomnia and workplace accidents and errors.[25,26] The AIS results are broadly consistent with those studies in finding that insomnia is associated with significantly elevated rates of workplace accidents and errors. We went beyond those earlier studies, however, to estimate the proportions of all accidents and errors associated with insomnia excluding the effects of comorbid conditions and to monetize the costs of these incidents based on respondent estimates of workplace costs. These estimates suggest that the costs of insomnia on workplace accidents and errors are substantial. The precise values of the estimates must be interpreted with caution because we have no way to validate the respondent estimates.

Methods exist to obtain a criterion standard estimate of the total costs of workplace accidents to employers.[52,53] However, these methods require labor-intensive qualitative interviews with workers, supervisors, and employers and quantitative analyses to monetize the many economic elements of each accident, including lost work hours (not just of the worker who had the accident but also of other workers, as when an accident shuts down an assembly line and everyone on the line has to remain idle until the line begins to move again), broken equipment, lost revenue for products not produced, costs of external services (eg, legal costs for lawsuits related to the accident), settlement costs (eg, fines imposed by the Occupational Safety and Health Administration and settlements with victims of the accident or their survivors), disability costs, health care costs, and public relations costs to the firm. The use of these methods to validate the respondent accident cost estimates in the AIS would have far exceeded project resources. Nonetheless, the data reported herein represent a useful starting point providing a motivation for future, more in-depth investigations.

Although previous evidence about the associations of insomnia with workplace accidents and errors is scant, we noted in the "Introduction" that considerable research exists on the association of insomnia with workplace injuries. The significant associations documented in these studies of workplace injuries are comparable in magnitude to those found herein for costly accidents and errors, although much of the injury research focused on general reports of sleep problems or short sleep durations that can occur in the absence of insomnia owing to lifestyle-induced partial sleep deprivation[54-60] rather than on insomnia per se.[13] A systematic review of these studies estimated that the annual costs of insomnia-related workplace injuries in the US civilian workforce exceed $100 billion.[61] Our results suggest that the costs of insomnia-related workplace accidents and errors add significantly to this total.

The AIS results are limited by the following 2 sampling issues: the 65.0% survey cooperation rate, which could have distorted estimates of prevalence and correlates of insomnia, and the fact that all respondents were members of a large national commercial health plan, meaning that results might not generalize to the roughly 15% of the US population that lacks health insurance or to segments of the population with insurance not provided by commercial health plans.

The AIS measures also have limitations. Insomnia was assessed with a fully structured scale rather than with clinical interviews that could introduce imprecision into the measurement of insomnia, although the AIS clinical reappraisal study found that BIQ diagnoses have good concordance with blinded clinical diagnoses.[27] In a related issue, diagnostic hierarchy and organic exclusion rules were not applied to insomnia diagnoses. However, we controlled for comorbid conditions to correct for any inflation in the estimated associations of insomnia with the outcomes. As noted in the "Measures" subsection of the "Methods" section, this use of comorbid conditions as controls rather than as diagnostic exclusions for insomnia is recommended by the 2005 National Institutes of Health State-of-the-Science Conference,[30] the 2006 recommendations for a standard research assessment of insomnia,[31] and the task force revising the *DSM-V* criteria.[62]

Perhaps the most important limitation of this report involves the fact that costly workplace accidents and errors were assessed using unvalidated questions developed for the AIS. Although we have no way to evaluate the accuracy of these reports from the data collected in the AIS, methodological research performed in studies of injuries might be relevant. This research shows that reports of occupational injuries during a 12-month recall period range from one-third to one-fourth lower than the 12-month projection of reports during a much shorter recall period.[63-65] Consistent with these results, retrospective occupational injury reports are substantially lower than reports based on prospective daily diaries.[66] Based on these results, we suspect that accidents and errors were underreported in the AIS. Whether respondent estimates of the respective costs of these accidents and errors were accurate is less clear. We know from studies of memory processes that minor events are forgotten more quickly than major ones.[67] The same has been found in studies of injury recall.[64] We consequently expect that very costly accidents and errors were recalled more completely in the AIS than less costly ones, suggesting that AIS estimates of average workplace accident and error costs are probably upwardly biased. The extent to which workers are able to provide accurate estimates of the true costs to their employers of the incidents they remember, however, is a separate matter that we cannot evaluate.

These limitations notwithstanding, the AIS findings are useful in several respects. First, they extend previous studies that documented association of insomnia and workplace absence and injuries by showing that insomnia is also related to workplace accidents and errors. The magnitude of this association is substantial. Second, we showed that the association of insomnia with these out-

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comes is among the largest at the individual level and the very largest at the population level among all the conditions we considered. Third, we demonstrated that the aggregate associations of insomnia with injuries are similar among workers who differ in age, sex, and educational level. These results suggest that workplace interventions aimed at screening for and treating insomnia to reduce workplace injuries, accidents, and errors could have broad-based effects. In targeting such programs, however, we should consider not only accidents and errors but also other human capital outcomes that might be the focus of workplace interventions, such as absence due to sickness and work performance. The effects of insomnia on these outcomes, unlike those on accidents and errors, might differ in strength across occupations and industries.[12,68,69]

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Online-Only Material: The AIS interview schedule and a complete list of AIS publications can be found at http://www.hcp.med.harvard.edu/wmh/affiliated_studies.php.

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